

Although we are still far from understanding why the tropics have such great biodiversity, molecular phylogenetic studies, despite their imperfections, are starting to provide important clues. From what we know now, it is apparent that many plant and animal species of the neotropics originated prior to the ice ages that began roughly 2.5 million years ago. However, many other species first appeared during the Pleistocene (from about 2.5 million to about 11,500 years ago). Thus, the known ages of species origins in the neotropics do not exclude the possibility of significant Pleistocene diversification as put forward by Haffer.

Whether these species originated in isolated refugia is a separate question, as is the matter of whether such refugia even existed. In tropical Africa, much evidence indicates that Pleistocene aridity *did* bring about a great increase in the extent of savannah at the expense of rain forest. Scientists doing research there thus are less resistant to the notion of species-rich Pleistocene forest refugia. Their disputes focus on the ages and locations of refugia, not the very existence of the refugia.

Unfortunately, paleoclimatic studies of the neotropical Pleistocene have produced less-definitive results than have similar studies in Africa. Although there is little doubt that Amazon surface air temperatures were significantly colder during the many glacial stages of the Pleistocene than they were during the intervening interglacial periods, we still do not know the timing and magnitude of past precipitation changes in the Amazon region. The studies of Colinvaux and his collaborators established that at the time of the last glacial maximum the Amazon was wet enough to retain a rain forest along the equator. In other regions of tropical South America, however, there is evidence for great variations in precipitation, in some cases accompanied by evidence for significant changes in flora. Maximum drying occurred in the southern tropics during warm interglacial stages—not during cold glacial stages, as many scientists previously assumed. (Incidentally, Haffer did not stipulate in his original hypothesis that the glacial stages were the arid periods.)

At the very least, it seems likely that Pleistocene climate variations, coupled with known major changes in atmo-

spheric CO₂ levels, forced changes in the composition and nature of Amazon forest communities, bringing about the extinction of some species, necessitating migration of some species, and resulting in the isolation and evolutionary divergence of some species. Yet in the equatorial Amazon there is no evidence for the sort of fragmentation of the forested landscape during the Pleistocene that is envisioned by the refugialists.

In sum, the evidence is mixed. Colinvaux has his widespread forest continuity and significant glacial-stage temperature decreases; the refugialists have their Pleistocene diversification and a likely significant interglacial drying. Haffer and his supporters, along with Colinvaux and his, have advanced our understanding of the history of the tropics and the origin of tropical diversity. And now, Colinvaux has given us a most entertaining behind-the-scenes account of his challenging quest and worthy accomplishments.

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NEUROSCIENCE

Musical Maladies

Norman M. Weinberger

MUSICOPHILIA: Tales of Music and the Brain. Oliver Sacks. xiv + 381 pp. Alfred A. Knopf, 2008. \$26.

Music and the brain are both endlessly fascinating subjects, and as a neuroscientist specializing in auditory learning and memory, I find them especially intriguing. So I had high expectations of *Musicophilia*, the latest offering from neurologist and prolific author Oliver Sacks. And I confess to feeling a little guilty reporting that my reactions to the book are mixed.

Dr. Sacks comes across as a kind, compassionate, careful observer, who is concerned above all with providing sensitive and humane treatment for his patients. Many of them have symptoms that cannot be relieved by drugs or other therapies. Often he can offer nothing more than reassurance, as when he comforts a woman by explaining that her constant musical hallucinations

have a real, physiological basis; she copes better knowing that she is neither crazy nor unique.

Sacks himself is the best part of *Musicophilia*. He richly documents his own life in the book and reveals highly personal experiences. The photograph of him on the cover of the book—which shows him wearing headphones, eyes closed, clearly enchanted as he listens to Alfred Brendel perform Beethoven's *Pathétique* Sonata—makes a positive impression that is borne out by the contents of the book. Sacks's voice throughout is steady and erudite but never pontifical. He is neither self-conscious nor self-promoting. Readers might easily imagine that they are listening to Uncle Oliver recount weird and wonderful "tales of music and the brain" around a campfire.

The preface gives a good idea of what the book will deliver. In it Sacks explains that he wants to convey the insights gleaned from the "enormous and rapidly growing body of work on the neural underpinnings of musical perception and imagery, and the complex and often bizarre disorders to which these are prone." He also stresses the importance of "the simple art of observation" and "the richness of the human context." He wants to combine "observation and description with the latest in technology," he says, and to imaginatively enter into the experience of his patients and subjects. The reader can see that Sacks, who has been practicing neurology for 40 years, is torn between the "old-fashioned" path of observation and the newfangled, high-tech approach: He knows that he needs to take heed of the latter, but his heart lies with the former.

