NATURAL HISTORY MUSEUM VISITORS' UNDERSTANDING OF HUMAN EVOLUTION

AN HONORS THESIS

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By

Shaye N. Smith

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Shaye N Smith

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ABSTRACT

Recent polls indicate that only 15% of Americans accept secular evolution as the cause of human origins and less than 10% possess a functional understanding of evolutionary concepts (Gregory 2009; Newport 2012). Due to various social and psychological barriers to the acceptance and understanding of evolutionary theory as well as a minimal educational focus on evolution, for some Americans visiting institutions of informal education like natural history museums is their only opportunity to obtain scientifically sound information about evolution (Diamond and Evans 2007; Spiegel et al. 2006). Many studies have investigated natural history museum visitors' understanding of evolution but few have examined understanding of human evolution in particular. Data were collected over a five-day period at the National Museum of Natural History in Washington, DC. Ninety-six museum visitors participated in an exit survey in the Hall of Human Origins. Fifty percent of visitors subscribed to young earth creationist or theistic evolutionary beliefs. Visitors' answers to questions pertaining to information presented in the exhibition and their understanding of the principles of evolution as the basis of human origins were scored for accuracy. Relationships were found between acceptance and understanding, with those who accepted secular evolution scoring on average 79%, those who accepted theistic evolution scoring on average 70%, and those who accepted young earth creationism scoring on average 41%. Results indicate that visitors held several misconceptions about evolution, e.g. new traits that arise in populations are always beneficial (54%) and adaptations arise in response to need or an intentional effort to change by individuals (68%). Because natural history museums house the objective scientific knowledge and fundamental evidence for evolution, they play an important role in educating the public. However, as these results indicate, personal beliefs influence visitors' ability to understand the principles of evolution as the basis of human origins.

KEYWORDS: human origins, evolution education, natural history museums, visitors

PART 1: Contextual Review

INTRODUCTION

Despite landmark achievements in evolutionary biology and the growing body of fossil and genetic evidence for human evolution, Americans' acceptance of secular evolution as the grounds of human origins has remained stagnant with no statistically significant increase for the past 30 years (Newport 2012). This stark reality begs the questions: Why is the theory of evolution difficult to accept? What makes the human mind so resistant to accepting evolution despite the vast amount of evidence that supports it? Several related factors contribute to the non-acceptance of evolution: religious belief, political ideology, social pressures, and psychology. These factors may prohibit an adequate understanding of the empirical evidence and the concepts behind modern evolutionary theory as well as a working understanding of the nature of science in general (Allmon 2011; Miller, Scott, and Okamoto 2006; Pigliucci 2002).

The stark divide between fundamentalist religion and Darwinian evolution—paired with the difficulty involved in conceptual change—has made evolution a largely unpopular and misrepresented issue in the United States. The relationship between fundamentalist religion, anti-intellectualism, and politics only adds to the issue (Pigliucci 2002). Recent studies in cognition reveal that in order to learn new theories, people must first 'unlearn' inherent naïve intuitions, thus making it incredibly difficult for people to disregard their previous "knowledge" in favor of correct understandings of evolution (Lehrer 2012; Shtulman and Valcarcel 2012). In a rapidly globalizing world, Americans' tenacious rejection of the theory of evolution as the basis of the diversity of life carries harsh consequences. The question remains: How can we begin to bridge this gap between

acceptance and understanding?

While drastic education reform is undeniably necessary, several scholars have suggested that sites where informal learning takes place, like museums, can effectively incorporate initiatives to increase acceptance and understanding among the public (Allmon 2011; Belin and Kisida 2012; Miller, Scott, and Okamoto 2006). Doing so, however, has proven to be more difficult than one would think. Despite the fact that many natural history and science museums in major metropolitan areas offer specific exhibits about the evolution and diversity of life on earth, several scholars have found that they are not truly effective at invoking conceptual change in visitors' acceptance and understanding of the fundamental underpinnings of evolutionary theory (Diamond and Evans 2007; Evans et al. 2007; MacFadden et al. 2007; Spiegel et al. 2006). This discordance appears to be even more present when the evolution of our species is conceptualized. Forty percent of museum visitors are reluctant or unable to explain evidence of humans and chimpanzees sharing a common ancestor and are more likely to argue for creationist explanations of human origins than for non-human species (Evans et al. 2007; Spiegel et al. 2006). To my knowledge, there are have been no in-depth studies conducted on natural history museum visitors' acceptance and understanding of human evolution in particular. The following review of the literature and resulting research intend to fill this gap.

Museums serve as an important place of informal education for the public. Although state standards mandate the teaching of evolution, very few states receive an adequate rating when their standards for the teaching of evolution are evaluated (Moore 2002). Furthermore, the mere presence of science standards supporting the teaching of

evolution does not necessarily mean that teachers follow these standards (Moore 2002). Thus, an adequate teaching of evolution depends very much on where a student lives and attends school. Visiting natural history museums, where the fundamental evidence for evolution is housed, is some people's only opportunity to learn about evolution (Diamond and Evans 2007; Evans et al. 2010). Due to several cognitive barriers that encourage misconceptions about evolution and the aforementioned failures of the public education system, museums not only have an obligation and social responsibility to present evolutionary information to visitors, but should also ensure they enhance visitors' understanding of that information (Diamond and Evans 2007; MacFadden et al. 2007). In order to do so, evolutionary concepts—particularly adaptation, inheritance, natural selection, as well as the nature of science—should be given a stronger emphasis in exhibits and public programs (MacFadden et al. 2007). This research set out to evaluate the use of said evolutionary concepts in the Smithsonian Institution's David H. Koch Hall of Human Origins presenting information on the origin and diversity of the human species.

Drawing from the cognitive psychology behind conceptual change, as well as a constructivist museum studies approach, the resulting research informs us of how curators can better mediate the gap between intended and observed learning outcomes in the human origins exhibition setting. Questionnaires administered to museum visitors scored for accuracy in understanding of evolutionary concepts shed light on the observed learning outcomes of the exhibit. Before I delve into my own research and findings, I lay the groundwork for the study by reviewing the relevant literature in evolution acceptance and understanding, evolution education, and evolution in the museum. Next, I elaborate

on the theoretical frameworks borrowed from cognitive and museum studies. I then present my methods and research results and follow with a discussion of my findings and their implications. I close with some potential limitations of the study and concluding remarks that project the study into the larger context of conceptual change around human evolution and evolutionary education in the United States.

ACCEPTANCE OF EVOLUTION

It is almost as if the human brain were specifically designed to misunderstand Darwinism, and to find it hard to believe.
— Richard Dawkins, 1996

The most recent Gallup poll indicates that only 15% of Americans accept secular evolution as the basis for the origin and development of human beings (Newport 2012). This contrasts drastically with the 80% or more of adults in Iceland, Denmark, Sweden, and France who demonstrated acceptance of the concept of secular evolution (Miller, Scott, and Okamoto 2006). In the 30 years that Gallup has conducted this poll, American acceptance of evolution has only risen by six percentage points, and the percentage of Americans who adhere to a strict creationist stance that God created humans in their present form at one time within the last 10,000 years has remained essentially unchanged at 46% (Newport 2012). Correlations exist with acceptance of evolution and church attendance, political affiliation, and level of postgraduate education—specifically if that education is in biology and genetics (Miller, Scott, and Okamoto 2006; see Newport 2012). American Protestant fundamentalism grounded in biblical literalism and the view that the creation story in Genesis is a true and accurate account of the origin of life strongly influences attitudes towards evolution, and "individuals who hold a strong belief in a personal God and who pray frequently are significantly less likely to view evolution as probably or definitely true than adults with less conservative religious views" (Miller, Scott, and Okamoto 2006:765; Than 2006). There is a link between conservative religious beliefs and conservative partisan views in the United States, contributing to the politicization of the opposition to evolution as part of a political platform adopted by the Republican Party to consolidate support in historically—both religiously and

politically—conservative states (Miller, Scott, and Okamoto 2006). Adults with postgraduate education are most likely of all educational groups to accept secular evolution as the cause of human origins, and those who have acquired some understanding of modern genetics in particular are more likely to hold positive attitudes towards evolution (Miller, Scott, and Okamoto 2006; Newport 2012).

While lack of adequate education certainly poses significant difficulty in improving acceptance and understanding of evolution, the problem is seated much deeper as a function of our country's cultural and historical structures. Increasing science education alone and expecting that rationalism will win over the public while ignoring the other factors contributing to the problem will be futile. As Director of the National Center for Science Education in California Eugenie Scott expresses contempt of the rationalistic fallacy, "The rejection of evolution is not something that will be solved by throwing science at it" (quoted in Than 2006). There are numerous factors that influence the non-acceptance of evolution that an increase of rationalistic teaching and scientific education alone cannot surpass, including the strength, diversity, and appeal of organized American religious and creationist belief as well as general public anti-intellectualism (Allmon 2011; Pigliucci 2002). If we are to attempt to understand the polarizing divide among our nation's public and one day turn the tables on the percentage of secular and creationist beliefs as demonstrated in the Gallup poll, a more thorough examination of American creationism and anti-rationalism is in order.

Born out of events and ideas in ancient and more recent European history, a multitude of influences have shaped creationism into its modern American form. From the great philosophers to the great debates of Darwin's time, several significant events in

European history likely influenced the earliest forms of American creationism. One of the great ancient philosophical thinkers, Plato developed the notion around the 4th century BCE that species were fixed types that remained unchanged after creation, which resembles one of the founding tenets of modern creationism (Bowler 2003). The Protestant Reformation of 1517 establishing the Bible, and not the Pope, as authority was the culmination of a decline of faith in the Catholic Church and gave rise to fundamentalism (Bowler 2003). Nearly 30 years later in 1543, the Copernican and scientific revolutions were important platforms for the advancement of science, but they were still founded on the notion of the Great Chain of Being, with humans uniquely occupying the top section of the chain reserved for the natural world (Bowler 2003; Figure 1).

Figure 1: Didacus Valades' (1579) *The Great Chain of Being*: A visual metaphor for the divinely inspired ranking of all forms of higher and lower life. God occupies the top of the chain, followed by angels, men, animals, plants, and minerals. Image credit: Stanford University, http://www.stanford.edu/class/engl174b/chain.html.

