

Teaching and learning about EVOLUTION: Part 2

In this second article on teaching evolution **George Branch** disusses how to deal with the controversies.

To some, evolution and religion are automatic enemies; to others they are compatible and complementary. Over the centuries, scientists have ranged from those implacably opposed to religion to others who have been deeply committed to a faith. Treading the right path in teaching evolution is important. People who accept evolution as an established fact rebel against what they perceive to be misinformed attacks on the subject. Others turn away from science if they feel their beliefs are derided or threatened. Antipathy feeds on antipathy, and polarisation is frequent – but seldom profitable. Ponder on Paul's biblical injunction in Romans 14: 19 *Let us therefore make every effort to do what leads to peace and to mutual edification.*

When persecuted by the church for his views on the solar system, Galileo (1564-1642) wrote: *It would be a terrible detriment for the souls if people found themselves convinced by proof of something that is made then a sin to believe.* People sometimes express disbelief that I can be a Christian and accept evolution. To glimpse the heat of feelings about evolution, consider this random sample of headlines from newspaper letters: 'Darwin's legacy is a recipe for school killers'; 'Holes in Darwin's "interim" theory'; 'No proof for evolution'; 'Every religion is a cult'; 'Believe in God's truth – or burn in hell' (hardly the spirit of Christian charity); and at least some more reconciliatory, such as 'Church to admit its Darwin mistake' and 'Good science and religion complementary'.

Christianity and evolution

As a practising scientist, I am absolutely convinced that evolution does take place. It has been my passion and delight to teach it. But as a Christian, I recognise that science is by definition limited to the material world; it provides no moral guidance. For me, science and religion have different but complementary aims.

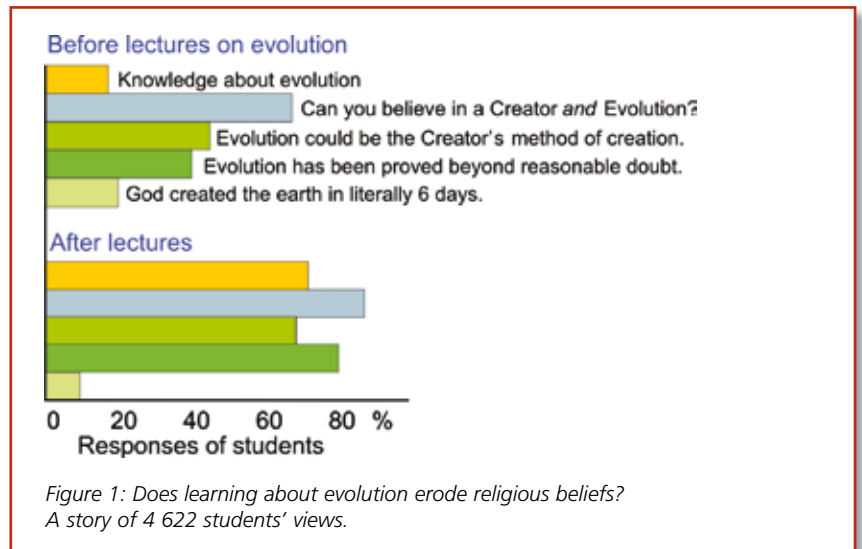


Figure 1: Does learning about evolution erode religious beliefs? A story of 4 622 students' views.

I cannot turn to the Bible for a literal description of how the world operates, and I cannot turn to science for life values.

In Part 1 of this pair of articles on evolution, I outlined four aspects that I believe should be presented to scholars:

1. the central ideas of Darwin's Theory of Evolution;
2. how evolution can be tested against evidence;
3. advances in scientific ideas since Darwin, and
4. the vital relevance of evolution in our modern world.

I concluded that evolution is a well-established fact, and that Darwin's ideas were correct but incomplete. In doing so, I distinguished between the *phenomenon* of evolution and the *mechanisms* that explain how it takes place. The distinction is useful when presenting the subject to learners, because the phenomenon of evolution is so well established that most scientists regard it as a fact; but the mechanisms are only partly understood and still being researched and expanded.

