Ideas and evidence in science: the portrayal of scientists in GCSE textbooks

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How accurate are the portrayals of scientists in our current GCSE textbooks and how useful are they in helping teachers deliver the ideas and evidence strand of the science curriculum?

With the introduction of the latest version of the National Curriculum (DfEE, 1999), came the integration of the history of science into the mainstream school science curriculum. Including the history of science in our curriculum is not new. In the original National Curriculum, introduced in 1988, attainment target 17 was devoted to the history and development of ideas in science. However, this never sat comfortably in the curriculum and has never been fully addressed in teaching and the textbooks.

The ideas and evidence strand is now examinable. Previously, the history of science sat within the programme of study and was never examined. It soon became clear that non-examined material was not taught to the same degree as examined material. It is likely that teachers, who are concerned with the relentless pressure to raise standards, decided for the most part that teaching non-examined materials might detract from the business of raising standards, those standards being judged solely by success in examinations. Now that the history of science will be examined, two questions immediately arise:

- How should we approach and teach this strand of the science curriculum?
- How do our textbooks currently meet the demands of this strand?

This article addresses these questions and provides suggested approaches to the teaching of ideas and evidence.

ABSTRACT
This article deals with the portrayal of scientists in commonly used school GCSE textbooks and addresses the issue of their suitability for teaching the ideas and evidence strand of the new English science curriculum. After detailing the results of a survey of GCSE textbooks, it looks at how the theory of evolution by means of natural selection is dealt with in a representative sample of 13 key stage 4 science/biology textbooks and concludes with a suggested approach for the teaching of ideas and evidence in science.

Current requirements

In the introduction to the science curriculum the importance of science is stressed, though the only reference directly to ideas and evidence in science states that '*through science, pupils understand how major scientific ideas contribute to technological change*' (DfEE, 1999, p. 15). At key stage 4, the ideas and evidence in science section requires that pupils should be taught:

> *a) how scientific ideas are presented, evaluated and disseminated.*
>
> *b) how scientific controversies can arise from different ways of interpreting empirical evidence (e.g., Darwin's theory of evolution).*
>
> *c) ways in which scientific work may be affected by the contexts in which it takes place (for example social, historical, moral and spiritual), and how these contexts may affect whether or not ideas are accepted.* (DfEE, 1999, p. 46)

The content sections of the new requirements detailing the biology, chemistry, geology, physics and astronomy that is to be taught are devoid of references to the history of science and to the scientists who made the discoveries and developed the concepts to be taught. There is little practical help in the curriculum requirements to guide teachers as to what elements of the history of science should be addressed in their everyday teaching and how this should be accomplished. Naturally, the consequence of this is that teachers will have to rely on textbooks and their own research in order to fulfil the requirements of the curriculum. A key concern here is that teachers are not equipped to deal with and teach the ideas and evidence component. The teaching methodology that the majority of science teachers employ takes a practical stance and issues that surround the teaching of science from a theoretical or historical viewpoint are largely ignored. As Jenkins stated in his evidence to the House of Commons Science and Technology Select Committee on 9 January 2002:

> *Put simply, science teaching without practical work is, for most science teachers, simply unthinkable. This is despite the fact that such work takes many forms and there is often confusion or ambiguity about its purpose, as well as considerable doubt about its effectiveness in promoting students' understanding of scientific ideas.*
> (Jenkins, 2002, p. 4)

How teachers acquire the skills, knowledge and understanding required to teach this strand successfully is a source of concern. Interestingly, another curriculum area, history, is equipping pupils to tackle this strand at key stage 3. The requirements for teaching key stage 3 history provide a set of requirements for teaching the history of science. In history, the knowledge, skills and understanding that pupils are required to have are as follows (DfEE, 1999a, p. 150):

- Chronological understanding.
- Knowledge and understanding of events, people and changes in the past.
- Historical interpretation.
- Historical enquiry.
- Organisation and communication.

In essence, all these elements are required for effective teaching of a historical aspect to science. So just how do our current textbooks meet the demands of the science curriculum for 2000 and how much can we rely on the validity of the historical aspects of science they present to teachers and pupils?

