Using real branches to model the 'Tree of Life'

'WHY ARE THERE STILL APES IF APES HAVE CHANGED INTO PEOPLE?'

Terry Russell *and* **Linda McGuigan**

pull together some exciting ways forward from their Nuffield-funded research to engage primary children with ideas about evolution

Figure 1 The interaction of geology and evolution (a free downloadable resource reproduced courtesy of the Howard Hughes Medical Institute – see end)

Primary pupils' appreciation of evolution can be nurtured and developed by awareness of the various underpinning ideas discussed in our previous articles in *Primary Science*: **variation**; **deep or 'evolutionary' time**; **the fossil record** and **inheritance** (*Primary Science*, **134**, **135**, **137** and **138**). This foundational knowledge provides the supporting evidence, frameworks and mechanisms for how evolution has occurred – and is still occurring. As children's science knowledge continues to deepen with the transfer to secondary schools, these ideas will be revisited and their complexity and interrelatedness should be better understood. Later, evidence from geology (Figure 1) and biogeography (species dispersal over time) will offer breadth, while anatomical, embryological and microbiological knowledge will provide detail. However, something different is needed at the primary level – less detailed, but a valid introduction that supports transition – a 'big picture' of macroevolution, something younger children can

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grasp that offers an accurate sense of evolutionary change over time, without being overwhelming in its detail. Interestingly, this could have much in common with what is required for adult public understanding, using the visual metaphors typically adopted in science communication to provide the scaffold.

Strategic support for evolution as a big idea

The sources of information that combined in Darwin's own mind to give rise to the theory of evolution were wide-ranging. His notebooks offer insight into his own intellectual struggles to make sense of his lifetime of fieldwork (Figure 2). His drawing and comments on the Tree of Life metaphor confirm the power of the image's simplifying but unifying function.

This visual representation could serve primary school children well as an overarching summary, as it seems capable of supporting the narrative of the branching diversity of species, the development from common ancestors, as well as extinctions over time. However, there is competition from a pervasive image that summarises hominid evolution (Figure 3).

Reading this latter image from left to right as a visual sequence through time, results in significant and widespread popular misunderstanding. The problem arises through inferring increasing complexity and intelligence from left to right. That's true in some limited sense for hominid evolution, but the real difficulty arises when the species *Homo sapiens* (modern human) is assumed to be the zenith of evolutionary development (and perhaps the 'end of the line'), with evolution itself being a process of 'ever onward and upward'. This trajectory of development – a straight line – is at odds with the reality of a spreading, multiply branching, course. In our research, this straight-line 'ascent of man' assumption led to questions being raised by children discussing this issue such as, '*Why are there still apes if apes have changed into people?*' and '*Why haven't all the apes been used up?*' As children engaged in science discourse and attempted to answer each other's queries, it was evident that many tended to think of evolution as having stopped for many species, while humans continued to evolve, having replaced earlier forms.

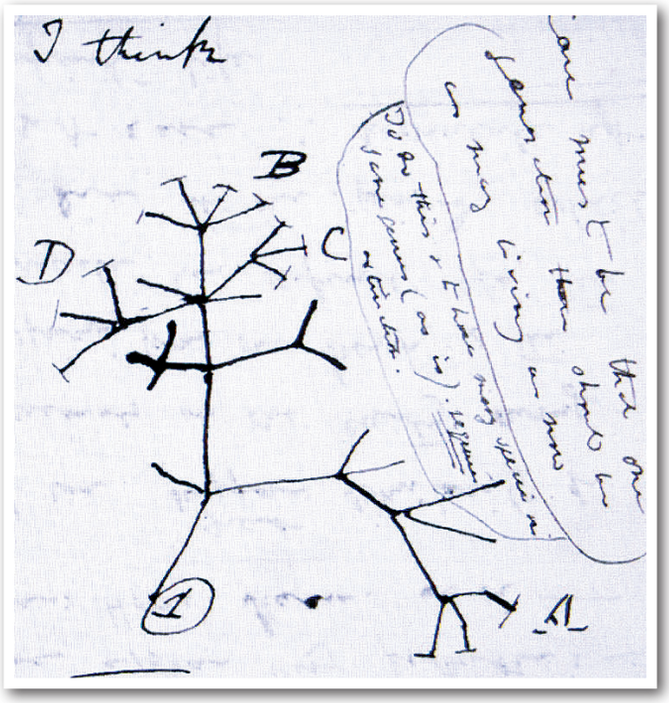

Figure 2 Darwin's 'Tree of Life' notebook sketch. (Cambridge University Library)

