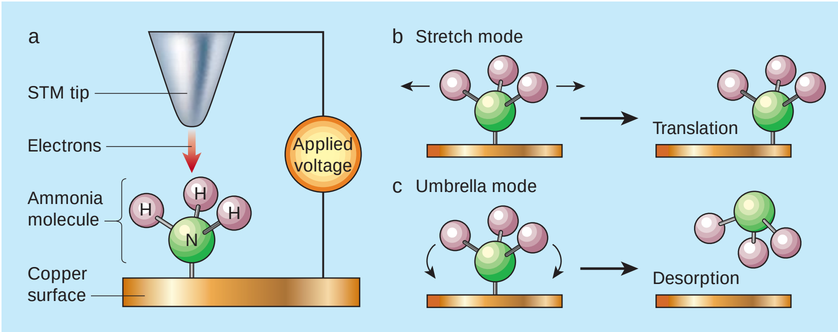

Figure 1 **Moving molecules. Energetic electrons emerging (a) from the tip of a scanning tunnelling microscope (STM) can selectively excite a specific vibrational mode within a molecule. For an ammonia molecule (NH_3) adsorbed on a copper surface, electrons with an energy of 420 millielectronvolts excite a 'stretch' mode (b), causing the molecule to be translated along the surface. If the electron energy is 320 millielectronvolts, the 'umbrella' mode (c) is excited instead, and this flexing of the hydrogen–nitrogen bonds — similar to an umbrella turning inside out — results in desorption of the molecule from the copper surface.**

umbrella mode tends to desorb the molecule, intact, from the surface; the symmetric breathing mode preferentially induces lateral translation of the molecule across the surface.

This pioneering experiment not only reveals how competing reaction mechanisms can be selectively activated within a single molecule, but also demonstrates a new approach for identifying reaction pathways in complex environments. Studies such as this expand the range of synthetic tools available for fabricating the next generation of molecular-scale nanostructures. ■

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Evolutionary biology

Fractious phylogenies

Thomas D. Kocher

Speciation has been unusually fast among the cichlid fishes of Lake Victoria. An unexpectedly distant ancestor, which perhaps already had a predisposition for rapid speciation, may have seeded this 'species flock'.

More than half of all living species of vertebrates are 'bony' fishes. Over the past 250 million years they have evolved into more than 25,000 species that span habitats from the highest mountains to the deepest oceans. Nowhere has their evolutionary radiation been more rapid than in the great lakes of East Africa. Several hundred species of cichlid fishes swim in the waters of Lake Victoria, and it has been assumed that this 'species flock' arose within the lake from one or a few common ancestors since the lake last dried up around 15,000 years ago[1]. In a paper in *Science*, Verheyen and colleagues[2] cast doubt on this assumption, and instead suggest that Lake Victoria was colonized several times, beginning more than 100,000 years ago, by fish from Lake Kivu, which lies 300 km to the west.

The very recent origin of the Lake Victoria flock poses two challenges for those wishing to reconstruct the historical relationships among species. First, there has been little time for mutation to alter the DNA sequence of each species. This means that there are precious few sequence characters on which to apply phylogenetic analysis. Second, there has not been enough time for new variant genes to become fixed between instances of speciation[3], a problem known as 'incomplete lineage sorting'. This means that although phylogenetic trees derived from DNA sequences accurately represent the history of genes, they do not necessarily reflect the history of the populations in which the variants are found (Fig. 1, overleaf).

The problem of too few mutations is usually addressed by focusing on rapidly evolving gene sequences. DNA in the cell's mitochondrion has been a particular favourite for such studies, because it evolves roughly ten times faster than the average gene in the nucleus of the cell. An earlier study of the Lake Victoria flock[4] found considerably more diversity of mitochondrial DNA than could have arisen since the lake last dried out 15,000 years ago. This means that the most recent radiation in Lake Victoria was seeded by several lineages, in which genes for important morphological and behavioural traits were already polymorphic.

The bit added by Verheyen and colleagues[2] is data on the mitochondrial DNA sequences of cichlids native to Lake Kivu, which lies quite far to the west of Lake Victoria. They construct a 'haplotype network' in which each sequence is joined to the next in a way that explains the sequence differences with a minimum of mutational events. Then they consider the frequency and geographical distribution of these haplotypes so as to reconstruct a plausible biogeographical scenario for the evolution of the fishes. Their analysis identifies the Lake Kivu species *Haplochromis gracilior* as the closest relative of the Lake Victoria superflock, and suggests that there has been a complex pattern of faunal exchange through the region.

Neither of these studies[2,4] overcomes the problem of incomplete lineage sorting, and so the gene trees must be interpreted with caution. An alternative is to score DNA polymorphisms at thousands of independent gene loci from the cell nucleus[5]. The average of these many gene trees should be an accurate estimate of the history of the populations in which the genes are segregating. Seehausen and colleagues[6] have used this second approach to analyse a number of potential riverine ancestors, and have identified several species of the genus *Thoracochromis* as the closest relatives of the Lake Victoria superflock.

The nuclear and mitochondrial studies provide complementary perspectives, but it is difficult to combine their results into a coherent whole because the various data sets do not overlap for certain key species. Even if complete data were available, it is not clear that convincing statistical support would emerge for either phylogenetic tree because of the short time-frames involved. Verheyen *et al.* report a Bayesian posterior probability of 80% in support of their main conclusion — the linkage of *H. gracilior* to the Lake Victoria superflock — but such probabilities have been shown to be excessively liberal[7]. Seehausen *et al.* make the uncomfortable suggestion that the short branches in their nuclear gene tree may reflect a period of extensive hybridization among species early in the history of the flock. In that case it may never be possible to completely reconstruct the relationships among these species.