The textbook surveys

For the purposes of the first survey six GCSE books were compared. They comprised two series that are commonly used in schools to support the teaching of double science award and separate science GCSEs. The first, *Biology for you*, *Chemistry for you* and *Physics for you* (Williams, 1996; Ryan, 1996; Johnson, 1993) is a series to which many schools subscribe and has developed from Johnson's original book *Physics for you*. The approach of this, and subsequent textbooks in the early 90s, broke away from the traditional school science textbook that was largely text-dominated with little regard to language level and difficulty. Johnson's approach, in providing text with low reading ages, proved very popular among teachers. The second series surveyed, *Key science* (Aplin, 1994; Ramsden, 1994; Breithaupt, 1994) included within its layout occasional sections called '*Who's behind the science?*', one of the first textbooks to specifically address the issue of the history of science in a systematic way. The occurrences of accounts of scientific discovery, the lives of scientists or simply references to scientists who figure in our teaching of science are given in Tables 1–3.

Some clear conclusions are discernible from this survey:

- Key stage 4 physics has a larger volume of unexplained names in the history of science than biology and chemistry.
- The history of science is often included as a non-essential 'add on' and serves little purpose in developing ideas and/or concepts.
- The figures mentioned and elaborated upon are mostly those that have traditionally been used, e.g. Newton, Einstein, Darwin, Mendeleeff, etc.
- There is little or no attention paid to the context within which the science was developed.
- Few accounts of the lives of scientists are given or how they worked.
- Some information is factually incorrect.

A second survey, comprising 13 textbooks, was undertaken to ascertain how one aspect of ideas and evidence is treated. The theory of evolution by means of natural selection was chosen as it is highlighted in the curriculum document as a topic suitable for

Table 1 Survey of GCSE biology textbooks.

Textbook	*Page number*	*Context*	*Scientist(s) mentioned*
Biology for you (Williams, 1996)	160	IVF in a mock headline in a graphic, no reference in the text	Edwards Bavister Steptoe
	164	Pasteur's work on microbes	Louis Pasteur Robert Koch
	169	Lister's work on antiseptic	Joseph Lister
	172	Jenner's work on smallpox vaccination and Salk's work on polio	Edward Jenner Jonas Salk
	173	Penicillin	Alexander Fleming Howard Florey
	273	Darwin's calculation on elephant breeding unchecked	Charles Darwin
	274	Theory of evolution by means of natural selection	Charles Darwin Alfred Russell (*sic*) Wallace
	275	The Galapagos finches (incorrect account)	Charles Darwin
Key science: Biology (Aplin, 1994)	vi	Reference to the history of science and unexpected discoveries	Francis Crick James Watson
	viii	Superconductors and electricity	Georg Bednorz Alex Muller Michael Faraday
	7	Binomial system of naming species	Carl von Linné
	109	The DDT story	Paul Mueller
	129	The Minamata story	None
	140	Cells first seen	Robert Hooke
	161	Structure of haemoglobin	Max Perutz
	163	Base pairings in DNA	Erwin Chargaff Francis Crick James Watson
	164–5	The story of the discovery of the structure of DNA, two-page spread	Francis Crick James Watson Rosalind Franklin Maurice Wilkins
	180	Cure for scurvy	James Lind
	206	Process of digestion	William Beaumont
	244	Smallpox vaccination	Edward Jenner
	298	Development of Braille	Louis Braille
	301	Conditioned reflexes	Ivan Pavlov
	336	Antiseptics	Joseph Lister

(continued)

Textbook	*Page number*	*Context*	*Scientist(s) mentioned*
	345	Inheritance of characteristics	Gregor Mendel
	359	The flask experiments	Louis Pasteur
	373–4	The story of penicillin	Alexander Fleming Howard Florey Ernst Chain
	382–7	Section on the life and work of Charles Darwin	Charles Darwin Charles Lyell
	388	Evolution by natural selection (incorrect account of the joint publication of the theory)	Alfred Russel Wallace Gregor Mendel
	393	Discovery of the coelacanth	None

meeting the statement concerned with scientific controversies. The results of this survey are detailed in Table 4.

It is clear from the surveys undertaken that the textbooks looked at are unsuitable for meeting the demands of the current science curriculum as listed previously. It must be recognised that when these particular books were written the demand for the teaching of the history of science was in effect non-existent, though by implication the demand was there in the programme of study. This leaves a worrying situation in our schools. Teachers have either to restock with new textbooks in the hope that they address the issue of ideas and evidence in science in a more systematic and coherent way, or to develop teaching programmes and materials to meet the current demands from their own research and resources.

