Mating and nesting behaviour, and early development in the tree frog *Polypedates maculatus*

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While the male of the tree frog, *Polypedates maculatus*, in axillary amplexus with female (i.e. with its vent closer to that of the female) constructs terrestrial foam nest by whipping up the released seminal fluid with its hind limbs, the female releases eggs (210–448) that are unpigmented. The duration of this process is about 2.5 h. The eggs complete their embryonic development in the foam nest within nine days, and the larvae complete their metamorphosis in 60 ± 10 days.

THE tree frog, *Polypedates maculatus*, is a common rhacophorid breeding between June to August in South India and is known to deposit eggs in the foam nest[1,2]. Here we report our observations on its mating behaviour, foam nest construction, fecundity, duration of embryonic development, size and stage at hatching and larval duration.

The process of foam nest construction by an amplexed pair of *P. maculatus* was witnessed (July 1997) in the early morning hours at 0615 h in a cement pond (30′ × 30′) having a depth of 2′. During the study period the rain water in the pond reached a level of about 1′ and the bottom was found to be completely covered with debris material, leaves and plenty of algae. The pond was inhabited by other sympatric anurans, such as *Rana cyanophlyctis* (adults and tadpoles) and the toad *Bufo melanostictus*. Insect fauna was also abundant in the pond. The amplexed pair of *P. maculatus* was about 10 inches above the water level (Figure 1). The female frog was larger than the male, greyish, and was found hanging at the inner aspect of the pond with its forelimbs placed on the upper surface of the pond. The male frog was dull yellowish on its dorsal side. During amplexus, the male frog grasped the female by her axilla. The amplexus was therefore axillary. During oviposition the male moved a little lower down so as to bring its vent closer to that of the female. Coinciding with emergence of the eggs the male began secreting large amounts of seminal fluid. This was followed by its beating the hindlegs upwards and downwards in a cyclic manner that whipped up the seminal fluid resulting in construction of a foam nest. The duration of this activity lasted for 2.5 h, from 0615–0845 h. The terrestrial foam nest thus constructed was above the water surface and remained attached to the wall of the pond for several hours (Figure 2). Later, it fell off into the water and continued to float till it once again came in contact with the edges of the pond. It then readhered to the wall of the pond that was in close association with the water surface. The foam nests provide protection to the eggs against desiccation and predation by aquatic insects[3,4].

Between July–August 1997, several already formed foam nests of *P. maculatus* were sighted in temporary ponds, puddles and man-made ponds. The foam nests were 4–5′ away from water body in case of natural ponds and puddles, while in cement cisterns they were found adhering to the wall some distance away from the water surface. Eight foam nests found in temporary ponds were brought to the laboratory. Until hatching of the eggs, the foam nests were kept in separate aquaria with water and substratum collected from the same pond. Eggs were pigmentless. The embryonic development was complete within 9 days. There was no mortality of the embryos. Hatching was nonsynchronous; it took 2 to 3 days for all the embryos to hatch and the number of hatchlings per nest ranged between 210 and 448 (mean = 339.7; SE = 24.3; $n = 8$). The hatchlings measured about 10 mm in total length, and were at stage 23 (ref. 5). The tadpoles continued to associate with