This article is devoted to a fifth aspect: the nature of the controversy and how to deal with it – both in the classroom and in life generally.

Let me begin with an analogy: toss an apple into a group of learners and ask why it descends to Earth. 'Gravity!' No hesitations? Nope. Yet science has over the years changed its views on the exact nature and mechanisms of gravity, and may do so again if we develop a 'Theory of Everything' as modern cosmologists are attempting to do. This does not negate the fact of gravity. As Steven J Gould (1987) wrote: *Facts don't disappear while scientists debate theories ... Einstein's theory of gravitation replaced Newton's, but apples don't suspend themselves in mid-air pending the outcome.* Similarly, the *fact* of evolution remains, regardless of whether scientists agree on all its *mechanisms*.

Does learning about evolution erode religious faith?

Mike Anderson, who did a PhD in the philosophy of evolution and taught evolution at university level, used to conduct a questionnaire of students' knowledge and attitudes about evolution, both before and after they had taken a course on the subject. I continued this tradition for 25 years. Figure 1 summarises the responses of students to five aspects of the questionnaire.

This demonstrates several

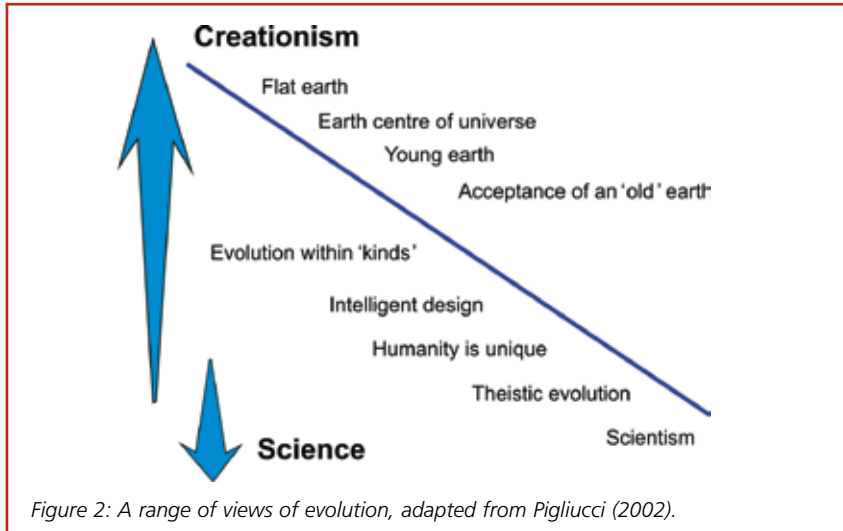


Figure 2: A range of views of evolution, adapted from Pigliucci (2002).

important things. First, the students improved from a scary 'before' mark of 20% for their knowledge about evolution, to 69%, much to my relief as an educator! Second, there were significant increases in the proportion accepting (1) both evolution and a belief in a Creator; (2) that evolution could be the Creator's way of creation; and (3) that evolution has been proved beyond doubt. A diminishing but significant 8% adhered to a belief in a young earth and a literal six-day creation.

What did I learn from this? Importantly, learning and accepting evolution does not need to threaten personal religious beliefs. However, an insistence on interpreting the Biblical Genesis account literally does compel a conflict – not just with evolution, but with all of science ... astronomy, geology, chemistry, physics ... 'the whole shebang', to use the title of a delightful book on the origins of the universe. This is the heart of the controversy. Literal interpretation of sections of inspired religious texts such as the Bible, Qur'an and Torah that deal with the creation and life does conflict with science. But there are many religious people who accept that these texts have eternal truths that are communicated in part by allegorical passages and poetic sections that were never intended to be literal word-for-word descriptions of how the world operates. As far back as 400 AD the great religious intellect St Augustine wrote about Genesis: *'In matters that are so obscure and far beyond our vision, we find Holy Scripture passages which can be interpreted in very different ways*

without prejudice to the faith we have received'. The renowned evangelist Billy Graham wrote in 1997 *'I think that we have made a mistake by thinking the Bible is a scientific book. The Bible is not a book of science. The Bible is a book of Redemption'*. St Augustine in a telling passage, as relevant today as when he wrote it, warned about uninformed criticism of science, saying that if non-believers find a religious person maintaining *'foolish opinions about our books, how are they going to believe those books and matters concerning ... hope of eternal life, and the kingdom of heaven, when they think their pages are full of falsehoods on facts which they themselves have learned from experience in the light of reason?'*

The diversity of views

There is a wide spectrum of views on evolution (Figure 2).