From a more detailed examination of how the history of science has been incorporated into textbooks, it is evident that most of the writers have not taken any specific approach to the use of history of science as a means of increasing knowledge and understanding in science. In many instances, the use of historical aspects is merely a device to 'break up' the text or introduce a distraction for pupils that gives them an opportunity to divert their attention from the core text of the book.

There is no consistent approach in the texts to the use of historical figures in science. In one series, *Key science*, an attempt has been made to address the history of science by using the device '*Who's behind the science?*' In this instance, either very brief biographical details are noted or, in place of biographical detail, the person's contribution to the idea, concept or discovery is given. For example, page 165 of *Key science: Chemistry* provides a brief paragraph describing the discovery of oxygen by Joseph Priestley on 1 August 1786. There is neither mention here of Lavoisier and his work, nor of George Stahl's theory of phlogiston. Add to this that other historical accounts of Priestley's work describe his production of oxygen from the heating of mercuric oxide in 1774 (Williams, 1994, p. 400) and Lavoisier's use of the ideas of Priestley in the late 1770s (Ronan, 1983, p. 388) and a far more complex picture than the one described emerges.

On page 51 of *Key science: Chemistry* there is a quote from John Dalton that '*Matter is composed of atoms*' dated as 1808. In *Chemistry for you* the same event is described and dated as '*around 1805'* (p.14). These small discrepancies indicate that problems are being created in the way we approach the history of science, with scant regard for the facts readily available from historians and historians of science. This point will be illustrated further in the section dealing with the treatment of one of the seemingly best known events in the history of science, the development of the theory of evolution by means of natural selection. Other problems are also evident from the survey, such as the different, yet distinct, spellings of the name of Dmitry Ivanovich Mendeleeff (Williams, 1994), variously spelled as Dimitri Mendeleev (Ramsden, 1994) and Dmitry Mendeleev (Ryan, 1996). His surname is also commonly seen with a 'y' between the last two 'e's. It is recognised that some name spellings will change as foreign names using alphabets distinct from our own are translated

Table 2 Survey of GCSE chemistry textbooks.

Textbook	*Page number*	*Context*	*Scientist(s) mentioned*
Chemistry for you (Ryan, 1996)	14	Dalton's use of the term 'atom'	John Dalton
	28	The history of the atom	J. J. Thomson Ernest Rutherford Niels Bohr Also in a timeline diagram: Democritis, Dalton, Thomson, Rutherford, Bohr, Chadwick
	42	Development of the Periodic Table	John Newlands Dmitri Mendeleeff*
	205	Egyptian discovery of work of yeast	None
	212	Le Chatelier's principle	Photo and caption of Le Chatelier
	216	Haber process	Fritz Haber Carl Bosch
	243	X-ray crystallography	Dorothy Hodgkin
	296	Continental drift	Alfred Wegener
	311	Avogadro's constant	Amedeo Avogadro
	321	Faraday's Law	Michael Faraday
Key science: Chemistry (Ramsden, 1994)	10–11	Continental drift	Alfred Wegener
	45	Brownian motion	Robert Brown
	51	Quote from Dalton on matter	John Dalton
	59	Haber process	Fritz Haber
	61	Discovery of bucky balls	None
	70–71	Discovery of radioactivity	Becquerel The Curies Rutherford
	77	History of the Periodic Table	Dmitri Mendeleeff
	92	Splitting the uranium atom	Otto Hahn
	94	The fusion bomb	Andrei Sakharov
	103	Electricity	Michael Faraday
	146	Fluoride story	Fred McKay
	165	Discovery of oxygen	Joseph Priestley
	315	Le Chatelier's principle	Fritz Haber Le Chatelier
	330	Explosives	Professor Sobrero Alfred Nobel
	371	Haemoglobin (duplicate of work in biology textbook)	Max Perutz
	377	Laughing gas	Humphry Davy
	378	Sulphonamide drugs Treatment for syphilis Penicillin	Gerhardt Domagh Paul Erlich Salvarsan Alexander Fleming

*The spelling used in this table is consistent with that of *Collins biographical dictionary of scientists* (Williams, 1994) and not necessarily with the spelling used in the textbook.

Table 3 Survey of GCSE physics textbooks.

