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An untold story in biology: the historical continuity of evolutionary ideas of Muslim scholars from the 8th century to Darwin's time

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ABSTRACT
Textbooks on the history of biology and evolutionary thought do not mention the evolutionary ideas of Muslim scholars before Darwin's time. This is part of a trend in the West to minimise the contributions of non-Western scientists to biology, human anatomy and evolutionary biology. Therefore, this paper focuses on the contributions of pre-Darwinian Muslim scholars to the history of evolutionary thought. Our review of texts from a wide range of historical times, and written in various languages, reveals that there were in fact several Muslim scholars who postulated evolutionary ideas, some with remarkable similarities to Darwin's theory. These ideas included the adaptation and survival of the fittest, a specific origin of humans from apes/monkeys, the notion of evolutionary constraints, the occurrence of extinctions within taxa and hereditary variability. Moreover, while both the scientific community and the broader public generally base their knowledge on Western textbooks, several parts of the Muslim world have indicated an overall rejection of biological–including human–evolution. Therefore, to improve historical accuracy and create a better understanding of scientific history, the world's diverse civilisations and their philosophies, this untold story should be widely disseminated to the scientific community and the general public.

KEYWORDS
Evolutionary thought; Arabic texts; Persian texts; Islamic Golden Age; history of science; scientific biases

Introduction

Modern science often assumes that evolutionary theories did not exist in the pre-Darwinian Muslim world. This is reinforced by the fact that, as in many religious communities, the theory of evolution is a controversial subject due to its perceived conflicts with Islamic teachings (Asghar, Wiles, and Alters 2007; Hameed 2008). During the twentieth century, evolution came to be associated with provocative ideas including atheism, materialism, colonialism and imperialism, leading Muslim scholars and communities to reject it (Dajani 2015). Interestingly, several Muslim philosophers and public figures between the late nineteenth century and early twentieth century, such as Ahmed Medhat, were vocal in their support of Darwin's evolutionary theory. Some authors go so far as to say that

> up to the modern era (early twentieth century), they (most Muslim intellectuals) by and large accepted biological evolution and even welcomed it, as long as it did not present itself in purely materialistic, atheist garb, even though the question of human evolution did often constitute a sore point; nowadays, however, the rejection of Darwinism is nearly unanimous (in the Muslim world). (Guessoum 2011, 303)

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Interestingly, some of the Muslim scholars that rejected the theory embraced a viewpoint similar to that of Western Christian creationists, thereby 'transferring the Western war between science and religion to Islam' (Dajani 2015, 409).

It is therefore not surprising that the contributions of pre-Darwinian Muslim thinkers to the history of evolutionary thought remain largely unrecognised today. In fact, evolution is such a sensitive topic in some parts of the Muslim world that even *fatwas* (legal opinion or decree handed down by an Islamic religious leader) are issued on it (Guessoum 2011). It should, however, be noted that while most Muslims continue to reject evolution on the basis of religious conflict, many of them, particularly young science students and professionals, are 'willing to accept evolution as a mechanism for the emergence of all species except humans' (Dajani 2015). Muslim professionals who do accept human evolution, however, are inclined to interpret Islamic texts so as to reconcile the theory with their religious beliefs (Asghar 2013).

Importantly, the anti-evolutionary ideas of many muslims over the last few centuries somewhat (Guessoum 2011) parallels the biased way by which Westerners have interpreted the history of science and scientific contributions of non-Westerners. For instance, in the nineteenth century, some Western researchers did acknowledge the biological theories of pre-Darwinian Muslim scholars, but today one struggles to find any mention of those scholars' contributions to evolutionary theory and anatomy in current history textbooks and specialised papers on those subjects. John William Draper (1812–1883), a renowned nineteenth-century scientist and contemporary of Darwin, was aware and critical of Western science's dismissiveness toward medieval Muslim thinkers (Shanavas 2010). He wrote: 'I have to deplore the systematic manner in which the literature of Europe has contrived to put out of sight our scientific obligations to the Muhammadans … Injustice founded on religious rancor and national conceit cannot be perpetuated forever' (Draper 1875, 1876; Shanavas 2010, 80). He recognised Muslim contributions to evolutionary science, and in 'The History of the Conflict between Religion and Science' he wrote,

> [Christian] (t)heological authorities were therefore constrained to look with disfavor on any attempt to carry back the origin of the earth to an epoch indefinitely remote, and on the Muhammadan theory of evolution which declared that human beings developed over a long period of time from lower forms of life to their present condition. (Draper 1875, 1876; Shanavas 2010, 108)

Draper further elaborated on the attitude common within Western science:

> Sometimes, not without surprise, we meet with ideas with which we flatter ourselves with having originated in our own times. Thus our modern doctrine of evolution and development were taught in their [Muslim] schools. In fact, they carried them much farther than we are disposed to do, extending them even to inorganic and mineral things. (Draper 1875, 1876; Shanavas 2010, 109)

Because their ideas are often deemed to be more religious or philosophical than scientific, medieval Muslim scholars such as Tusi and ibn Tufayl have neither been credited as evolutionists by Westerners, nor have they received due attention for their theories. But as Draper pointed out, this also appears to be at least partially a reflection of historical prejudice, because scientific history has been shown to recognise theories far more abstract and less plausible than those of the scholars discussed in the present paper.