One extreme embraces insistence on a flat Earth and anti-Galileo views about the Earth being the centre of the universe – views that are now rare. The other extreme is scientism – which proposes that science is all we need. Between these extremes lie (1) a belief in a young Earth, (2) agreement to an 'old' Earth on the grounds that 'a thousand years in your sight are but a day...' (Psalms 90: 4), and (3) various levels of acceptance of evolution, ending with theistic evolution, a belief in a God who operates through natural laws such as gravity and evolution.

Considering anti-evolutionary views

Criticisms about evolution range from simple ignorance of the subject, through to serious scientific concerns.

My guideline on their validity is to ask:

1. whether they are testable by observation or experimentation, and
2. if they are based on information that has been reviewed by independent specialists in the field.

It is easy to open up the 'web' and be flooded with views on evolution; but be sceptical if it is not based on peer-reviewed information. Let's explore some of these criticisms.

1. Darwin's ideas can't explain the origin of life.

Let's be fair to Darwin. He made it clear that his ideas applied to life once it had arisen: not to the origin of life. But let's also be equally honest in acknowledging that scientists have several plausible ideas about the origin of life but they are a long way to being confident that any of them is correct. Once life arose, I am firmly convinced of the power and mechanisms of Darwinian evolution. But just because mysteries remain about the origin of life, this does not negate science – mysteries are a challenge, not a threat to science. For some, the absence of secure scientific explanations is a reason for inserting a divine intervention. I am cautious of this 'God-of-the-gaps' approach because many early gaps in knowledge have now been filled.

2. Evolution is 'just a theory'

Ronald Reagan, then President of the USA, infamously dismissed evolution with these words. Shame on him! If he had done his homework, he would have appreciated that in science, a theory is not some airy-fairy invention sucked up by a scientist (usually referred to as a 'boffin' to further denigrate the idea). Ideas are turned into hypotheses, which must be tested with new data to see if they can be upheld. Just like the atomic theory, or the germ theory, or the theory of gravitation, the theory of evolution is a body of evidence that unites and explains a range of observations, and does so to such an extent that it is regarded as fact. Some aspects of evolution can be observed and experimentally proven before our eyes. Diversity among individuals, the fact that not all individuals survive to reproduce, and inheritance of characteristics (three cornerstones of Darwin's ideas), all fall into this category. As a class exercise, learners >>

can discuss their own family trees, and soon come to the conclusion that all three are facts.

3. Microevolution is OK, but macroevolution isn't

Many people accept microevolution (adaptation of individual species to the environment) but refuse to take the next step – that evolution leads to the formation of new species – let alone accepting changes from one major group to another. In one sense they have a point. The evidence for these changes is largely historical. It is not something we can easily test by experimentation in our modern world. Some people even argue that because of this, evolution is a religion – a belief – that is untestable. If that is true, then we have to throw out all of geology and all of astronomy. And while we are about it, let's toss out courts of law, because most times crimes are not observed ... they are deduced from other evidence. Development of new species of plants is something that has been observed (and can be experimentally induced) in our own life spans. Indeed, one of the plants of immense importance to humans, bread wheat, was formed by two steps of hybridisation and doubling up of chromosomes (polyploidy) that led to a population that is reproductively isolated from any of its parental stocks and is thus by definition a new species. Most animal species don't seem to arise this way. They do so by gradual divergence of populations that are geographically separated (geographic isolation). That takes more than a lifetime to complete, and the whole sequence has never been observed. But the circumstantial evidence for this process, derived from the geographic distribution of species (biogeography), is substantial. Similarly the fossil record documents changes of several major groups into other major groups. In South Africa, the Karoo fossils are famous for their transition from reptiles to mammals via a group known as 'mammal-like reptiles' for the very reason that they are 'half-way-houses'. Fish to amphibians and amphibians to reptiles have similar intermediates that are arranged in the fossil record in the sequence that would be predicted if ancestors give rise to later groups.