Textbook	*Page number*	*Context*	*Scientist(s) mentioned*
Physics for you (Johnson, 1993)	39	Boyle's and Charles's law	None
	85	First Law of Motion	Isaac Newton
	95	Magdeberg hemispheres	None
	121	Question and answer (humorous)	James Watt
	212	Geiger-Müller tube mentioned	None
	242	Van de Graaff mentioned	None
	251	Ohm's law	Georg Ohm
	284	Magnetic effect of electricity	Christian Oersted
	288	Fleming's left-hand rule	None
	296	Electricity from magnetism	Michael Faraday
	296	Fleming's right-hand rule	None
	297	Lenz's law	None
	341	Geiger-Müller tube mentioned	None
	344	Nucleus of atom	Rutherford
	356–61	The nature of science	60 scientists, discoveries/inventions listed. 8 scientists profiled: Galileo, Newton, Einstein, Faraday, Curies (Pierre, Marie and Irene), Rutherford
Key science: Physics (Breithaupt, 1994)	11–12	Geocentric and heliocentric models of the universe	Pythagoras, Aristarchus Ptolemy
	14	Calendar	Julius Caesar (scientist?)
	73	The joule	James Joule
	87	The calorie	Humphry Davy Count Rumford James Joule
	123–4	Discovery of radioactivity	The Curies (duplicate of chemistry text)
	141	Splitting the uranium atom	Otto Hahn (duplicate of chemistry text)
	143	Fusion bomb	Andrei Sakharov (duplicate of chemistry text)
	143	$E = MC^2$	Albert Einstein
	167–8	Light	Isaac Newton Christiaan Huygens Thomas Young
	213	Photons	Isaac Newton Thomas Young Albert Einstein
	242	Pressure	Blaise Pascal
	244	Displacement	Archimedes
	324–5	Current	André Ampère William Gilbert Benjamin Franklin Alessandro Volta Hans Oersted William Sturgeon
	333	Electricity	Michael Faraday

into an anglicised form. This effect either needs a brief explanation to explain why variations in spelling occur or points to the need for a common reference to avoid problems that will inevitably occur as pupils try to research information about such scientists from several books or sources.

Other more worrying issues also arise such as incorrect accounts of events. Aplin (1994) states in *Biology for you* that '*[Charles Darwin and Alfred Russel Wallace] recognised [each] other's contribution and acted generously over the matter. They agreed to the joint publication of their ideas*' (p. 388). In fact, Wallace was not aware of the events unfolding in London after the delivery of his essay to Darwin as he was in the Malay Archipelago. He learned of the events surrounding the joint publication at a later date (Wallace, 1905, vol. i, p. 359; Marchant, 1916, vol. ii, p. 107). Neither Wallace nor Darwin 'agreed' on a joint publication. This event is elaborated on in more detail later in this article.

The survey highlights some worrying trends in the treatments of the history of science and the portrayal of scientists in our commonly used textbooks:

- Constant and frequent re-telling of events seems to have led to slightly altered accounts that, over time, become further removed from fact.
- In authors' efforts to simplify or reduce text, the events, ideas and profiles of scientists included sometimes bear little relation to actual happenings.
- Little information about the context within which a discovery or concept was made or developed is given and few textbooks give information about the development of ideas over time.

The treatment of the theory of evolution by means of natural selection

One of the most recognisable names in the history of biology is that of Charles Darwin (1809–1882). Many textbooks give an account of 'his' theory and some also give a brief account of his life. No textbooks looked at in this survey considered the context within which Darwin made his discovery. Thirteen common GCSE textbooks were looked at and notes made on their treatment of the theory of evolution by means of natural selection. The full story surrounding the life and work of Charles Darwin, Alfred Russel Wallace (1823–1913) and Darwin's friends, the geologist Charles Lyell (1797 –1875) and the botanist Joseph Dalton Hooker (1817–1911), is a long, complex one. It still generates a plethora of books, papers and articles. The events can be represented fairly, simply and concisely, yet it is astonishing that this seemingly well-known story has so many inconsistencies and inaccuracies in the textbooks surveyed. Interpretations of history are common, as we cannot actually know the exact events, thoughts and motives of those involved, but matters of fact that can be checked should always be presented as accurately as possible. Table 4 details the instances where Darwin or any of the main characters (listed above) are mentioned in the 13 texts.

