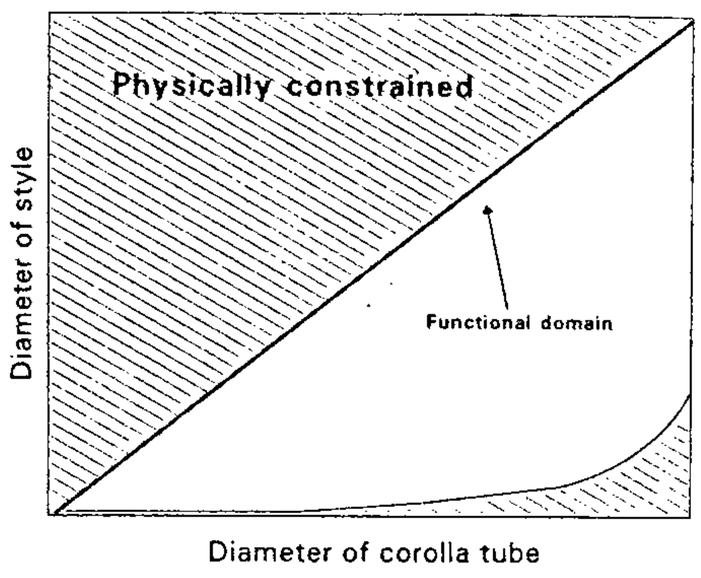

Figure 3. The physical constraints for the evolution of style and corolla diameters. Owing to the floral designs of the angiosperms, the style thickness shall always be less than that of the corolla, such that the upper left portion of the space (above the solid line) is physically constrained. Wider corollas are likely to be longer with long styles. In order to bear their own weight, the long styles have to be thicker as well such that the lower portion of the space below the curve is also physically constrained. The angiosperms have to occupy the space in between the diagonal and the curve. The functional advantage of the style as envisaged in the cardamom arises only in the shaded area because in this space the effective diameter of corolla is small enough to raise the liquid by adhesive forces. But any given plant species might occupy this space purely by chance or by their historical constraints and not necessarily by the 'design' of natural selection.

such as style and corolla in cardamom. The style constitutes the innermost whorl of the flowers and is contained within that of corolla in the angiosperms. Thus there is a basic design that limits the range of possibilities permitted for the relative diameters of the corolla and the style; the style has to be always less thicker than the corolla. All the angiosperms can only occupy the morphospace where style is smaller than corolla and the rest of the space is physically constrained (Figure 3). Further, styles and corollas that are too thin may not be able to support themselves and hence physical constraints limit certain other combinations of style and corolla diameters as well (below the curved line in Figure 3).

Obviously, there is a limited range of possibilities of corolla and style thickness and some of these, as spin-off, might result in raising the level of nectar as seen in the cardamom. These combinations occupying the functional domain of the morphospace (shown as the shaded area in Figure 3) could occur purely without any selection operating and cardamom flowers could represent one such combination. When bees start using this design, the cardamom plant accrues advantage as a spin-off and not by design of natural selection. In other words, the observed diameters of present-day cardamom might have arisen purely by chance and not by design. Note that this is different from the selection operating on the chance mutations. Darwinian evolution emphasizes selection of the best among the chance variants but does not generally recognize the constraints *per chance* offering fitness without selection[6].

Alternatively, it is also likely that the corolla and style of ancestors of cardamom occupied a non-functional domain that does not offer any advantage to the plant and selection has shaped them to move to the functional domain to derive advantage. It is indeed difficult to resolve this issue unless the immediate ancestors of cardamom are available. It would in fact be interesting to plot a set of random species on this morphospace to examine if there is more density of plant species in the functional domain than in the non-functional domain. A higher density of plants in the functional domain might suggest the role of natural selection in shaping the diameters of the corolla and style. But in the specific case of cardamom it may be difficult to delineate the two alternatives if the ancestors also fall in the functional domain.

Precisely for these reasons, it would be relishing to relate the examples from historical and archaeological contexts. In fact Gould and Lewontin's example of spandrels from San Marcos[3] is more illustrative than biological examples could be. But I have found that our students have more difficulty relating the spandrels than *Gomukha* to the Panglossian paradigm probably because of a lack of exposure.

While explaining the evolution of biological design, the constraints, both physical and phylogenetic are often recognized but 'are usually dismissed as unimportant or else and more frustratingly, simply acknowledged and then not taken to heart and invoked'[3]. Thus it is difficult to visualize the extent to which our interpretations in evolutionary biology are in the Panglossian style. But it is important that we need to be wary of such interpretations and if we are not, we may not be any more objective than the tourist guides attributing functions to all of their personal perceptions.

1. Belavadi, V. V., Venkateshalu and Vivek, H. R., *Curr. Sci.*, 1997, **73**, this issue.
2. For example, readers are invited to examine the dancing Krishna's statue printed in *Sunday*, 8–14 July 1997, p. 36.
3. Gould, S. J. and Lewontin, R. C., *Proc. R. Soc. London*, 1979, **B205**, 581–598.
4. Joshi, N. V., *Curr. Sci.*, 1997, **72**, 771.
5. Veena, T., *Avalanche Meetings I*, 1991, **1**, 78 (unpublished).
6. I should hasten to confess that Belavadi's group does not propose that the placement of style in the corolla in itself is a naturally selected feature but that their relative sizes probably are. But what is not generally recognized by adaptationists is that even these features could also be a consequence of constraints operating on the design with the fitness advantage merely being a spin-off.

K. N. Ganeshaiah is in the Department of Plant Genetics and Breeding, University of Agricultural Sciences, GKVK, Bangalore 560 065, India and Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore 560 064, India.

Correction

In "Vaccines for the 21st century: The big picture" (Ramalingaswami, V., *Curr. Sci.*, 1997, **73**, 18–20) read 'Something to *munch*!' instead of 'something to *march*!' on page 20, last sentence under "Plant-based human vaccines".