In short, the evidence for

macroevolution is compelling. Certainly there are 'missing' links between some groups, but enough links have now been recorded to be confident that large-scale changes from one group to another can and have taken place.

4. Evolution contradicts the second law of thermodynamics

In simplified form, the second law of thermodynamics states that the degree of disorder (entropy) in a system can never decrease. On these grounds, it is argued that evolution cannot occur because it has resulted in an increase in organisation and complexity over time. There is one main problem with this line of thought. The law applies in a closed system. As long as energy can be drawn from outside, part of the system can become more complex (more organised) at the expense of another part losing its organisation. A young student of mine once made a not-very-flattering but amusing cartoon of me eating a Christmas turkey. In it, I get fatter (and maintain my organisation), but the products of the turkey are distinctly less organised than before: the combined level of order for the consumed turkey and myself is less than before the meal. In the bigger picture, the sun fuels growth of plants, which are in turn eaten, allowing herbivores to develop. Thus, there are local events that increase order, but they are bought by inputs of energy or materials, and the net effect is an overall decrease in order (i.e. an increase in entropy).

Pause for a moment and think about embryology – the 'little miracle' of the emergence of a human child from a simple, single-celled fertilised egg. If we consider an increase in evolutionary complexity as 'impossible according to the second law of thermodynamics' we should treat embryology in the same light. Embryos, too, get more complex. We understand how. So why should evolution be considered a problem, when we comfortably accept embryological development?

5. Random mutations and selection never create anything beneficial or 'new'

Twenty years ago, it might have been defensible to say that mutations produce no increase in complexity. Mutations are random. They can be bad (quite often), neutral (very often)

or good (occasionally). Selection whittles out individuals that are less 'fit'. For a time, it was possible to argue that changes in genetic composition don't add to the diversity of genes available, so complexity can't alter. But two important things must now be added to this story. First, while mutations are random, natural selection clearly is not: it increases adaptation to the environment. Second, we now know that genes quite often multiply. Two copies of the same gene can be produced. Sometimes this is no advantage and the second copy may slowly atrophy and become 'junk DNA'. But the more interesting case is when one copy retains its original function, and the other is free to mutate and take on a brand new function. We call these 'homologous genes' because they have almost identical structures except for mutational changes, but they may have quite different functions. A clear example of this occurs in 'ice fishes', which live in Antarctica under freezing conditions. They have a gene coding for a precursor of trypsin – a digestive enzyme. This gene has multiplied and been re-arranged to develop another gene, which codes for antifreeze proteins that allow the fish to live under freezing conditions. Something new from something old. The antifreeze genes appear to have developed about 5-14 million years ago, coincident with both the time when Antarctica cooled to freezing and the period when the ice fish family started diversifying into the 95 species that now exist.

6. 'Irreducible complexity' disproves evolution

'Irreducible complexity' is a mouthful for an old idea that if any complex organ or biochemical pathway can be found that could not be simplified and still have a function, then it could not have evolved from simpler beginnings. And if this is true, it implies an 'intelligent design' (and an intelligent designer) for its origin.

The idea has its root in words taken from Charles Darwin himself: *'If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down...'*

When I first encountered 'irreducible

complexity', I was fascinated. Initially, I felt it was a legitimate scientific approach to testing the validity of evolution. Its status is best explored by examples, starting simple and getting more complex. First, the mammalian eye (Figure 3) is often held up as an example of a complex structure.

Indeed, it is. 'What use is half an eye?' is the clarion challenge of proponents of irreducible complexity. But the animal kingdom is full of examples of eyes that are much simpler, right down to the pigment spots in unicellular plankton that allow detection of light and orientation with respect to it, and they are all clearly an improvement on having no eye. Simpler structures do exist and do 'work'. So the eye, wonderful as it is, is a poor candidate for irreducible complexity. It certainly could have evolved by gradual improvements from a humble origin.