The story surrounding the development of a theory of evolution by natural selection often omits the work of Alfred Russel Wallace and frequently misspells his name as Alfred Russell (*sic*) Wallace. In particular, Wallace is often cast as an assistant or collaborator with Darwin. The true events surrounding this episode in the history of science are, as has been mentioned, complex. In essence Wallace worked independently of Darwin and had a paper published on the subject of evolution in 1855. He was known to Darwin, though not personally, in the late 1850s through his collecting and his published work. Wallace sent his essay on a mechanism for evolution, written in February 1858, directly to Darwin at Downe House in March 1858. Darwin, on receiving Wallace's essay in June, was aghast. Words, spoken by his friend the geologist Charles Lyell to the effect that he should publish his theory before someone else did, had come back to haunt him. He looked to Lyell and another friend, Joseph Hooker, to find a way out of his predicament. They arranged, independently of Darwin and Wallace, for a joint presentation that carefully preserved Darwin's precedence in the development of the theory of evolution and history has since marginalised and largely forgotten Wallace's work.

The name of Charles Darwin is not forgotten. Indeed his image now graces the back of the £10 note. There are several features of the way in which Darwin is portrayed in science textbooks that are disturbing and sometimes result in a false image of the man. For example, few people realise that the only time Darwin ever referred to himself as some sort of scientist in his notes he regarded himself first and foremost as a geologist; in fact, he went so far as to refer to himself in his notebook at the end of the voyage as *'I, a geologist'* (Secord, 1991, p. 154). In his autobiography he even states that if he had attended the geologist

Table 4 References to Darwin *et al*. in GCSE textbooks.

Textbook	*Page*	*Person(s) mentioned*	*Comment*
Examining GCSE: Integrated science (Stone *et al*., 1990)	34	Darwin	No birth or death dates, mentions *Beagle* voyage (5 years), map of route.
Balanced science 2 (Jones *et al*., 1991)		None	Sections on variation, natural selection and evolution.
Biology (Mackean, 2nd edn, 1995)	222	Charles Darwin Alfred Russel Wallace	'*In 1858 Charles Darwin and Alfred Russel Wallace published a theory of evolution by natural selection which is still an acceptable theory today*.' Goes on to describe the theory.
	224	Lamarck, Aristotle	Outlines their contributions.
Biology for life (Roberts, 2nd edn, 1986)	400	Charles Darwin Alfred Wallace (*sic*)	Picture of Darwin and the *Beagle*. '*He [Darwin] visited many countries and islands and he studied the animals and plants there*' – true, but no mention of his geological work. '*Independently of Darwin, another naturalist Alfred Wallace came to the same conclusions, but with less evidence. Darwin and Wallace wrote a short paper together a year before the "origin of species" was published*' – incorrect. They did not write the paper together and nothing that was actually published was intended for publication by Darwin in 1858.
Collins GCSE Sciences: Biology (Price and Taylor, 1997)	191	Charles Darwin Alfred Russell (*sic*) Wallace	Describes Darwin's voyage as a mapping voyage (true), states that '*Darwin's job was to record the plants and animals they encountered*' – incorrect. Darwin was aboard the *Beagle* as a geologist and companion to the captain. He took over as naturalist from the ship's surgeon.
	192	Alfred Russell (*sic*) Wallace Charles Darwin	Describes Wallace as a forester – incorrect. At no time has Wallace ever been described as a forester in biographies. '*Darwin and Wallace jointly put forward their ideas*' – implies contact and agreement (see above). '*Darwin called his idea "survival of the fittest"*' – this term was suggested to Darwin by Wallace and originated from Herbert Spencer.
	194	Charles Darwin	'*Darwin discovered that this [evolution] had happened to the finches living in the Galapagos islands*' – incorrect. Darwin failed to realise the significance of the finches until they were studied on his return; they are named Darwin's finches in his honour.
Focus on science: Life and living (Vellacott, 1996)		Charles Darwin	'*in the 1830s the naturalist Charles Darwin sailed around the world, studying plants and animals*' – implies that this was the sole purpose of the voyage and ignores his geological work.
The living world (Roberts, 1991)	250	Charles Darwin Alfred Wallace (sic)	'*He [Darwin] visited many countries and islands and he studied the animals and plants there*.' '*Independently of Darwin, another naturalist Alfred Wallace came to the same conclusions, but with less evidence. Darwin and Wallace wrote a short paper together a year before the "origin of species" was published*.' (See above for comments.)