The book consists mainly of detailed descriptions of cases, most of them involving patients whom Sacks has seen in his practice. Brief discussions of contemporary neuroscientific reports are sprinkled liberally throughout the text.

The book's 29 chapters are divided into four main sections by topic. Part I, "Haunted by Music," begins with the



Oliver Sacks listens to Alfred Brendel perform Beethoven's *Pathétique* Sonata. From *Musophilia: Tales of Music and the Brain*.

strange case of Tony Cicoria, a nonmusical, middle-aged surgeon who was consumed by a love of music after being hit by lightning. He suddenly began to crave listening to piano music, which he had never cared for in the past. He started to play the piano and then to compose music, which arose spontaneously in his mind in a "torrent" of notes. How could this happen? Was the cause psychological? (He had had a near-death experience when the lightning struck him.) Or was it the direct result of a change in the auditory regions of his cerebral cortex? Electroencephalography (EEG) showed his brain waves to be normal in the mid-1990s, just after his trauma and subsequent "conversion" to music. There are now more sensitive tests, but Cicoria has declined to undergo them; he does not want to delve into the causes of his musicality. What a shame!

Switching from musicophilia to musicophobia, Sacks devotes most of the rest of the book's first section to music that people don't want in their heads—hallucinatory music, for example, or a jingle that repeats itself endlessly. In one particularly poignant passage, he describes a boy of nine who hears one song after another without cease. This music is sometimes unbearably loud, causing what his mother refers to as "acoustic agony." The child screams in pain and in frustration. Drugs that reduce cortical excitability help, but only a little—respite from the internal music is very brief.

Part II, "A Range of Musicality," covers a wider variety of topics, but unfortunately, some of the chapters offer little or nothing that is new. For example, chapter 13, which is five pages long, merely notes that the blind often have better hearing than the sighted. The most interesting chapters are those that present the strangest cases. Chapter 8 is about "amusia," an inability to hear sounds as music, and "dysharmonia," a highly specific impairment of the ability to hear harmony, with the ability to understand melody left intact. Such specific "dissociations" are found throughout the cases Sacks recounts.

To Sacks's credit, part III, "Memory, Movement and Music," brings us into the underappreciated realm of music therapy. Chapter 16 explains how "melodic intonation therapy" is being used to help expressive aphasic patients (those unable to express their thoughts verbally following a stroke or other cerebral incident) once again become capable of fluent speech. In chapter 20, Sacks demonstrates the near-miraculous power of music to animate Parkinson's patients and other people with severe movement disorders, even those who are frozen into odd postures. Scientists cannot yet explain how music achieves this effect.

Musophilia closes with several chapters on "Emotion, Identity and Music." Sacks is perhaps at his best dealing with this material. He enthuses about the special musicality of children and adults who have Williams syndrome

and gives an intriguing summary of evidence that frontotemporal dementia may "release" artistic abilities. He is particularly insightful and inspiring in the final chapter, "Music and Identity: Dementia and Music Therapy." Here Sacks emphasizes his belief, with which I am in wholehearted agreement, that humans are a "musical species." He could have made his case, which relies on the universality of music, even stronger by bringing in evidence that neonates, and even third-trimester fetuses, have the ability to perceive music.

In his closing thoughts, Sacks speaks eloquently of the preservation of musical ability and music appreciation in patients with advanced Alzheimer's disease:

Music is part of being human, and there is no human culture in which it is not highly developed and esteemed. Its very ubiquity may cause it to be trivialized in daily life: we switch on a radio, switch it off, hum a tune, tap our feet, find the words of an old song going through our minds, and think nothing of it. But to those who are lost in dementia, the situation is different. Music is no luxury to them, but a necessity, and can have a power beyond anything else to restore them to themselves, and to others, at least for a while.

To readers who are unfamiliar with neuroscience and music behavior, *Musophilia* may be something of a revelation. But the book will not satisfy those seeking the causes and implications of the phenomena Sacks describes.

For one thing, Sacks appears to be more at ease discussing patients than discussing experiments. And he tends to be rather uncritical in accepting scientific findings and theories.

There are a number of examples of this tendency, but I will describe in detail just one. In considering why musical hallucinations are so vivid, Sacks cites the 1967 monograph of the late Jerzy Konorski, a brilliant, currently underappreciated behavioral neuroscientist. Konorski's thesis is that hallucinations are caused by connections going from the sensory regions of the brain to the sense organs (so-called "retro" or "descending" connections). He hypothesizes that hallucinations are normally inhibited by sensory experiences but that when sensory stimulation falls below a certain level, the "retro" fibers act on the sense organs

to produce “virtual” experiences that are as vivid as real ones.