It is striking how current Western textbooks differ from Draper's statements. The idea repeatedly defended in such texts, including those specifically dedicated to the history of biology, is that 'after Galen we encounter no biological activity for centuries', the 'Dark Ages in science' expanding 'from the death of Galen until the 13th century' (Singer 1959, 63–64, 98). Interestingly, these scholars do recognise that in the eighth/ninth century the intellectual leadership passed to the Muslim scholars and remained with them until the thirteenth century (Hehmeyer and Khan 2007; Singer 1957, 1959). There is, however, a crucial question that is not addressed in most textbooks about the history of biology: If Muslim scholars had intellectual leadership from the eighth or ninth century to the thirteenth century, and if they made progress in various fields including mathematics and medicine–which is so deeply connected to biology–then why did they not also contribute to the study of human and

comparative anatomy, which could have led them to eventually propose some type of evolutionary theory? This seems very odd because it implies that Muslim scholars were merely passive players, that their single contribution to anatomy was to translate from the Greeks–who made significant progress in biology–to Arabic, and then from Arabic to Latin and other languages, to allow the Westerners to continue making further advances in biology.

To illustrate how biologists and historians of science tend to view this issue, and to show that we are not providing here just some 'straw-man' cases to reinforce this view, we cite here a passage by one of the most respected biologists of recent times, Ernst Mayr, from his highly influential book about the history of biology (The Growth of Biological Thought: Mayr 1982, 91):

> The Arabs, so far I can determine, made no important contributions to biology–this is even true for two Arab scholars, Avicenna (…) and Aberrhos (Averroes *sensu* the present work) (…), who showed a particular interest in biological matters; it was, however, through Arab translations that Aristotle again became known to the Western world–this was perhaps the greatest contribution that the Arabs made to the history of biology.

Methods

Our goal for this study is to provide a review of the evolutionary ideas of pre-Darwinian Muslim scholars. The search engines we used to procure references were Google, Google Scholar, Internet Archive (archive.org) and the Washington Research Library Consortium. Initial search parameters were limited to peer-reviewed articles and books cited and published since 2009, then broadened in order to obtain any relevant works published 10 years prior and so on, until an exhaustive search was completed. Keyword combinations included, but were not limited to, 'Islam evolution', 'Muslim evolutionist', 'Muslim evolution', 'Islam Muslim evolution contributions anatomy Darwin', 'Muslim evolution anatomy' and 'evolution Muslim Islam Darwin theory' From the hundreds of sources we found, we selected only those that (1) contained information about works by Muslim scholars from before the publication of Darwin's (1859) book 'On the Origin of Species'; (2) referred directly to evolution in some way (i.e. describing not just anatomical or developmental changes, but primarily the significant changes that organisms undergo in geological time); and (3) did not merely repeat information from the sources already chosen by us. It is important to note that the definition of 'evolutionary ideas/thought' used in this paper is the simplest and most consensually accepted one: *the notion that species change over time* (e.g. Mayr 1982). Using the dozens of sources selected through this methodology, we then conducted a second type of search: reading all of the references cited in these chosen works and choosing any relevant ones; obtaining PDFs and/or printed copies of those chosen references; and finally, using the three requirements listed above to select the references that are included in our paper. This procedure was thoroughly repeated until we determined that there were no further relevant citations to acquire from the chosen sources.

It is also important to note that the references included here are not *all* of the existing sources referring to evolutionary ideas amongst pre-Darwinian Muslim scholars. Rather, these are crucial references that most specifically summarise the evolutionary ideas *of the eight key Muslim scholars* listed below (Figures 1 and 2). These scholars are those who, according to our overall literature search, had more articulated and/or developed ideas–i.e. more written texts and explicit statements about–biological evolution. Accordingly, our purpose is to summarise these evolutionary ideas, examine their similarities to both Darwin's theory and current scientific views and bring these scholars' stories to light.

Notably, our extensive literature research indicates several instances of evolutionary thought among Muslim scholars, ranging from the eighth century to fourteenth century, and therefore effectively exposes an important historical bias present in current textbooks on the history of science, biology and evolutionary thought. In order to improve historical accuracy and attain a more complete understanding of scientific history, this untold story should be widely disseminated within both the scientific community and the general public.

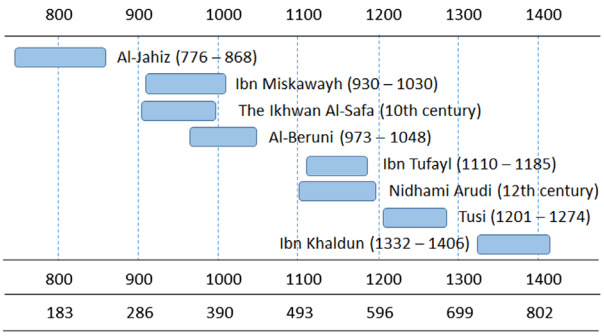

Figure 1. Timeline of key pre-Darwin Muslim scholars with evolutionary ideas from eighth to thirteenth century AD.
Note: The lower row shows the years in Hijri, i.e. after the Islamic calendar.

Figure 2. Key pre-Darwin Muslim scholars with evolutionary ideas: (A) Al-Jahiz (776–868; Boulter 2013); (B) Ibn Miskawayh (930–1030; DailyNews 2010); (C) The Ikhwan Al-Safa (tenth century; Wikipedia 2015b); (D) Al-Beruni (973–1048; Wikipedia 2015a); (E) Ibn Tufayl (1110–1185; University of Chicago Press 2009); (F) Nidhami Arudi (twelfth century; Muslim Heritage); (G) Tusi (1201–1274; Wikipedia 2015c); (H) Ibn Khaldun (1332–1406; Ahmedullah 2014).

Eight key pre-Darwinian Muslim scholars with evolutionary ideas

A common theme of 'kingdoms' in nature was described by ibn Miskawayh, Al-Beruni, the Ikhwan Al-Safa, Nidhami Arudi, Tusi and ibn Khaldun. These scholars proposed a hierarchy consisting of minerals, plants, animals and humans, with each 'kingdom' giving rise to and/or serving the next (Diamandopoulos and Goudas 2007; Ibn-Khaldūn 1377; Nasr 1993). This theory was originally posited by Aristotle in the fourth century BC (Leroi 2014) and adopted by these Muslim scholars after the seventh century AD, during which Arabic translations of Aristotle's works were made available (e.g. Singer 1941).

