NATURAL HISTORY MUSEUM

# Evolution

## a public engagement literature review

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# Executive summary

This paper explores what people know and understand about evolution and their attitudes to it. It examines some of the issues raised in the learning research literature, and highlights implications and recommendations for our practice in engaging NHM audiences in learning about evolution

There are several key points emerging.

- Although many people in the UK are persuaded by the science of evolution by natural selection, there is evidence that a significant minority are not. For example, a recent poll (Ipsos MORI, 2014) found that while 41 per cent of people in the UK believe in evolution, one-fifth (19 per cent) have a creationist viewpoint, saying that 'humans and other living things were created by god and have always existed in their current form'.
- There is evidence of many misconceptions among public audiences about what evolution is and how it works, eg that evolution applies to other species but not humans, and that evolution is a linear progression, a process that enables species to improve over time.
- Research in psychology shows us that many of the central ideas of evolution run counter to the way humans think about the world around them.
- Some misunderstandings arise because of conflict between technical (scientific) and everyday usages of the same word, such as 'theory' for example.
- Many people in the UK think that creationist perspectives should be taught in science lessons alongside scientific accounts of evolution (Ipsos MORI, 2009).

The implications of these findings for our engagement practice include that we should:

- focus on presenting an evidence-based case for evolution rather than attempt to overturn people's religious beliefs
- provide situations in which our audiences can examine their prior conceptions about evolution, and discuss and test them
- directly engage with people's misconceptions about evolutionary concepts
- be very careful about the language we use when explaining evolution
- present science as a process of critical thinking and a robust way of generating reliable explanations of natural phenomena.

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# 1 Introduction

The purpose of this paper is to inform Natural History Museum (NHM) colleagues about research on the public's awareness, knowledge and understanding of, and their attitudes towards, evolution and successful ways of engaging the public with the subject. This is a living document that will be updated frequently.

Evolution underpins much of the Museum's scientific work and, together with sustainability and biodiversity, forms one of the core narratives upon which the Museum's work in both science and public engagement is organised.

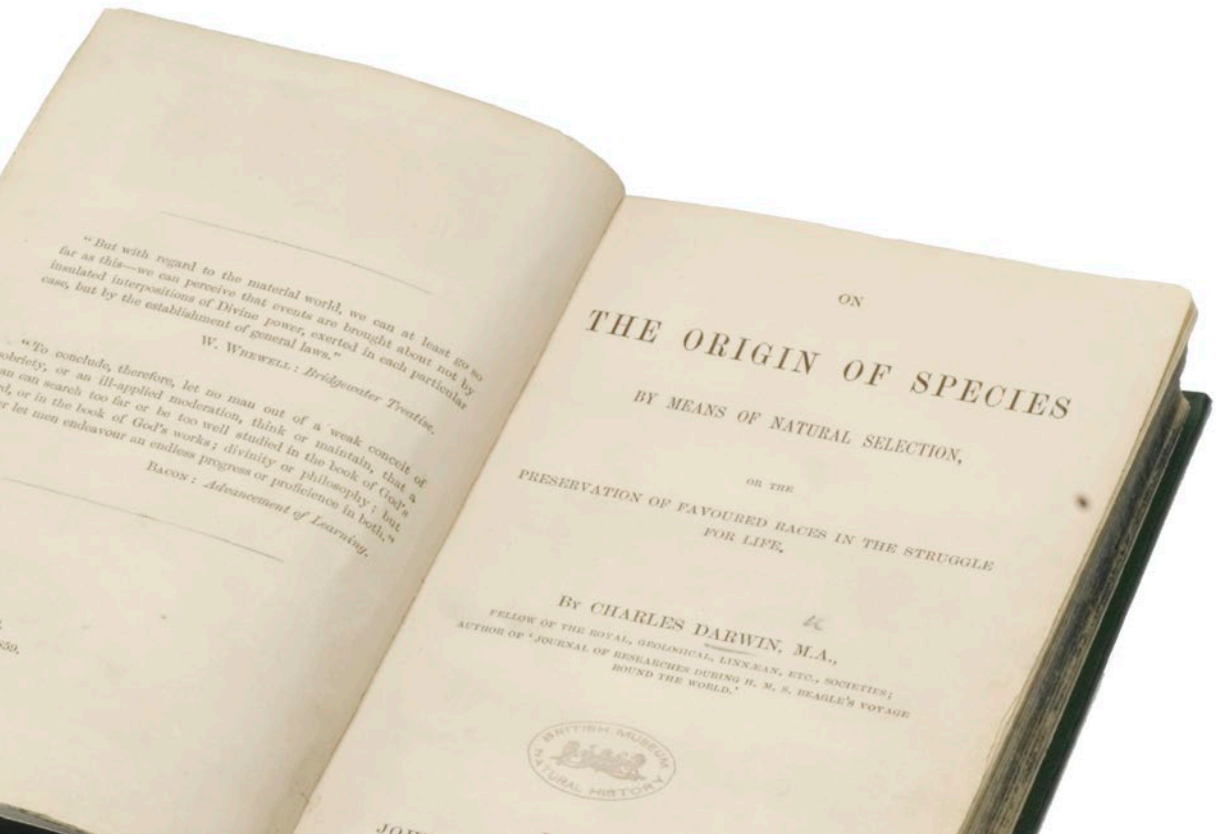
"Biological evolution is one of the most important ideas of modern science. Evolution is supported by abundant evidence from many different fields of scientific investigation. It underlies the modern biological sciences."

