With the development of brain imaging in the 1990s, it became possible to actually visualize the brains of musicians and to compare them with those of nonmusicians. Using MRI morphometry, Gottfried Schlaug at Harvard and his colleagues made careful comparisons of the sizes of various brain structures. In 1995, they published a paper showing that the corpus callosum, the great commissure that connects the two hemispheres of the brain, is enlarged in professional musicians and that a part of the auditory cortex, the planum temporale, has an asymmetric enlargement in musicians with absolute pitch. Schlaug et al. went on to show increased volumes of gray matter in motor, auditory, and visuospatial areas of the cortex, as well as in the cerebellum.[2] Anatomists today would be hard put to identify the brain of a visual artist, a writer, or a mathematician—but they could recognize the brain of a professional musician without a moment's hesitation.

How much, Schlaug wondered, are these differences a reflection of innate predisposition and how much an effect of early musical training? One does not, of course, know what distinguishes the brains of musically gifted four-year-olds before they start musical training, but the effects of such training, Schlaug and his colleagues showed, are very great: the anatomical changes they observed with musicians' brains were strongly correlated with the age at which musical training began and with the intensity of practice and rehearsal.

Alvaro Pascual-Leone at Harvard has shown how rapidly the brain responds to musical training. Using five-finger piano exercises as a training test, he has demonstrated that the motor cortex can show changes within minutes of practicing such sequences.

2. See, for example, Gaser and Schlaug's 2003 paper and Hutchinson, Lee, Gaab, and Schlaug, 2003.

Measurements of regional blood flow in different parts of the brain, moreover, have shown increased activity in the basal ganglia and the cerebellum, as well as various areas of the cerebral cortex—not only with physical practice, but with mental practice alone.

There is clearly a wide range of musical talent, but there is much to suggest there is an innate musicality in virtually everyone. This has been shown most clearly by the use of the Suzuki method to train young children, entirely by ear and by imitation, to play the violin. Virtually all hearing children respond to such training.[3]

It has been said that even a brief exposure to classical music can stimulate or enhance mathematical, verbal, and visuospatial abilities in children—the so-called Mozart effect. This has been disputed by Schellenberg and others, but what is beyond dispute is the effect of intensive early musical training on the young, plastic brain. Takako Fujioka and her colleagues, using magnetoencephalography to examine auditory evoked potentials in the brain, have recorded striking changes in the left hemisphere of children who have had only a single year of violin training, compared to children with no training.[4]

Can musical competence be seen as a universal human potential in the same way as linguistic competence? There is exposure

3. Even profoundly deaf people may have innate musicality. Deaf people often love music and are very responsive to rhythm, which they feel as vibration, not as sound. The acclaimed percussionist Evelyn Glennie has been profoundly deaf since the age of twelve.

4. It is not always easy or possible for children to receive musical training, especially in the United States, where music instruction is being eliminated from many public schools. Tod Machover, a composer and leading designer of new technology for music, seeks to address this problem by "democratizing" music, making it accessible to anyone. Machover and his colleagues at MIT's Media Lab have developed not only the Brain Opera, the Toy Symphony, and the popular video game Guitar Hero, but Hyperinstruments, Hyperscore, and other interactive systems used by professional musicians from Joshua Bell, Yo-Yo Ma, and Peter Gabriel to the Ying Quartet and the London Sinfonietta.

to language in every household, and virtually all children develop linguistic competence (in a Chomskian sense) by the age of four or five.[5] This may not be the case with regard to music, since some households may be almost devoid of music, and musical potential, like other potentials, needs stimulation to develop fully. In the absence of encouragement or stimulation, musical talents may not develop. But while there is a fairly well-defined critical period for language acquisition in the first years of life, this is less so for music. To be languageless at the age of six or seven is a catastrophe (it is only likely to occur in the case of deaf children given no effective access to either Sign or speech), but to be music-less at the same age does not necessarily predict a music-less future. My friend Gerry Marks grew up with very little exposure to music. His parents never went to concerts and rarely listened to music on the radio; there were no instruments or books on music in the house. Gerry was puzzled when classmates talked about music, and he wondered why they were so interested in it. "I had a tin ear," he recalled. "I could not sing a tune, I could not tell if others sang in tune, and I could not distinguish one note from another." A precocious child, Gerry was passionate about astronomy, and he seemed all set for a life of science—without music.

But when he was fourteen, he became fascinated by acoustics, especially the physics of vibrating strings. He read about this and did experiments in the school lab, but, increasingly, craved a stringed instrument for himself. His parents gave him a guitar for his fifteenth birthday, and he soon taught himself to play. The sounds of the guitar and the feeling of plucked strings excited

5. There are very few exceptions here—some children with autism and some with congenital aphasia. But for the most part, even children with marked neurological or developmental problems acquire functional language.

him, and he learned rapidly—by the time he was seventeen, he came in third in a contest for "the most musical" in his senior class in high school. (His high-school friend Stephen Jay Gould, musical from infancy, came in second.) Gerry went on to major in music at college, where he supported himself by teaching guitar and banjo. A passion for music has been central to his life ever since.

Nevertheless, there are limits imposed by nature. Having absolute pitch, for example, is highly dependent on early musical training, but such training cannot, by itself, guarantee absolute pitch. Nor, as Cordelia shows, can the presence of absolute pitch guarantee that there will be other, higher musical gifts. Cordelia's planum temporale was no doubt well developed, but perhaps she was a bit lacking in prefrontal cortex, in judgment. George, on the other hand, while doubtless well endowed in those areas of the brain involved in emotional reaction to music, may have been lacking in other areas.

The examples of George and Cordelia introduce a theme that will be echoed and explored in many of the clinical case histories that follow: that what one calls musicality comprises a great range of skills and receptivities, from the most elementary perceptions of pitch and tempo to the highest aspects of musical intelligence and sensibility, and that, in principle, all of these are dissociable one from another. All of us, indeed, are stronger in some aspects of musicality, weaker in others, and so have some kinship to both Cordelia and George.