turn, we will find that the ongoing expansion of our field to other repertories—including popular and non-Western cultures—will allow us to share a wealth of perspectives on a common theme: how music interacts with humans and cultures in ways that are meaningful, expressive, and fundamental to our lives.

Robert S. Hatten

Music Theory, Music Cognition, and 'The Case of the *Iguanodon*'s Thumb'

Six years have passed since I was last asked to comment on the state of music theory. At a joint meeting of AMS and SMT in New York I put my money on forging closer ties with music cognition.[1] I knew, of course, that many would disagree. For some, the goals of music cognition and music theory are simply different and there is nothing to be gained from using the one to inform the other. As Nicholas Cook puts it, "it is up to the psychologist or the social scientist, and not the music theorist to study music scientifically."[2] Even music psychologists have warned against making facile connections between the two disciplines; Eric Clarke, in particular, has stressed that music psychologists and music theorists are concerned with very different phenomena and inevitably rely on very different methods and standards of verification.[3] Clarke insists, therefore, that we "mind the gap" between the two disciplines.

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[1] This commentary was later published as Matthew Brown, "Adrift on Neurath's Boat: The Case for a Naturalized Music Theory," *Journal of Musicology* 15/3 (1997): 330-342.

[2] Nicholas Cook, *Music, Imagination, and Culture* (Oxford: Oxford University Press, 1990): 243.

[3] Eric Clarke, "Mind the Gap: Formal Structures and Psychological Processes in Music," *Music Perception* 3 (1989): 1-13.

Up to a point, Clarke's warning is well taken. Given the many differences between music theory and music cognition, it is surely dangerous to transport ideas willy-nilly from one domain to the other. But minding the gap is not the same as treating the gap as an insurmountable obstacle. Indeed, there are good reasons to suppose that the latter is ultimately impossible. This is because listening, performing, composing, and theorizing about music are all forms of human behavior; when we look at any of these activities, we inevitably learn as much about the mind as about the music. To illustrate what I mean, I will follow the same strategy as I did in New York six years ago and tell a short story. This time, I've taken my tale from the annals of paleontology. Strange as it may seem, I'm not the first music theorist to mention dinosaurs. According to William Sarjeant, the legend of Siegfried slaying the dragon may have been inspired by the discovery of dinosaur tracks in Medieval Germany; we can find an illustration of these tracks in *Mundus subterraneous* (Amsterdam, 1665) by the capricious music theorist Athanasius Kircher.[4] But I digress. Let's now recount 'The Case of the *Iguanodon*'s Thumb.'

Our story begins in London at a meeting of the Royal Society on 10 February 1825. A doctor and amateur naturalist named Gideon Mantell reported on certain fossils that he had found in south England. In particular, he discussed some fossil teeth that resembled those of a living iguana. He concluded that they belonged to a 60-foot lizard that he named *Iguanodon*, or "iguana tooth." In 1833, Mantell acquired more remains, including a vicious spike. Since some species of Iguana have horns, Mantell imagined that *Iguanodon* sported a spike on the end of its snout. Not all experts agreed. Sir Richard Owen, for example, proposed that *Iguanodon* was a higher form of reptile. According to him, it looked more like a scaly rhinoceros than a super-sized iguana. Its body was compact, its limbs firmly planted under the torso, and its circulatory system was powered by a four-chambered heart, just like modern mammals and birds.

But during the 1860s, the image of the *Iguanodon* changed more dramatically. Given that its front limbs were much shorter

[4] William A. S. Sarjeant, "History of Dinosaur Discoveries. I. Early Discoveries," in Philip J. Currie and Kevin Padian, eds., *Encyclopedia of Dinosaurs* (San Diego: Academic Press, 1997): 340-341.

than its back limbs, Joseph Leidy proposed that *Iguanodon* probably walked on its hind legs. Thomas Huxley reached the same conclusion. Thanks to the discovery of bird-like dinosaurs, Huxley listed many anatomical parallels between dinosaurs and birds, including the possibility that many dinosaurs were bipedal. The work of Leidy and Huxley was apparently vindicated a few years later. Miners working in the village of Bernissart, Belgium uncovered the remains of about thirty complete skeletons in April 1878. Four year later, a young scientist name Louis Dollo set about reconstructing them. Like Leidy and Huxley, he envisioned *Iguanodon* not as a lumbering pachyderm, but as a majestic 3-ton biped, akin to a kangaroo. Dollo also reinterpreted the role of *Iguanodon*'s spike: it was not a horn, but a greatly enlarged thumb. In 1926, Gerhard Heilmann took Dollo's image of *Iguanodon* even further: his *Iguanodon* was agile, like a bird, and zipped through the early Cretaceous landscape on two legs, spiked-thumbs raised, and a Fonz-like grin on its face.