A century later in 1658 came Archbishop James Ussher with his calculation of the exact date of Biblical creation in the year 4004 B.C., the date to which modern young earth creationists continue to subscribe (Bowler 2003). With the rise of natural theology in the 1690s, it was thought that adaptations observed in organisms were proof of an intelligent creator that eventually led to Paley's watchmaker argument of irreducible complexity that is appropriated by proponents of intelligent design today (Bowler 2003; Mayr 2001). These historical ideas and events have culminated in the modern creationist argument: humans hold an essential and unique place in nature, scripture should be taken as ultimate and literal truth, and certain biological phenomena are too complex to not have been created by a wise and almighty creator.

Modern American creationism, although influenced by European Protestant ideas, is a breed of its own. If we are to believe the most results of the most recent Gallup poll, 46% of Americans believe that God created humans in their present form within the last 10,000 years, a statistic that has remained unchanged for nearly 30 years (Newport 2012). Such stark opposition to secular evolution is unparalleled elsewhere in the world with the exception of the fundamentalist Islamic country of Turkey (Miller, Scott, and Okamoto 2006). Originating at the turn of the 19th century, American creationism began as a backlash at attempts led initially by Seventh Day Adventists to shift the creationist movement towards a more progressive position resembling the idea of theistic evolution (Pigliucci 2002). Following World War I, fundamentalists increasingly began to attribute the teaching of evolutionary theory as the cause of deep social problems (Pigliucci 2002). In response to the perceived loss of moral values associated with modernity in the 1920s, the creationism movement emerged in full force, vilifying evolution as the cause of

slavery, the Holocaust, racism, promiscuity, and other social ills (Moore 2000; Pigliucci 2002).

Probably the aspect that sets modern American creationism apart is its now intrinsic bond with policy and political agendas. Anti-intellectualism and anti-rationalism in particular led to a multitude of anti-evolution laws in educational policy and eventually the first of many legal cases with the Scopes trial in 1925 (Pigliucci 2002). The rise of anti-intellectualism in the McCarthy era in the 1950s, its comeback during the Reagan presidency in the 1980s, and its resurgence in the George W. Bush age in the early 2000s only strengthened ties between fundamentalist religion and right-wing politics (Pigliucci 2002). Political adherence to creationist views is not limited to the right alone. Democratic politicians also typically endorse the teaching of creationism in schools because they know that their pro-creationism position will be popular among their constituents whose beliefs are reinforced by a "vast network of seminars, television shows, newsletters, books, and religious organizations" (Moore 2000). This promulgation of creationist ideology in the media and through the rise of creationist organizations like Answers in Genesis and the Discovery Institute has led to a growing battle in American classrooms and courtrooms alike.

Despite the fact that teaching creationism in schools is unconstitutional, and although creationists have lost every legal contest on the matter, it appears they have won the public debate (Moore 2000). Randy Moore (2000) suggests that due to its widespread appeal and scientists' dismissal of or refusal to acknowledge the controversy, creationism will remain popular unless, that is, scientists and scientific institutions rise to the occasion and promote a better understanding of the nature of science and the scientific method

(Pigliucci 2002). Creationists will continually win the public debate, and evolutionary theory will continue to be rejected by the public until this happens. Perhaps the strongest movement within creationism today is intelligent design, which instead of rejecting science outright in favor of biblical literalism, appropriates it as a revitalized form of natural theology in an attempt to poke holes in the scientific basis for evolution. Intelligent design is the youngest relative brand of creationism that reached prominence among the public in the mid-1990s and continues today (Pigliucci 2002).

Operating under the guise of pseudoscience, intelligent design is a growth of the neo-creationist movement and, despite claims of non-denominationalism, continues to be funded and promoted by Christian sources and a religious agenda (Pigliucci 2002). It is clear how intelligent design proponents explicitly distort and misrepresent scientific knowledge in their argument against evolution (Kitzmiller v. Dover 2005). Additionally, *Of Pandas and People*, a popular book among proponents written by several well-known intelligent design theorists included the word "creationism" in earlier drafts but was later changed to "intelligent design" after an important Supreme Court case (Kitzmiller v. Dover 2005). Thus, intelligent design is merely creationism relabeled, and we are really no better off now than we were several hundred years ago when Paley introduced natural theology. Unfortunately, the reality may be that we must radically alter our practices with which we have become so complacent if we are to make evolutionary theory better understood and thus accepted among the public (Pigliucci 2002). As Jonah Lehrer (2012) notes, "It took a few hundred years for the Copernican revolution to go mainstream. At the present rate, the Darwinian revolution at least in America, will take just as long."

But perhaps with the proper combination of research and implementation, we can

rethink and address the issue at hand and hasten the rate of the Darwinian revolution going mainstream. The perpetuation of the 'religion vs. science' controversy in some ways sets up a false dichotomy and ignores a host of other factors that influence acceptance and understanding of evolution. Evans (2008) points out that even among the small percentage of the public who accept secular evolution as the basis of human origins, most invoke non-Darwinian concepts to explain species change. Along with the obstacles to accepting evolution caused by general anti-intellectualism and the increased strength, diversity, and decentralization of American religious belief, sociopolitical and psychological obstacles contribute to low scientific literacy and insufficient knowledge or misunderstanding of evolutionary theory and the nature of science in general (Allmon 2011). According to Allmon (2011), if we are to address the issue of widespread non-acceptance of evolution, we "must therefore involve not just further resolution of the 'religion vs. science' controversy" but must also explicitly address the numerous, diverse, and complex factors that affect an adequate understanding of evolutionary theory (648).

UNDERSTANDING EVOLUTION

Belief simply is not the point here; rather a thorough grounding in science as a human endeavor is.
— Niles Eldredge, 2000

Rates for understanding evolution among Americans are lower than rates of acceptance. It is estimated that less than 10% of people possess a functional understanding of evolutionary concepts, even among educators (Gregory 2009). Gregory (2009:167) notes "the source of this larger problem seems to be a significant disconnect between the nature of the world as reflected in everyday experience and the one revealed by systematic scientific investigation." Misconceptions about human evolution, evolutionary theory, and the nature of science in general run rampant among members of the public and students of all ages and at all levels, "from elementary school pupils to university science majors" as well as in many aspects of education, policy, and popular culture (Gregory 2009:163). Results from one study reveal that "substantial numbers of American adults" hold misconceptions about the core concepts of contemporary biology (Miller, Scott, and Okamoto 2006:766). The scientific community has been quick to mock the "intelligence" of creationists without recognizing the underlying social and cognitive factors that may present creationism as a more appealing explanation than science.

Indeed, there are a host of different social and cognitive phenomena that can provide a more nuanced understanding of the appeal of religion and the rejection of evolution. Social identity theory provides insight into the immediate social factors that influence an individual to hold distinct attitudes, make certain decisions, or behave in a particular way (Monroe, Hankin, and Van Vechten 2000). The theory is rooted in the

observation that individuals disproportionately show favoritism towards their in-group over out-groups, even when the in-group is arbitrarily constructed (Monroe, Hankin, and Van Vechten 2000). This phenomenon can be explained by the supposition that groups provide members with positive self-esteem, motivation to belong, and ultimately social identities (Monroe, Hankin, and Van Vechten 2000). Experiments underlying social identity theory consistently support the notion that "individuals identify with the in-group, support group norms, and derogate out-group members along stereotypical lines" (Monroe, Hankin, and Van Vechten 2000:435). Thus, belonging to a group—within a religious institution, for example—compels one to support the norms and beliefs that the institution maintains, not only because of the positive self-esteem that the one experiences but also by the deep motivation to belong to and identify with something larger than oneself.

While social identity theory provides an explanation for the motivation to belong and to propagate the views of a group, cognitive dissonance theory informs our understanding of the phenomenon of identity crises whereby conceptions of self are no longer validated during interaction with others (Monroe, Hankin, and Van Vechten 2000). This phenomenon motivates a change in attitudes when one holds inconsistent parallel cognitions or one's beliefs are inconsistent with one's actions, for example in cases where one holds highly salient attitudes or schemata, "a conflicting cognition may itself be ignored or rationalized away in order to guarantee cognitive consistency" through manipulative cognitive procedures (Monroe, Hankin, and Van Vechten 2000:425-426). Creationists seemingly ignore or rationalize the scientific evidence for evolution while still accepting the scientific evidence for other theories in order to

maintain consonance with and adhere to their religious beliefs. As with the denial of evolution, the dissonance created when acknowledging the realities of climate change and daunting behavioral shifts necessary to fulfill mitigation measures are met with denial mechanisms (Stoll-Kleemann et al. 2001). The ability to accept such a paradox, Massimo Pigliucci (2002) notes, is due to the high human threshold of cognitive dissonance that ironically is likely a result of natural selection itself.

The existence of such a paradox has been supported by evidence that natural and supernatural explanations can operate and coexist simultaneously within the same individual (Gelman and Legare 2011; Legare et al. 2012). Contrary to what some science proponents may think, supernatural explanatory frameworks are neither primitive nor immature ways of thinking (Legare et al. 2012). Rather, they are socially and culturally constructed and elaborated through socialization and cultural learning just as natural explanatory frameworks are. Though supernatural explanations may be founded on earlier intuitive explanations, they do not always appear early in development, and in fact, the tendency to invoke such explanations increases with age (Legare et al. 2012). When posed with a question about a single event—about human origins, for example—individuals may recruit one of three combinations of different explanatory frameworks: target-dependent thinking keeps the natural and supernatural domains as separate alternative views of the world; synthetic thinking brings natural and supernatural frameworks together to explain the phenomenon; and integrated thinking combines the two frameworks (Legare et al. 2012). Fundamentalist creationists and proponents of evolution alike employ target-dependent thinking when reasoning about human origins. Theistic evolutionists or proponents of intelligent design employ either integrative or

synthetic thinking, whereby Darwinian natural selection is seen as a proximate cause, and divine intervention or creation of life by God is seen as the ultimate cause (Legare et al. 2012).

While coexistent explanatory models operate and play a role in forming beliefs at an individual level, most religious practices depend on an expert to serve as an agent of cultural transmission and testimony and thus play an important role in forming religious beliefs and transmitting religious ideas and practices to a larger audience (Souza and Legare 2011). Individuals are heavily reliant on the testimony of others to acquire information to which they would otherwise not have access and are likewise sensitive to group consensus when making a judgment—a phenomenon known as social proof (Souza and Legare 2011). Religious ideas, like creationism, operate within the larger scope of cognitive schemas and "basic features of human cognition provide explanatory information for the evaluation and transmission of supernatural beliefs and practices" (Souza and Legare 2011:7). The transmission of scientific information operates in a comparable way, relying on the testimony and expertise of others—in this case, scientists, professors, teachers, and scientific institutions (Souza and Legare 2011). While the expert roles of religious leaders and scientists hold a certain amount of prestige, the media plays a less esteemed part in disseminating information and propagating beliefs and thus, in a sense, also holds the title of expert. A blind and uncritical following of any of these experts, while in some ways necessary for a belonging to social groups, is also hindering of the important discussions needed with regard to the aforementioned issues.