(continued)

Textbook	*Page*	*Person(s) mentioned*	*Comment*
Science foundations: Biology (Milner and Martin, 1997)		None	Theory outlined and horse evolution described.
Science to GCSE (Pople and Williams, 1995)		Charles Darwin	Names and dates of birth and death only.
GCSE science classbook (Bayliss *et al*., 1996)	99	Darwin (no first name)	'*the hypothesis which Darwin used to explain evolution*', a description of natural selection.
Biology for you (Williams, 1996)	273	Charles Darwin	Briefly describes Darwin's calculation of the number of elephants possible from one breeding pair if left unchecked.
	274	Charles Darwin Alfred Russell(*sic*) Wallace	A long account of Darwin, brief mention of Wallace, no mention of the joint publication.
	275	Charles Darwin	Incorrect account of the finches (illustrated).
Key science: Biology (Aplin, 1994)	382–6	Charles Darwin Charles Lyell Thomas Malthus	Correctly states that he took over as naturalist, mentions collecting fossils before plant and animals.
	388	Alfred Russel Wallace Charles Darwin	Provides the best account, falls down on the incorrect fact that they jointly agreed to publish.
Nelson modular science (Collison *et al*., 2001)	72–3	Charles Darwin Alfred Russell (*sic*) Wallace	Describes the main points of the theory of evolution by natural selection. Uses incorrect examples of horse evolution and the peppered moth. Also includes antibiotic resistance and rats' resistance to warfarin.
	77–8	Charles Darwin	Brief biography of Darwin, incorrectly states he was appointed as naturalist on the *Beagle* and that '*Origin*' was sold out on the first day of publication. Also implies that '*Wallace knew of Darwin's long-term work and interest and insisted that Darwin should take the greater credit*' at the time of publication. This happened much later.

Adam Sedgwick's lectures at Cambridge, rather than the dull lectures given in geology at Edinburgh, he would have '*become a geologist earlier than I did*' (Darwin, 1958, p.19).

Many people are also not aware that originally Darwin was not the naturalist aboard the *Beagle*. His role on the voyage was to undertake geological mapping and surveying of the countries visited to assess their economic importance. He was also on board as a companion to Captain FitzRoy. Darwin took over as the ship's naturalist from the ship's surgeon, Robert McCormick. The ship's surgeon was the person usually appointed as naturalist on board Royal Navy vessels. Finally, there is the evidence of Darwin's notebooks from his voyage. While most textbooks state that he studied plants and animals on the voyage, which is true, they fail to mention that this was only a minor part of his work. His notebooks reveal a different picture, with some 1383 pages of notes on geological topics and only 368 pages devoted to biological topics. We are left then in our textbooks with a portrait of a man that bears little resemblance to the man who actually sailed for five years on an expedition around the world, spending more time on land than aboard ship. On his return, Darwin's first published theories were geological and his first affiliation to any scientific society was to the Geological Society of London, where he became secretary, only giving up this role through ill health.

Darwin's credibility in the field of biology was established not with the theory of evolution, but by his seminal work on barnacles. On the advice of Hooker, he undertook a taxonomic study of barnacles with the express intent of making his mark as a 'biologist' (Keynes, 2002, p. 264). The term biology was first used in 1800 and was at that time restricted to the study of man. Interestingly it was the promoter of another theory of evolution, Jean Baptiste Lamarck (1744–1829), who was in part responsible for broadening the definition of biology in 1802 to encompass the functioning of living things. So at the time of the voyage of the *Beagle* the science of biology and the concept of a biologist as a person who studies plants and animals was very new. Whether Darwin ever regarded himself as a biologist first and foremost is doubtful as he would probably have referred to himself as a naturalist – the term most widely applied to men of science. Darwin's major contribution to science is of course his work on natural selection. In simply referring to this and ignoring the contributions of others and Darwin's other contributions to science we only serve to create an iconic status for Darwin that perpetuates a myth that he, and he alone, conceived, developed and more or less invented evolution as a concept.

