14

Have humans evolved from apes?

An inquiry-based approach to understanding Evolution

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Inquiry-based investigations are at the heart of current innovative approaches to teaching and learning Science. Learning is considered effective when students engage with concepts to be learnt and also develop abilities of scientific inquiry. This was especially apparent when I recently taught a course on "Evolution" using such investigations. The experience of one activity was particularly satisfying, and I have narrated it here. Though this was done as part of an optional course at the Azim Premji University, it can be done with students from Classes 9 to 12. Heredity and Evolution is first introduced in Class 9 (Science), further explored in Class 10 (Science), and detailed in Class 12 (Biology) as per the National Council of Educational Research and Training (NCERT) textbooks[1].

The topic itself is significant, and I kept recalling the oft quoted, perhaps now clichéd words of evolutionary biologist Dobzhansky (1973): "Nothing in Biology makes sense except in the light of evolution". I spent time right from the first class on the plot of the story of evolution: natural selection. Discussions in class left me doubtful. Theories in science have a way about them: once understood, they startle you with their explanatory power, yet astonishing simplicity. The theory of natural selection propounded jointly by Charles Darwin and Alfred Russell Wallace in 1858, is no exception. Sensing alternative conceptions among students during class discussions, I realised that an engaging activity which could consolidate understanding of different concepts had to be the key.

During my searches I came across a set of simple, hardly resource intensive activities on Evolution from the National Academy of Sciences, U.S.A.[2]. One such activity was titled "Investigating Common Descent: Formulating Explanations and Models". This activity brought together the fundamental concepts leading to an understanding of evolution by natural selection, though the thrust was on the molecular evidence. At the same time it led students through an inquiry-based investigation by formulating hypotheses, conducting an investigation, examining molecular evidence, inferring from it, and if necessary modifying or even rejecting the initial hypothesis. Students were also led to examine and answer the question: "Have humans evolved from apes?" Prior to this class, they were led through the history of development of the theory through an interactive time-line[3]. They were also introduced to the life and work of Darwin through the PBS NOVA documentaries[4]. They had read extracts from the works of Lamarck, Wallace and Darwin to understand changes in understanding the process of evolution and the development of Science[5].

Understanding the conventions of a discipline: tables and cladograms

The investigation was divided into three parts. It was written in the form of a teacher's guide with diagrams and worksheets which could be easily adapted / modified. Students worked in small groups of about 4-5. The first part required examination and comparison of characteristics of apes and humans. The comparison was on several features such as posture, leg and arm length, brain size, etc. This was followed by a tree diagram (morphological tree, cladogram) which compared relationships between apes and human beings. Like shared conventions in a discipline, cladograms are used by evolutionary biologists to represent relationships between organisms based

on common descent. The presentation of data in this form, gave me a chance to explain features of this convention to them. For this I sought the help of a paper by Gregory, R.T. (2008) [6].

Formulating hypotheses

The table and evolutionary tree brought out relationships between different mammals and human beings, and students were asked to draw out relationships between the apes: gorillas and chimpanzees (designated G and C respectively), human beings (designated H) and a common ancestor (A). This was to be done using another tree-like representation. However the tree diagram did not indicate this explicitly. Students were a bit confused then as to how they may draw such a relationship. The expectation was to hypothesise or come up with a verifiable or testable relationship represented using a tree diagram.

Being a visual learner, I sensed at least some of the students may also like to see pictures of the two apes mentioned to help them formulate this hypothesis. So I obtained a few pictures from the internet and projected it so that they could get a sense of the features. A couple of examples are given in Figures 1 and 2.

Figure 1

Figure 2

The hypotheses that came from students were varied. Most groups had formulated more than one hypothesis. Figures 3, 4 and 5 are taken from submissions of students (VS, TS and NK).

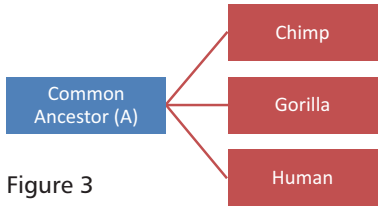

Figure 3

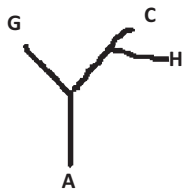

Figure 4

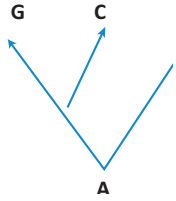

Figure 5

Comparing gene sequences: what can molecular evidence reveal about relatedness?