Sacks swallows this theory whole, stating that although evidence of such connections was scant in the 1960s, it is now overwhelming. In fact, the descending connections of the auditory system to the cochlea were well known even in the 1960s. However, the existence of retro connections cannot validate a particular theory about their function.

The explanation that a deficiency of input from the sense organs will facilitate a backflow “now seems obvious, almost tautological,” Sacks says. But Konorski’s schema is light-years away from being self-evident. It fails to explain why hallucinations can occur without any strong sensory deprivation. Nor does it shed any light on why the brain, which already possesses the hallucinatory material, needs to send extremely detailed hallucinatory scenes to the retina or cochlea, where they must be precisely reconstituted into a “real” sensory experience and returned to the sensory cortices. After all, the brain could produce the vivid images itself, as it does in the case of phantom limb sensations.

It’s true that the causes of music-brain oddities remain poorly understood. However, Sacks could have done more to draw out some of the implications of the careful observations that he and other neurologists have made and of the treatments that have been successful. For example, he might have noted that the many specific dissociations among components of music comprehension, such as loss of the ability to perceive harmony but not melody, indicate that there is no music center in the brain. Because many people who read the book are likely to believe in the brain localization of all mental functions, this was a missed educational opportunity.

Another conclusion one could draw is that there seem to be no “cures” for neurological problems involving music. A drug can alleviate a symptom in one patient and aggravate it in another, or can have both positive and negative effects in the same patient. Treatments mentioned seem to be almost exclusively antiepileptic medications, which “damp down” the excitability of the brain in general; their effectiveness varies widely.

Finally, in many of the cases described here the patient with music-

brain symptoms is reported to have “normal” EEG results. Although Sacks recognizes the existence of new technologies, among them far more sensitive ways to analyze brain waves than the standard neurological EEG test, he does not call for their use. In fact, although he exhibits the greatest compassion for patients, he conveys no sense of urgency about the pursuit of new avenues in the diagnosis and treatment of music-brain disorders. This absence

echoes the book’s preface, in which Sacks expresses fear that “the simple art of observation may be lost” if we rely too much on new technologies. He does call for both approaches, though, and we can only hope that the neurological community will respond.

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COMPUTER SCIENCE

Touring Turing

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THE ANNOTATED TURING: A Guided Tour through Alan Turing’s Historic Paper on Computability and the Turing Machine. By Charles Petzold. xii + 372 pp. Wiley Publishing, Inc., 2008. Paper, \$29.99.

As the 20th century drew to a close, *Time* magazine devoted an issue to the 20 greatest thinkers of the century. Along with such obvious choices as Albert Einstein and John Maynard Keynes, the editors included the less familiar name of Alan Turing. In the issue’s article on Turing, Paul Gray gave this explanation:

So many ideas and technological advances converged to create the modern computer that it is foolhardy to give one person the credit for inventing it. But the fact remains that everyone who taps at a keyboard, opening a spreadsheet or a word-processing program, is working on an incarnation of a Turing machine.

In the same issue of *Time*, Turing’s importance was also acknowledged in an article by Nathan Myhrvold on John von Neumann:

Virtually all computers today, from \$10 million supercomputers to the tiny chips that power cell phones . . . , have one thing in common: they are all “Von Neumann machines,” variations on the basic computer architecture that John von Neumann, building on the work of Alan Turing, laid out in the 1940s.

Turing expounded remarkable insights that revolutionized the way people think about computation in a paper

published in 1936 with the forbidding title “On Computable Numbers, with an Application to the Entscheidungsproblem.” Although it appeared in a technical mathematical journal (the *Proceedings of the London Mathematical Society*), for the most part very little mathematical knowledge is needed to understand the article, because its focus is the clarification of the concept of computation itself. In his paper, Turing describes “machines” that have only a pencil-and-paper existence; their simple workings could readily be explained to a child. They “operate” on a linear tape with no limit on its length. The tape is ruled into symbol-containing squares; a machine is at any moment sensitive to the contents of only a single one of these squares and changes the symbols according to instructions contained in a table. These Turing machines, as later writers called them, derive their significance from Turing’s remarkable claim that any symbolic process that can be carried out algorithmically can also be accomplished by such a machine. In *The Annotated Turing*, the well-established technical writer Charles Petzold has undertaken to make Turing’s seminal classic paper accessible to the general educated public by providing a line-by-line close reading of the full text, with careful explanations of background material as needed.

Petzold’s other books are aimed mainly at the professional software