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Synthesis

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"Synthesis" commonly refers to a consolidation of discrete parts into a whole. It is often paired, conceptually and practically, with the reciprocal process of analysis, which entails the separation or isolation of constituent elements in a whole entity or system. In popular and experimental music cultures, the idea of synthesis is typically materialized in the form and action of a synthesizer: an electronic musical instrument designed to synthesize sounds. Synthesized sounds and synthesizer instruments are routinely associated with notions of the synthetic: contrasted to the so-called natural sounds of acoustic instruments or ecological domains and considered to be artificial substitutes or imitations of them. Such associations have a long history, as electronic and synthesized sounds and synthetic materials emerged alongside one another in contexts of nineteenth-century scientific research and industrial capitalism. Attributes of synthesized sounds, like amplitude and decay, also trace to nineteenth-century graphical methods, whereby sounds were analogized to living bodies in motion through the common figure of the waveform. The history of sound synthesis thus manifests the renewable promises of technologies to improve on what presents itself in nature, and the enduring cultural fascinations and fears of lively and unpredictable characteristics of new technologies, which may exceed human controls.

This essay begins by tracing how the concept of synthesis, and its travels through cultural fields, helped to engender the possibility of synthesizing sound. It then sketches a lineage of kindred devices and instruments that preceded commercially available synthesizers and discusses how cultural ideas of synthesis and synthetics informed ways that inventors and musicians shaped synthesizer instruments and sounds. I conclude with a more speculative claim about how synthesis reveals relations among cultural histories, sonic epistemologies, and the audible contours of electronic sounds and soundscapes.

Meanings and Materials

The term "synthesis" surfaced in seventeenth- and eighteenth-century philosophy to refer to the action of proceeding in thought from causes to effects, or from principles to their consequences. In the early eighteenth century, contemporaneous with Newton's writings, "synthesis" began to appear in medical and chemistry texts to refer to the unification of parts by application of scientific techniques. "Synthesis" was defined in a 1706 text on surgery as "that Method whereby the divided Parts are re-united, as in Wounds" (*OED*: "synthesis"). Before this point, the concept of synthesis existed in the comparatively immaterial realm of logic; now, it was mapped onto the material of the human body and made tangible through scientific practice. This was an important shift that anticipated the articulation of synthesis to sound and music technologies.

Sound synthesis is indebted to concepts in mathematics and physics that emerged in the early nineteenth century. In the 1820s, Joseph Fourier developed the idea that periodic waveforms can be deconstructed into many simple sine waves of various amplitudes, frequencies, and phases (Roads 1996: 1075–1076). In the early 1840s, Georg Ohm applied Fourier's theory to the properties of musical tones and perception, proposing that "all musical tones are periodic [and] every motion of the air which corresponds to a complex musical tone . . . is capable of being analyzed into a sum of simple pendular vibrations, and to each simple vibration corresponds a simple tone which the ear may hear" (Miller 1937: 62; see also Roads 1996: 545).

Hermann von Helmholtz's experiments in physiology and acoustics tested out these nascent theories of sound synthesis and extended them in his landmark treatise, *On the Sensations of Tone* (1863). Helmholtz built on Ohm's theories to argue that the quality of a tone depends on the number and relative strength of its constituent partial tones. He demonstrated this theory with a tuning fork apparatus that was further refined by the instrument maker Rudolph Koenig in the 1870s (Pantalony 2004). The work of Helmholtz and Koenig ushered in the technological possibility of synthesized sound, suggesting that any sound could be analyzed into component parts and then synthesized anew based on this information (Helmholtz 1954 [1863]; Holmes 2002: 13–14; Peters 2004: 183).

As Helmholtz conducted his experiments, the concept of synthesis was infiltrating a variety of scientific fields. In chemistry, it referred to techniques for the production of compounds from elements; in physics, it described the composition of white light from constituent colors (*OED*, "synthesis"). Synthesis techniques also manifested in other new devices. One of the first documented technologies to be called a synthesizer was Lord Kelvin's mechanical device to predict the tides, developed in the 1870s. Kelvin's harmonic synthesizer did not generate sound, but in demonstrating the synthesis of a waveform from its component elements it influenced the design of subsequent instruments devoted to the analysis and synthesis of sound waves (Miller 1937: 110–111).