Having come up with tentative hypotheses, students then proceeded to test their hypotheses in Part II. The method involved comparing relationships between gorillas, chimpanzees and the common ancestor by

comparing genes coding for the protein haemoglobin (pigment giving rise to the red colour of blood in most vertebrates). Students were given handouts of the procedure and guiding questions for discussion in the previous class and asked to read it before the investigation was conducted. The commonly heard acronym 'DNA' evoked feelings of complexity in several of them.

The procedure however was akin to a child's game. A strand of DNA is composed of a sugar-phosphate backbone, nitrogenous bases: Adenine (A), Guanine (G), Thymine (T) and Cytosine (C), and hydrogen bonds between bases of a complementary strand forming a double helix. Adenine pairs with Thymine; and Guanine with Cytosine. A gene is a segment of DNA and hence students had to work with segments of DNA composed of 20 bases each. The sequence was given for each species (as per currently available evidence) in the description of the investigation. For example, the sequence of the human (H) DNA strand is: A-G-G-C-A-T-A-A-A-C-C-A-A-C-C-G-A-T-T-A. Similarly sequences coding for haemoglobin in Gorillas (G), Chimpanzees (C) and a hypothetical Common Ancestor (A) of these organisms were given. Paper clips of different colours: one for each base was distributed in assorted boxes for each group. Students had to synthesise DNA strands for each species as shown in Figure 6.

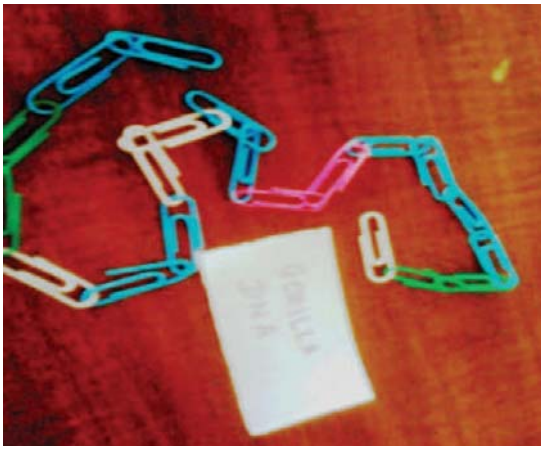

Figure 6: Photograph taken by a student (BJ) of a strand of gorilla DNA made with paper clips

The first base was marked to indicate the sequence. Human DNA was compared with gorilla DNA and then Chimpanzee DNA separately. The comparison was done base to base (paper clip to paper clip). The number of matched bases was counted along with the number of unmatched bases (which could also be inferred). The final numbers were entered in a table. The Common Ancestor DNA was saved for Part III of the procedure.

One of the students (VS) represented her comparisons with colour coding as shown in Figure 7.

"The created sequences (with color coding) looked like this:

Human	A	G	G	C	A	T	A	A	A	C	C	A	A	C	C	G	A	T	T	A
Chimp	A	G	G	C	C	C	C	T	T	C	C	A	A	C	C	G	A	T	T	A
Gorilla	A	G	G	C	C	C	C	T	T	C	C	A	A	C	C	A	G	G	C	C
Common	A	G	G	C	C	G	G	C	T	C	C	A	A	C	C	A	G	G	C	C

By comparing Human DNA with that of Gorilla and Chimp respectively, we got the following results:

Human	A	G	G	C	A	T	A	A	A	C	C	A	A	C	C	G	A	T	T	A
Chimp	A	G	G	C	C	C	C	T	T	C	C	A	A	C	C	G	A	T	T	A

15 matches, 5 unmatched bases

Human	A	G	G	C	A	T	A	A	A	C	C	A	A	C	C	G	A	T	T	A
Gorilla	A	G	G	C	C	C	C	T	T	C	C	A	A	C	C	A	G	G	C	C

10 matches, 10 unmatched bases

Figure 7: Representation of the matching of DNA strands by a student (VS) using colour codes for each base

Mutations from a common ancestor: how are we related to the apes?