If we move forward to 1858, the events surrounding Darwin's receipt of Wallace's letter and the subsequent publication of the theory as a joint paper are also little known and often incorrectly stated. Alfred Russel Wallace was a professional collector who, from the outset of his collecting career in the Amazon in 1848, was interested in discovering the origin of species. His first trip resulted in professional disaster as his entire collection of plants and animals was destroyed by fire on the way back to Britain from the Amazon in 1852. The ship on which he was sailing caught fire and sank. After being rescued and on his return to England he was determined to travel once more. In 1854 he set off for the Malay Archipelago; it was here that he first published his thoughts on evolution, in a paper in 1855 commonly called the 'Sarawak' essay after the location where it was written. We know that it was read by Charles Lyell and Charles Darwin, as correspondence between them mentioning the essay exists. The essay describes the 'when' and the 'where' of evolution, but the mechanism, the crux of the problem, is not described. Wallace conceived a mechanism for evolution – natural selection – in February 1858. He wrote his theory in the form of an essay and sent it to Darwin. On receipt of Wallace's essay, Darwin was disposed to publish it and relinquish priority for discovery of the mechanism to Wallace. It was Lyell and Hooker who devised the scheme of publishing notes and an extract of a letter written by Darwin and, in second place in the order of the paper, Wallace's essay. All this took place without Wallace's knowledge and Darwin, who was trying to cope with the death of his youngest son Charles and the illness of another child, Etty, had requested help to solve what was for him a difficult and unenviable position. Neither Darwin nor Wallace attended the meeting where the joint paper was read. It is true that Wallace never disputed Darwin's priority and referred to the theory as Darwin's. In addition, his major work on the subject was, self-effacingly, entitled *Darwinism* (Wallace, 1912).

This alternative picture of the events surrounding the announcement of the theory of evolution highlights a potential problem in the representation of ideas and evidence in textbooks. Which version of events are we to accept as a 'true' representation and, when we simplify events or lives, how much detail can we omit or should we omit? To answer these questions we must consider how we are to teach this aspect of the science curriculum and what methodology we should employ. Perhaps, in answer to the question '*which version should we accept?*', teachers should adopt some of the teaching pedagogy of historians, presenting pupils with source materials to debate interpretations of the events.

An approach to the teaching of ideas and evidence in science

Before embarking on any teaching, we must examine the intended approach and make informed decisions as to its effectiveness. Science is often taught as a practical subject, as noted earlier. Historically, the training of science teachers has concentrated on this approach. The teaching of the history of science is often neglected in the training of science teachers and many are left to develop a methodology out of personal interest. Otherwise they rely on the textbook to supply this aspect. As we have seen, the textbooks have an inconsistent approach, have no underlying methodology and are often incorrect. Just as good science teachers plan for effective practical lessons, ensuring that they are aware of the science behind the practical activity, so too must they plan effective lessons in the history of science by understanding the events, the context and the people involved. The approach described here requires a decision be made as to the purpose of the lesson. Using people and events in the history of science can lead to:

- A greater understanding of the concept.
- A greater understanding of the context within which the discovery or idea occurred.
- A greater understanding of the person or persons involved in the idea or discovery.

It is possible to produce lessons that address all three of the above or one or two aspects. This has to be determined from the outset and the approach advocated has therefore been developed from these three perspectives.

Promoting understanding of the concept

If this approach is taken then the key elements used in teaching will be the evidence supporting the concept, how the evidence was obtained (e.g. by experimentation) and how the evidence led to the development of a theory to explain the results of the experiments. In this instance, a lesson on the theory of evolution, we may take the evidence as it presented itself to both Darwin and Wallace, for example Darwin's observation of the results of artificial selection and geographical distribution, or Wallace's observation that new species are always found in an area populated by closely allied species. We can then look at how they struggled to find a mechanism to explain their observations, finally coming up with the mechanism presented by Thomas Malthus (1766–1834), the inspiration to both Darwin and Wallace. By examining the evidence in much the same way that Darwin and Wallace examined their evidence, pupils may gain a better understanding of natural selection, artificial selection and evolution in general.

Promoting understanding of the context

This requires an understanding of why a discovery or idea is important and how other scientists and society reacted to that discovery or concept. This approach fulfils two of the key stage 4 curriculum requirements detailed earlier:

> *a) how scientific ideas are presented, evaluated and disseminated.*

and

> *c) ways in which scientific work may be affected by the contexts in which it takes place (for example social, historical, moral and spiritual), and how these contexts may affect whether or not ideas are accepted.* (DfEE, 1999, p. 46)

The first of these involves discussing how ideas are translated into papers and published in journals and how these ideas are subsequently interpreted and reported through other media such as the press. For the second, it is well documented that Darwin and Wallace's theory disturbed the church and that the theory created a stir in society. It is not well known that the theory was hardly given a second glance by scientists when it was announced and that for many years, continuing until today, some scientists still refuse to accept the central idea of evolution as a non-directional event. Many scientists and teachers have a fundamental misunderstanding of evolution as a directive process that leads from simplicity to complexity, resulting in the most complex organism, human beings. This is a fundamental misconception. Looking at the context in which the theory was introduced, and introducing other theories of evolution from Aristotle down through Darwin's grandfather, Erasmus Darwin, we can get our pupils to see that the theory of evolution did not originate with Darwin and has not remained static since. In fact Darwin used the term evolution very sparingly, preferring instead to use the term 'descent with modification', with no reference to whether the modification might lead to more or less complexity.