Electronic tones were produced as early as the 1830s (Davies 1984, 667–669; Page 1837), but it was not until the late nineteenth century that methods of harnessing electricity to synthesize composite sounds took hold. The inventor Thaddeus Cahill combined insights from Helmholtz's work with novel techniques of electronic tone generation when developing his instrument the Telharmonium in the 1890s. In his 1897 patent, Cahill wrote of the "electrical vibrations corresponding to the different elemental tones desired," and explained: "out of them I synthesize composite electrical vibrations answering to the different notes and chords required" (Cahill 1897: 2; see also Holmes 2002: 44–47). This usage arguably justifies the Telharmonium's colloquial designation as "the first synthesizer" employed for musical purposes (Williston 2000).

Although a handful of experimental electronic musical instruments emerged in the late nineteenth and early twentieth centuries that can be considered as precursors of the modern synthesizer (Davies 1984; Martel 2012; Rhea 1979), the terms "synthesis" and "synthesizer" were applied to musical devices only sporadically until midcentury. In communications research, speech synthesis techniques flourished in the 1930s and 1940s (Dudley 1940, 1949, 1955). The fields of music and communication were brought together in the work of Harry Olson and colleagues at RCA Laboratories in Princeton, New Jersey, who embraced and popularized the idea of sound synthesis in the 1950s. Comparing earlier theories by Fourier and Helmholtz to Norbert Wiener's *Cybernetics* and Claude Shannon and Warren Weaver's *The Mathematical Theory of Communication*, Olson and his colleagues concluded that the analysis and synthesis of musical sound was analogous to the process of decoding and coding a signal in a communication channel

(Olson and Belar 1950: 5). Effectively, they updated Helmholtz's ideas of synthesis, which had emerged through analogies among waveforms based on graphical methods, to an idea of synthesis suitable for a cybernetic era, where a multiplicity of forms could be expressed as patterns of data on the punched-paper coding system of the RCA synthesizer instruments (Hayles 1999: 98; Manning 1985: 103).

From the 1950s on, synthesis techniques and synthesizer instruments were adopted and refined by composers, musicians, and inventors around the world (Best 2005; Born 1995; Chadabe 1997; Demers 2010; Guilbault 1993; Meintjes 2003; Niebur 2010; Théberge 1997; Young 1989). In the 1960s and after, synthesizer design and manufacturing companies emerged in the United States, United Kingdom, Russia, and Japan and underwent various patterns of growth, recession, and resurgence (James 2013; Johnstone 1994; Mishra 2009; Pinch and Trocco 2002; Reiffenstein 2006; Smirnov 2013; Takahashi 2000). RCA did much to register the term "synthesizer" in the public imagination through numerous popular and professional publications in the 1950s that described its synthesizers' design and functions ("Electronic synthesizer" 1955; Plumb 1955a, b) and through instructional content on a 1955 demonstration record that was marketed to the general public and sold upward of sixty-five hundred copies (*The Sounds and Music* 1955; Synthesizer records sold n.d. [c. 1957]). The term "synthesizer" then moved into widespread circulation in U.S. popular culture following Robert Moog's adoption of it for his mass-marketed keyboard instruments in the late 1960s.

There are numerous methods of sound synthesis: of these, additive and subtractive synthesis techniques informed the design of most electronic musical instruments and synthesizers through the 1970s. Additive synthesis is based on the concept that a complex waveform can be approximated by the sum of many simple waveforms; it informs the design of instruments such as Cahill's Telharmonium at the turn of the twentieth century and the Hammond electronic organs popular in the mid-twentieth century. Subtractive synthesis techniques, which were popularized by Homer Dudley's vocoder system for synthesizing speech at the 1936 World's Fair and continued to inform the designs of many analog synthesizers through the 1970s and beyond, are based on a premise that a wide range of timbral variations can be achieved by the controlled removal or attenuation of harmonic frequencies from a basic waveform. A classic technique of subtractive synthesis involves the independent regulation of the pitch, volume, and timbre of waveform, as controlled by an oscillator, amplifier, and filter, respectively. Many techniques for synthesizing sound have emerged in recent decades, including physical modeling, granular synthesis, and numerous other digital synthesis methods (Roads 1996: 134, 163–169, 197–198, 265–267).