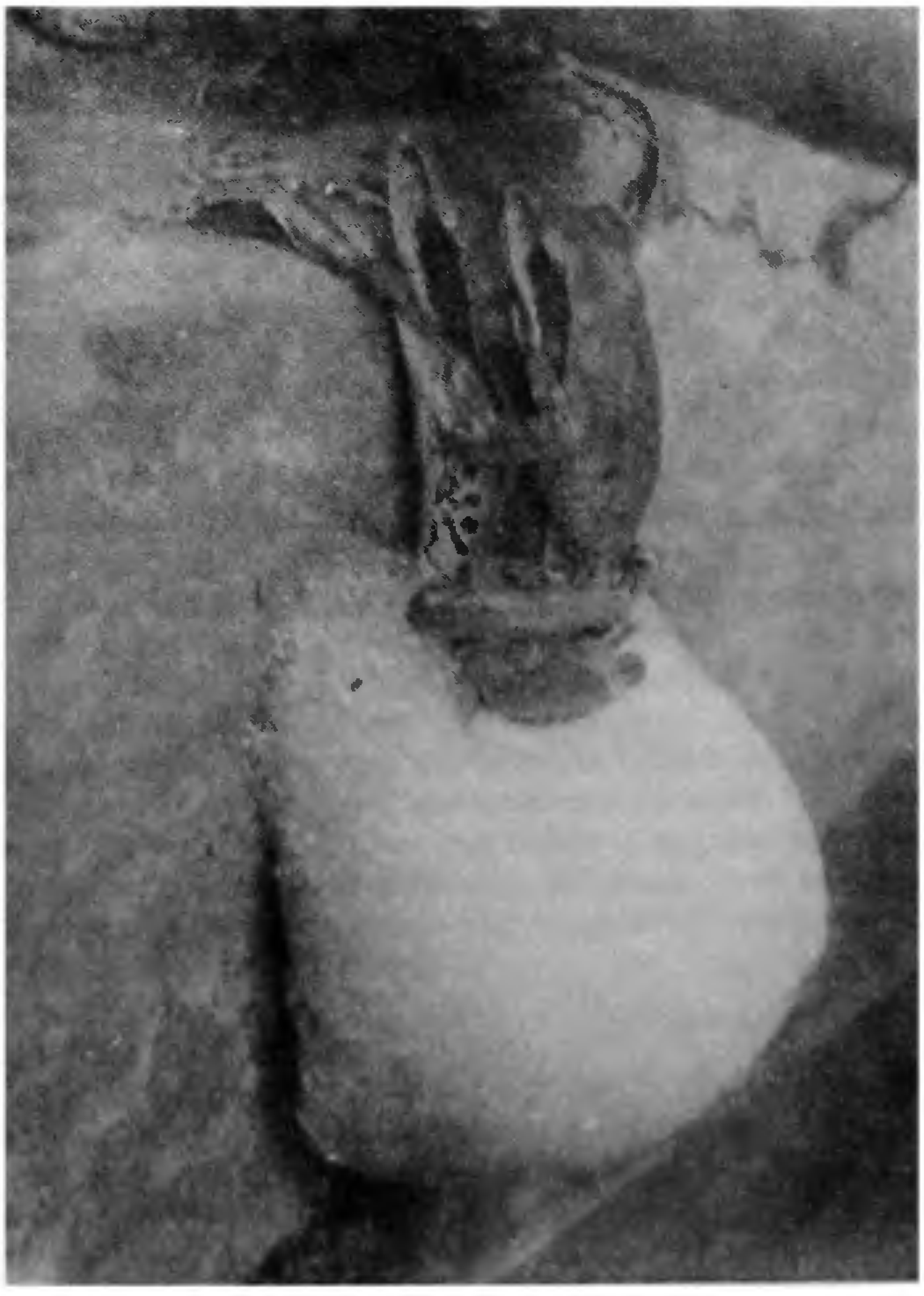

Figure 1. Amplexed pair of *P. maculatus* during nest construction.