National Academy of Sciences and Institute of Medicine, 2008

The NHM position statement on evolution states that:

**"The Museum's policy for public engagement is to present the theory of evolution as the best explanation, which is supported by rigorous scientific examination, of the on-going generation of the diversity of life on earth"** and **"We strongly endorse the teaching of the theory of evolution in UK schools as a core part of the science curriculum and we use the Museum's assets to support this."**

**Natural History Museum, 2015**



# 2 Definitions

The following are key terms and concepts that Museum visitors will encounter when engaging with and learning about evolution.

- **Evolution:** Change in the hereditary characteristics of groups of organisms over the course of generations (Darwin referred to this process as 'descent with modification')
- **Species:** In general, a group of organisms that can potentially breed with each other to produce fertile offspring and cannot breed with the members of other such groups
- **Variation:** Genetically determined differences in the characteristics of members of the same species
- **Natural selection:** Greater reproductive success among particular members of a species arising from genetically determined characteristics that confer an advantage in a particular environment

  National Academy of Sciences, 1998

Coley and Muratore (2012) describe the logic of natural selection in the following way.

Four facts:

1. Populations have the potential to expand exponentially (superfecundity).
2. Natural resources are limited and constant (resource limitation).
3. Individuals vary, populations vary enormously (trait variation).
4. Much of this variation is heritable (trait heritability).

Three inferences:

1. There is a fierce struggle for existence, and only a few succeed.
2. Survival is not random but depends upon the hereditary constitution of succeeding individuals in the process of natural selection.
3. Over generations, natural selection produces gradual change in the population and the production of new species.

For those wanting a brief and straightforward summary of Evolution, Gregory provides a good introduction especially to natural selection: as well as a review of many of the common misconceptions about it. (Gregory T.R. 2009).

# 3 Knowledge and attitudes towards evolution

While many people in the UK are persuaded by the science of evolution by natural selection, there is evidence that a significant minority are not. For example, a recent poll in the UK (Ipsos MORI, 2014) found that:

- two-fifths (41 per cent) of people in the UK believe in evolution, agreeing that 'humans and other living things evolved over time by natural selection, in which god played no part'
- just over one-quarter (26 per cent) of people in the UK think evolution happened as 'a process guided by god'
- one-fifth (19 per cent) of people in the UK take a creationist viewpoint, saying that 'humans and other living things were created by god and have always existed in their current form.'

An earlier UK-based survey (Spencer and Alexander, 2009) found that:

- 37 per cent of people believe that Darwin's theory of evolution is 'beyond reasonable doubt'
- 32 per cent say that Young Earth creationism ('the idea that God created the world sometime in the last 10,000 years') is either definitely or probably true.