At the same time, historians have applied the concept of synthesis liberally and retrospectively when identifying precursors to modern devices—such as the instruments of Helmholtz, Cahill, and others, as well as Wolfgang von Kempelen's eighteenth-century speaking machine, which some refer to as the "first speech synthesizer" (see DEAFNESS). The proliferation of so-called first synthesizers across historical accounts suggests that modern synthesis techniques have numerous conceptual roots and technological precursors. Indeed, "synthesis" proves to be an expansive term that can refer to any of the specific methods listed above and more; it also circulates in the present as a generic term that can signify any mechanical or electronic production of sound.

Synthetic Sounds and Lively Bodies

Synthesizers now make themselves heard all over the place: they are behind the sounds of countless popular music hooks and bass lines, scaled down to the format of mobile phone apps, and celebrated in documentary films (Fantinatto 2013; Fjellestad 2005; Harrison 2005; Truss 2013). The term itself did not settle into mainstream usage unchallenged. Both Robert Moog and Don Buchla resisted adopting the term "synthesizer" for their electronic musical instruments in the late 1960s. Moog initially wished to distinguish his more compact, voltage-controlled machines from the room-sized, punched paper–controlled RCA synthesizer (Pinch 2008: 472 n. 14). But he conceded that RCA had made the word familiar, and he considered it well suited for characterizing his "complete systems" for sound generation. The Moog catalog began to incorporate the word "synthesizer" in 1967 (Moog 1996: 21; Pinch and Trocco 2002: 67–68). Buchla disliked the connotation of "synthetics" as imitative substitutes and consequently avoided applying the word "synthesizer" to his electronic musical instruments in favor of names like "Electric Music Box" (Buchla 1997: 2–3; Pinch and Trocco 2002: 41). He believed that electronic musical instruments were better directed toward the exploration of new sonic possibilities, such as complex timbral variations, rather than toward imitative functions (Buchla 1997: 3). Referencing the pervasive marketing of synthesizers since the 1970s for their capacities to emulate acoustic instruments, the composer David Dunn has echoed Buchla's position, arguing that the term "synthesizer" is "a gross misnomer . . . more the result of a conceptual confusion emanating from industrial nonsense about how these instruments 'imitate' traditional acoustic ones" (1992: 19).

This "conceptual confusion" arguably persists because synthesized sounds evolved in relation to an industrial history of synthetic substitutes. The conceptual and technical possibility of synthesizing sound, which emerged from Helmholtz's research in the late 1800s and was taken up by early electronic instrument inventors such as Cahill, coincided with developments of various synthetic substances through similar applications of scientific methods. For example, following advances in organic chemistry in the late nineteenth century, developments of synthetic dyes were increasingly applied to consumer products. The idea of synthesis took on new connotations as public opinion registered the meanings and merits of synthetic materials. Synthetic materials were understood to be "manmade" imitations of natural substances, produced by processes of analysis and synthesis. This held two conflicting connotations. On the one hand there was suspicion that synthetic materials were not as good as natural ones. On the other, a certain faith in science and technology cultivated expectations that the synthetic could exceed the natural and provide a better, brighter, more durable substitute (*OED*: "synthetic"; "Synthetic sugar," 1944).

As social and technological processes of sound reproduction produced the very ideas of "original" and "copy" (Sterne 2003), the emergence of sound synthesis techniques produced audible, interdependent categories of "natural" and "artificial" sounds. This unfolded in the context of debates about synthetic and natural materials happening across cultural fields (Smulyan 2007: 44–45; *OED*, "synthetic"). Some inventors and musicians embraced synthesized sound as a means of transcending bodily limitations in performance, since myriad sound-producing tasks could be delegated to electronic signals or machine processes. Synthesizers promised to mimic, or even sound better than, a human performer (Holmes 2002: 12; Olson and

Belar 1955: 595; Plumb 1955b). At the same time, there were concerns over what this delegation meant for conventional ideas of musicianship and creative authority. Was technology "somehow false or falsifying" when mediating acts of musical expression (Frith 1986: 265, quoted in Théberge 1997: 2)? Or, if synthesized sounds were too "realistic," would synthesizers put musicians out of work (Strongin 1969; Taubman 1955a, b)? Synthesized sounds thus exemplified broader debates about the roles of emerging technologies in musical practice and the place of science and technologies in everyday life.