Acquiring an understanding of macroevolution implies a significant change in children's worldview, one that takes them towards an understanding that informs all modern biology. To bring the 'big picture' within children's grasp needed further exploration but proved possible. Discussions with teachers led to the emergence of some strategies for moving children's thinking forward positively:

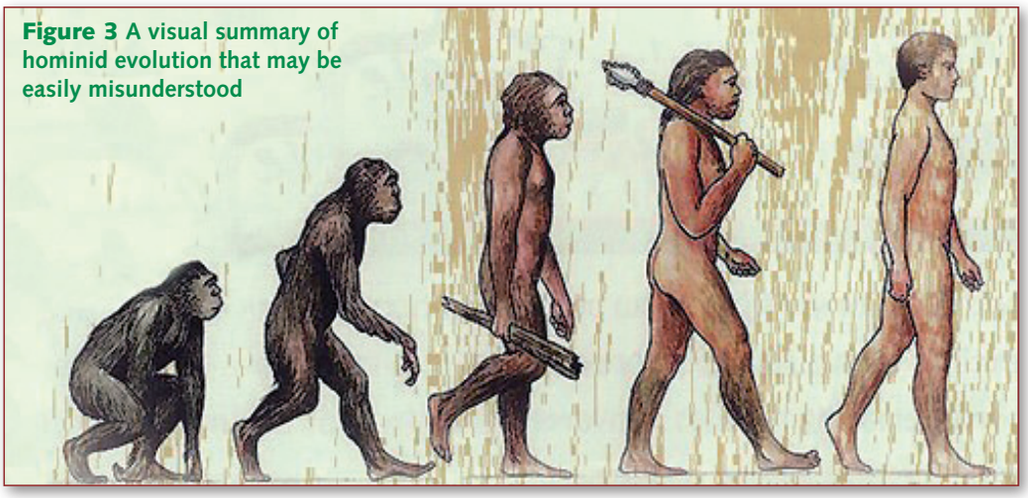

Figure 3 A visual summary of hominid evolution that may be easily misunderstood

- **reflection on, and discussion of, the Tree of Life metaphor, perhaps by starting with a fictional narrative;**
- **exploration of 'cladograms' (branching diagrams) with a focus on one or more branches (or 'clades', as they are known) to establish the concepts of Most Recent Common Ancestor (MRCA) and the diversity through which familiar species have become separate;**
- **direct 'hands-on' transformations of 2-D cladograms into 3-D models, using practical activities to clarify the branching nature of hominid (and other species') evolution.**

These three strategies are discussed below.

Narrative fiction

One smart fish (Wormell, 2011) proved to be an enjoyable story for the primary audience, and popular amongst our research group of teachers, throughout the sample age range. Key stage 1 (ages 5–7) children were gripped by the story of the transition of animal life from water to land (in 'real science' terms, during the Carboniferous period, about 360 to 290 mya). Many children anticipated changes as their teacher read the story, suggesting: '*They were dinosaurs*', '*They were reptiles*' and '*They were the first fish in the world*'. Estimates of time were also included in comments. Following the story, which ends with a colourful illustration of species variation from a common ancestor fanning across a double-page spread, one class teacher asked children to re-describe in words and drawings what they thought had

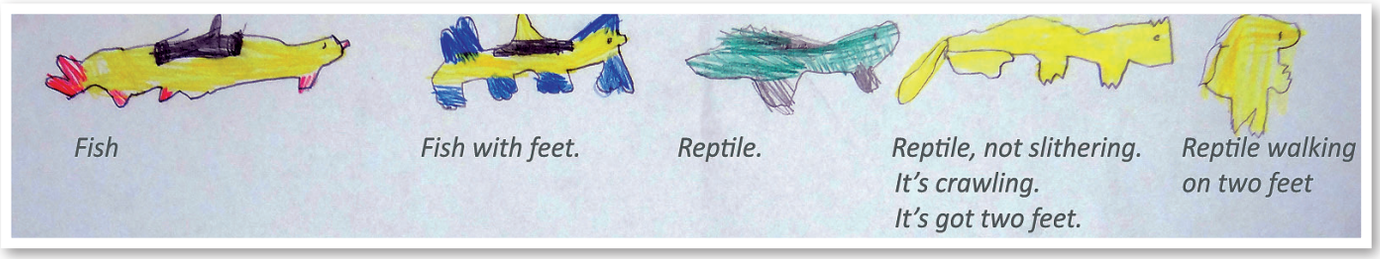

Figure 4 A child's drawing of the transition from water to land, with teacher transcriptions of comments

happened in the story. Many used the images provided for them by their teacher but several decided to make their own drawings (Figure 4).