A second oft-quoted example is the bacterial flagellum, which has nine outer and two inner microtubules and 27 complex proteins, all said to be necessary for it to function. Yet simpler flagella are known: 9+1, 9+0, 6+0 and 3+0 arrangements of microtubules exist. Moreover, some parasitic bacteria use a subset of the 27 proteins for a completely different purpose ... to drill through the cell walls of their host. So, again, simpler structures do exist. The bacterial flagellum is not 'irreducibly complex'.

My third example is perhaps the most interesting. The human blood-clotting mechanism is extremely complex. Ultimately, it depends on a protein (fibrinogen) being acted upon by an enzyme (thrombin) that converts it into fibrin – which has sticky portions that adhere to form a clot. But thrombin itself depends on a 'Factor X' being produced, and that in turn needs another factor ... and so on until eventually a chain of 15 different chemicals called 'serine proteases' is involved. Complex? Yes indeed. Irreducible? No. Simpler clotting systems do exist in invertebrates. Moreover, the serine proteases are all closely related (homologous) and arose by gene duplication. Even thrombin itself is homologous to trypsin, and probably arose by duplication of the gene producing trypsin ... now where have

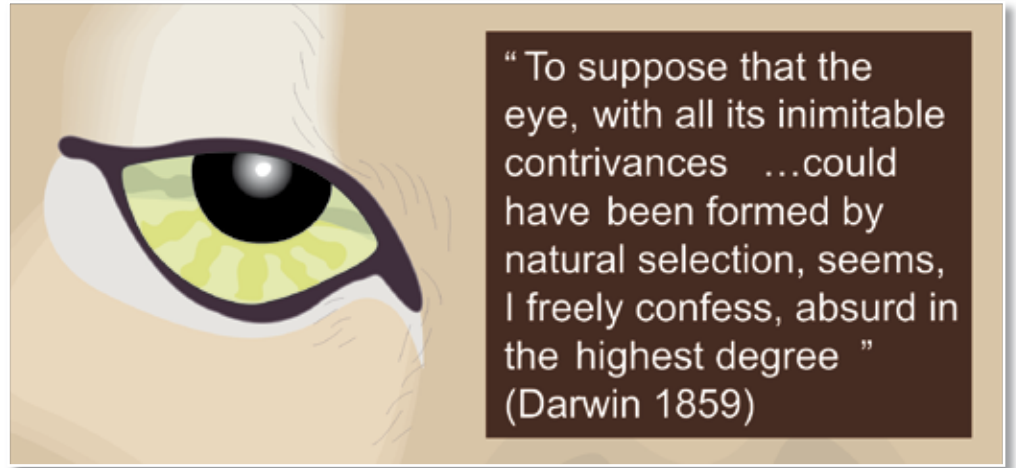


Figure 3: Darwin's views on the eye

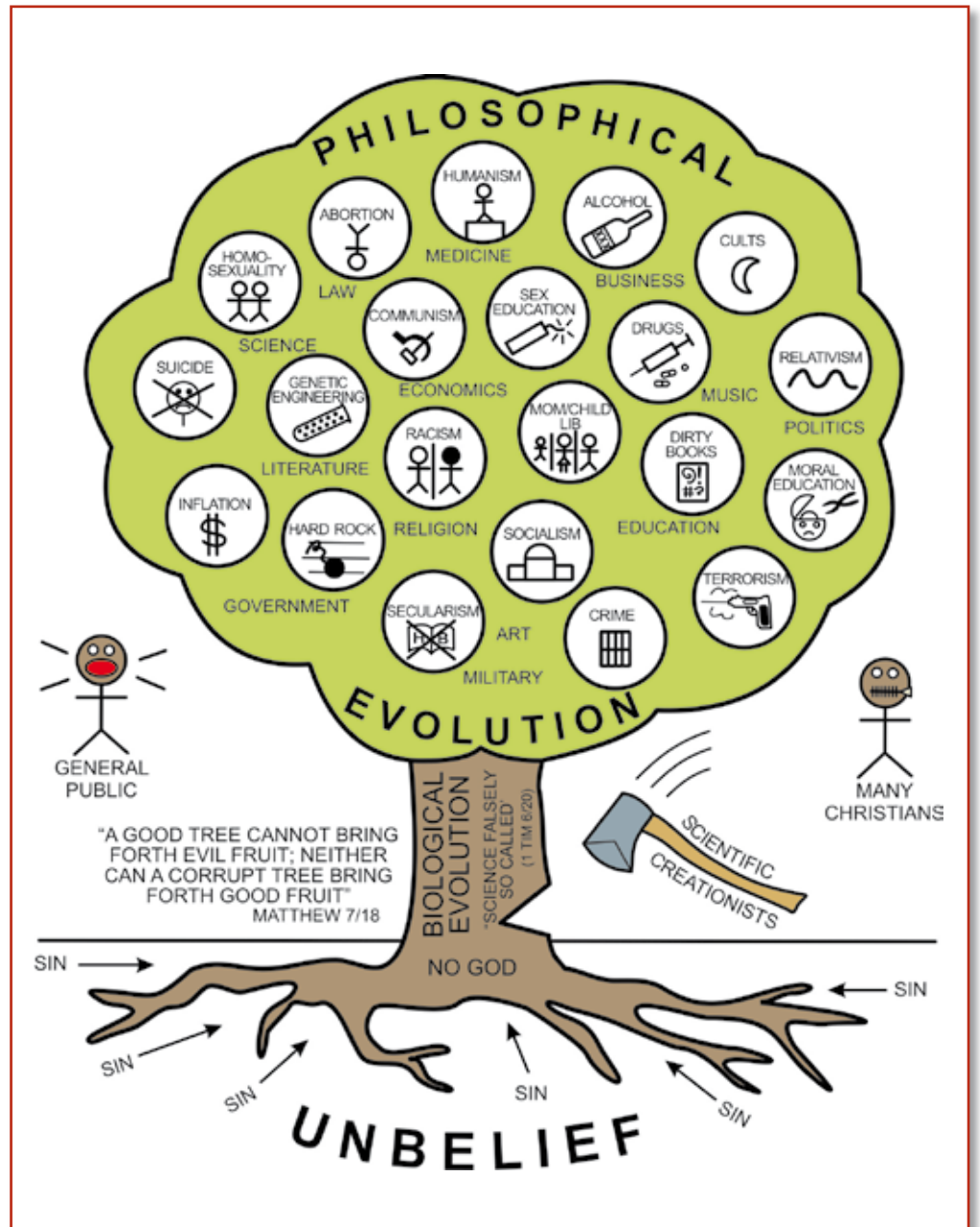


Figure 4: 'Blame all the maladies of humanity on evolution...' Pigliucci (2002).

Table 1: A range of views on how science relates to religion.
Adapted from Pigliucci (2002)

No God			Atheism and scientism
Deistic God		Non-overlapping worlds	
Naturalistic God	Anthropic principle	Theistic science	
Personal God	Scientific theism	Faith and reason	Irreducible complexity and intelligent design Classical 'young Earth' creationism