Much of the attitudinal research and learning-focused literature originates in the USA. The US literature also indicates significant resistance to the idea of evolution by natural selection and that the US public understanding of evolution has changed little over the last 25 years (Gallup, 2007) and that resistance to evolutionary explanations remains as strong as ever. Key findings include that:

- around 30 per cent of people in the US believe that 'humans and other living things have existed in their present form since the beginning of time' (Pew Research Center, 2013)
- only 16 per cent of the US public accept that humans evolved from an earlier species (Gallup, 2007; Coyne, 2009)
- visitors to natural history museums are more likely to accept evolution than the general public are (Storksdieck, 2006).
- Research (Tare et al. 2011) has shown that families visiting natural history museums tend to spend less time at Human evolution exhibits than at non-Human evolution exhibits.
- Evans et al.(2009) found that visitors were more likely to reference evolutionary explanations when discussing non-Human animals, but were more likely to prefer creationist explanations when talking about Humans.

Studies of children's attitudes and understanding of evolution in the USA have also found resistance:

- younger elementary school children are quite resistant to the idea that one 'kind' of animal could be the ancestor or descendent of a completely different kind (Evans, 2000a)
- regardless of parental beliefs, US 8- to 10-year-olds spontaneously endorse creationist ('God made it') explanations for the origin of species (Evans, 2000a)
- early adolescents propose need-based mechanisms of adaptive change operating at the level of the individual, not Darwinian natural selection mechanisms operating at the level of the population (Evans, 2000b).

However, research at The Natural History Museum in London (To et al. 2016) suggests that the British audience does not feel the same resistance to evolution, and especially Human evolution, as the two American studies above (Tare 2011 and Evans 2009). This study found that families tended to produce more 'evolution talk' at a Human-chimp evolution exhibit than at one devoted to non-Humans, in this case artiodactyls.

Evaluation commissioned by NHM for the exhibition *Britain: One Million Years of the Human Story* found some interesting insights into visitor understanding of evolution. Curioser (2014) found that most visitors to the Museum see evolution as 'ordered linear progression i.e. a process with a beginning and an end that enables species to improve on each other'. Fisher (2011) found that visitors cannot easily imagine or conceptualise deep time, which is essential for a solid understanding of evolution. Vomvyla and Hobson (2015) found that there was uncertainty and confusion around the definition of important terms associated with evolution. For example, visitors were unsure of what constituted a 'species' and did not know that Homo sapiens is the scientific name for humans; they were also uncertain of the meaning of the terms 'natural selection' and 'survival of the fittest' and the relationship between them.

An international survey on behalf of the British council (Ipsos MORI, 2009) explored attitudes to the teaching of evolution and other perspectives on origins of life in science lessons by asking, 'Which, if any, of the following statements comes closest to your own opinion about how evolutionary theory should be taught in science lessons in schools?' In several countries (Argentina, UK, Mexico, Russia and USA) a majority of people felt that creationist perspectives should be taught in science lessons alongside scientific accounts of evolution (see Table 1).

Table 1

| Country | Evolutionary theories alone should be taught in science lessons in schools | Evolutionary theories should be taught in science lessons in schools together with other possible perspectives, such as intelligent design and creationism | Other perspectives on the origins of species should be taught in science lessons in schools and not evolutionary theories | Theories about the origins of species and development of life on earth should not be taught in science lessons in schools at all | Don't know |
|---|---|---|---|---|---|
| | % across | | | | |
| Argentina (1,000) | 23 | 65 | 6 | 3 | 3 |
| China (1,048) | 19 | 42 | 19 | 9 | 10 |
| Egypt (1,277) | 18 | 19 | 8 | 18 | 36 |
| Great Britain (973) | 21 | 54 | 6 | 3 | 16 |
| India (909) | 37 | 40 | 13 | 1 | 9 |
| Mexico (1,012) | 28 | 56 | 9 | 4 | 2 |
| Russia (1,600) | 10 | 53 | 13 | 4 | 20 |
| South Africa (2,000) | 11 | 29 | 12 | 9 | 39 |
| Spain (958) | 34 | 31 | 7 | 5 | 23 |
| USA (991) | 21 | 51 | 9 | 14 | 5 |
| All 10 nations (11,768) | 20 | 43 | 10 | 7 | 19 |

*BASE: All respondents aged 18+* *SOURCE: Ipsos MORI (2009)*

*Table 1: Attitudes towards the teaching of evolution*

The research literature indicates that there are issues relevant to our public engagement work regarding both the acceptance and understanding of the theory of evolution.

Many people reject evolutionary explanations 'based upon the perception that an acceptance of evolution contradicts religious assertions about how the universe and everything in it came to be.' Others, without fundamentalist religious belief, do not accept evolution because it does not make sense to them or runs counter to their intuitive beliefs or experience of the world around them (Gelman and Rhodes, 2012).