In Part III, students' previous understanding of mutations and their significance as 'molecular clocks' in the evolutionary process was reinforced. Comparison of strands of DNA of each species with the common ancestor would lead to information about mutations and hence help predict how and when speciation occurred: or when a new species formed and diverged from a common ancestor in the evolutionary tree. The common ancestor DNA was therefore compared with each of the others: human, gorilla and chimpanzee, and matches and mismatches were again counted and tabulated as before. The completed tabulation looked like this representation made by one of the students (BJ).

Hybridization data for human DNA (from Part II)		
Human DNA compared to:	Number of matches	Unmatched bases
Chimpanzee DNA	15	5
Gorilla DNA	10	10
Data for common ancestor DNA (from Part III)		
Common ancestor DNA compared to:	Number of matches	Unmatched bases
Human DNA	10	10
Chimpanzee DNA	12	8
Gorilla DNA	17	3

The data was discussed in class. They were asked to re-look at their hypotheses in the light of the data. Were they happy with it, did they want to make any modifications to what they had formulated?

Looking at the table and cladogram presented in the beginning of the exercise, as well as the photographs of the chimpanzee and gorilla, most of the groups had hypothesised that gorillas and human beings were more closely related. However, the data obtained in Part II indicated that chimps and humans shared more bases in the gene coding for haemoglobin than gorillas. Also, from Part III, gorillas had more matches with the common ancestor, followed by chimps and then humans, indicating greater relatedness between gorillas and the common ancestor. The tree that is then perhaps most explanatory would be that shown in Figure 4 (Hypothesis b).

Students enjoyed conducting this investigation, and arriving at the data and the simple inference drawn from it. However the answer to the question posed in the beginning "Have humans evolved from apes?" was still not apparent at this point. Since the designated 2 hours for the class was over, I asked them to complete this discussion as homework after inferring from data analysed in class.

The grand conclusion: Inferring from evidence which runs contrary to popular notions

The surprising and thought-provoking element of the activity was still to come. Several assignments reasoned with the available evidence that humans had indeed evolved from apes, bringing out the common alternative conception of a 'ladder-like', 'gradual progress' model! However the data that they had presented as evidence was correct and in keeping with the shared understanding that had developed in class. In the case of one student, TS, conceptual change could be sensed in his writing: "The conclusion that can be derived is that although humans have evolved from apes...." he had left off there to go into elaborate details of the analysed evidence, finally concluding: "This exercise gives evidence for the fact that all the three organisms (gorillas, chimpanzees and humans) might have evolved from a common ancestor and in due course of time due to mutations in DNA there might have been these changes observed."

Voila! However looking at the trend in a couple of other assignment submissions, I decided that more reinforcement was required to make this leap from the evidence and the tree diagram (Figure 4) to the logical inference, and hurriedly composed this mail to the class: "Dear all, If you have a few minutes' time today, I request all of you to go through the video: http://www.pbs.org/wgbh/evolution/library/11/2/quicktime/e_s_5_100.html[7]. You need QuickTime or Real Player to view it. Without considering the investigation in the last class, could you think about what it means to say 'Humans have evolved from apes.' Doesn't it mean that an ape in the course of evolution became a human being, or a chimp / gorilla evolved to a human being? Can you claim that based on the analysed evidence? We will discuss this in class today."

The video viewing in class brought out further clarifications and discussion. A few of the early assign-

ment submitters, re-submitted based on their changed understanding. Subsequent assignments showed greater reasoning on the process of natural selection that could have led to the evolution of humans, chimps and gorillas.

In all an exciting activity which clarified and brought together key concepts leading to an understanding of evolution by natural selection, revealed underlying, resistant alternative conceptions, and was engaging for students to assimilate and accommodate. As a teacher, the use of this method of inquiry was an immensely satisfying and fruitful experience.

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Image credits

Figure 1: Inaglory, B. (2009). Male gorilla in SF Zoo. Retrieved from: http://en.wikipedia.org/wiki/File:Male_gorilla_in_SF_zoo.jpg on 7th December 2012. Licence: Creative Commons Attribution-Share Alike 3.0 Unported

Figure 2: Lersch, T. (2005). Common chimpanzee in the Leipzig zoo. Retrieved from: http://en.wikipedia.org/wiki/File:Schimpanse_zoo-leipig.jpg on 7th December 2012. Licence: Free Software Foundation: GNU Free Documentation License, Version 1.2.

Figures 3 – 7 and Table 1: Assignment submissions of students: VS, TS, NK and BJ as indicated in the body of the article. Permission obtained.

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