Legare and Souza (2012) posit that despite the incredible human ability to reason about the causal mechanisms that explain the world around us, causal judgments are not

only constrained by putting trust in expert testimony but also by intuitive reasoning capabilities and principles. The rigid and repetitive characteristics of ritual—particularly of the religious kind—are the product of "an evolved cognitive system…of intuitive causal principles" that allows individuals to evaluate the efficacy of rituals without the requirement of the presence of a specialized expert (Legare and Souza 2012:11). Similarly, there are persistent cognitive biases that influence the consideration of information and the formation of beliefs (Gelman and Legare 2011). Intuitive theories, such as theory of mind, theory of living kinds, psychological essentialism, and teleological reasoning organize individual experiences, produce inferences, guide learning and acceptance of information, and influence behavior, interactions, and beliefs while being at once causal and explanatory (Gelman and Legare 2011). These cognitive biases emerge in early childhood and persist if unchallenged, which leads people to believe that they understand things when in fact they do not and paves the way for the potential to reject evolution (Gelman and Legare 2011).

Several scholars have suggested that various psychological barriers hinder people from gaining a complete understanding of and thus accepting evolutionary concepts (Allmon 2011; Shtulman and Valcarcel 2012; Sinatra et al. 2008). As Allmon (2011) notes, evolution is in many ways counterintuitive:

> Evolutionary thinking states that the apparently stable present world of everyday experience is a result of ceaseless change and that complex structures arise from less complex without a conscious designer. Some of these 'everyday' modes of thinking may be innate patterns and modes of understanding, which coincidentally frequently tend to resonate better with creationist views (657).

It is apparent that we are predisposed with constraints that challenge learners to approach the world of evolutionary science in a very different way than that of everyday life.

Conceptual change is at the very core of helping people to better understand evolution (Shtulman and Valcarcel 2012; Sinatra et al. 2008). The difficulties inherent in invoking this conceptual change, however, are identified by Sinatra et al. (2008) as constraints present during development, experiences that reinforce prior knowledge or intuitive of thinking, and reluctance brought on by emotional and motivational factors.

Many of the misconceptions that hinder a complete understanding of evolution develop in childhood or perhaps earlier (Gregory 2009). As infants, we are endowed with "default ways of making sense of the world that are biologically based…that allow us to learn about the world much more effectively than we would if we had to learn everything from scratch" (Sinatra et al. 2008:190). Intuitive ways of making sense of the world contribute to the appeal of creationist ideas at a very young age, essentially leading to non-acceptance of evolution (Allmon 2011). These default biases develop very early in human infancy, constraining "human cognition such that creationist ideas are attractive and easier to spread, whereas evolutionary ideas are less contagious" (Evans 2008:269). In order to alter the basic structure of these innate creationist and naïve intuitions, the goal of education should be to "supplant existing conceptual frameworks with more accurate ones" (Gregory 2009:167; Sinatra et al. 2008). Three outcomes of this developmental constraint are the inherent notions of essentialism, teleology, and intentionality.

Essentialism has been historically identified as one of the principal cognitive obstacles to accepting evolution prior to Darwin and continues to hinder acceptance today (Allmon 2011). Most common among children, but certainly persistent in adults, essentialism is the idea that all living things are stable and unchanging, determined by a

hidden underlying essential nature or essence (Allmon 2011; Sinatra et al. 2008). This clearly makes the concept of evolution and particularly macroevolution extremely difficult to grasp. For example, even well-educated adults scoff at the notion entertained by evolutionary biologists that the ancestor of ocean-dwelling whales originally walked on land as a terrestrial mammal (Evans 2008). This strong intuition that living creatures are unique and unchanging appears to translate to our view of the world as stable and unchanging, functioning as "a very useful aspect of everyday reasoning in that we ignore the dynamic aspects of the world around us and focus on the stability" (Evans 2008:269).

Teleology, or the concept that organisms have some kind of self-directing or divine goal-oriented function has been identified as a major source of misunderstanding about how evolution works (Allmon 2011). This "tendency toward explanations based on purpose" or "tendency to view behavior as directed towards a goal" appears to originate early in development and, unless it is challenged or supplanted by a higher level of scientific education, remains into adulthood (Allmon 2011; Evans 2008:270; Gregory 2009:167; Sinatra et al. 2008). For example, the behavior of an ant colony appears to be goal directed, when "in reality, insects are responding to environmental cues and internal signals, acquired over their evolutionary history" (Evans 2008:270). Intuitive teleological thinking may have been selected for cognitively as a means of telling the difference between living and non-living things but falsely gives the impression that evolution is an adaptive process driven by goals (Evans 2008). As Evans (2008:270) notes, "Evolution is adaptive in the sense that it is contingent on particular environmental conditions, but it is not directed towards the goal of adapting to those conditions."

Closely related to teleological thinking, intentionality is "intimately tied to the

misconception that individual organisms evolve in response to challenges imposed by the environment," thereby giving individuals the agency and conscious intent to purposefully change in response to need (Gregory 2009:168; Sinatra et al. 2008). As E. Margaret Evans (2008:270) explains, this is where creationist reasoning becomes appealing:

> Creationists, it would appear, transfer their intuitive understanding of the human as a manufacturer of tools, such as watches, and apply it to objects that have arisen naturally, such as the human eye. They use the artifact analogy to reason that anything as perfect as the human eye must have had a designer, a supernatural creator in this case; this is the crux of the intelligent design argument. The eye could not have arisen naturally. Some researchers argue that creationism and intelligent design are so appealing because they elicit the well honed human capacity for intentional and purposive or goal-directed reasoning—a naïve theory of mind.

People who hold such a naïve theory of mind as intentionality also tend to adopt a human exceptionalism perspective, whereby biological explanations for the existence, relationships, and behaviors of animals are accepted and understood except for when applied to humans (Miller, Scott, and Okamoto 2006). In this sense, humans are viewed as occupying a place above animals and are unaffected by the same properties of nature, recalling images of the Great Chain of Being and supporting the central tenets of intelligent design detailed above.

These conceptual barriers account for many of the misconceptions that people have about evolution, thus making it imperative yet incredibly difficult to bring about conceptual change if a better public understanding and acceptance of evolution is desired. Given the variety of social and cognitive factors that inhibit understanding and acceptance of science, it is no surprise that many people turn to religion or other organized groups for reassurance that they are not alone in their beliefs. Belonging to a social group, whether it be one of scientific merit or a religious organization provides

people with a sense of identity and belonging in addition to a boost in self-esteem.

Experts and rituals play a significant role in transmitting information and solidifying knowledge. Intuitive cognitive theories and coexisting reasoning models present misinformed explanations of seemingly commonsensical phenomena while hindering understanding and acceptance of scientific explanations. Both organized religion and anti-scientific movements function well as a platform for collective identity and community, operate upon the repetition and rigidity of rituals, and take advantage of early indoctrination to solidify intuitive cognitive barriers. Moreover, that organized religion is both socially and cognitively appealing as an institution are both indications that it will persist indefinitely. To posit that creationists are lacking in intelligence or to subscribe to the secularization hypothesis—that as science and technology advance, religious explanations will become increasingly displaced—is to commit the rationalistic fallacy (Legare et al. 2012; Pigliucci 2002). There are clearly deeper social and cognitive barriers at work, and to think that merely "all you need to do is explain things just a little better and people will see the light" is counterproductive (Pigliucci 2002:234).

Scientists must abandon the notion that creationists are stupid, recognize the multitude of factors influencing the development of beliefs, and acknowledge the existence of different realities, different ways of knowing, and different ways of explaining the experience of everyday life. That is not to say, however, that scientists should simply abandon their cause of promoting scientific knowledge or defer entirely to supernatural explanations at the expense of science. Instead, scientists and scientific institutions should recognize the factors that contribute to low scientific literacy, acknowledge that it will be impossible to change every naysayer's mind, but work

towards constructive solutions to bridging the cognitive gap, put an end to the self-fulfilling prophecy that is the religion-evolution divide, and work with willing political and religious leaders to promote the importance of scientific knowledge and inquiry.

Above all, if we are to improve formal and informal public education about evolution and scientific literacy in general, we must invoke radical conceptual change. Helping people to understand evolution goes beyond adding to their existing knowledge; "helping them to revise their previous models of the world to create an entirely new way of seeing" is necessary (Sinatra, Brem, and Evans 2008:193-194). Educators, then, are charged with the task of first helping students learn the correct scientific theory at hand, and second, helping students *unlearn* earlier, less accurate, and naïve theories and misconceptions (Shtulman and Valcarcel 2012). With a goal of conceptual change in mind, it becomes abundantly clear that "simply describing the process of natural selection to students is ineffective and that is imperative that misconceptions be confronted if they are to be corrected" (Gregory 2009:167). Beyond acknowledging the various factors that affect a proper understanding of evolution, we must investigate what we can do to confront misconceptions and improve public evolutionary knowledge. The clear solution is to critically analyze the state of public evolutionary and science education. Such low scientific literacy caused by the aforementioned factors is also a product of a public education system in which the teaching of science generally, and evolution in particular, is abysmal (Allmon 2011). National and state science standards mandate the teaching of the nature of science in primary science courses and the basic concepts of evolution in secondary life science courses, but the "growing number of adults who are uncertain about these ideas suggests that the current science instruction is not effective" (Bybee

2004b; Miller, Scott, and Okamoto 2006:766). In addition to a total rehaul of formal science education, better integration of evolutionary concepts through informal learning opportunities is essential (Allmon 2011; Miller, Scott, and Okamoto 2006).

EVOLUTIONARY EDUCATION IN THE UNITED STATES

I know of no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome direction, the remedy is not to take it from them, but to inform their discretion by education.
— Thomas Jefferson, 1820

The poor state of evolutionary education specifically and science education in general is the result of several fundamental and widespread problems. Evolutionary education is under attack by creationists, and national science standards that mandate the teaching of evolution are being undermined by state science standards and the teachers who choose not to follow them (Lerner 2000; Moore 2002). In 2012, the majority of states received a rating of 'D' or 'F' for their science standards; only six received a rating of 'A,' and each state is at liberty to formulate its own standards, which are the foundations upon which curriculum is built, textbooks are written, and teachers are trained (Kuchment 2012; Lerner et al. 2012). Additionally, whether or not a student receives an adequate science education depends largely on teachers' acceptance and understanding of evolution and various pressures to de-emphasize the topic (Berkamn, Pacheco, and Plutzer 2008; Moore 2000, 2002, 2004). Furthermore, adequate guidance and support for teachers to integrate the history of science, scientific inquiry, and evolution into their lessons is lacking (Kuchment 2012; Moore 2002).