In various polls and surveys, US acceptance of evolution comes out somewhere between 30 and 40 per cent, but rates of acceptance fall dramatically when humans are introduced as the case study (Gallup, 2007). In other words, many people think evolution applies to other species but not humans.

This has been a consistent finding in U.S. research, but a British based study (To et al. 2016) reported that family visitors to The Natural History Museum London show different engagement patterns with evolution exhibits. To et al. found that families spent longer at a Human evolution exhibit than at an exhibit about non-Humans and that the Human exhibit generated more conversation about evolutionary relatedness and common characteristics.

# 4 Issues in evolution education

### Misconceptions

The University of California Museum of Paleontology and the National Center for Science Education website 'Understanding Evolution' **http://evolution.berkeley.edu/evolibrary/misconceptions_teacherfaq.php** lists common misconceptions about the theory of evolution, which we as natural history museum practitioners need to be aware of and consider when engaging visitors with evolution. Examples of misconceptions include:

- life does not descend from one common ancestor
- humans did not descend from apes
- natural selection is organisms trying to evolve
- some features of organisms are irreducibly complex, eg the eye.

### What makes the theory of evolution difficult to understand?

Cognitive psychology has identified a set of features of the theory of evolution that run counter to human intuitive beliefs, making the theory difficult for people to understand: psychological essentialism, teleological thinking and our use of language (Gregory T. R. 2009).

### Psychological essentialism

The term 'psychological essentialism' refers to an apparently hard-wired set of intuitive human beliefs about organisms:

- that certain categories of organism are 'real' rather than human constructs
- that these natural categories possess an underlying causal force (essence) that is responsible for members being the way they are and having so much in common.

These have been described as 'a fundamental component of human cognition' (Gelman and Rhodes, 2012).

This kind of thinking poses real challenges when trying to understand evolution. For example, it can lead to people thinking that:

- species can't change
- there are no intermediate categories
- variability is minimal and/or only superficial
- individuals change, not populations
- evolution is progressive.

(Gelman and Rhodes, 2012)

Research from Sinatra et al (2003) suggests that people who view knowledge as fixed and unchanging have less understanding of evolution.

In summary, essentialist thinking (common to all humans) leads to the theory of evolution being deeply counter-intuitive for many people, most particularly young children and those not immersed in it. The challenge for educators like us is not simply to present a clear account of evolution by natural selection but to do so within a framework that intuitively rejects the principles upon which the theory rests.

We can take the example of dogs to demonstrate how essentialist thinking works in practice and explore how this runs counter to what the theory of evolution by natural selection teaches.

There is obvious, visible variety within the group that we call dogs. However, in spite of this variety, essentialist thinking holds that they all dogs possess an 'essence of dogginess' within them that makes them dogs, and makes them behave like dogs. This essence cannot change, as it is this that defines a thing as a dog. The variation we see within dogs must, therefore, be superficial and unimportant. Individuals may be different from other individuals but their 'doggy essence' means that they have the important, defining characteristics in common. As being a dog means having a 'doggy essence', then an organism either has it or it doesn't. This means that intermediate or transitional forms cannot exist. The boundaries between groups are thus assumed to be impenetrable.

### Teleological thinking

The term 'teleology' (from the Greek words telos, 'end,' and logos, 'reason') refers to an explanation by reference to some purpose, end, goal or function. It is regarded as faulty reasoning in terms of biology, as evolution does not progress towards pre-specified ends and cannot be said to have intentions or purposes.

Kelemen (2012) asserts that mistaken teleological explanations of evolution come in three broad types).

1. Basic function-based: These are stated in a way to suggest that a trait's current ability to perform a function is the only factor needed to explain why that trait came into being. For example, "Giraffes have long necks so they can reach food high up in the trees"
2. Basic need-based: These appeal to an animal's antecedent physiological need as the factor that prompted the change. For example, "Giraffes have long necks because they needed them to reach food high up in the trees"
3. Elaborated need-based: Effort-based explanations feature here, as do explanations featuring a personified Mother Nature or Evolution, who conferred the trait to aid survival. For example, "Giraffes have long necks because Nature evolved them to reach food high up in the trees."

