own and other species, juvenile sparrows tend to choose the songs of their own species[2]. But this innate tendency can be overcome if a bird has a live tutor of another species: if the song structure falls within the capabilities of the sparrows, they can learn to sing the alien songs[3].

In general, the morphological structure of song segments (phrases) is a surprisingly weak constraint on song acquisition for white-crowned sparrows. For example, although the trill phrase normally consists only of downward-sweeping frequency modulations, birds can learn songs with upward-sweeping modulations[4,5]. But what about the order in which phrases are sung? Sparrows tutored on only individual phrases assemble a more complex and species-typical pattern but fail to produce a normal song[6].

In their research, Rose *et al.*[1] found a similar limitation. However, they then went on to show that when sparrows were presented with phrase pairs (for example AB, BC, CD, DE or DE, CD, BC, AB) in fixed order, the birds tended to assemble the song correctly (ABCDE). Remarkably, if birds were trained with BA, CB, DC, ED, they tended to learn the song EDCBA. These results show that, for white-crowned sparrows, the acquired template represents sequence information; that the minimal information for identifying a sequence of appropriate length is sufficient to describe song; and that environmentally supplied sequence information can overcome the innate tendency to start songs with whistles ('A' in the above examples).

How is this information represented in the brain? How are the early memories of songs laid down, and how do they guide vocal learning? Songbirds possess a set of distinct forebrain cell groups ('nuclei') associated with song production, perception and learning — the so-called song system. Early studies of adult birds showed that playback of a bird's own song elicits much stronger responses from song-system neurons than does playback of virtually any other song, a clear result of the learning process. In white-crowned sparrows, some neurons in the nucleus HVC, a site of sensory and motor integration in the song system, exhibited own-song selective responses, but only when a bird was presented with sequences of two phrases drawn in proper order from the bird's song[7]. The individual phrases failed to stimulate such combination-sensitive neurons, whereas most neurons in the HVC responded to individual phrases[5].

Rose and colleagues' results[1] imply that an acquired template sufficient for normal song learning can be assembled from sequential pairs of phrases. It is tempting to link these two observations: auditory memories are laid down (in part) as sequences that are represented by combination-sensitive neurons in the HVC. This also requires that such neurons have special 'status' as auditory memory neurons (for example, they could be disproportionately common as HVC output neurons), or strongly influence the discharge of the more numerous HVC neurons that respond to single phrases. One caveat is that the observed responses of own-song-selective neurons, recorded in adults, could be the result of establishing early auditory memories, but could also result from practice during vocal development. Evidence from young zebra finches, constrained to sing abnormal songs, shows that at least some song-system neurons achieve selectivity for auditory memories apparently independently of what the bird is singing[8].

A related question is whether the acquired template exists as a single group of cells that is modified by early auditory experience, or whether it has a more distributed representation. In the bird forebrain, secondary auditory pathways give rise to at least some of the auditory input to the song system[9]. Recent evidence, again in adult birds, ties specific changes in auditory responses within these pathways to perceptual learning of songs from different individuals[10]. If these same pathways are also modified during juvenile acquisition of auditory memories, at the same time that combination-sensitive responses are first specified in the song system, this would be evidence for a distributed representation across multiple cell groups.

Rose and colleagues' studies extend Peter Marler's classic work on white-crowned sparrows that started more than 40 years ago[11]. They add confidence to the view that the next decade will see dramatic progress in tackling the fundamental physiological questions about the song system. The promise of this system is that research can go beyond addressing which neurons and currents are modified during various phases of learning, to explore how they are arranged into a code for larger units of behaviour and how they produce physiological variation and adaptation. Playing Mother Sparrow to nestlings can be gruelling work, but the new results[1] emphasize that behavioural biology is an essential part of this research programme. ■

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100 YEARS AGO

The sale of Chartley Park, Staffordshire, the hereditary seat of Lord Ferrers, involves also a change of ownership of the remnant of the celebrated herd of white cattle which have been kept there for the last 700 years… It was long considered that the herds of cattle in various British parks were direct descendants of the wild aurochs, but it is now generally admitted (largely owing to the writings of Mr. Lydekker) that they are derived from domesticated albino breeds nearly allied to the Pembroke and other black Welsh strains, some of which show a marked tendency to albinism… The theory advocated by a later writer… that the British park cattle are the descendants of a white sacrificial breed introduced by the Romans rests upon no solid basis. The Chartley cattle, believed to be reduced to nine head, are to be captured by the purchaser — no easy task.

From *Nature* 8 December 1904.

50 YEARS AGO

***The Conquest of Plague.* This is a comprehensive study of plague. The author, Dr. L. Fabian Hirst… reminds the reader that primitive beliefs and observations may hold truths that are only revealed to the man of science centuries later. Instances of this are the epidemics of plague among the Philistines, described in the Old Testament (I Samuel, v, vi), which are associated with the presence of small rodents. The Hebrew word *akbar* may mean rat or mouse. If the civic authorities of London had read their Bible more carefully, they would not have favoured the rat population in ordering the destruction of cats and dogs as possible vectors of plague in 1665. Dr. Charles Singer has pointed out that during the seventeenth century natural causes were first assigned to plague, and even that it was due to the multiplication of minute organisms, a hypothesis not verified for two hundred years… On the vexed question as to whether Kitasato or Yersin discovered the bacillus of plague at Hong Kong in 1894, Dr. Hirst examines the evidence and states (p. 108): "The conclusion must be that both bacteriologists discovered the plague bacillus within a few days. Kitasato saw it first, but Yersin, the former *preparateur* of the Pasteur Institute, was probably the more accomplished technician and gave by far the best description of the micro-organism".**

From *Nature* 11 December 1954.