Al-Jahiz

Al-Jahiz, born Abu Uthman Amr Bin Bahr Al-Fukaymi Al-Basri (776–868) in Iraq, was an eighth-century Muslim zoologist (Bayrakdar 1983; Guessoum 2011). Learned in subjects including philosophy,

literature and Arabic, he earned recognition for his *Kitab Al-Hayawan* (Book of Animals) (Bayrakdar 1983), a book detailing his evolutionary theory in relation to the natural selection of animals, particularly birds (Guessoum 2011). He is widely considered to be the first Muslim scholar to propose an evolutionary biological theory which, according to some sources, was also the first one in the field of science (Bayrakdar 1983). Al-Jahiz devoted years to the scientific study of animals, closely observing their behaviours and classifying them by their characteristics and similarities (Bayrakdar 1983).

Al-Jahiz's theories are said to have impacted the fields of zoology and biology, heavily influencing Arab Muslim and European thinkers alike (Bayrakdar 1983). Later scholars, such as ibn Miskawayh and ibn Khaldun, are thought to have based their own theories on his ideas. Our comparative research supports the idea, also proposed by other researchers (e.g. Bayrakdar 1983), that there are obvious parallels between Al-Jahiz's ideas and Darwin's theory. Some authors go as far as to state that Darwin and other eighteenth and nineteenth-century scientists used Al-Jahiz's work as a foundation for their evolutionary theories, but in a more modern scientific format (Bayrakdar 1983). For instance, regarding species transformation, Al-Jahiz explained the great impact of environmental conditions in driving organisms to adapt: they develop new traits for survival. However, an important difference between the two thinkers is that, contrary to Darwin, Al-Jahiz took God's role into account, believing that organisms ultimately evolve by divine will and guidance, developing new traits for survival as part of God's plans to keep nature in order.

Al-Jahiz described a 'natural selection' process resulting from an animal's innate desire to live, stating that biological fitness is essential to this phenomenon (Saniotis 2012). He observed that individuals of the same species struggle against each other and that the stronger, more adapted species prevail with lesser mortality rates. His understanding of the circle of life is shown in an example of a rat that feeds on smaller animals and digs underground dwellings for protection against predators; those predators in turn have their own defenses against even larger predators, and so forth. Al-Jahiz wrote: 'This is the law that some existences are the food for others … all small animals eat smaller ones; and all big animals cannot eat bigger ones. Men with each other are like animals …' (Bayrakdar 1983, 311).

Zirkle (1941, 85) elaborates with that same passage from Al-Jahiz, translated by the Spanish writer Miquel Asin Palacios:

> All animals, in short, cannot exist without food … Every weak animal devours those weaker than itself. Strong animals cannot escape being devoured by other animals stronger than they. And in this respect, men do not differ from animals, some with respect to others, although they do not arrive at the same extremes. In short, God has disposed some human beings as a cause of life for others, and likewise, he has disposed the latter as a cause of the death of the former.

Al-Jahiz recognised the role of environmental conditions in determining human skin colour, after noting the skin tone variations between northern and southern people (Kechichian 2012). Furthermore, Al-Jahiz wondered about the evolution of 'al-miskh', or the original quadrupedal (tetrapod) ancestor: 'People said different things about the existence of al-miskh … some accepted its evolution and that it gave existence to dog, wolf, fox and their similars. The members of this family came from this form' (Bayrakdar 1983, 311).

Another portion of Al-Jahiz's texts alludes to human evolution and the similarities between animals and apes:

> 'We have seen that some nabatheen [Nabataeans] navigators resembled the ape in some geographical environment, likely we have also seen some people from Morocco and have found them as like al-maskh [a kind of ape, not to be confused with al-miskh'], except for a little difference … And it is possible that the polluted air and water, and dust made this change in the character of these Moroccans … those changes in their bristles, ears, colours, and form (similar to apes) increase more …. (Bayrakdar 1983, 312)

It should be noted that when these Muslim scholars referred to "apes", they probably could refer to the "barbary ape", which is not a true ape but instead a peculiar monkey without a tail that inhabited the north-west region of Africa and the island that is now know as Gibraltar. However, it is also possible that they did refer to true apes. This is because the first written accounts on the existence of true apes seemingly occurred in the fifth century BC, when the Greek Herodotus described African apes in *The*

Histories. Herodotus followed the description of the Phoenician Hanno's *Periplus or circumnavigation of Africa*: a strange creature inhabiting a fabulous land (far-) west of Cyrenaica (probably coinciding with the extant Cameroon: Marco Masseti, pers. comm.).

Ibn Miskawayh

Ibn Miskawayh (930–1030) was a tenth-century Persian Muslim philosopher whose evolutionary ideas may have been influenced by those of Al-Jahiz (Bayrakdar 1983; Hawi 1974). Hawi (1974, 123) cites a passage from ibn Miskawayh's 'Al-Fawz Al-Asghar', stating that ibn Miskawayh 'possessed a profound awareness of the evolution of life that stands on a par with the views of Darwin, Huxley and others'. In that passage, ibn Miskawayh wrote:

> The first step of the ascension of plants, of a higher order, is to free themselves from the ground and from their need to consolidate their veins in it … This first animal stage is weak … Animals in this stage remain weak in locomotion even though they have freed themselves from the ground and evolved a new life … Then they evolve from this to another stage: here their capacities of movement and sense become stronger; such is the case of worms, many kinds of butterflies and crawling beings … Sensitivities in these new animals becomes stronger and from them emerge animals having four senses such as the mole and the like … From here they [the animals] progressively evolve to a higher stage in which sight is generated; this is the case with ants and bees … then they approach the last stage of the animal kingdom. Although this rank is superior, nevertheless it remains base and inferior, far from the level of monkeys and the like. These become near to man in structure and human appearance. There is no difference between those types and man except a little, which if surpassed they become humans. (Hawi 1974, 123)

Here ibn Miskawayh postulated that humans evolved from other animals, the main difference between them being intellect, which God has gifted to humans (Kaya 2012). He believed that human evolution brought 'psychological changes with the growing power of discrimination and spirituality until humankind passed from barbarism to civilization' (Shanavas 2010, 121). Furthermore, according to Hawi (1974), this passage heavily suggests that ibn Miskawayh possessed an understanding of the naturalistic evolution of life in a modern sense, an opinion shared by Mohammad Iqbal, a renowned Indian scholar of the twentieth century (Hameed 2008).