Examination of the context of Darwin and Wallace's theory, which essentially characterised the development of new species as a random act, with no 'creator', will also aid understanding of why the theory created an outburst from church leaders. As a result, there were no home-grown honours for Darwin in the form of a peerage or knighthood, something that was bestowed on many other scientists for work that was far less prestigious.

Understanding the people

An understanding of the people, what motivated them, the background from which they came, the education they received and the course of their careers, can also help to create for science a more human, more acceptable face. How scientists work, think and behave is not often considered. By approaching the teaching of the history of science from this viewpoint we begin to address the curriculum requirement that pupils should be taught to see

> *b) how scientific controversies can arise from different ways of interpreting empirical evidence (e.g., Darwin's theory of evolution).* (DfEE, 1999, p. 46)

Pupils often do not see science as a human endeavour involving shades of grey or uncertainty: it is perceived as a subject where there is a correct or an incorrect answer, much like mathematics. That scientists may disagree with each other or that there may be different interpretations of the same evidence is not evident from our teaching and from the history of science as currently portrayed in our textbooks. Science is, in the minds of pupils, devoid of humanity. Scientists are often presented simply as discoverers who observe and describe and do not think of the social implications. Lewis Wolpert, a distinguished scientist of our time, has openly stated that there should be no moral considerations for science and for scientists. Technologists are the people, Wolpert claims, who need to examine the ethical uses of any discovery. It is technology and technologists that create the weapons, bombs and ways of cloning humans, not the scientist who simply hypothesises, experiments, observes and theorises. Again, it is well known that Darwin had misgivings about publishing his theory but not so well known that Wallace and Darwin differed, so much so that Wallace was moved to claim that he was more Darwinian than Darwin; indeed, Wallace described himself as '*the advocate of pure Darwinism*' in the preface to his seminal work on evolution, *Darwinism* (Wallace, 1912, p. xii). Darwin retracted a number of aspects of his early work, and the final, most often published version of *Origin* is perhaps the least satisfactory one. It is full of errors where Darwin, trying to please all his critics, made significant changes to his original text. Indeed, in an attempt to pacify his religious wife, Darwin even alluded to a 'creator' in later versions (Montagu, 1984, p. 14). Mayr concludes that '*the 1859 [first] edition of the "Origin" is a far more mature and finished product than is usually conceded*' (Mayr, 1998, p. xxvii).

Conclusion

The current textbooks widely used in our schools are inadequate to teach the now-examined 'ideas and evidence' aspect of science. Textbook writers must change their approach and fundamentally rethink the reasons why they include people, ideas, events and concepts drawn from the history of science. We must also look beyond a simple, simplistic story in science and take great care that the events presented are as true and accurate as we can make them. We need a revolution in science teaching in much the same way that history moved from a simple regurgitation of dates, names and events to a new, modern synthesis that encourages people to look at source material. We should not simply accept one account of events, but compare sources. We need to question and evaluate the sources presented. We need to develop the skills in our pupils that the history curriculum is already equipping them with at key stage 3, namely historical interpretation and historical enquiry. The skills are being taught. As science teachers we must make use of them in our own subject. As teachers we must develop materials that address the three approaches outlined above – understanding concepts, understanding contexts and understanding people – if we are to achieve the goals set by our new curriculum and develop not just our pupils' skills but interest in the subject of science as well. A shift in our pedagogy and approach to science teaching is essential. Our new generation of textbooks must utilise a variety of approaches in dealing with the history of science and provide accurate stories and descriptions of events presented in informative, imaginative and interesting ways that pupils respond to in class. Now that the new GCSE specifications are in force and ideas and evidence in science is being examined, we must ensure that the new generation of GCSE science textbooks takes a better approach to the history of science and portrayal of scientists than the current texts.

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