While nature and artifice are well-worn topics for twenty-first-century readers familiar with cultural theory, these categories held great significance to the inventors, musicians, and listeners who greeted new sound synthesis technologies over the last century. Indeed, stories of synthesized sound in practice are often marked by movements around and across perceived boundaries of nature and artifice, of human and machine, and of what counts as fully human in the course of human histories. Many inventors of electronic musical instruments have devised and revised touch-sensitive interfaces in efforts to humanize expressive possibilities of otherwise unwavering electronic tones (Chadabe 1997: 14; Holmes 2002). Disco and house music producers, and their dance floor interpreters, have heard in "unnatural" (i.e., not acoustic) electronic beats and synthesized strings a sonic metaphor for queer identities and communities (Currid 1995; Dyer 1990; Gilbert and Pearson 1999: 61–66, 91). R & B musicians have taken up the vocoder and other explicitly technologized voice synthesis effects to challenge cultural inscriptions of black subjects and voices as "the epitome of embodiment" and authentic "soul" (Weheliye 2002: 30–31). In these examples, sonic artifice—as it is so marked by distinctive timbral and tone-shaping dimensions of synthesized sound—is a machine-produced veneer that always reflects back on human conditions, relations, desires. Synthesized sounds themselves are complex *naturecultures*—instances of the imploded and deeply interwoven categories of natural and cultural, "where the fleshy body and the human histories are always and everywhere enmeshed in the tissue of interrelationship where all the relators aren't human" (Haraway and Goodeve 2000: 106).

As a corollary of their synthetic connotations, synthesized sounds are also associated with notions of otherworldliness and alien or artificial forms of life. As early as the 1950s, composers of film scores, television jingles, and experimental radio plays in the United States and United Kingdom utilized percolating electronic sounds to signify outer space or alien life forms (Taylor 2001: 72–95; Wierzbicki 2005). A *Daily Tribune* headline on the RCA synthesizer succinctly registered how listeners perceived synthesized sound in terms of artifice and alterity: “Electronic Synthesizer ‘Makes’ Music; Gives Sounds Never Heard on Earth” (1955).

Synthesized sounds began their association with notions of life and liveliness a century earlier, through graphical methods and the dynamic figure of the waveform. By the late nineteenth century, scientists had distilled the organic processes of plants, animals, and humans —as well as the forms of electronic sounds—into a universal language of waveform representations. Electrical activity was a common, animating presence that enabled scientists to analogize myriad forms to one other and describe them with the same terms, like amplitude and decay. The shape of a waveform signified lively matter in motion, like the extension of a moving body into space and its variations over time, held still for observation and analysis (Brain 2002; Rodgers 2011: 518–521).

Moreover, techniques of sound analysis and synthesis developed alongside new scientific practices for analyzing dead bodies and producing diagnoses in nineteenth-century medicine. As autopsies and dissections of bodies became routine, perceptions of the relationship of life and death changed (Curtis 2004: 229–234; Foucault 1994: 142). Medical practitioners gained increasing authority to extend life artificially through applied knowledge or techniques. Diagnoses and plans for the sustenance of living bodies were synthesized from aggregated information about a corpse, as analyses of body parts and bodily processes in isolation made possible the restoration of a living whole. Likewise, the graphical distillation of sound waves into waveform representations endeavored to hold sounds still, like forms of life to be broken down by analysis. The expert analytic techniques of acoustic researchers, together with the animating force of electricity, made possible the synthesis of new, dynamic waveforms, and technoscientific dreams of creation permeated the realm of electronic sounds.

Synthesized sounds thus grew as lively, synthetic wonders, embodying both the technical achievements of scientific practice and the unsettling potential of laboratory creations to resist containment—like Frankenstein’s monster—and become more than the sum of their parts. The latter tendency is on display in the matter of unstable oscillators, which are at once a technical "problem" and a celebrated aesthetic feature throughout the history of synthesizer instruments. Synthesizer designers and performers have long grappled with "audible drift," the tendency of analog oscillators to fluctuate and go out of tune, due to environmental conditions or wear (Chadabe 1997: 157). Stable oscillators were a notable feature that electronics manufacturers marketed to synthesizer designers (Belar 1949), which competing synthesizer companies in turn marketed to consumers. Yet some artists embrace the fact that no two analog synthesizers are alike and that each one manifests an individual character and lifelike quirks. Describing her relationship to an old analog synthesizer, the electronic music composer Mira Calix concludes: "when it goes off on its own accord I find it quite interesting. They're like little creatures, you know, they breathe" (Rodgers 2010: 131).

