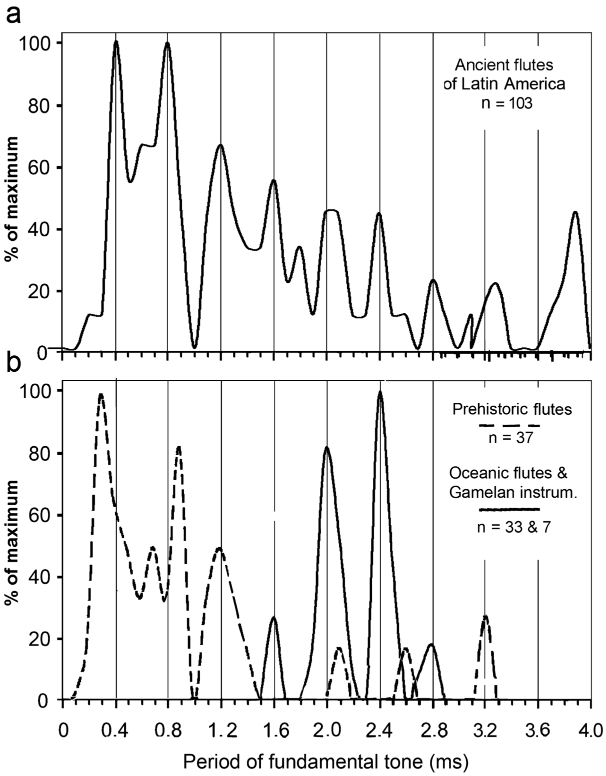

Fig. 5.9 The distribution of fundamental tones of 103 ancient flutes from South America and Mexico, some of them probably more than 2000 years old. The fundamental tones of 52 flutes were determined acoustically (courtesy of Ulrich Hoffmann, Gallery Old-America, Stuttgart, Germany), and 51 fundamental tones were computed from flute lengths and inner diameters (Ellen Hickmann, 2007). The preference for tunings at fundamental periods that are integer multiples of 0.4 ms is highly significant (Gauss-test, 0.40 ± 0.01, *p* < 0.1%). **(a)** Carl Stumpf found that flutes from the South Seas, South America (33) and gamelan instruments from Indonesia (7) were often tuned to the same pitch (Stumpf, 1939). As shown, they cluster around integer multiples of 0.4 ms (n = 4–7; Gauss-test: 0.40 ms ± 0.01 ms, *p* < 0.1%). **(b)** Although less significant, the same is true for 37 prehistoric flutes, according to geometric measures published by Clodoré-Tissot (2009) and others (n = 1–8; Gauss-test: 0.4 ms ± 0.1 ms, *p* < 5%).

surprising precision to the same tones (Hornbostel, 1928; Kunst, 1948). The same was true for panpipes from Bolivia, Peru and the Solomon Islands. In his book about epistemology Carl Stumpf mentioned these mysterious findings and still found it quite hard to explain them (Stumpf, 1940). His final conclusion was that of a ‘common origin’, especially since a ‘general necessity, especially of the human hearing system that would constrain people of distant parts of the world to tune their instruments to the same pitches was not apparent’ (translations from Stumpf, 1939).

Obviously, Carl Stumpf had thought of an auditory property as the right explanation for the universal tuning phenomenon. Nevertheless, he preferred the quite unlikely assumption of unknown worldwide intercultural contacts as a basis of absolute and response to pure tones, principal cells may synchronize extremely well to periodic sounds and are therefore able to faithfully code the fluctuations and modulations of acoustic signals (see Chapter 7). Consequently, I will suggest in Chapter 9 that these cells play an important role in temporal coding and periodicity analysis.

6.5 Olivary nuclei

Many cell types in the CN transfer information to higher processing centres, with different cell types having different response properties, different projection pathways and targets. The neuronal structures which receive the binaural temporal and intensity information about sound localization from the bushy cells are the superior olivary nuclei (Fig. 6.1). Because these nuclei receive (direct or indirect) input from both sides of the brain, their neurons are able to compare features of the signal at the two ears.

When our head shadows a signal on one side more than on the other, because the signal source is lateralized, neurons in the lateral superior olive (LSO) are able to compare the different response strength at the two ears. In contrast, neurons in the medical superior olive (MSO) are sensitive to the timing differences in the activation of both ears. They process the difference of the arrival time at the two ears with a precision of 10 µs. As a consequence we are able to localize the direction of a sound within a few degrees. This high binaural accuracy may be considered as an indisputable proof of the power of temporal processing in the auditory system.

In both olivary nuclei, the sensitivities to temporal disparities or intensity differences, respectively, are distributed along the spatial axes of the nuclei and are laid out in topographical maps. Since these maps are the result of neuronal processing or computation, they are also often called ‘computational maps’. We will encounter another such computational map for temporal information in the auditory midbrain, in this case for signal periodicities (Chapter 10).

6.6 Lateral lemniscus

Octopus cells do not project directly to the inferior colliculus, in contrast to stellate cells and DCN principal cells; this is an essential aspect of the pitch theory presented in Chapter 9. In addition, they send their axons mostly to the other side of the brain. Their major target is the ventral part of an elongated cell group embedded in the fibres of the lateral lemniscus, located immediately below the inferior colliculus. Besides the ventral nucleus of the lateral lemniscus (VNLL), a dorsal nucleus (DNLL) has been distinguished and in some animals anatomists even recognize three distinct nuclei, all of them sending inhibitory projections to the inferior colliculus (Zhang *et al.*, 1998; Riquelme *et al.*, 2001).

Just like the primary-like cells in the CN, the cells of the VNLL receive their information via giant synapses (Vater *et al.*, 1997). This allows the innervating octopus