Brains out of tune

Thomas F. Münte

Is lack of musical ability simply the result of failure to practise? Probably not, if new investigations are anything to go by. They show that a disorder akin to dyslexia affects the processing of pitch.

There was an old fellow of Sheen
whose musical sense was not keen.
He said: "It is odd,
I can never tell 'God
save the weasel' from 'Pop goes the Queen'!"

The old fellow of Sheen was in good company. Two presidents of the United States, Ulysses S. Grant (Fig. 1) and Theodore Roosevelt[1], were tone deaf, as was Che Guevara[2]. Music educators often ascribe[3] lack of musical aptitude to lack of practice. But in a paper published in *Brain*[4], accompanied by a case report in *Neuron*[5], Isabelle Peretz and colleagues suggest that 'congenital amusia' is a developmental disorder that can be placed alongside developmental dyslexia and specific language impairment.

The possibility that people can be subject to a selective, potentially inborn deficit of music processing has been entertained for more than a hundred years. But there have been only a few anecdotal reports to support such a notion. For example, the neuropsychologist Norman Geschwind described[6] a man from a family with several musically impaired members who was fluent in three foreign languages yet could not sing a song, discriminate the pitch of two tones, or keep a rhythm, despite having had music lessons as a child.

Peretz and colleagues[4,5] set out to put these observations on firmer grounds. To rule out a general learning disorder, they selected 11 subjects from a larger group of self-declared unmusical volunteers who had achieved a high level of education, had been exposed to music during childhood lessons, and had been unsuccessful in mastering music from the start. Previous research has shown that memory for songs and different aspects of music — such as interval (the pitch difference between two tones), contour (the general direction in which a melody is moving), rhythm (the local temporal structure of a piece) and metre (its global temporal structure) — can be distinguished and are selectively impaired in patients with damage to particular parts of their brain[7].

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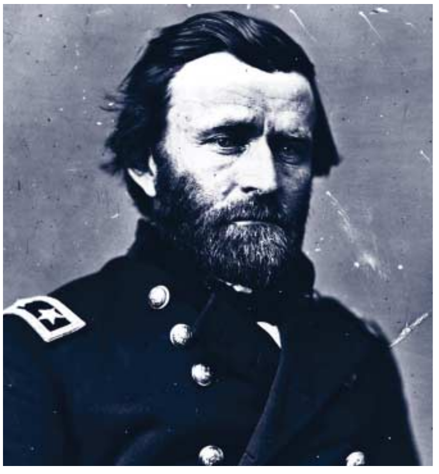

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Figure 1 **"I only know two tunes. One of them is Yankee Doodle and the other isn't." So said the tone-deaf Ulysses S. Grant (inset) to a reporter. Music annoyed Grant, so the band shown here, playing at his second inauguration in 1873, is unlikely to have set his toes tapping. Peretz and colleagues[4,5] consider such 'congenital amusia' to be due to impaired processing of musical pitch.**

When their unmusical subjects were given a standardized battery of tests assessing these different dimensions, Peretz and co-workers found that there was a general failure in those tests involving pitch perception, whereas results in rhythm and metre tasks were more varied. In addition, the unmusical subjects were also insensitive to distortions of familiar tunes, and indifferent to dissonant chords. But they had no problem in recognizing familiar voices, environmental sounds and song lyrics. So a pitch-processing deficit was at the heart of the subjects' problems.

Peretz and colleagues next asked whether this deficit is specific to music, or whether it extends to other domains that depend on pitch information, such as language. In spoken language, crucial information is transmitted by modulating the pitch contour, or prosody. Consider, for example, the differences in intonation between "She is rich?" and "She is rich." Questions are indicated by a final rise in pitch of the order of six semitones, whereas for statements the pitch falls by about three semitones. The unmusical subjects had no difficulties in picking up these differences — that is, they could detect whether a stimulus was spoken as a question or as a statement — which suggests that the deficit is selective for music-like stimuli and spares the language domain.

What is the cause of this remarkable disturbance in pitch processing? Is it congenital, as Peretz and colleagues maintain? And if so, does it indicate the existence of a specific, genetically determined music-processing system? In support of the view that the deficit is hereditary, the authors point out that 6 of the 11 subjects described one of their parents, as well as some of their siblings, as unmusical, with other family members being said to be 'normal' musically.

These family histories hardly qualify as hard evidence. But fortunately it turns out that, as far back as 1925, geneticists found evidence for the heritability of pitch discrimination[8]. Last year, this issue was re-examined by Drayna *et al.*[9] using state-of-the-art genetic modelling on a large sample of identical (monozygotic) and fraternal (dizygotic) twins in Britain. Such twin studies allow the influence of shared environments to be separated from that of shared genes. Drayna *et al.*[9] presented subjects with a set of simple

100 YEARS AGO

It is possible to believe that all the past is but the beginning of a beginning, and that all that is and has been is but the twilight of the dawn. It is possible to believe that all that the human mind has ever accomplished is but the dream before the awakening. We cannot see, there is no need for us to see, what this world will be like when the day has fully come. We are creatures of the twilight. But it is out of our race and lineage that minds will spring, that will reach back to us in our littleness to know us better than we know ourselves, and that will reach forward fearlessly to comprehend this future that defeats our eyes. All this world is heavy with the promise of greater things, and a day will come, one day in the unending succession of days, when beings, beings who are now latent in our thoughts and hidden in our loins, shall stand upon this earth as one stands upon a footstool, and shall laugh and reach out their hands amidst the stars. **H. G. Wells**

From *Nature* 6 February 1902.