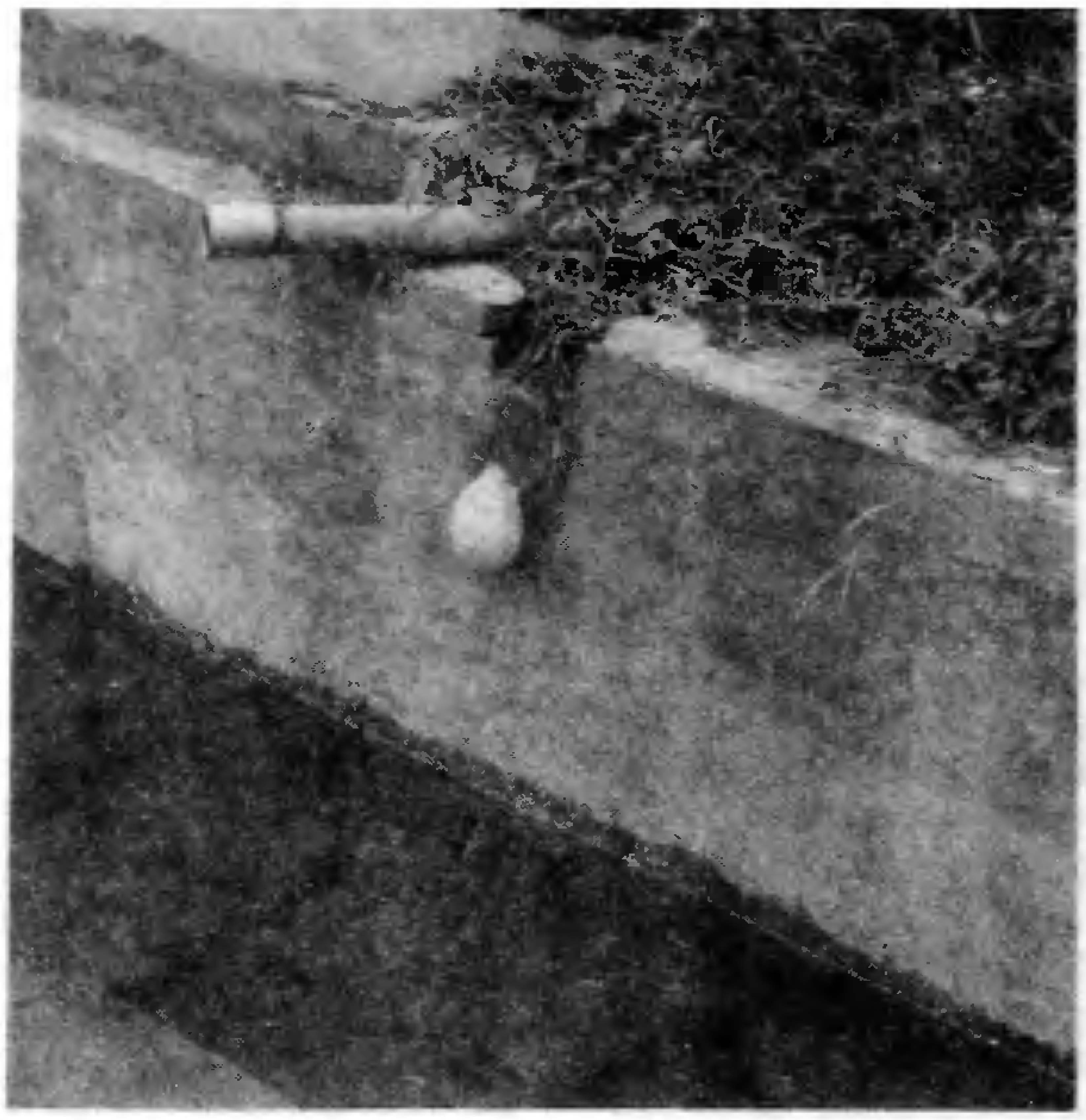

Figure 2. A foam nest attached to the wall of the pond above water surface.

the foam nest till stage 25, i.e. about 4–6 days after hatching. The tadpoles, maintained at a density of 50/25 l water/aquarium and fed on boiled spinach, completed metamorphosis in 60 ± 10 days (day of oviposition being day 0).

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Trigonometric Delights. Eli Maor. Princeton University Press, 41 William Street, Princeton, NJ 08540, USA. 236 pp. Price: US $ 24.95.

I immensely enjoyed reading Maor's book! Teachers of high school mathematics, which is where students learn trigonometry, will find a great deal of usable and interesting resource material in it; and so will high school and undergraduate students – at any rate, those with an historical bent of mind.

The author states his intentions plainly in the preface. '[The] book is neither a textbook ... nor a comprehensive history of ... [trigonometry]. It is an attempt to present selected topics in trigonometry from a historic point of view and to show their relevance to other sciences. It grew out of my love affair with the subject, but also out of my frustration at the way it is being taught in our colleges'. The 'frustration' is at the treatment that that curious invention of the 1960s, the 'New Math', meted out to old-fashioned geometry and trigonometry. Many definitions and explanations were cast in the language of set theory and functions, with the result that relatively simple concepts became 'obscured in meaningless formalism', as the author puts it. With the change in focus, formalism took over and the level and depth of the typical textbooks used in the trigonometry class steadily declined. The author has the western countries in mind when he writes this, but the situation in India, though less dismal, is far from encouraging.