Ibn Miskawayh also discussed species transmutation in his works, according to some sources:

> [These books] state that God first created matter and invested it with energy for development. Matter, therefore, adapted the form of vapor which assumed the shape of water in due time. The next stage of development was mineral life. Different kinds of stones developed in the course of time, their highest form being marjan [coral] … After mineral life evolves vegetation. The evolution of vegetation culminates with a tree which bears the qualities of an animal … Then is born the lowest of the animals. It evolves into an ape. This is not the statement of Darwin. This is what ibn Miskawayh states … that ape then evolved into a lower kind of barbarian man. He then became a superior human being. (Shoja, pers. com.)

The Ikhwan Al-Safa

The Ikhwan Al-Safa ('Brethren of Purity') were a tenth-century esoteric society of Arab Muslim thinkers based in Basra, Iraq (Guessoum 2011; Hameed 2012). While they were reportedly deemed heretical by orthodox communities in Iraq, the Ikhwan's work 'spread as far as Spain, where it influenced philosophical and scientific thought' (Singer 1941). Often referred to as a Platonic or Neoplatonic, Shiite, 'Pre-Sufi' group of scholars (Guessoum 2011; Siddiqi 1995), the Ikhwan are known for their work 'Rasa'il Ikhwan al-Safa' or 'Epistles of the Brethren of Purity', in which they explored subjects including cosmology, philosophy, logic, theology and mathematics (Săvoiu 2014).

Nasr (1993, 70) notes that the Ikhwan grouped all matter into three 'kingdoms' (minerals, plants, and animals), with members of each one

> … connected to the first member of the next domain. Minerals are connected below to water and earth, and their lowest types are alum, hyacinth, and vitriol, which are very close to earth. Red gold, on the other hand, stands highest among the minerals and approaches the world of the plants … moss is the lowest order approaching

> the mineral kingdom, while the palm tree, which already has a differentiation of sexes, stands between the plant and animal worlds.

These ideas are comparable to the scala naturae ('great chain of being') concept developed by Greek philosophers such as Aristotle (Leroi 2014, see below).

The Ikhwan described animals in relation to humans as follows: 'Among animals, the snail is mentioned as being closest to the plant world and the elephant – being highest in intelligence among the animals, nearest to man' (Nasr 1993, 70). Nasr explains,

> Inasmuch as this hierarchy is based on the degree of intelligence and the development of internal faculties rather than on external similarities, we find that the Ikhwan name the elephant rather than the monkey as the closest animal to man. This is a good example of the difference between the traditional idea of gradation, which is based on internal qualities and ontological status, and the modern theories of evolution which are based on the physical behavior and the external similarities of creatures. (Nasr 1993, 70)

In fact, it is consensually accepted that the elephant brain and mental capacity is highly complex, being in some aspects remarkably similar to that of humans, and in other aspects unparalleled throughout the animal kingdom (Garstang 2015).

The Ikhwan believed that life developed gradually and that minerals, plants and animals existed before humans did (Shanavas 2010). They emphasised that God created animals for the benefit of humans, and that He equipped animals with all the necessary means to live. They wrote,

> The first stage of the plant kingdom is connected with the last stage of minerals and the highest stage of the plant kingdom with the first stage of animal … the highest stage of the animal kingdom is connected with the first stage of the human. Be it known to you! The imperfect animals preceded the most perfect animals *in time* and in the process of creation … The animals were created for man's sake. (And) everything that is created for the sake of something else will precede the beneficiary. By the grace of God's wisdom and care, animals were bestowed with organs, joints, vessels, nerves, membranes, and chambers according to their needs for benefitting themselves or to avoid injury, so that it can survive and will be completed and perfected to reach the highest stage. (Shanavas 2010, 118)

Although some have claimed that the Ikhwan believed in evolution, Nasr (1993, 71) states that their 'divergence from modern theories of evolution should be clear'. They emphasised that all changes that occur on earth are caused by the 'Universal Soul' (God), and that one species cannot change into another:

> The species and genus are definite and preserved. Their forms are in matter. But the individuals are in perpetual flow; they are neither definite nor preserved. The reason for the conservation of forms, genus, and species, in matter is the fixity of their celestial cause because their efficient cause is the Universal Soul of the spheres instead of the change and continuous flux of individuals which is due to the variability of their cause. (Nasr 1993, 72)

Furthermore, the Ikhwan were adamant in their belief that creation occurred both sequentially and instantly, in an 'emanation' process from God (Guessoum 2011).

Nevertheless, there are clear similarities between modern evolutionary ideas and those of the Ikhwan, namely their theory that 'the date of the beginning of terrestrial existence of plants precedes that of animals, just as minerals precede the plant' (Nasr 1993, 72) and that animals can adapt to environment. They wrote:

> Plants come before (taqaddama) animals in the series of beings and serve them as material for the forms of animals and food for the nutrition of their bodies … plants would be like a mother who eats raw food … and transforms it into pure milk which is absorbed very gently by those who drink it. The plants subsequently present this to the animals considered as their sons … Plants occupy an intermediate position–necessary and salutary–between the four elements and the animals … All the parts of the vegetables which the animals consume such as seeds, leaves, fruit and so on, come from the four elements digested and transformed by the plants. (Nasr 1993, 72)

Thus, just as minerals preceded and service plants, plants preceded and service animals, who in turn service humans, 'who therefore comes to this world later than all of them, since each has come after the kingdom on which it depends' (Nasr 1993, 72).