The adverse reaction to evolutionary education by religious fundamentalists and the political right has plagued the educational system for decades (Moore 2000). We have many reasons to believe that scientists and proponents of evolution have won in the courts, but they appear to be losing in the classroom (Berkman, Pacheco, and Plutzer 2008). Despite the fact that court decision upon court decision have ruled in favor of

teaching evolution and against various infusions of creationism, "creationism is alive and well in biology classrooms" (Moore 2002:380). Moreover, although in theory, standards for teaching evolution are integral for science education reform, they seem to mean very little in practice in the typical classroom (Moore 2002). Though legal rulings and legislation are necessary for evolution to hold its rightful place in the curriculum, they are not sufficient: "implementation of state standards, adherence to court decisions, and the full integration of textbook material rests in the hands of classroom teachers throughout the country" (Berkman, Pacheco, and Plutzer 2008:0921).

Many of these teachers believe in creationism, and as many as half of American high school students receive an education shaped by creationist influences with at least 25% of teachers devoting time to creationism or intelligent design in their biology classes (Berkman, Pacheco, and Plutzer 2008; Moore 2000). Even if they do not specifically endorse creationism in the classroom, many teachers are fearful of taking a public stand on the issue because they either know relatively little about the subject and/or feel pressured by administrators, parents, and the communities in which they teach to downplay or ignore the topic outright (Berkman, Pacheco, and Plutzer 2008; Moore 2000). Few teachers also have a proper understanding of the legal issues regarding the teaching of creationism and evolution (Moore 2004). The result of all of this, Moore (2000) explains, is "sadly predictable: many students graduate from college with a poor understanding of one of the most powerful ideas in science." Exacerbating the problem is that many of these students go on to become teachers themselves. Thus, caught in a cyclical feedback loop, low acceptance of evolution and a poor understanding of biology among the public combined with inadequate state science standards create powerful

incentives for teachers to do a poor job of teaching evolution, ignore it, or discredit it altogether (Moore 2000).

While identifying the roots of poor evolutionary education in the United States is the first step in public evolutionary education progress, the solution for improving acceptance and understanding of evolution and ultimately invoking radical widespread conceptual change will undoubtedly be lengthy and complex. The next steps of implementing solutions to this problem will be difficult and will certainly be met with setbacks and opposition. Neither victory in the courts nor rigorous state science standards are enough to ensure that evolution is taught in science courses (Berkman, Pacheco, and Plutzer 2008). A bigger impact in improving widespread understanding of the nature of science and evolution may instead come from focusing on the certification standards for science teachers, emphasizing to students and teachers alike that evolution is the unifying concept in biology without which the discipline cannot be properly taught, and educating teachers about the legal issues associated with teaching creationism (Berkman, Pacheco, and Plutzer 2008; Moore 2002, 2004). Additionally, increasing the requirements for the number of evolution-based courses that students must take will positively impact future generations of students and teachers caught in the feedback loop, as studies have shown that "teachers who have a better understanding of evolution and the nature of science—because they took more courses about evolution, for example—allocate more time to the subject and do a better job of teaching it" (Moore 2002:380-381).

The key in all of this will be to put a precedent on teaching about the nature of science and scientific inquiry. As Janet Gerking (2004) notes:

> Teaching evolution does not just require aligning our curriculum to the National Science Education Standards (NSES) or putting the material in a textbook or unit

> on change and adaptation. Teaching evolution requires us to develop a whole way of thinking among our student population. Understanding the nature of science is fundamental to understanding evolution and understanding theories. We can build our case for evolution throughout the school year, but we cannot change the way our students think about evolution without focusing on the nature of science and working to dispel myths about the word 'theory' itself (ix).

A successful science curriculum that emphasizes the nature of scientific knowledge will include the following fundamental principles and concepts (from Bybee 2004a:33): 1) science is a human endeavor and a way of knowing produced through the use of empirical standards, logic, and skepticism that lead to the best possible explanations about the natural world; 2) scientific knowledge, explanations, and theories must meet the criteria of logical consistency, parsimony, empirical testability and falsifiability, verifiable predictability, and experimental reproducibility in order to be considered valid; and 3) the study of historical perspectives of scientific inquiry show us that though scientific knowledge is progressive, it is also tentative and is subject to change in areas where our understandings are incomplete, and this is where the opportunity for making advances is the greatest. The theory of evolution is one that was shaped by all of the above principles and is supported by over 150 years of evidence (Mayr 2001). It must also be emphasized that theistic evolution, intelligent design, and 'creation science' all share the characteristics of pseudoscience and thus should not replace our scientific understandings of evolution (Pigliucci 2002).

While most of the literature and attention given to the topic of non-acceptance and misunderstanding of evolution has focused on the formal classroom setting, little has been given to informal resources for evolution education and venues like museums, zoos, parks, and aquariums, which Allmon (2011) contends "are more numerous, and arguably, more important for life-long learning" (649). Because most Americans spend the majority

of their lives outside of school, places of informal education like museums must provide meaningful and successful opportunities to hear and learn about evolution (Allmon 2011). Due to the difficulty in changing perspectives on acceptance and understanding of evolution, however, museums also must navigate the same complex issues and implement a comprehensive framework to address religious, social, and psychological barriers and scientific misunderstandings.

Museums, by their very nature, are important institutions where education takes place (Hein 2011). The ancestral style of museum reflects a positivist view of an ordered and rule-governed world that is concerned with the visiting public passively receiving ideas (Russell 1994). The modern style of museum reflects a constructivist view of the world and is concerned primarily with engaging visitors in intellectually active explorations of ideas, emphasizing the active and imaginative dimensions of learning and discovery and providing visitors with a self-directed day out (Russell 1994; Tishman 2009). Modern museums are particularly well suited to foster visitor experiences that utilize active learning and personal agency, two features that tend to result in more meaningful and robust learning (Tishman 2009). In order to learn in the museum, visitors must engage with exhibits in a process of transforming the information into a personal, internalized representation (Russell 1994). According to Terry Russell (1994), the most common and feasible goal of museum learning is conceptual understanding, whereas "the intellectual processes with which we manipulate, organize, and test our knowledge and understanding tend to be neglected by museums, which are more likely to see themselves as information banks."

Museums have enormous potential, though, as sites for learning and have

opportunities to go beyond passively providing information and instead "act across society for the purpose of social justice in a way open to few other institutions" (Hooper-Greenhill 2006:242). If the role of the museum is, as Russell (1994) claims, "to engage, to make contact with existing ideas, in order to further the development of understanding and awareness," and a constructivist educational mission emphasizes social change, then modern natural history museums must embrace their role as public educator and do more to ensure that learning takes place, misunderstandings are supplanted by factual information, and visitors are challenged and presented with open-ended questions, plentiful materials, and alternative possible approaches to inquiry (Hein 2011). Due to the aforementioned failures of the public formal education system, the first time some adults encounter scientifically sound information about evolution may be in natural history museums (Diamond and Evans 2007; Spiegel et al. 2006). Because natural history museums house the objective scientific knowledge and fundamental evidence for evolution, they play an important role in educating the public about it (Diamond and Evans 2007; MacFadden et al. 2007). While the people who choose to frequent natural history museums are much more likely than the general population to endorse evolution as the explanation for change in organisms in the first place, their conceptual understanding and ability to explain evolutionary mechanisms are often guided by misconceptions (Spiegel et al. 2006). If museums are the primary place where many citizens learn about evolution and they house the direct scientific evidence for it, their curators have an obligation to ensure that museum visitors accurately learn the knowledge their exhibits present.

Despite the fact that many natural history and science museums in major

metropolitan areas offer specific exhibits about evolution, several scholars have found that they are not truly effective in invoking conceptual change in accepting and understanding the fundamental concepts of evolutionary theory. MacFadden et al. (2007) found that while a higher percentage of natural history and science museum visitors accepted evolutionary theory than the national population, only about one third of the respondents showed an understanding of natural selection as a framework to explain micro- and macroevolution. Diamond and Evans (2007) found that many museum visitors were able to apply evolutionary principles to some organisms, but the majority understood few concepts of evolutionary theory and were guided by common misconceptions. As for an understanding of human evolution, Evans et al. (2007) found that nearly 40 percent of visitors were reluctant or unable to explain evidence of humans and chimpanzees sharing a common ancestor, and Spiegel et al. (2006) hold that visitors are more likely to hold a human exceptionalist naïve theory of mind and argue more for creationist explanations of human origins than for non-human species.

The number of natural history museums in the United States that house permanent exhibitions specifically on human evolution and variation is miniscule, especially compared to our European and Australian counterparts which boast entire museums on the subject. The first half dozen pages of an online search for "human evolution exhibit" only reveal five museums in the entire country that have permanent human evolution exhibits: the San Diego Museum of Man in San Diego, CA; the Yale Peabody Museum of Natural History in New Haven, CT; the University of Pennsylvania Museum of Archaeology and Anthropology in Philadelphia, PA; the American Museum of Natural History in New York, NY; and the National Museum of Natural History in Washington,

DC. Such exclusion of significant time and space afforded to human evolution is a result of reluctance to offend creationists, apprehension that most people will not accept the evidence for the evolution of humans, and concerns about addressing issues of human diversity like skin color (Marks 1998; Moore 2000). The following research adds to the growing body of literature on natural history museum visitors' understanding of evolution (Diamond and Evans 2007; Evans et al. 2007; MacFadden et al. 2007; Spiegel et al. 2006) but focuses specifically on museum visitors' understanding of human evolution.

PART 2: Research

METHODS

Data were collected over a two-week period from December 3 to December 16, 2012 at the David H. Koch Hall of Human Origins at the Smithsonian Institution's National Museum of Natural History in Washington, D.C. This specific exhibition was chosen because the National Museum of Natural History is among the top ten most visited museums in the world, it is the most visited natural history museum in the world with approximately seven million visitors annually, and it is one of the few museums in the country that houses a permanent exhibition focusing specifically on human origins (Smithsonian Institution 2013; Zafar 2012). First, the exhibit was surveyed for content use of evolutionary concepts and information provided to visitors. In order to comprehend museum visitors' understanding of human evolution and the misconceptions that persisted after visiting the exhibition, it was necessary to identify the observed learning outcomes as demonstrated by museum visitors at the museum site. Exit surveys were administered over the course of five days.