Children have a broad tendency to categorise natural phenomena by reference to purpose. Piaget (1929) concluded that 'children are 'artificialists' who egocentrically view all things as made by people for a purpose.' These ideas appear very early in development (pre-school) and for many they persist into adulthood. Many ideas have been advanced in attempts to understand and explain this phenomenon. These include the following.

- Parental responses to incessant 'why' questions: Experimental results with young children examining the way parents answer their children's questions seems to discount this one (Kelemen, 2012).
- Storybook conventions: The personification of animals acting towards specified intentional ends is common in children's books and may give children erroneous notions about the world. Studies indicate that there are as many books that do not do this as there are books that do. Also the effect of this does not necessarily persist into adulthood (Kelemen, 2012).
- Our use of language: See below.
- Goal sensitivity and teleology: Experiments show that children are very sensitive to the intentions and goal-directed actions of others from one year of age. If they see someone use something in a goal-directed way they may enduringly decide that this is what the object is 'for' and why it is here. It is only a short step from: 'that's what it's used for' to: 'that what it's for' (Kelemen, 2012).

**Our use of language**

Some misunderstandings arise because of conflict between technical (scientific) and everyday uses of the same word.

The word 'theory' is a good example (National Academy of Sciences, 1998): In everyday language the word's definition is close to that of 'guess', whereas in science, 'theory' is a level to which only the hypotheses best supported by evidence can aspire. It is this conflict in usage that allows anti-evolutionists to claim that 'Evolution has not been proven, it's just a theory'.

A slightly different case is the word 'so'. This has two contrasting everyday meanings:

- with the result that...
- in order to...

In the statement 'giraffes have long necks so they can reach food high up in the trees', visitors are left confused about whether the giraffes have long necks intentionally or not.

# 5 Implications for practice

1. Museum learning practitioners should be aware of the common misconceptions/ misrepresentations of evolution and be ready to address them with evidence and a clear explanation of evolution. We should directly engage people with the essentialist and teleological misconceptions that they are likely to hold as they encounter evolutionary concepts (Dagher and Boujaoude, 2005; Kelemen, 2012).
2. Don't try to overturn people's religious beliefs. It is better to present a compelling evidence-based case for evolution. There is research evidence to suggest that even the most fundamentalist of anti-evolutionists will tend to incorporate evolution into their thinking if this is done carefully (Reiss, 2008; Diamond et al, 2012).
3. Evidence presented by Keleman and Emmons (2014) suggests that a good way to start the process of learning about evolution with young children is to present the components of evolution by natural selection in a narrative form within a picture storybook.
4. Diamond et al (2012) found that successful understanding of evolution by natural selection was enhanced by applying the logical sequence of the following elements of natural selection: variation, inheritance, selection, and time (VIST) as a cognitive organiser for case studies in programmes and exhibits.
5. Provide situations in which people in museums can examine the adequacy of their prior conceptions about evolution and discuss and test them. Thoughtful and thought-provoking programming can make a real difference. A study at The Natural History Museum London (Tenenbaum et al. 2015) reported that school students who participated in a programme recreating the Oxford Great Debate between Darwin and Wilberforce, were more likely to later use Informed Naturalistic Reasoning and less likely to employ Naïve Naturalistic Reasoning (based upon intuitive and often fallacious understandings of the Universe) when explaining various evolutionary scenarios.
6. Present science as a process of critical thinking and a robust way of generating reliable explanations of natural phenomena. Implicit in this is the notion that if people do not accept this premise there is no reason why they should accept evolution as one of the products of this process (National Academy of Sciences, 1998; Alters and Nelson, 2002; Anderson, 2007).
7. Contemporary examples of evolution in action, ie where visitors may have some prior knowledge of the topic, make it easier to grasp difficult evolutionary concepts, such as disease vectors becoming drug resistant (MacFadden, 2008).

8. We need to be really clear about what we're trying to achieve. Are we trying to:
    - explain evolutionary theory
    - convince people that evolutionary theory is the best current explanation for how the diversity of life around us came to be
    - counter the arguments of the anti-evolutionary movement
    - provide the evidence for evolution
    - challenge people's faith-based 'understandings' of the diversity of life?
9. Be extremely careful about the language we use when explaining evolution.
10. Implement training in evolutionary theory for public engagement staff and in how to respond to some of the more common challenges to it.

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