Al-Beruni

Abu Alraihan Muhammad Ibn Ahmad Al-Beruni (973–1048) was an eleventh-century Muslim astronomer, mathematician, geographer and historian from what is now Turkmenistan and Uzbekistan (Figures 1 and 2; Singer 1941; Starr 2009). He lived in India and aspired to 'control the Hindu language in order to impart its knowledge to Arab-speaking nations at the beginning of the eleventh century' (Wilczynski 1959, 459). One of his most famous works, entitled 'India', (Wilczynski 1959), gained him recognition as the first Muslim and one of the most prominent scholars to objectively write about Hinduism (Guessoum 2011; Sharma 1991). An 'independent thinker' who viewed the study of nature as a religious duty, he created theories that adhered to both Quranic teachings and to the scientific approach (Guessoum 2011).

Wilczynski (1959) commented on Al-Beruni's theories:

> Nature performs natural selection of the most adequate, well-adapted beings through the extermination of others, and, in this case, it proceeds in the same way as farmers and gardeners … Darwin's great idea of natural selection through the struggle for life and survival of the fittest was already reached by Alberuni approximately eight hundred years before Darwin. It is true that he seized it in the most general outlines only, but, curiously enough, even the very meaning and the way in which he came to it were the same as Darwin's. (Rainow 1943, cited by Wilczynski 1959, 459)

Al-Beruni expressed the idea that man 'migrated' through the 'kingdoms' of minerals, plants and animals 'in order to reach perfection and therefore contains within himself the nature of the creatures of the other realms' (Nasr 1993, 147). His work 'Kitab al-Jamahir' hints at the Darwinian theory of human evolution, namely that monkeys were the final stage from which mankind '"migrated" to reach his present state' (Nasr 1993). He wrote: 'Man reached his maximum degree of perfection compared to other animals below him … He ascended to the present state from other kinds of beings such as dog-like, bear-like, ape-like, etc. Then finally he became man' (Shanavas 2010, 119). This is similar to the current scientific view that, due to phylogenetic and developmental constraints in human evolutionary history, we retain some features that were present in our distant ancestors (e.g. Diogo and Abdala 2010; Diogo and Wood 2012; Shubin 2008).

While Al-Beruni may have been influenced by Hellenistic thinkers (Hameed 2012), his Darwinian-like ideas are present in his book about Hinduism and 'general natural processes in the whole world', specifically within a chapter entitled 'On Vasudeva and the Wars of the Bharata' (Wilczynski 1959, 460). His evolutionary views are summarised in passages about 'four different phenomena', the first of which is: 'The life of the world depends upon the sowing and procreating. Both processes increase in the course of time, and this increase is unlimited, whilst the world is limited' (Wilczynski 1959, 460).

The second passage addresses Al-Beruni's ideas on species expansion:

> When a class of plants or animals does not increase any more in its structure, and its peculiar kind is established as a species of its own, when each individual of it does not simply come into existence once and perish, but besides procreates a being like itself or several together, and not only once but several times, then this will as single species of plants or animals occupy the earth and spread itself and its kind over as much territory as it can find. (Wilczynski 1959, 461)

This parallels Darwin's own writings of natural selection, indicating that Al-Beruni had some ideas about reproduction, natural selection and speciation 800 years before Darwin (Shanavas 2010).

A third excerpt refers to artificial selection:

> The agriculturist selects his corn, letting grow as much as he requires, and tearing out the remainder. The forester leaves those branches which he perceives to be excellent, whilst he cuts away all others. The bees kill those of their kind who only eat, but do not work in their beehive. (Wilczynski 1959, 461)

Wilczynski (1959) suggests that the fourth relevant passage is comparable to Darwin's theory of natural selection. Al-Beruni wrote: 'Nature proceeds in a similar way; however, it does not distinguish for its action is under all circumstances one and the same. It allows the leaves and fruit of the trees to perish … It removes them so as to make room for others' (Wilczynski 1959, 462).

Moreover, Al-Beruni attributed all natural processes, and even any apparent "imperfections" that occur during an animal's evolution and development, to God's infinite wisdom. He wrote:

> … When Nature does not find the substance by which to complete the form of that animal in conformity with the structure of the species to which it belongs…she forms the animal in such a shape, so that the defect is made to lose its obnoxious character, and she gives it vital power as much as possible … Frequently … you find in the functions (actions) of Nature which it is her office to fulfill, some fault (some irregularity), but this only serves to show that the Creator who had designed something deviating from the general tenor of things is indefinitely sublime, beyond everything which we poor sinners may conceive and predicate Him. (Shanavas 2010, 124, 125)

Ibn Tufayl

Abu Bakr ibn Tufail, also known as Abubacer or ibn Tufayl (1110–1185), was an Andalusian Muslim scholar born in Gaudix, Spain during the early twelfth century (Cerdá-Olmedo 2008). A physician and teacher of the Andalusian philosopher ibn Rushd (Averroes), ibn Tufayl is most famous for his Arabic philosophical novel entitled 'Risala Hayy ibn Yaqzan fi asrar al-hikmat al-masriqiyya' or simply 'Hayy ibn Yaqzan', which is translated as 'Philosophus Autodidactus', 'The Story of Alive, Son of Awaken, On the Secrets of Oriental Wisdom' and 'The Journey of the Soul' in Latin and English, respectively (Cerdá-Olmedo 2008).