DESCRIPTION OF THE HALL OF HUMAN ORIGINS

Opened on March 17th, 2010, the 15,000-square-foot David H. Koch Hall of Human Origins is based on decades of research by Smithsonian scientists and is the result of international collaboration of over 60 research and educational organizations and over 100 researchers from around the world (Smithsonian Institution 2012). According to Cristián Samper, the director of the National Museum of Natural History at the time of the exhibition opening, the goal of the exhibition "is to provide visitors and online guests with an exciting educational experience that will encourage them to explore for

themselves the scientific discoveries about what it means to be human" (quoted in Smithsonian Institution 2012). Through a combination of wall text, skeletal and facial reconstructions, fossil casts, artifacts, bronze statues, interactive computer screens, and videos, the exhibition invites visitors to explore the relationship of paleoclimate change and human origins, focusing on the emergence of the characteristics that define our species.

While a complete description of the floor plan and features of the exhibition is beyond the scope of this paper, I will briefly touch on the main sections of the Hall here (Appendix A). The exhibition is located on the first floor of the National Museum of Natural History and is accessible from two entrances — one through the Ocean Hall and one from the Mammals Hall. Docents begin guided tours through the exhibition at the Ocean Hall entrance, and the Educator Guide recommends that visitors enter through this access as well because "chronologically and conceptually, the displays are easiest to follow from this direction" (Smithsonian Institution 2010). Upon entering the exhibition from the Ocean Hall through the Time Tunnel, visitors "travel through time" and are presented with a mural depicting hominid ancestors and a video inviting them to explore the evidence for human evolution inside the Hall (Figure 2).

Figure 2: Composite view from the entrance of the Time Tunnel. Visitors are presented with a mural of hominid ancestors to the left and a video to the right. Copyright: Smithsonian Institution.

From the very beginning of the exhibition, dramatic shifts in Earth's climate and

the human traits that emerged during times of extreme climate shifts are highlighted as paramount. Beyond the Time Tunnel, visitors are presented with a silent projection of a presentation on a partition wall titled "Humans Evolved in Response to a Changing World" which describes how Earth's changing climate over millions of years drove human evolution. Beyond the partition, visitors have the option of going a more genetic route to the left to the "Where Are You on the Human Family Tree?" and "How Are You Related to Other Living Things?" displays, the former providing a timeline of hominid history and introducing the genera *Ardipithecus*, *Australopithecus*, *Paranthropus*, and *Homo* and the latter providing the genetic similarities of humans to various organisms like banana trees, chickens, and mice as well as to primates like rhesus monkeys, orangutans, gorillas, and chimpanzees. On the left side of the hall following these genetic displays, visitors can browse answers to their questions about human evolution at the "What Do You Want to Know About Evolution?" station which provides frequently asked questions and answers about the process of evolution, evolutionary advancements since Darwin, radiometric dating, and the coexistence of the concept of evolution and religious faith.

The alternative option for visitors entering the exhibition is to turn to the right to a partition labeled "What Does It Mean To Be Human?" outlining defining human characteristics in a corner containing a Lucy reconstruction and a replica of the Laetoli footprints (Figure 3). The wall text next to Lucy describes that her species *Australopithecus afarensis* survived for over 900,000 years and adapted to the widely fluctuating climate between wet and dry and cool and warm and living arboreally as well as using bipedal locomotion. The wall text and display above the Laetoli footprints

invites visitors to compare their stride with that of *A. afarensis* who left the fossilized footprints and think about the physiological requirements for bipedal locomotion.

Figure 3: Upon entering the Hall, visitors may turn right to this corner display outlining the defining characteristics that make us human, showing a lifelike reconstruction of Lucy, and inviting visitors to walk in the footsteps of their ancestors on a replica of the Laetoli footprints. Copyright: Smithsonian Institution.

Following this display on the right side of the Hall, visitors can explore the progression of and fossil evidence for six major milestones in human evolution (Figure 4). These milestones include: 1) upright posture and bipedal locomotion; 2) using tools; 3) physical adaptations to diverse climates and diets; 4) large and complex brains; 5) social life for group survival; 6) and creative and symbolic expression. Evidence and information are presented through various mediums including wall text, videos, fossil remains, and other artifacts. Each of the milestones displays emphasizes the relationship of changing environments and such physical and cultural adaptations that helped human ancestors survive and thrive in a variety of unpredictable environments. Many of these

displays present some of the detriments of possessing these adaptations, indicating the cost-benefit aspect of evolution.

Figure 4: A view of several milestones in human evolution displays. A combination of wall text, illustrations, videos, and artifacts provide explanations of the evolution of and evidence for defining human traits. Copyright: Smithsonian Institution.

Parallel to the human characteristic displays on the right are three interactive media displays titled "Snapshots of Survival" that present visitors artifact replicas and lead them through the process of using the fossil evidence to make hypotheses about scenes from the past. The artifact replicas and casts present evidence for a *Paranthropus robustus* individual falling prey to a leopard in Swartkrans, South Africa; the butchering of an elephant by *Homo erectus* in Olorgesailie, Kenya; and a *Homo neanderthalensis* burial in Shanidar Cave, Iraq (Figure 5). Near these displays, the "Smithsonian Research Station" provides information about current Smithsonian Human Origins Program research initiatives in East Africa and northern China. In addition, fossil artifacts and soil

samples are on display explaining how radiometric dating is used to discover the age of fossils.

Figure 5: The Olorgesailie interactive media display allows visitors to select fossil evidence and use it to create a scene from the past and hypothesis about what took place. Copyright: Smithsonian Institution.

The "Meet Your Ancestors" section of the Hall is situated in the angular vertex of the L-shaped hall. The display titled "Six Million Years of Human Evolution" presents a wall of over 75 fossil skulls from 15 different hominid species and invites visitors to compare fossils of different species and explore through several potential phylogenic trees how the species are related to each other based on variations, differences, and similarities among the fossil skulls. The display of an original fossil Neanderthal skeleton encourages visitors to examine how anthropologists are able to determine age, sex, diet, and injuries from fossil remains. The ever-popular "Morphing Station" allows visitors to see what they would look like as one of eight early human species and is accompanied by John Gurche's nearby head reconstructions of the same species.

The “Changing the World” section of the Hall focuses on how our species became the sole surviving human species through adaptations that allowed modern humans to navigate some of the environmental challenges that Neanderthals could not. The entire left side of this section is devoted to information about how modern humans became so successful, beginning with the advent of agriculture, leading to the formation of cities, and eventually allowing humans to migrate to every climate and populate nearly every region on earth (Figure 6). This section ends with information about the unintended consequences of technological progress and the new survival challenges that we have created for our species, and visitors are invited to play two games depicting several imaginary survival challenges that teach about adaptation and extinction and emphasizing that our species continues today and will continue in the future to evolve in response to our changing environment.

Figure 6: A media display in the “Changing the World” section showing an estimation of the rapidly increasing human population in real time and the range of our species worldwide. Copyright: Smithsonian Institution.

The section titled “One Species, Living Worldwide” displays casts of fossil skulls of the earliest known members of our species from six continents, providing evidence for when our species may have migrated to various parts of the world. An accompanying five-minute video explores the origins of modern humans in Africa by 200,000 years ago and details the migrations that members of our species took out of Africa to populate five other continents. The video emphasizes that every human living today has a shared genetic history, and despite differences in skin color and other physical characteristics, the DNA of all humans is 99.9% identical.

The final display of the exhibition before exiting to the Mammal Hall is titled “Our Ape Heritage,” exploring the physiological characteristics and genetic similarities that humans share with other apes. Information about the endangerment or near extinction of our close ape relatives like orangutans, gorillas, chimpanzees, and bonobos emphasizes the role of naturally and human-caused climate change and habitat loss. Visitors are invited to touch replicas of extinct apes that may represent the last common ancestor of humans and living apes and exit the Hall after passing through similar fossil skull casts of several hominid species. Visitors who enter the Hall from this side thus experience the aforementioned sections and displays in reverse order as described above; are posed with the question of how humans are different from other apes, primates, and mammals; and are invited to explore the characteristics that make us human and how humans evolved over six million years during periods of drastic climate change.

SURVEY

A survey was developed to gauge visitors’ understandings of human evolution after going through the exhibition (Appendix B). Two of the questions were demographic

asking participants their age and country of residence. One partial open-ended question presented statements about personal beliefs about human origins modified from the Gallup Poll. Four questions dealt with self-reported levels of understanding and evolutionary education. Nine scaled questions presented statements about human origins that were designed to determine the degree to which participants thought the statements were true as they pertained to biological evolution (the explanations of which are present in the Hall). The last three questions were open-ended and were designed for visitors to explain evidence and evolutionary processes pertaining to human evolution.

PARTICIPANTS

Adult visitors were approached as they exited the exhibition towards the Mammal Hall. Participation was solicited with the phrase, "Excuse me, I am collecting data for my senior thesis. Do you have about 10-15 minutes to take a survey?" Those who refused cited several common reasons: not interested, did not have time, or did not speak English. Because of the lack of extra researchers, rate of rejection was not recorded. Visitors with small children were not approached to participate in the survey. I had approached several visitors with small children in the first few days of data collection but was met with rejection due to lack of time and inability to spend the necessary amount of time to complete the survey with a small child eager to see the taxidermic animals visible in the Mammal Hall. Ninety-six museum visitors participated in the exit survey. All subjects gave written consent, acknowledged the risks associated with participation, and took part under the assurance of confidentiality.

RESULTS

AGE

The majority of participants were in their 20s (n = 56). The age breakdown of participants is as follows: 6% were less than 20 (but greater than age 18), 58% were in their 20s, 13% were in their 30s, 8% were in their 40s, 11% were in their 50s, and 3% were in their 60s or older.

GEOGRAPHIC DISTRIBUTION

Most participants lived in the United States (n = 79). The remaining participants lived in one of ten other countries (Figure 7). There were countless other visitors who likely lived outside of the United States, but their lack of representation as participants is likely due to inadequate English language skills.