Regardless of the details, none of these analyses refutes the conclusion that most of the current species diversity has arisen within

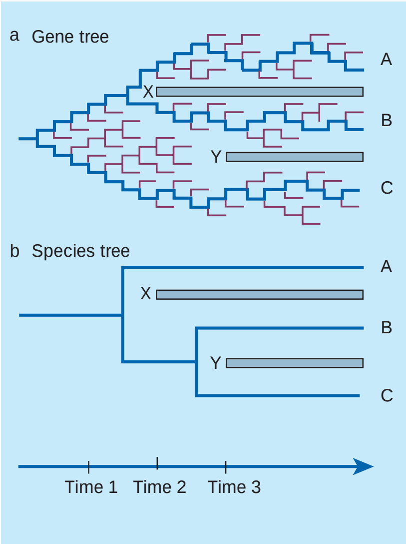

Figure 1 **The difference between gene trees and species trees.** a, **An ancestral species contains many mitochondrial DNA variants (time 1). The evolution of a species barrier (X) separates the ancestral population into two gene pools (time 2). A second species barrier (Y) arises later, producing the full set of species (A, B, C). Phylogenetic reconstruction from the mitochondrial gene sequences suggests that species A and B are most closely related. But as shown in** b**, B and C are the most recent and closely related species, having shared a common gene pool until time 3.**

the confines of Lake Victoria. These cichlids still represent the fastest known rate of vertebrate speciation, whether they shared an ancestor 10,000 or 100,000 years ago. So, what can these phylogenetic studies tell us about the characteristics that predisposed the ancestor of the Lake Victoria flock to undergo such rapid radiation? Verheyen *et al.* suggest that the immediate ancestors were already well adapted to the lake environment because *H. gracilior* shares the key ancestral haplotype with six other, ecologically diverse species from Lake Kivu. Likewise, Seehausen *et al.* point out that the genus *Thoracochromis* is already diverse in colour pattern and feeding habits, presaging the variation among species that occupy different ecological niches in Lake Victoria. But in fact the capacity for rapid and extensive radiation lay already in a *Haplochromis* species that lived at least a million years ago, because that species was the common ancestor of both the Lake Victoria flock and the spectacular parallel radiation of Lake Malawi cichlids in the southern Rift Valley[8].

The challenge is to extend these phylogenies down to the level of incipient species. Only at this level can we study the selective forces acting on particular morphological and behavioural characteristics. Genomic techniques now enable us to identify the genes underlying key adaptive differences. It is the evolutionary history of these genomic regions in particular that should illuminate the selective mechanisms responsible for the fantastic diversity of East African cichlids. ■

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Earth science

A slice of history

Paul D. Asimow

Investigations of an exposed slice of oceanic crust and mantle have provided a dramatic picture of temporal variation in the activity of the Mid-Atlantic Ridge — including its pulse rate of 3–4 million years.

In textbooks, mid-ocean ridges are often described as 'tape recorders': new crust is continuously being created by the partial melting of upwelling mantle and its eruption onto the ocean floor, where it solidifies and is 'rafted' away to either side of the ridge by seafloor spreading. The result — at least in textbooks — is an easily accessible map-view record of the formation of tectonic plates on the sea floor. The reality is much more messy. Not least, the tape is quickly obscured by sediments. In the central Atlantic, however, at about 11° N, a quirk of movement has elevated a slice of sea floor and exposed a section through the crust and upper mantle at the Mid-Atlantic Ridge. This slice, known as the Vema transverse ridge, provides a view of 310 km, or 20 million years of Earth history. On page 499 of this issue[1], Bonatti *et al.* describe the insights into mid-ocean-ridge activity that may be gained from the Vema exposure.

To geophysicists using 'remote' techniques, the tape-recorder history remains

100 YEARS AGO

The extraction of the perfume from flowers such as jasmine, tuberose, violet and cassia has long been carried out by the process of enfleurage, the blossoms being left in contact with purified lard for a few days, and then replaced by fresh blossoms. The lard is either sold as such, or the essential oil may be extracted from it by melting it under strong alcohol. As the process of enfleurage is somewhat tedious, attempts have frequently been made to extract the oil directly from the flowers by means of light petroleum, but these processes have not as a rule proved successful, and it has recently been found that a very large proportion of the perfume is actually produced for the first time in the blossoms during the time occupied by the enfleurage. An interesting illustration of this is given by Dr. Albert Hesse in a recent number of the *Berichte*, in which he states that a ton (1000 kilos.) of tuberose blossoms only yielded 66 grams of oil when extracted with light petroleum, but during enfleurage yielded 801 grams of oil to the fat in which they were embedded, whilst a further 78 grams remained in the faded blossoms and could be separated by extraction or distillation.
From *Nature* 28 May 1903.

50 YEARS AGO

Although many papers have been written, there is still much that is not understood concerning the external and internal factors responsible for the cyclic nature of reproduction in reptiles. Investigations of the seasonal fluctuations in various parts of the reproductive system of several species of lizards, snakes and turtles have revealed interesting species differences. For a more complete understanding of reptilian reproduction it would appear that detailed descriptions of the seasonal changes of many species are desirable… Such a study was carried out by Wade Fox on the common garter snake (*Thamnophis*), several species and subspecies of which could easily be obtained throughout the year in the vicinity of San Francisco Bay. These investigations showed that the gonads of the male garter snake, *Thamnophis elegans terrestris*, exhibit marked seasonal variation. The testes begin to increase in size in the early spring, reach their maximum size and weight in late July, decline in the autumn, and are of minimum size during the winter months.
From *Nature* 30 May 1953.