	Science can prove religion	Separate but complementary worlds	Conflicting worlds

we heard that name before? Aha: it seems that this is not the only time that gene duplication has led to the development of 'new' proteins.

In short, we still do not have a convincing case of irreducible complexity. The quote above from Darwin ends with the words: '*...but I can find no such cases*'. That remains true today.

Irreducible complexity and intelligent design have been cast as legitimate scientific enquiries into evolution and alternatives to Darwinism. They became the subject of court cases in the USA when they were advocated for inclusion in the science curriculum. This in itself says much about the origins of these ideas. Federal policy in the USA separates church and state, and religion may not be taught in schools. But if these ideas are scientific, they can (and should) be taught. If they are based on religion, they may not. The courts have ruled that 'intelligent design' is identical to 'creation science', which is inherently religious in nature.

In South Africa we do not have such constraints on teaching religion. I believe that irreducible complexity and intelligent design should feature in a curriculum dealing with evolution, and that the evidence for and against the ideas must be examined as rigorously as it is for evolution. That way, scholars learn to evaluate different ideas based on tests of their validity.

7. Evolution is responsible for the social ills of the world

If scientific attacks on evolution fail, it is possible to turn to moralistic assaults, such as 'blaming all the maladies of humanity on evolution'. I have borrowed this phrase and Figure 4 from Massimo Pigliucci's book *Denying Evolution*.