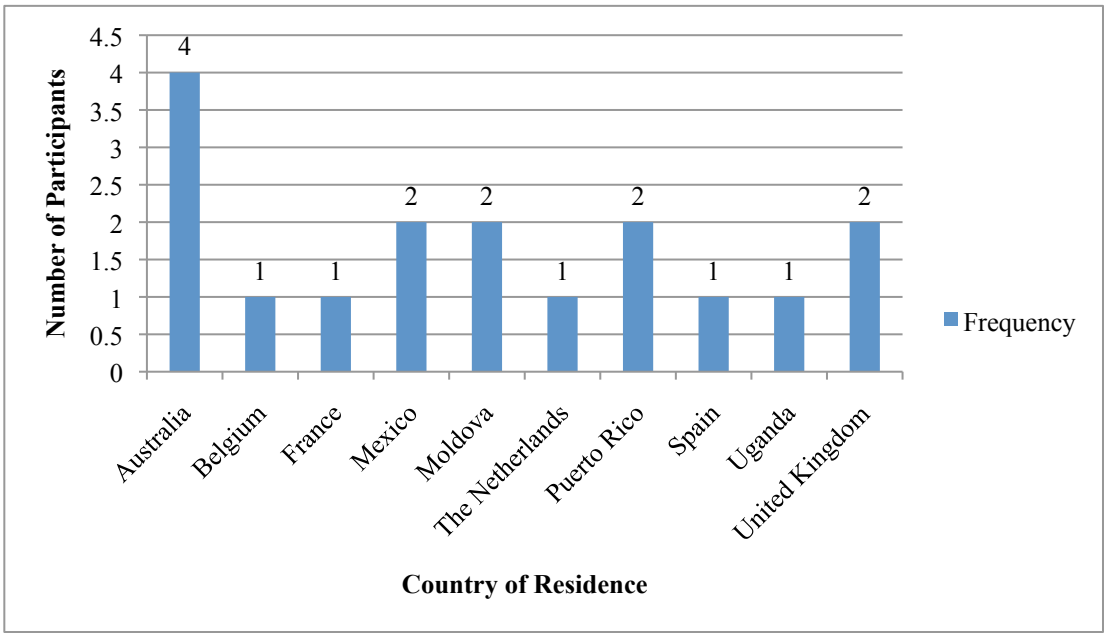

Figure 7: Frequency of foreign participants and their countries of residence.

FORMAL AND INFORMAL LEVELS OF EVOLUTION EDUCATION

Participants were asked to rate their levels of formal and informal education about evolution (Figure 8). For formal evolution education, 25% of participants rated their level

as minimal, 66% of participants rated their level as moderate, and 9% of participants rated their level as extensive. For informal evolution education, 32% of participants rated their level as minimal, 55% of participants rated their level as moderate, and 13% rated their level as extensive.

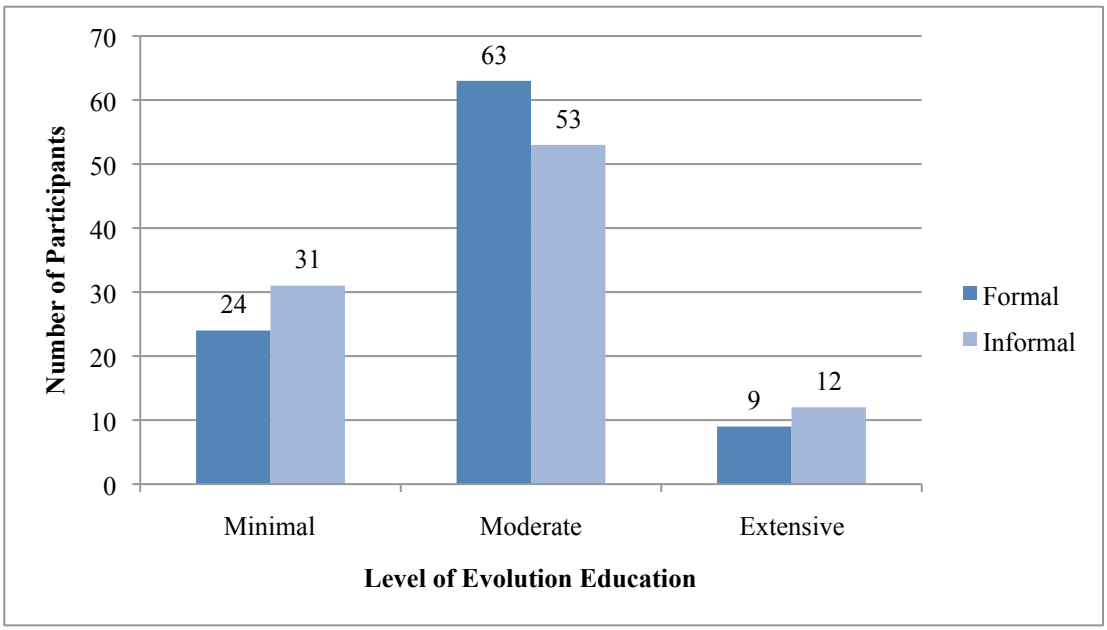

Figure 8: Participants' levels of formal and informal evolution education.

SOURCES OF INFORMAL EVOLUTION EDUCATION

Participants were asked to choose the informal source(s) of their evolution education (Figure 9). Museums were the second most common source of participants' informal evolution education, behind films/TV for which some participants provided examples like National Geographic, Discovery Channel, History Channel, NOVA, documentaries, and other educational and popular programming.

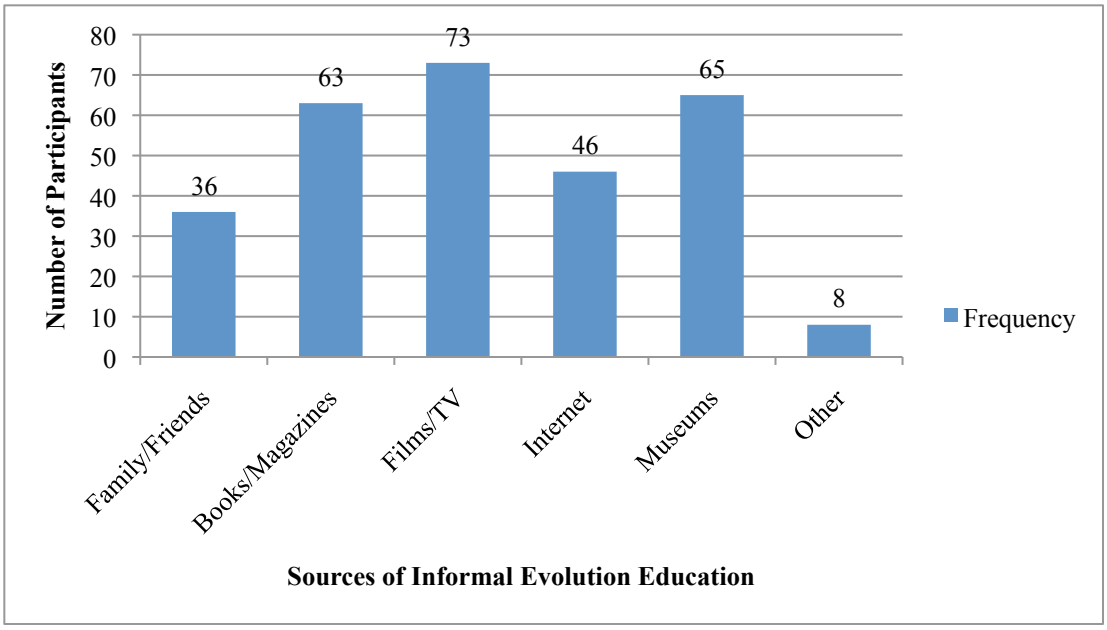

Figure 9: Sources of participants' informal evolution education.

ACCEPTANCE

Participants were asked to choose from three statements that most aligned with their personal beliefs about human origins (Figure 10). The statements were taken from the Gallup Poll and modified to be more inclusive of non-denominational/agnostic spirituality. Four participants indicated "Other." Of the remaining participants, 49% indicated "Humans have developed over millions of years from other forms of life without the involvement of a creative force" (hereafter referred to as "secular evolution"); 37% indicated "Humans have developed over millions of years from other forms of life, but God or a creative force guided the process" (hereafter referred to as "theistic evolution"); and 9% indicated "God or a creative force created humans in their present form at one time within the last 10,000 years" (hereafter referred to as "young earth creationism"). Overall, the participants who did not live in the United States had a higher rate of acceptance of secular evolution (65%).

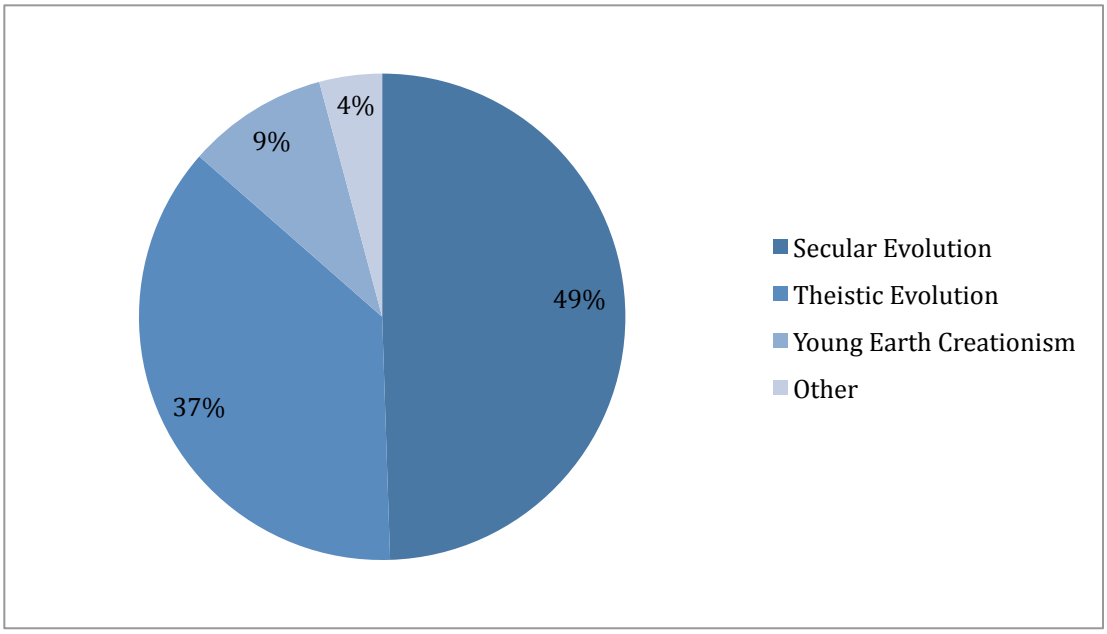

Figure 10: Participants' beliefs about human origins.