Widely recognised for its influence on Arabic, Islamic and European philosophy and literature between the sixteenth to nineteenth centuries, this book is thought to have inspired Daniel Defoe's 'Robinson Crusoe' (Attar 2007), Rudyard Kipling's 'The Jungle Book' and other works about human beings living in isolation (Cerdá-Olmedo 2008). The first Latin and English translations were published in 1671 and 1708, respectively, followed by those in German, Dutch and French (Shanavas 2010). It tells the story of Hayy, a boy growing up on an island with only animals for company as he struggles to survive, defends himself against nature and discovers philosophical truths (Hawi 1974). The tale's themes are reportedly based on ibn Tufayl's own philosophical beliefs, suggesting that ibn Tufayl believed in a naturalistic origin of life but also hinting at evolutionary ideas (Hawi 1974). It is unclear what exact evolutionary theory the scholar subscribed to but according to Hawi (1974), ibn Tufayl's writings show that he believed 'in the generation of life from matter and that man is a product of the interworking of the natural elements, whether man was generated spontaneously or was a result of an evolutionary process'.

Ibn Tufayl described the boy, Hayy, spontaneously originating from a hot, damp, 'fermented' clay 'that labored and churned like bubbles over boiling water' over the course of several years (Hawi 1974, 106). This clay had the 'suitability to be formed into all the protective membranes and the like which would be needed in the forming of a man. When the embryo was complete these coverings were sloughed off as if in labor; and the clay which had already begun to dry, cracked up' (Hawi 1974, 106). According to Hawi (1974), these descriptions suggest that ibn Tufayl believed in biogenesis: that organic compounds existed before life in an 'inorganic world', and that inorganic compounds slowly transform, leading to 'a spasmodic emergence of life'.

Although this idea of change from an inorganic to organic world is expressed in both the Bible (Genesis 2:7) and Quranic verses stating that all life forms were created from water and that human beings were shaped from clay (Quran 21:30, 24:45, 25:54, 55:14; Asghar, Wiles, and Alters 2010), ibn Tufayl's story is particularly interesting because his descriptions of clay and boiling water agree with one of modern science's most discussed hypotheses about the origin of life, i.e. that life originated from warm ponds including a mixture between water and other inorganic components over a long period of time. And by describing the gradual morphing of clay he also recognised, as modern scientists do, 'the very lengthy period that the autogeneration of living beings (i.e. from inorganic substances) takes … Life does not arise spontaneously overnight' (Hawi 1974, 115). Furthermore, he theorised that inanimate matter is the foundation for all forms of life and that balance is essential to life (Hawi 1974). Importantly, the concept of long periods of geological time is in stark contrast with ideas now defended by religious fundamentalists who are inclined toward the view that all life was created almost instantly in a geological time set.

The details of Hayy's origins also strongly capture ibn Tufayl's factual scientific knowledge. Hawi (1974) wrote of ibn Tufayl's descriptions:

> Under the influence of heat and sunshine, the embryo is formed. These were not wild guesses, but facts dictated by the searching and observant mind of a scientist. The fermented clay, viscous mass, light and heat are hypotheses presented by ibn Tufayl to account for the emergence of life; but, so are the modern interpretations by Darwin, Haldane and Keosian in terms of 'warm ponds', ammonia, phosphoric salts, light, heat and electricity … ibn Tufayl is equally aware as these scientists are of the effect of light and heat in enhancing the preparatory chemical process.

Furthermore, Hayy's use of observation and reasoning throughout his journey may reflect modern scientific method. Cerdá-Olmedo (2008, 160) wrote of the story: 'The idea that knowledge must be acquired through observation, experimentation, and thought was not new, but it had not been expressed as clearly and forcefully before'. Hayy's dissections of animal cadavers, in order to understand the 'principle of life', may also have stemmed from ibn Tufayl's knowledge of anatomical dissections (Cerdá-Olmedo 2008, 161, 162).

In describing Hayy's attempts to compete for food and protect himself, ibn Tufayl evidently understood adaptation to environment and the struggle for existence, which are evolutionary concepts that modern textbooks attribute to Darwin (Hawi 1974). Upon seeing that animals possess horns, claws and other features, Hayy contemplates his own lack of natural defenses but soon discovers the means to fashion his own weapons and tools (i.e. spears, shields), and begins training animals to service him. Ibn Tufayl wrote,

> This was due to [Hayy's] realization that despite his lack of natural weapons, he could manufacture everything to make up this lack … There were wild horses on the island as well as wild asses … Then out of thongs and rawhide he contrived saddles and bridles. So, as he had hoped, he was able to chase animals he had found difficult to catch. (Hawi 1974, 120)

While some evolutionary ideas are indicated in ibn Tufayl's descriptions of spontaneous generation of organic matter from inorganic substances, they do not explicitly define him as an evolutionist, according to Hawi (1974): 'To pronounce him an evolutionist, in the full Darwinian sense, is to place him in a naturalistic perspective for which his brief remarks do not qualify him' (Hawi 1974, 116). Nevertheless, ibn Tufayl's commentary on the origin of life from inorganic matter does seem to indicate an evolutionary view (Hawi 1974), and his ideas share various similarities with those of both Darwin and recent evolutionary biologists, as explained above.

Nidhami Arudi

Ahmad bin Umar bin Ali an-Nidhami as-Samarqandi, Nidhami-i-Arudi-i-Samarqandi, or Nidhami Arudi of Samarqand, was a twelfth-century Persian Muslim thinker and poet who explored the natural sciences, philosophy and politics in his book entitled 'Chahar Maqala' ('Four Discourses') (Khodadoust et al. 2013, 290; Wikipedia 2014).

Browne's (1899) English translation of 'Chahar Maqala' was used here to study Arudi's ideas of evolution (Singer 1941). On the origins of vegetation Arudi wrote,

> But when time began … and the composition of this lower world became matured, and the time was come for the fertilization of that interspace which lay between the water and the air, the vegetable world was manifested. Then God, blessed and exalted is He, created for that substance whereby the plants were made manifest four subservient forces and three faculties.