Variations of the figure appear in several anti-evolutionary publications.

The heart of the idea is that if natural selection acts on random mutation to produce adaptations via competition between individuals, then what room is there for absolute moral guidelines and constraints on how we should behave. Quite how some of the items listed in the figure – such as inflation – can be blamed on evolution, is obscure.

But before we glibly dismiss this diagram with a derisive laugh, it should not be forgotten that Darwin's concepts *have* been used to promote views that most of us would now find offensive, as indicated by the following quotes justifying colonialism and racism: '*The British colonist is... carrying out a preordained rule... the inexorable law which Darwin has aptly termed 'survival of the fittest'...*' (FC Selous 1896); and an injunction to '*draw a sharp boundary ... between the most highly developed civilised people ... and the crudest primitive people ... and unite the latter with the animals*' (Ernst Haeckel 1868). But in reality, Darwin's ideas cannot validly be extended to the political and social sphere. In the words of Massimo Pigliucci: '*The theory of evolution tells us how living things have changed and come to be ... it is not a guide to how we should live our lives, nor was it intended as such by Darwin*'.

It is possible to take Figure 4 and mischievously alter it to put 'religious dogma' as the root of all evil and 'science' as the axe that chops it down, and to blame everything on religion. Indeed, many sins can be laid at the door of religion, including examples of terrorism, sexism and racism. But whether the diagram is anti-evolution or anti-religion, it is a meaningless cheap device to score points rather than rationally examining ourselves and our world. Rejecting religion on these grounds misses the

point that all of us have free will to decide for ourselves how we should behave. And rejecting evolution because it has been corrupted by some to promote a false social agenda is equally invalid.

None of this denies that evolution has philosophical, social and moral implications. For example, modern evolutionary and molecular biology have taught us two things about the human race: We all originated in Africa, and comparatively recently – perhaps 80 000 to 120 000 years ago; and there is less genetic diversity within our species than within almost any other species that has been examined. The racial division and supremacy that have bedevilled our country are based on myths.

Science and religion, or science versus religion?

A wide range of views exists in human societies about how science and religion relate to each other, as summarised in Table 1 – which is neither complete nor rigid in its 'boxes'.

The columns show three options: (1) science can uphold religion; (2) science and religion are different and neither can prove or disprove the other, (3) the two are at war. In the first row of 'no God' is atheism, the belief that God does not exist, and scientism, which argues that all we need in the world is science. Under 'deistic God' are people who have a distant view of God who created the universe and then let it run; and who accept that religion and science are different worlds. A 'naturalistic God' created the laws of the universe, including the process of evolution, but intervenes rarely at miraculous and sometimes very personal points. 'Theistic evolutionists' like myself would place themselves in this 'box', as would people who believe in the 'anthropic principle' that the universe and its constants (the rate of expansion of the universe, the strength of nuclear forces, gravity etc.) are so finely tuned that they reflect God's creation. Stephen Hawking, one of the world's most extraordinary scientific minds, wrote in *A Brief History of Time*: '*It would be very difficult to explain why the universe should have begun in just this way, except as the act of a God who intended to create beings like*

us'. At the bottom of the table is a final category, a 'personal God' who intervenes in our lives and our world continuously: whose actions can be examined scientifically (scientific theism), or run in parallel with scientific laws (faith and reason). Pope John Paul II would probably fall in the latter group, and it was he who accepted 'evolution as more than a hypothesis', and who officially recognised that Galileo was not in conflict with the church (albeit 350 years after Galileo's death).

Only in the left of the table do worldviews create conflict between science and religion. Classical creationism adheres to a literal belief in the Bible, including a young Earth, about 6 000 years old, and the individual creation of all 'kinds' of life in a six-day period, bringing it into conflict with not just evolution but all fields of science. 'Irreducible complexity' and 'intelligent design' are more sophisticated offspring of creation science (once caustically described as 'creationism dressed up in a cheap tuxedo'), and vary in their acceptance of different ages of the earth and different aspects of evolution; but at their heart they attempt to discredit evolution or at least aspects of it. Similarly, atheism and scientism are at loggerheads with religion. For me, science cannot either prove or disprove the existence of a God, which is by definition a faith. Nor can it supply the wisdom to judge how to use the knowledge we gain from science.