UNDERSTANDING

Visitors were asked to mark the degree to which they thought nine statements were true as they pertained to the principles of biological evolution as the basis of human origins (Table 1). These questions were designed to reveal visitors' knowledge and understanding of the principles and processes of evolution regardless of their personal beliefs about human origins. Each of the questions pertained to information and themes presented multiple times throughout the Hall of Human Origins.

Table 1: Survey questions and responses pertaining to the principles of biological evolution as the basis of human origins. Percentages corresponding to the correct answers are shaded in blue.

Survey questions 8-16:	*Not at all*	*Somewhat*	*Very Much*
Human ancestors evolved.	4.17%	15.63%	80.21%
Human ancestors evolved during periods of drastic climate change.	4.17%	29.69%	66.15%
New traits or behaviors that have arisen in human populations are never detrimental.[1]	44.79%	44.79%	9.38%

[1] This question was suggested to me by the director of the Human Origins Program. In retrospect, I likely would have rephrased the question to eliminate the double negative.

Modern humans and chimpanzees share a common ancestor.	12.5%	27.08%	60.42%
Our species *Homo sapiens* most likely originated in Africa.	7.29%	27.08%	64.58%
Species like *Australopithecus afarensis* (the famous "Lucy" fossil skeleton) are our species' extinct relatives.	7.29%	42.71%	48.96%
Living human populations are still evolving.	8.33%	21.88%	68.75%
Modern humans represent the pinnacle of evolution.	42.71%	35.42%	20.83%
Human ancestors intentionally evolved in response to the need to survive.	32.29%	21.88%	45.83%

Visitors' answers to these questions pertaining to information presented in the exhibition and their understanding of the principles of evolution as the basis of human origins were scored for accuracy, with each question being worth one point for a correct answer, 0.5 for the answer of "Somewhat," or zero for an incorrect answer (Figure 5). The average score for all participants was 71%. Because the number of non-US resident participants was so low, it was not possible to identify if there was a significant difference between the average score for those participants who lived in the United States and those who did not. Relationships were found, however, between acceptance and understanding. A moderate positive direct relationship was found between belief and understanding ($r = 0.6398$, $p = 5.84699E^{-12}$), with those who accepted secular evolution scoring on average 79%, those who accepted theistic evolution scoring on average 70%, and those who accepted young earth creationism scoring on average 41%.

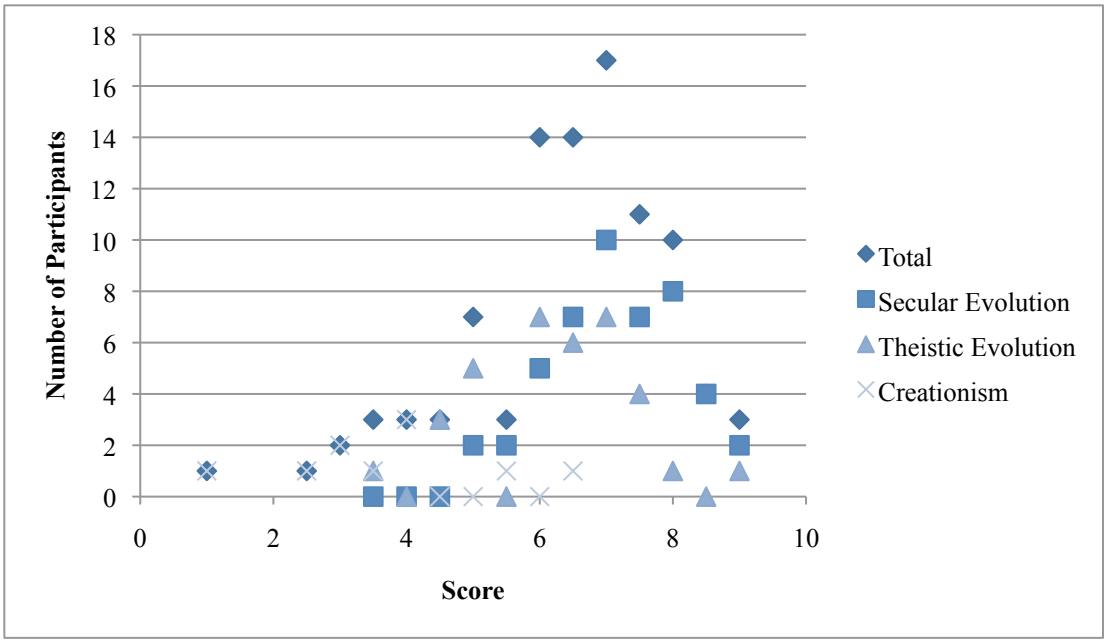

Figure 11: Distribution of visitors' scores for understanding of evolutionary concepts.

Results indicate that visitors held several misconceptions about evolution: adaptations somewhat or very much arise in response to need or an intentional effort to change by individuals (68%), modern humans somewhat or very much represent the pinnacle of evolution (56%), and new traits that arise in populations are somewhat or very much never detrimental (54%). Less drastic but still important misconceptions include species like *A. afarensis* are somewhat or not at all our species extinct relatives (50%), humans and chimpanzees somewhat or not at all share a common ancestor (40%), humans somewhat or not at all evolved during periods of drastic climate change (34%), our species somewhat or not at all most likely originated in Africa (34%), and living human populations are somewhat or not at all still evolving (30%).

Nearly all participants completed the final three open-ended questions, but due to time restrictions, answers were not coded for use of evolutionary concepts or screened for misconceptions.

DISCUSSION

Overall, participants were much more likely to accept secular evolution than the greater American population. Additionally, personal beliefs about human origins and the rejection of secular evolution coincide with decreasing levels of understanding of human evolution and evolutionary concepts. It is important to keep in mind here, however, that correlation does not necessarily indicate causation. The correlation of the variables of personal beliefs about human origins and understanding of human evolution may or may not have a causative connection, and it is not feasible in this case to tease out which is the dependent or independent variable. The relationship found between the two variables is interesting, nonetheless, and provides some insight into how beliefs influence understanding and perhaps vice versa. Correlation tests were not conducted between other variables (age, reported level of understanding, levels of formal and informal evolutionary education) but would likely also provide interesting insights.

Large percentages of participants' answers indicated that they held common misconceptions about evolution after viewing the exhibition. This is undoubtedly a function of the constructivist museum, whereby visitors engage in varying degrees self-guided learning that does not necessarily fulfill the ideal learning objectives of the curator. Moreover, some could argue that the fact that visitors chose to even frequent the exhibition out of their own volition is a victory in and of itself. If the goal of the exhibition is to encourage visitors to explore the evidence for human evolution, that goal has been accomplished as soon as a visitor steps through the Time Tunnel.

I contend, however, that given the prestigious role of the Museum as an informal public learning institution and because it is one of very few museums that houses such a

comprehensive and large permanent exhibit on human evolution, the Museum has a social responsibility to close the gap between those visitors who leave the exhibition retaining grievous misconceptions about human evolution. Simply sparking a conversation is not enough. That over half of participants held misconceptions about the evolutionary processes of adaptation indicates an area where the Museum can incorporate more accessible evolutionary information to increase scientific literacy among visitors. Additionally, that fewer percentages of participants held misconceptions about information on human evolution that the exhibition presents multiple times indicates that visitors are missing or are not committing to memory the central themes of the exhibition. Certainly, the Hall of Human Origins is commendable in many ways. Its sheer size and number of artifacts alone is unparalleled. Its presentation of information about the vast timeline of human evolution, the mosaic quality of the evolution of human traits, and the role of climate and environmental change in human evolution are all unmistakable repeated themes throughout the exhibition.

While there are very positive aspects to the exhibition, I have identified three areas where the curators should consider change. First of all, I believe the exhibition—and perhaps even the entire Museum—is lacking in a thorough explanation of the processes of evolution in general and in particular the cause of variation and the process of natural selection. One of the original tenets of evolutionary biology, explanations of differential survival and reproduction should be prominent in an exhibition such as this in a natural history museum founded on the notion that evolution—and thus the processes that drive it—is at the heart of biological knowledge. This holds even more true considering the opportunity the Museum has to educate visitors who have likely been

failed by the formal education system in learning the central concepts of evolutionary biology. Though colloquially referenced at least several times within wall text, there is no prominent definition of the process of natural selection. Phrases like "Any new traits that increased their ability to meet these basic needs increased their chances of survival" hint at variation and natural selection, but without an explanation of the sources of variation within a population or the driving force of natural selection, visitors may not possess a complete understanding of evolutionary change (from the "What Does it Mean to Be Human?" partition at the beginning of the exhibit). The "What Do You Want To Know About Evolution?" interactive computer display does answer the question "How does evolution work?" but it is easily missed by visitors who do not stop at the station or click through several screens to discover the answer (Figure 12). While its explanation is basic yet complete, it commits the second flaw that should be addressed.

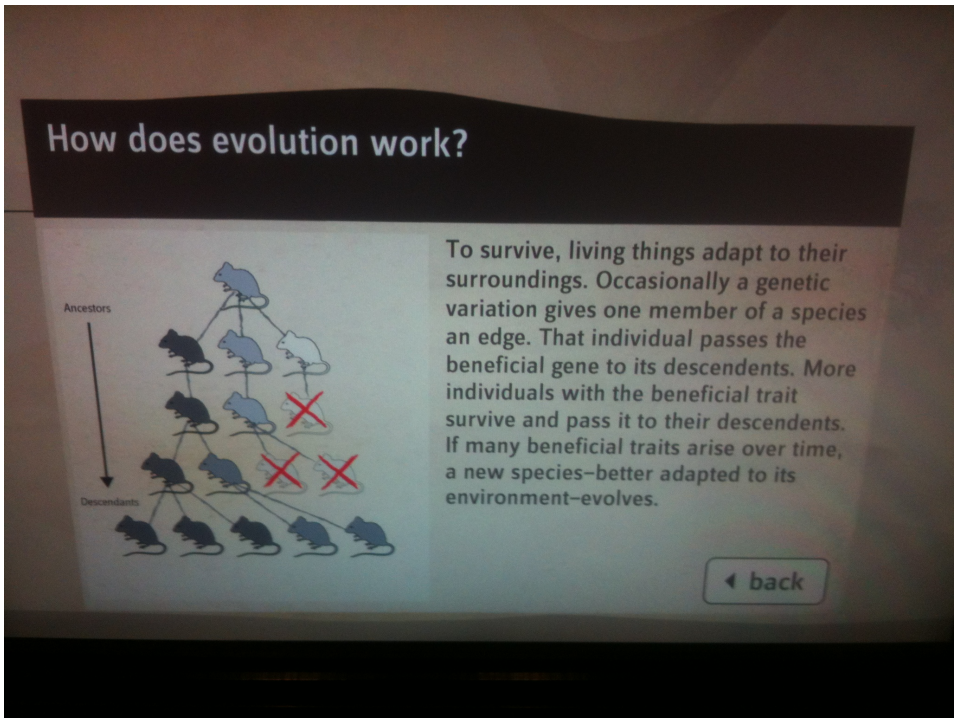

Figure 12: An explanation of how evolution works (via the alluded to processes of mutation and natural selection) in the "What Do You Want To Know About Human Evolution?" interactive display. Copyright: Smithsonian Institution.