This child's drawing shows an appreciation of the link between fish and reptiles (incidentally overlooking amphibians), revealing awareness that new animals are formed and suggesting that this happens gradually. With each step a new feature is added and these traits affect locomotion. (Sequenced drawings of ideas about evolution were a useful ploy throughout the topic.)

A year 6 (ages 10–11) teacher expressed initial concerns about introducing a fictional element, because of the possibility of creating 'misconceptions'. The plot of *One smart fish* uses anthropomorphism: the fish has human-like aspirations. There is also an assumption of individual (rather than species) adaptation in the transition from the sea to land. During the storytelling, this teacher was observed to check that children were able to distinguish fact from fiction – a critical skill required explicitly by the language curriculum. Following the narration, she asked further questions to challenge assumptions about fact or fiction: '*What have the pretend parts of the story tried to do?*' and '*Why is evolution being told to us as a story?*' The class consensus was that the story was half fact and half fiction. Children suggested that stories make ideas more accessible and interesting. One child's suggestion that there might be doubt about evolution triggered a class argumentation sequence in which claims and challenges were exchanged:

Evolution might not be true. No one knows if it ever happened.

If it didn't happen how did we get species?

At one point we were animals. I think we were fish, apes, then human.

The snippets of information children brought to the debate illustrated the deluge of informal information to which they are exposed, including references to origins '*from DNA or a germ*' and '*asteroids in space brought cells*', and so forth. (Incidentally, do not miss the opportunity to discuss humans as animals!) Clearly signalling their science (i.e. non-fictional) agenda, teachers built on the interest aroused by drawing children's attention to secondary sources. An on-line clip, **www.bbc.co.uk/nature/life/Latimeria,** was found to be particularly useful. This features images and information about the coelacanth (*Latimeria menadoensis*). David Attenborough narrates over the film:

to the scientist, the coelacanth was of paramount interest, for it seems certain that fish very like it were the creatures from which the whole of the amphibians, reptiles, mammals and indeed man himself, are ultimately descended … If any animal on the Earth deserved the much used expression 'living fossil', it is surely this.

This quality of follow-up should reassure those who feel nervous about the role of fiction in science education. Our sense was that, provided teachers use such materials within a clearly considered strategy and 'work with' the children's ideas formatively, the benefits far outweigh any potential problems.

Another fictional work that offered a starting point was *Charlie and Kiwi* (Campbell, 2011), a story that uses the device of a time machine to travel back to observe the transition from dinosaurs to birds. There are many other fictional titles useful to science education and these narrative possibilities for bridging fiction and fact are increasingly receiving serious attention by science educators (Blanquet and Picholle, 2012).

Exploring cladograms

A cladogram or 'branch diagram' is a way of representing the pattern of evolution from common ancestors. It is a more formalised representation than the tree metaphor, but a logical step forward. Research confirms that children in the 7–11 age range do remarkably well in interpreting and applying the logic of cladograms (Ainsworth and Saffer, 2013). However, the role of cladograms in supporting the idea of macroevolution in the primary curriculum had not been explored.

Cladograms provided excellent opportunities for 'working scientifically'. A simplified cladogram of primate evolution was used to stimulate argumentation (Figure 5). Children were each encouraged to draw one inference from the diagram and state it as a claim that would be the starting point for discussion. The rich potential of this activity warrants further classroom exploration.