'Science without religion is lame, religion without science is blind'
– Albert Einstein.

Where do *you* belong? Two of the joys of humanity are the capacity for conceptual thought, and the free will to decide our destinies. Joys they may be; but with them they bring awesome responsibilities. For teachers especially, the responsibilities are huge, for they powerfully influence the lives of the next generation.

How should teachers handle evolution?

In my previous article, I outlined aspects that should be covered. Building understanding, testing ideas, comprehending how science operates and is ongoing, and appreciating the relevance of evolution in our lives today are all prerequisites to handling

'There is a grandeur of this view of life, with its several powers. Having been breathed into a few forms or one; that ... from so simple a beginning, endless forms most beautiful and wonderful have been, and are being, evolved.'

Charles Darwin's concluding words to
On the Origin of Species 1859.

the controversies. But the 'how' of teaching is a different question. From discussions with teachers and learners, five principles have emerged:

1. *Respect the views of others.* Scorn and arrogance simply close people's minds. Sympathetic understanding, rational discussion and exchanges of views break barriers.
2. *Insist on testability of ideas.* You are teaching a science curriculum, and evolution is science. If opposing ideas arise, ask if they can be tested by observation or experiments.
3. *Acknowledge ignorance.* No-one knows all the answers; nor can science provide answers to all things. If you don't know the answer, say so (but search for it later!) If science doesn't yet have an answer or will never be able to provide one, say so.
4. *Encourage discussion and thought.* No subject is better suited than evolution to generate discussion and encourage independent thought. Use this to advantage.
5. *Distinguish the goals of science and religion.* Science and religion have different objectives and methods. Separate the two and you avoid many of the potential conflicts.
6. *Enjoy yourself.* Some teachers dread teaching evolution because they haven't been trained in the subject, fear the controversy, and don't know how to tackle it. Ironically, the subject is enormously rewarding for the same reasons. It is a never-stop-learning topic; it invokes intense interest in young minds; and it teaches one to think about 'big' issues.

Conclusions

- Evolution is a well-established fact, supported by multiple lines of evidence.
- Science doesn't answer all questions, especially moral, spiritual, philosophical and ethical 'why?' questions.

questions.

- Science and religion cannot be used to test one another; their goals, methods and philosophies are far apart.
- But they can be complementary, not antagonistic. □

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He has spent decades teaching undergraduate and postgraduate zoology students, inspiring generations of young scientists and offering a balanced approach to the science of evolution.

SUGGESTED READING

- Collins FS. *The Language of God*. New York: Free Press, 2006. (The perspectives of a Christian who led one of the groups unravelling the human genome.)
- Collins FS. Faith and the human genome. *Perspectives on Science and Christian Faith* 2003; 55: 142-152. (A brief summary of his views.)
- Miller KR. *Finding Darwin's God*. New York: Harper Perennial, 2007. (A careful analysis of the controversies from someone who is both a Christian and an authoritative molecular biologist.)
- Pigliucci M. *Denying Evolution. Creationism, Scientism and the Nature of Science*. Mass., USA: Sunderland, 2002. (An exposé of the errors of creationism and the limits of science.)
- Bryson B. *A Short History of Nearly Everything*. London: Black Swan, 2004. (A magnificent popular guide to everything from the big bang to mankind. If you can afford it, luxuriate in the fully illustrated version.)
- Dobzhansky T. Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher* 1973; 35: 125-129. (A succinct view from a leading evolutionist and Christian.)
- Bateman PW. and Moran-Ellis J. The science in the intelligent design debate: teach it like it is. *South African Journal of Science* 2007; 103: 271-273. (A concise review of intelligent design, advocating that it should be taught in our schools.)
- http://www.maropeng.co.za/index.php/exhibition_guide/sterkfontein/creation_beliefs/ (The website of the Maropeng world heritage site, with a brief review of different religions and their creation beliefs.)