50 YEARS AGO

Studies have been made of the probable 'handedness' of prehistoric man by investigating the various relics of his tools and weapons. It appears from the way they are carved that prehistoric man was predominantly right-handed. The choice of one hand, usually the right but occasionally the left, and not either hand indiscriminately, is characteristic of man. It would seem that ambidexterity is an animal rather than a human characteristic… although to be left-handed in a right-handed society has numerous disadvantages, in spite of attempts to stamp it out in Britain, Greece, the United States and France, approximately 4–6 per cent of the population are still left-handed. Why should this be? Left-handedness appears to be inherited; how is not known. In certain families there seems to be a high incidence of left-handedness. Some investigators have found that such families also have more than the usual number of twins, so that there might be some connexion between twinning and left-handedness. That more males than females are left-handed seems to be agreed by investigators and raises the interesting question of whether this is the original distribution, or whether it is the result of the pressure of society.

From *Nature* 9 February 1952.

popular tunes, some of which had been altered by inserting a wrong note. The subjects differed greatly in their ability to detect the altered melodies, and genetic model-fitting indicated a heritability of pitch discrimination of 70–80%.

Does this mean, then, that the basic building-blocks of our music-processing system are to a large part inherited? Hundreds of pages have been filled over the past 150 years with attempts to explain the appearance of music, starting with Charles Darwin[10], who believed that systems of calling in animals have a musical quality and evolved into speech. This view is echoed in a recent article by Gray *et al.*[11], which draws parallels between the songs of birds, whales and humans. Steven Pinker, the outspoken cognitive neuroscientist, on the other hand, notes that "of [all] mental faculties… music shows the clearest signs of not being [adaptive]"[12] and probably occurred as an epiphenomenon, as "auditory cheesecake".

The new data provided by Peretz *et al.*[4,5] establish congenital amusia as a specific developmental disorder. But to go further and help settle the debate, combined behavioural and genetic study of subjects with music-processing deficits will be needed to reveal more about the biological origins of our musical faculty. ■

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Microbiological oceanography

Hidden in a sea of microbes

David M. Karl

The photosynthetic activities of bacteria in the oceans are more diverse than previously thought. A full picture of the marine energy budget will require their separate contributions to be teased apart.

Green plants have been using oxygenic photosynthesis, in which oxygen is released, for more than 3 billion years. But there are two other non-oxygenic photosynthetic pathways, used not by green plants, but by certain bacteria. One pathway is known as anaerobic anoxygenic photosynthesis (AnAnP), because it can occur in the absence of oxygen; it pre-dates oxygenic photosynthesis, and is nowadays restricted to a few groups of bacteria that inhabit sunlit, oxygen-free habitats. The other pathway — aerobic anoxygenic photosynthesis (AAnP) — requires oxygen but does not generate it as a by-product; this pathway was discovered in marine bacteria only twenty years ago[1].

Most photosynthetic microorganisms in the open ocean were thought to be oxygenic, but there is growing evidence[2,3] that oxygen-consuming, light-harvesting AAnP bacteria could make up as much as 11% of the total marine community. On page 630 of this issue, Béjà *et al.*[4] identify new groups of AAnP bacteria in the sea, and show that these are much more diverse than expected.

All of these various photosynthetic bacteria harvest light energy using specialized pigments (the 'photo' part) and can convert CO_2 into organic carbon (the 'synthesis' part), albeit with differing efficiencies. This is why the oceans are thought to act as carbon sinks: marine bacteria and algae convert atmospheric CO_2 into organic matter, some of which then enters the food web, where it remains for variable time periods. In oxygenic photosynthesis, chlorophyll *a* is the primary pigment responsible for harvesting light energy, and water is the hydrogen donor for CO_2 reduction, so oxygen is generated as a by-product (Fig. 1). Much of the oxygen will be consumed by non-photosynthetic organisms during respiration, when they metabolize organic matter to generate energy and to synthesize cellular constituents.

Before the dawn of oxygenic photosynthesis, AnAnP bacteria used hydrogen sulphide or hydrogen gas, which were both abundant, as the hydrogen donors — this is why they do not produce O_2 (Fig. 1). These bacteria use bacteriochlorophyll *a* (Bchl*a*) as the pigment for harvesting light energy. AAnP bacteria, on the other hand, use oxygen to metabolize organic carbon, to synthesize Bchl*a* for example, but do so more efficiently when sunlight is available (Fig. 1). Like AnAnP bacteria, they do not use water as the hydrogen donor, so oxygen is not produced. These bacteria are being found in surprising amounts in the open sea[2,3], and could make