Trigonometry is often regarded as a 'glorified geometry with superimposed computational torture', and it is the author's intention to dispel this view. Accordingly, he has adopted a semi-historical approach, but not with a strict chronological order in mind. Topics have been selected on the basis of broad aesthetic appeal, and of course relevance to other sciences. For instance he derives a result due to Euler,

$$\frac{\sin x}{x} = \cos\frac{x}{2}\cdot\frac{\cos x}{4}\cdot\frac{\cos x}{8}\ \ldots,$$

and the special case of this result when $x=\pi/4$, obtained by Viete in 1593 using very different ideas. This is just one of many gems that the author offers the reader.

The author has kept the high school reader in mind and avoids for the most part topics that require a knowledge of calculus higher than what is taught in schools. Keeping the same reader in mind, he also avoids topics related to spherical trigonometry (though, as he adds, plane trigonometry originally came from spherical trigonometry which in turn came from astronomy). Starting with material related to angles and chords and their treatment in ancient Egypt, Babylon and Greece, he traces out how the familiar functions of trigonometry (the sine, cosine, tangent, cotangent, secant and cosecant functions) took shape and name. He describes the amusing story behind the word 'sine' (it comes from the Hindu word for half-chord, *ardha-jyā*), and briefly mentions the contributions to trigonometry at the hands of Āryabhatā in India (6th century), Abul-Wefa in Arabia (10th century), Ulugh Beg in Samarkand (14th century), ...; then at the hands of the Europeans: Muller alias Regiomontanus in Germany (15th century), Rhaeticus in Denmark and Girard in Holland (16th century), ...

The historical sidebars are among the most attractive features of the book. There are pieces on *Plimpton 322*, regarded as the earliest trigonometric table (dating from the Babylonian period), on Regiomontanus and an appealing problem in geometry that is attributed to him, on Viete, on de Moivre, and on Maria Agnesi and her famous curve – the *witch*. Some chapters are highly readable: there is one on map projections ('A Mapmaker's Paradise'), probably the best in the book; one titled '$(\sin x)/x$' (it would seem hard to write a reasonable chapter with such a title – but the author pulls it off); one on cycloidal curves ('Epicycloids and Hypocycloids'); one titled '$\tan x$' in which he derives the decomposition of $\tan x$ into partial fractions, then uses it to prove that $\Sigma\, 1/n^2=\pi^2/6$ (first shown by Euler, but via the infinite product for $\sin x$) and $1-1/3+1/5-1/7+\ldots=\pi/4$ (first shown by Mādhavā of the Kerala school and later by Gregory and Leibnitz, each in a different way); and one on surveying ('Measuring Heaven and Earth'). What I find most appealing about the author's treatment is the fine blend of history and mathematics throughout the book. Towards the end of the book are chapters on Lissajous figures (not generally studied at the school level) and Fourier series; once again, presented against an historical backdrop.

A review is not supposed only to praise a book, so I must look for some negative comments to make! But these are hard to come by here. I would only say that there are a few 'missed opportunities', in the form of gems that have aesthetic as well as pedagogic appeal but which the author has somehow missed. For instance, he could have included some material on Buffon's needle problem. He could have shown how to construct a regular pentagon via ruler and compass, using the elegant but easily proved relation $\cos 72° = (\sqrt{5}-1)/4$, and he could have shown how higher algebra and trigonometry join hands in tackling the ancient problem of trisecting an arbitrary angle via compass and ruler. He could also have included material on trigonometric identities that have elegant 'proofs without words'; e.g. the identities $\tan 15° = 2-\sqrt{3}$ and $\tan^{-1}\frac{1}{2}+\tan^{-1}\frac{1}{3}=45°$. However his choice of historical material cannot be faulted.

Another delicate point: can the author's assessment of the Indian contribution to trigonometry be considered accurate? Chapter 3 opens casually with the words 'An early Hindu work ..., the *Surya Siddhanta* (ca 400 A.D.), gives a table of half-chords based on Ptolemy's table ....' Should this be regarded as a typically Eurocentric view, in which essentially all mathematics of any significance has western and *only* western roots? The prevailing views on this matter are now under question. However this is not the occasion to launch forth into such matters, and we leave the question as something to be kept in mind while reading the book.

In sum, this is a book with a great deal to recommend for itself. I feel that it has considerable pedagogic value, and can be read for pleasure and profit by anyone with a serious interest in mathematics.

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