A question of intent: when is a 'schematic' illustration a fraud?

Sir — Scientific images are at the centre of recent allegations of 'bad science' (for example, the 'Indonesian coelacanth' story[1]). How can we identify fraudulent alterations in scientific illustrations?

We suggest that the key is to identify changes, then examine them in the light of the scientist's intent. Take, for example, the old dispute between biologists Ernst Haeckel and Wilhelm His about embryos and evolution. Haeckel and others said that different animals pass through, or 'recapitulate', similar embryonic stages[2]. Indeed, fish and human embryos do look similar because they share primitive features — 'symplesiomorphies' in modern terms. Professor His[3] disagreed, saying that embryos show distinctive hallmarks (synapomorphies) of their species group.

The evidence on both sides included drawings of embryos[2,3]. Haeckel's young embryos look similar, whereas His's look different. Things turned nasty when His and others accused Haeckel of doctoring pictures[4]. The defence, even today, is that Haeckel's figures are only schematic: it is acceptable for schematics to show alterations that help to explain the data.

We have found evidence of sleight of hand, surprisingly, on both sides. His's deer embryo has cloven hooves, but a standard work on deer embryology[5] shows no such feature. This disparity arouses our suspicion. However, we have not identified His's source, so we cannot be sure that he changed anything. His embryos are at more advanced stages than Haeckel's, though, so are not valid counter-evidence.

We can make a persuasive case with Haeckel because we have identified some of his sources. When we compare his drawing of a young echidna embryo with the original[6], we find that he removed the limbs (see Fig. 1). This cut was selective, applying only to the young stage. It was also systematic because he did it to other species in the picture. Its intent is to make the young embryos look more alike than they do in real life.

Haeckel's other intent is to support recapitulation, as revealed in his text for the young embryos: "There is still no trace of the limbs or 'extremities' in this stage of development … [this] proves that the older vertebrates had no feet" (ref. 2, p. 371). The altered drawings support theories which the originals did not. Therefore, these are not legitimate schematic figures.

Haeckel and His both published technical works of great importance to biology. Their dubious embryo pictures

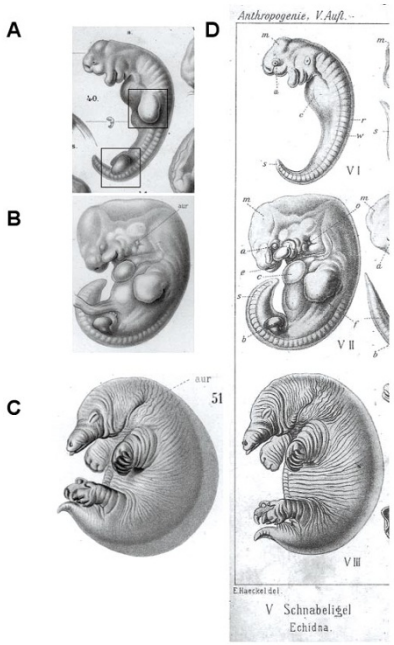

Figure 1 **Deleting the synapomorphies from young embryos: Haeckel's echidna embryo.** A–C, **Taf X, figs 40s, 43s and Taf XI fig. 51s, respectively, from the original drawings[6].** D, **Haeckel's copy in the** *Anthropogenie*, **5th edition (ref. 2 Taf XI, figs VI-VIII). The limb buds of the young embryo (boxed) were deleted by Haeckel. Significantly, the other stages were copied accurately.**

appeared in non-technical, polemical books. Ironically, there was some truth on both sides: in fact, embryos show a mixture of symplesiomorphies and synapomorphies[7].

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Conservation should be a high priority in Singapore

Sir — The Singapore Genomic Project was created in June 2000 with funding of S$62 million (US$35 million) over five years[1]. Singapore is certainly becoming a hotspot for life sciences — basically to develop drugs, medical and food products and agro-biotechnology. But it is ignoring serious environmental conservation issues, both at home and in neighbouring countries.

When the state of Singapore was founded in 1819, it had a population of 150 people. The main island (544 km^2, to which another 30 km^2 was later added by land reclamation) was almost entirely covered by rainforest. Today, more than half the island is urbanized to accommodate 3 million inhabitants. Less than 100 ha of rainforest and 500 ha of mangrove forest survive, in a degraded state[2]. About 594 of a total of 2,277 native vascular plant flora have become extinct[3].

The lack of natural resources means the city-state depends on drinking water from Malaysia and Indonesia, but it makes little financial commitment to conserve natural resources in these countries. Ecology and biodiversity conservation are not popular in Singapore's universities, as the government has been heavily promoting genetics and biomedical-related life sciences and research during recent years. We are worried that the emphasis on the Genomic Project may reduce the number of future students of ecology and conservation in Singapore.

The economy improved in 1999 with surplus of US$1.96 billion registered[4]. But environmental spending was restricted to deep-tunnel sewerage systems, wastewater treatment and management of nature reserves. International environmental conservation activities were limited to Singapore's participation in meetings.

Being an economic giant in the Asia–Pacific region, Singapore has the responsibility to care for its own shrinking natural environment. It must reorient its strategies and make a financial commitment both to conserve its own environment and to help conserve natural resources in the neighbouring mega-biodiversity countries such as Malaysia, Indonesia and Vietnam[5].

The government has recently set up Wildlife Reserves Singapore, bringing together three of the world's most progressive animal parks: the Jurong Bird Park, Singapore Zoological Gardens and the Night Safari. It has also established a conservation fund to support wildlife preservation projects locally and globally, owing to the desperate need to promote biodiversity conservation in the region.

It is not too late for other governmental and non-governmental agencies to join this effort to save the rapidly diminishing natural environment in South-east Asia.

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