Based on our own understanding of this text, these four 'subservient forces' appear to represent Arudi's theories of organismal function, while the 'three faculties' refer to how organisms sustain themselves and reproduce.

The first two 'faculties' involve nutrition (i.e. how a plant attains and distributes nutrients to each of its structures), while the third refers to reproduction. Arudi wrote:

> … when the organism has attained perfection and begins to tend towards defect, appears and produces germs, in order that, if destruction overtake the parent in this world, these may become its substitute and representative, so that the order of the world may be guarded from detriment, and the species may not cease. This is called the 'Reproductive Faculty'.

This shows Arudi's understanding of the mechanisms by which organisms function, ensure the survival of their species and essentially contribute to balance in the natural world.

Like the Ikhwan Al-Safa two centuries before him, Arudi discussed God's creation of three 'kingdoms': (1) minerals, followed by (2) plants and vegetables, then (3) animals. He alluded to animals' superiority to minerals and plants, theorising that coral was the first organism to undergo a transformation from mineral to living plant:

> So this kingdom rose superior to the mineral and vegetable kingdoms in several ways … and the far-reaching Wisdom of the Creator so ordained, that these kingdoms should be connected successively and continuously, so that in the mineral kingdom the first thing which attained completeness and underwent the process of evolution became higher in organization until it grew to coral … which is the ultimate term of the mineral world, until it was connected with the first stage of plant life.

Also like the Ikhwan, Arudi stated that date palm trees are the most superior members of the plant kingdom due to their methods of reproduction. He explained: 'And the first thing in the vegetable kingdom is the thorn, and the last the date palm, which has been assimilated to the animal kingdom since it needs the male to fertilize it so that it may bear fruit'. Then, once the plant kingdom had 'attained perfection', a 'finer offspring resulted, and the manifestation of the animal world took place'. The animal kingdom not only retained all the 'faculties' of the vegetable and plant kingdoms, but also gained two more: the 'Perspective Faculty' which is further divided into the five senses (touch, taste, smell, hearing and sight), memory, imagination and cognition; and the 'Motor Faculty' which allows animals the power of voluntary movement. Here Arudi postulates organic evolution with ancestors and their progeny, although the specifics of his idea do not fit modern evolutionary knowledge: animals did not evolve from plants, but from the common ancestors that also gave rise to plants.

Arudi went on to describe a hierarchy within the animal kingdom, stating that 'perfect' animals possess all Perspective and Motor Faculties, and that ants, snakes, maggots and worms are the lowest, 'defective' members of the hierarchy because they lack sight and hearing. He also mentioned a creature called a satyr ('nasnas'), being of 'erect carriage, of vertical structure, with wide flat nails', an intermediate between animals and humans, and the highest ranking member of the animal kingdom after mankind. Older literature often uses the word 'satyr' to refer to apes; for instance, orangutans have been scientifically designated as 'Simia satyr' (e.g. Owen 1830), so Arudi's idea is notable in that he clearly suggests a direct connection between apes and humans (see also note above, about "barbary apes" and true apes).

Additionally, Arudi stated that humans' superiority is in their intelligence, which empowers them to manipulate the 'kingdoms' in order to suit their needs by, for example, using minerals to create jewellery, metals to form tools, vegetation to prepare food and other objects, and animals for labor.

Tusi

Nasir ad-Din Tusi (1201–1274) was a thirteenth-century Persian Muslim thinker who postulated evolutionary ideas more than 600 years before Charles Darwin (Saniotis 2012). While known for his Arabic and Persian writings on medicine, philosophy, geography and ethics, Tusi's evolutionary theories are present in his work 'Akhlag Nasiri' (Nasirean Ethics), in which he discusses his belief in mankind's spiritual and material perfection (Alakbarli 2001). His writings contain recurrent use of the word 'takamul', which is translated to mean 'perfection' or 'evolution' in Arabic and Azeri (Alakbarli 2001). It is thought that Tusi is not credited as an evolutionist because Western science tends to interpret his ideas as being based upon Islamic philosophy, thereby assuming that his theories are more religious than scientific or naturalistic (Alakbarli 2001).

According to Alakbarli (2001), the evolutionary ideas of ancient Greek scholars such as Empedocles and Aristotle were further built upon by other Muslim writers before Tusi, including Al-Beruni (b. 973) and Ibn Tufayl (b. 1110). Tusi, in turn, was influenced by those scholars and reportedly 'foreshadowed' the theories of Lamarck and Darwin with his approach (Alakbarli 2001). He moved

> from theory to facts, instead of the other way around … When he wrote about evolution (he called it 'perfection') as a theory, he therefore didn't dwell on the details. For instance, he didn't write specifically about natural selection or the struggle for existence. In modern terms, he was more of a philosopher than a scientist. (Alakbarli 2001)

Tusi's theories on hereditary variability (Saniotis 2012) and organisms' ability to change according to environmental conditions are comparable to Darwin's concepts of variation and natural selection, as he wrote: 'The organisms that can gain the new features faster are more variable. As a result, they gain advantages over other creatures … The bodies are changing as a result of the internal and external interactions' (Saniotis 2012, 6). He further observed that such changes allow organisms to survive: 'Look at the world of animals and birds. They have all that is necessary for defense, protection, and daily life, including strengths, courage and appropriate tools [organs]' (Saniotis 2012, 6). Additionally, Tusi described a hierarchy of living things in nature:

> Animals are higher than plants, because they are able to move consciously, go after food, find and eat useful things … There are many differences between the animal and plant species … the animal kingdom is more complicated. Besides, reason is the most beneficial feature of animals. Owing to reason, they can learn new things and adopt new, non-inherent abilities. For example, the trained horse or hunting falcon … is at a higher point of development in the animal world. The first step to human perfection begins here. (Alakbarli 2001)

Tusi wrote about transitions between humans and animals: 'Such humans live in the Western Sudan and other distant corners of the world. They are close to animals by their habits, deeds, and behavior …' (Alakbarli 2001). This idea was echoed by Diamandopoulos and Goudas (2007, 92), who agree that Tusi not only echoed his predecessors' theory on the hierarchy of 'kingdoms', but also described humans' differences from animals: 'The human has features that distinguish him from other creatures, but has other features that unite him with the animal world, the vegetable kingdom or even with the inanimate bodies'. Moreover, humans are both biological and social creatures, yet are also 'distinct' from animals due to intellect: 'the human being is placed on the middle step of the evolutionary stairway. According to his inherent nature, the human is related to the lower beings, and only with the help of his will can he reach the higher development level' (Alakbarli 2001).