The exhibition's use of colloquial language to explain adaptation in particular is problematic. While on the surface it appears to provide an explanation of complex processes to visitors who may have had no previous exposure to them, upon closer examination, the language has the potential to promote teleological reasoning. Phrases like "To survive, things adapt to their surroundings" (from the "How does evolution work?" page of the "What Do You Want To Know About Human Evolution?" interactive display) or "They adapted by evolving traits that helped them survive" (from the "Humans Evolved in Response to a Changing World" partition) slips dangerously into the possibility of visitors interpreting human evolution teleologically—that organisms have some kind of self-directing or goal-oriented function. The above statements could lead visitors—and in fact, it likely did lead nearly 70% of participants—to believe that human ancestors intentionally evolved in response to the need to survive. Additionally, it is important for the Hall to differentiate between biological and cultural adaptation due to the issue of agency (or lack thereof) inherent in the two.

The third aspect of the exhibition that I find problematic are the interactive computer games in the "Changing Our World" section. While the intention of the games is to allow visitors to imagine what the future of our species might entail and to encourage visitors to think about the ways in which humans are very much still evolving, they have the potential to perpetuate misconceptions about human evolution instead of challenge them and allow the visitor to "play God" so to speak. The game called "Keep your Species Alive" challenges players to make choices about an imaginary population of humans as they face different survival challenges. According to the Educator Guide, the game teaches visitors that our species' survival "depends in part on how adaptable we are

and how well we cooperate with each other" (Smithsonian Institution 2010). This speaks to the above point about the emphasis of agency inherent in cultural adaptations but ignores the passivity involved in biological adaptations. The other game "Imagine Your Descendants" is even more problematic, allowing the visitor to control outrageous hypothetical environmental situations to determine what future humans might look like by manipulating how different body parts might evolve (Figure 13). While there is certainly entertainment value in such a game, uncritical visitors might mistakenly take the game seriously as one with scientific merit. Without a proper explanation and understanding of the processes by which new adaptations arise, the game takes on an extremely Lamarckian angle, positing that as humans become more lazy and sedentary, their arms will become long so they can reach across the room without having to get out of a chair. Additionally, the game teaches that individuals can acquire adaptations during their lifetimes that, though not explicitly stated as such, could be assumed to be heritable.

Figure 13: Screen from the "Imagine Your Descendants" game. In this example, I created a human with green arms from toxic waste and knobby leg joints. Copyright: Smithsonian Institution.

Due to the nature of a modern constructivist museum and because of the limitations of public informal education in general, making realistic changes to existing permanent exhibitions like the Hall of Human Origins is not only contingent on funding but also on the anticipated impact and message that doing so will produce. Acknowledging the problematic aspects of the exhibition above, however, and making low-scale changes could drastically improve the educational value of the visitor experience. While the comprehensiveness and prestige of the Hall of Human Origins is an excellent model for providing informal educational opportunities for an otherwise educationally-disadvantaged population, future curators should take into consideration the consequences of excluding concrete explanations of evolutionary processes, using colloquial language that appeals to naïve intuitions but not scientific understandings of human evolution, and creating games that perpetuate common misconceptions. Future research in this area should focus on the cognitive and developmental relationship between beliefs and knowledge acquisition. Teasing out how personal beliefs about human origins influence a person's understanding of the science behind it and vice versa is critical. Additionally, more research on successfully invoking conceptual change is integral for the future of evolutionary education in this country. Finally, we need more learning research that takes advantage of experimental opportunities inherent in a museum setting.

Future research specifically conducted at the Hall of Human Origins should examine the contexts under which the exhibition was constructed and the significance of the role of David H. Koch in providing the majority of the funding for the exhibition. It would also be interesting to investigate the role of the Broader Social Impacts Committee

in informing aspects of the exhibition and public programming through the Museum. Furthermore, future researchers—given more time, funding, and research capacity—can examine the countless aspects of the exhibit to which I could not afford sufficient analysis.

CONCLUSION

I stress that the view of 'science' which informs this article is very broad; it is a view of science as being about understanding objects and phenomena in the world that we all inhabit. In a sense, such learning is not optional: it has adaptive value and is inescapable, for it is only through knowing enough about how the physical world works that each individual can survive.
— Terry Russell, 1994

This research makes an important contribution to the discipline of anthropology and joins the growing body of literature regarding natural history museum visitors' understanding of evolution. While previous studies have focused on a general understanding of evolution, this research is a comprehensive study focusing specifically on natural history museum visitors' acceptance and understanding of human evolution. Through a combination of cognitive and museum studies, one can begin to understand the gap in evolutionary knowledge acquisition, conceptual change, and learning outcomes in the museum. Surveys completed by museum patrons have led to a more complete understanding of the misconceptions prohibiting visitors' ability to accept and understand the central tenets of human evolution. It is essential to address these misconceptions immediately if large-scale conceptual change is to take place. Understanding the processes behind human origins is imperative for a holistic understanding of what it means to be human, recognizing our place in nature, and realizing the way in which the world operates.

Without question, our country must increase educational support for the teaching of evolution. Opponents to evolution and those in favor of "teaching the controversy" will never be able to reconcile their personal beliefs with scientific pedagogy until their predisposed naïve intuitions that lead to common misconceptions are supplanted by evolutionary knowledge based in evidence and factual support. While this is certainly

most effective when introduced at a young age, we must first encourage drastic conceptual change by the parents, educators, and policy makers whose actions and beliefs all influence how children conceive of the world. Anthropologists, museum educators, and educational policy makers have an obligation and social responsibility to present the fundamental evidence for human evolution especially in a globalizing world where our citizens and children are falling behind in scientific achievement and understanding. Furthermore, an adequate understanding of our species' place in nature is essential for making crucial decisions involving climate change, mitigating epidemic disease, and creating a sustainable planet for generations to come.

Because of its prestige as an informal learning institution, the museum plays an important role in educating the public, and particularly, adults. Museums house the objective and fundamental scientific evidence and knowledge about human evolution, and thus their curators and educators have an obligation to ensure that visitors are encouraged to challenge their preconceived misconceptions about human evolution and in so doing, gain a more informed understanding of it. This is essential if we are to expect the wider public to think critically about what it means to be human, understand the intrinsic relationship between all forms of life, or realize that we occupy a particular place in the world.

The results of this research have not only shed light on the ways in which museum exhibitions can be reconsidered in order to more effectively teach visitors about human evolution but also how anthropologists can disseminate this knowledge to a wider public in a more effective way. This research joins the growing literature on what museum visitors do and do not understand and effectively learn from exhibitions that

provide information about and evidence for human evolution. Curators and scholars alike have an obligation to present the fundamental evidence for human evolution, both in museums and academic literature, to the general public as well as to policy makers so that future generations of children will not be denied the opportunity to learn about what makes us distinctly human, how our species originated, how we as a species continue to change, or how we at once shape and are shaped by the world around us.

APPENDIX A

Hall of Human Origins exhibition floor plan (Smithsonian Institution 2010):

APPENDIX B

Copy of Museum Visitor Questionnaire

Museum Visitor Questionnaire

Visitor Profile and Background Information

1. **Age (please circle)**
   <20 20s 30s 40s 50s 60s 70s >70
2. **In which country do you live?** _____
3. **Which of the following statements most align with your personal beliefs about human origins? (Check all that apply)**
   - ☐ God or a creative force created humans in their present form at one time within the last 10,000 years.
   - ☐ Humans have developed over millions of years from other forms of life without the involvement of a creative force.
   - ☐ Humans have developed over millions of years from other forms of life, but God or a creative force guided the process.
   - ☐ Other: _____
4. **How would you rate your level of understanding of the essential principles of biological evolution as the basis of human origins?**
   Minimal Moderate Extensive
5. **What degree of formal education (from schooling) have you received on the principles of biological evolution as the basis of human origins?**
   Minimal Moderate Extensive
6. **What degree of informal education (from outside of school) have you received on the principles of biological evolution as the basis of human origins?**
   Minimal Moderate Extensive
7. **What were the sources of this informal education? (Check all that apply and provide examples if possible)**
   - ☐ Family/Friends: _____
   - ☐ Books/Magazines: _____
   - ☐ Films/TV: _____
   - ☐ Internet: _____
   - ☐ Museums: _____
   - ☐ Other: _____

Based on your visit to the Hall of Human Origins, please mark the degree to which you think the following statements are true as they pertain to the principles of biological evolution as the basis of human origins:

8. **Human ancestors evolved.**
   Not at all Somewhat Very much
9. **Human ancestors evolved during periods of drastic climate change.**
   Not at all Somewhat Very much
10. **New traits or behaviors that have arisen in human populations are never detrimental.**
    Not at all Somewhat Very much
11. **Modern humans and chimpanzees share a common ancestor.**
    Not at all Somewhat Very much
12. **Our species *Homo sapiens* most likely originated in Africa.**
    Not at all Somewhat Very much
13. **Species like *Australopithecus afarensis* (the famous "Lucy" fossil skeleton) are our species' extinct relatives.**
    Not at all Somewhat Very much
14. **Living human populations are still evolving.**
    Not at all Somewhat Very much
15. **Modern humans represent the pinnacle of evolution.**
    Not at all Somewhat Very much
16. **Human ancestors intentionally evolved in response to the need to survive.**
    Not at all Somewhat Very much
17. **List at least two (2) things that you learned today from the Hall of Human Origins.**
    _____
    _____
    _____
    _____
    _____

Please answer the following questions as precisely as you can using the principles of biological evolution, regardless of whether you personally believe this explanation:

1. **List the kinds of evidence that scientists use to understand human evolution.**
   _____
   _____
   _____
   _____
   _____
2. **There is evidence for the coexistence of modern humans (*Homo sapiens*) and at least three other species of early humans that later became extinct (*Homo erectus, Homo neanderthalensis,* and *Homo floresiensis*). Explain, as if to a friend, how modern humans persisted unlike the three other species.**
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____
   _____

Thank you for your time. Please return this questionnaire to the researcher.

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