Machine Logics and Sonic Epistemologies

Synthesis is a means of generating new sounds based on prior knowledge of sound, and each synthesizer thus "brings with it a particular logic," a means of ordering or making sense of the world (Greene 2005: 5). The logic of an instrument's design and use is informed by social history and prevailing cultural metaphors and meanings (Rodgers 2011; Sterne 2003; Waksman 2001). An instrument's applications in creative practice may rework the "script" that its design presents (Akrich 1992 [1987]) and, concurrently, alternate instrument designs embody the multiple and culturally varying ways of knowing sound (Diamond 1994).

Jessica Rylan, a noise musician and synthesizer designer who runs her own musical instrument company called Flower Electronics, provides an example of how knowledge about sound inhabits the material forms and functions of synthesizer instruments. In an interview we did in 2006, she observed that the so-called fundamental parameters of sound have played a defining role in synthesizer designs and techniques. Conventional synthesis, Rylan explained, is characterized by "this very scientific approach to sound, like, What are the fundamental parameters of sound? Volume, pitch, and timbre." She continued: "What a joke that is! It has nothing to do with anything" (Rodgers 2010: 147). These "fundamental parameters of sound" do have to do with something, namely Helmholtz's analogies of eyes and ears, and of light and sound waves. In the 1860s, Helmholtz theorized that loudness, pitch, and timbre corresponded to the primary properties of color: brightness, hue, and saturation (Helmholtz 1954 [1863]: 18–19; Lenoir 1994: 198–199). His resolution of sound into these basic elements, in connection with a logic of resolving complex waveforms into simpler sine waves, laid an epistemological foundation for synthesis techniques. Helmholtz's tripartite structure of sound also shaped subsequent designs of analog synthesizers, which in their simplest form have three separate modules—an oscillator, filter, and amplifier—devoted to regulating these three constituent elements of sound. Rylan's critique is that Helmholtz's model of perception and approach to analyzing sounds need not determine the form of synthesizers to the extent that it has across the history of electronic instrument design.

Rylan departs from a Helmholtzian logic to design synthesizers that generate sounds and patterns that remind her of things in the world that evoke her curiosity, such as the varying sizes and ever-shifting temporal organization of raindrops. She incorporates unpredictable and chaotic elements into her designs of analog circuits, in contrast to what she describes as the "top-down," orderly approach of Helmholtz and followers. As Jonathan Sterne and I have noted elsewhere: "the Helmholtzian approach creates sound by breaking it into components and imitating and manipulating them. The Rylanian approach begins from an experience of sound and undertakes synthesis to approach and modulate it" (Sterne and Rodgers 2011: 45). Rylan centers the hearer's experience of sound versus positioning sound as an external phenomenon to be analyzed and controlled by the performer (Rodgers 2010: 145–47).

Rylan's approach also foregrounds the complexity of overlapping sounds in the world, whereby the act of synthesizing sounds—an exercise in setting chaotic and unpredictable patterns in motion—proceeds as a dynamic "sequence of interconnections" (Dunn 1992, 19). As the technical writer and historian of electronic musical instruments Tom Rhea has observed, the process of synthesis contains an implicit question: "What makes up this totality of sound that we hear?" (1979: 4). Rylan's work seems to propose that sounds are not individually discrete wholes with rationally ordered and consistent internal structures; instead, the "totality of sound" to be heard and resynthesized is a whole world of complex systems and interactions. Synthesis, then, is not merely a means of creating of novel electronic sounds. It also directs us to a charged moment: that fleeting "interruption of time" (4) that follows a retrospective analysis and precedes a new synthesis. Through this opening, we may listen for the cultural histories and sonic epistemologies that reside within technological forms, and for logics of part-whole relations and complex systems that frame the contours of everyday soundscapes.

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