A 3-D representation of evolution

Following the introduction of the Tree of Life metaphor, a year 6 teacher provided groups of children with real branches to handle to help them to visualise the branching course of evolution in three dimensions. Using the branch as a kind of story stick, she

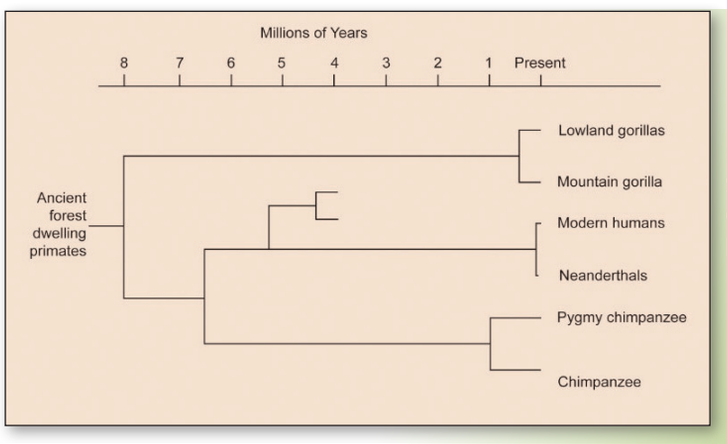

Figure 5 Simplified cladogram of primate evolution

moved her hands along, stopping at forks, to tell the story of evolution (see opening picture). She referred to the fact that all life shares the same starting point (common descent), with 'deep time' being traced from the base to the tips of branching twigs, the nodes or forks in the branch marking points of MRCAs (Most Recent Common Ancestors) and abrupt endings representing extinction. It is important to recognise that not all children appreciated immediately that the branch was being used as a metaphor. Models are core to science, but children may need help to appreciate analogies and models as offering links with the phenomena being studied. In this example, care has to be taken to avoid some children assuming the topic has turned from evolution to trees!

Using different representations of the same information is an important metacognitive strategy. In this instance, Darwin's sketch, the 'ascent of man' image and a cladogram (three different 2-D modes of presenting information) were used in conjunction with the 3-D branch. Children were then invited to use straws and pipe cleaners to make their own 3-D model to tell the story of human evolution (Figure 6). We advocate this kind of deliberate multimodal strategy for 're-representing' understanding.

Children adopted various approaches to their constructions, some starting by drawing out their idea in 2-D to help them to externalise or share their mental representations. Others worked directly in 3-D, cutting pieces of straw to match the cladogram and assembling the parts. Discussions with children provided insights into their newly developing understanding as scaffolded by the Tree of Life metaphor:

They separate and one goes one way and one goes the other way. It will have different features.

The way branches are. They are all different species because of evolution.

That one's going off in all different directions.

It splits and gets new features, makes a new species.

Following a similar set of experiences in another school's year 6 class, a child compared the cladogram she had drawn with the ascent of man image:

This cladogram shows they split. They can do new things, teach their babies.

While comparing it with the ascent of man pictorial image she remarked,

This one says there might not be any more monkeys.

Concluding thoughts

'Evolution' is an area of the curriculum in which children show great interest and enthusiasm to learn more. They also bring considerable prior (though incomplete) knowledge from their informal 'life worlds'.

Most children have encountered the term 'evolution' from an early age and tend to define it in terms of organisms changing over time. One problem is that the changes they refer to are likely to include maturation and individual lifespan growth. They may also point, again mistakenly, to metamorphosis – radical changes in form within one individual organism's lifespan (as in the frog or butterfly) – as an example of evolution. As for the time taken for evolutionary change, this tends to be hugely underestimated.

The Tree of Life is an extremely useful metaphorical summary of macroevolution, especially when presented multimodally. Getting children to generate their own transformations between these representations is an invaluable way to help them to construct and crosscheck their understanding. Inferences drawn from these various formats can also serve to provide useful starting points (or 'claims') to initiate 'working scientifically' via science discourse and argumentation.

The ascent of man image is unlikely to disappear, but there is surely a market niche for a 'branching' 3-D perspective poster version. (Maybe even one that includes the 'ascent of woman'?) Meanwhile, potentially invaluable interactive digital Trees of Life are beginning to be developed, as at **www.onezoom.org/about.htm**.

Teachers responded positively and creatively to the invitation to explore teaching and learning in this area. Many described the value of listening to children's ideas and the importance of modelling and argumentation techniques. A year 5 (ages 9–10) teacher, summing up his experiences, identified three surprises:

Children's enthusiasm and sustained enthusiasm in the topic.

Figure 6 Children using art straws to tell the story of human evolution

Diverse knowledge in the class, which really showed the children's home background having an influence on their knowledge and understanding.

Finding so many exciting and creative ways to teach it.

We hope that reading about the efforts of our project teachers and their children will stimulate others to follow suit, informed by some of the ideas we have presented.

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