But 'The Case of the *Iguanodon*'s Thumb' doesn't stop there. Over the past few decades, paleontologists have proposed that our trusty herbivore may have been a quadruped after all. It seems that Dollo literally bent the evidence to fit his model: he broke several vertebrae to give *Iguanodon*'s backbone the right shape for it to walk upright. Paleontologists have also offered alternative accounts of how *Iguanodon* used its thumb; besides skewering predators, the spike could also be used to grip objects, and may even have been used in courtship rituals or to ward off rival males.[5] Having said this, paleontologists still believe that *Iguanodon* displayed many avian characteristics: they apparently lived and nested in flocks, may have migrated, and, *pace* Barney, may have sung to one another and even been brightly colored![6]

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[5] David Norman, *Dinosaur* (New York: Prentice Hall, 1991): 164; and Kenneth Carpenter, *Eggs, Nests, and Baby Dinosaurs: A Look at Dinosaur Reproduction* (Bloomington, IN: Indiana University Press, 1999): 65.

[6] For example, when discussing the duckbilled dinosaur *Parasaurolophus*, David Weishampel has suggested that the complex air chambers in its skull resonate just like crumhorns; see D. B. Weishampel, "Acoustic Analysis of Potential Vocalization in Lambeosaurine Dinosaurs (Reptilia: Ornithosischia)," *Paleobiology* 7 (1981): 252-261, cited by Richard Cowen, *History of Life*, 3rd ed. (Oxford: Blackwell, 2000): 199.

But what has 'The Case of the *Iguanodon*'s Thumb' got to do with the relationship between music theory and music cognition? How can studying dinosaurs help us study music? Music theorists and music psychologists can learn a couple of lessons from our story. First, both groups tend to have a narrow view about how to test empirical claims; they over-emphasize the need for direct testability under laboratory conditions and undervalue indirect methods. While inter-subjective testability is surely the hallmark of scientific research, many sciences cannot run the sorts of direct tests demanded by many music theorists and music psychologists. Paleontology is one such science. Obviously, it is impossible to perform direct experiments on creatures that have been extinct for 65 million years. Yet, paleontologists are able to explain dino-anatomy and dino-behavior because they can draw on powerful general theories of evolution and vertebrate biology. These theories allow them to use evidence from living organisms to fill in the missing information. In fact, each stage in our story depended on making connections between *Iguanodon* and modern animals: Mantell picked iguanas; Owen rhinoceri; Dollo kangaroos; Huxley and Heilmann, birds. They even made hypotheses about *Iguanodon*'s internal anatomy: for example, Owen's notion that *Iguanodon* was warm-blooded was based on Lamarck's cardiovascular criteria of evolution.[7] This idea has recently been revived and has even forced naturalists to reconsider the metabolism of living creatures.[8] Music theorists and music psychologists can do the same. By focusing their attention less on laws with limited scope that can be tested directly and more on those with wide range, then they, too, might be able to develop theories with much greater predictive power. In fact, many music theorists already produce work that is quite respectable from a scientific standpoint.

Second, music theorists and music psychologists often underestimate the extent to which the one discipline already makes assumptions about the other. It should be clear from 'The Case of the *Iguanodon*'s Thumb' that there is an intimate interrelationship

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[7] Adrian Desmond, *Archetypes and Ancestors: Paleontology in Victorian London 1850-1875* (Chicago: University of Chicago Press, 1982): 119.

[8] Frank Seebacher et al., "Crocodiles as Dinosaurs: Behavioral Thermoregulation in Very Large Ectotherms Leads to High and Stable Body Temperatures," *Journal of Experimental Biology* 202 (1999): 77-86; cited in Cowen: 211ff.

between our understanding of dinosaur anatomy and dinosaur behavior. The one informs and is informed by the other. As we saw in our story, sometimes paleontologists use evidence about *Iguanodon*'s behavior to shed light on its anatomy; for example, we know from its eating habits that *Iguanodon* primarily walked on four legs, not two. But on other occasions, they use knowledge of *Iguanodon*'s anatomy to figure out its behavior. For example, Dollo determined the function of the *Iguanodon*'s spike because he recovered complete skeletons of the dinosaur. By the same token, there is an intimate relationship between music theory and music cognition. Just as music psychologists make numerous theoretical assumptions about the materials and structure of music, so music theorists constantly make assumptions about the ways in which different groups (composers, performers, ordinary listeners, and so forth) cognize music. Many music psychologists, for example, take it for granted that music is organized by scales, even though scales are concepts with a somewhat controversial theoretical pedigree. Similarly, many music theorists make constant appeals to what is and what is not hearable, even though they seldom subject such appeals to psychological testing. In other words, the crucial issue is not whether music theorists should ground their work in music cognition, but rather to show how it is so grounded and to make sure that the latent cognitive components are made as explicit as possible. Music theorists should accept this fact and exploit it. If they do not, then future scholars may have another kind of dinosaur to study: the discipline of music theory.

Matthew Brown