Ibn Khaldun

Ibn Khaldun (1332–1406), was a fourteenth-century North African Muslim thinker, historian and polymath (Guessoum 2011). Best known for his book 'Al-Muqaddimah', or 'Prolegomena' in the West (Asghar, Wiles, and Alters 2010), which contains ideas resembling modern evolutionary theory (Saniotis 2012), Ibn Khaldun strongly emphasised human evolution. He wrote:

> One should then look at the world of creation. It started out from the minerals and progressed, in an ingenious, gradual manner, to plants and animals. The last stage of minerals is connected with the first stage of plants, such as herbs and seedless plants. The last stage of plants, such as palms and vines, is connected with the first stage of animals, such as snails and shellfish which have only the power of touch. … The animal world then widens, its species become numerous, and, in a gradual process of creation, it finally leads to man, who is able to think and to reflect. The higher stage of man is reached from the world of the monkeys, in which both sagacity and perception are found, but which has not reached the stage of actual reflection and thinking. At this point we come to the first stage of man after (the world of monkeys). This is as far as our (physical) observation extends. (Ibn-Khaldūn 1377)

It is fascinating to see that amongst the eight Muslim scholars discussed here, ibn Khaldun most clearly professed his belief that humans themselves evolved specifically from an ape/monkey ancestor–a concept that a majority of both Muslims and people of other religions, including Christian creationists, find particularly difficult to accept.

On animal and human evolution, Ibn Khaldun further explained:

> It is also the case with monkeys, creatures combining in themselves cleverness and perception, in their relation to man, the being who has the ability to think and to reflect … plants do not have the same fineness and power that animals have … Animals are the last and final stage of the three permutations. Minerals turn into plants, and plants into animals, but animals cannot turn into anything finer than themselves. (Ibn-Khaldūn 1377)

Ibn Khaldun believed, as his predecessors did, in the evolution of life over time. Shanavas (2010, 113) suggests Ibn Khaldun stated that

> transmutations of one species into another over a long period of time resulted in the gradual evolution of life, from primitive organisms into a bush with numerous branches. Thus, life forms are not independently created but are evolutionary products from ancestral species.

He also rejected the Talmudic and Christian belief of dark African skin being a curse inflicted upon sinful human beings (Saniotis 2012; Shanavas 2010). Like Al-Jahiz in the eighth century, he observed the contrast in skin color between northern and southern people, namely the dark skin of the Sudanese, and suggested a causal relationship between hot southern climates and dark pigmentation, an idea now known to be correct (Saniotis 2012). Regarding the hereditary changes that humans can undergo, Ibn Khaldun wrote,

> [There also is regard of the fact that physical circumstances and environment] are subjected to changes that affect later generations; they do not necessarily remain unchanged. This is how God proceeds with his servants … And verily, you will not be able to change God's ways. (Shanavas 2010, 78)

Conclusions

We briefly summarised the evolutionary ideas of eight of the most renowned Muslim scholars between the eighth and fourteenth century, showing that these theories were proposed in a *continuum* of time during the Islamic Golden Age, well before Charles Darwin's time. All eight Muslim scholars suggested that humans underwent some type of phenotypic evolution. Some of them specifically wrote about similarities between humans and apes/monkeys, in many cases stating that humans derived from an ape/monkey ancestor. This is in complete contrast with the view, defended nowadays by most Muslims and Christian creationists, that humans did not undergo evolution, specifically from apes/monkeys.

Six of these scholars proposed a hierarchy in nature, consisting of mineral, plant, animal and human 'kingdoms', each one respectively preceding and benefiting the next. This idea derived from the *scalae naturae* concept of thinkers such as Aristotle, but with one major difference: unlike the atemporal (non-evolutionary) way in which the *scalae naturae* was subsequently interpreted by religious authorities, most of these Muslim scholars referred to *temporal* changes and different times of origin for different taxa and groups. That is, their theories were evolutionary because they supported *the notion that species change over time*.

Moreover, each Muslim scholar emphasised his belief that evolution and all changes in nature occur by God's will and guidance. This is, therefore, their major distinction from Darwin and most current evolutionary biologists who, either believing or not in God, consider that He is not directly involved in the specific changes occurring during biological evolution. In this sense, some of these scholars' ideas resemble those of the defenders of 'intelligent design', who accept that species change over time but maintain that those changes are always determined/planned by a 'designer'.

Most importantly, for the purpose of this work, is that the evolutionary theories of these Muslim scholars remain unrecognised in both the Muslim world and modern Western science, in part due to bias, Eurocentrism and perceived conflicts between evolution and Islamic teachings. Such views neglect the fact that those perceived conflicts originated in the early twentieth century and then manifested throughout the Muslim world during recent decades. Notably, some authors argue that the evolutionary theories of these and other pre-Darwinian Muslim scholars profoundly influenced some Western pre-Darwinian scholars and even Darwin himself (e.g. Guessoum 2011). We intend to further explore and test this latter idea, in our future studies.

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