After a break in compositional flow during World War I (1914–1918), composers explored new, uncharted musical domains. In the 1920s and 1930s, some composers created intricate and complex avant garde music, demonstrating the ultimate limitations of human musicians. They did not know it at the time, but these pioneers were attempting to write electronic music before the needed technology had been invented.

After World War II (1939–1945), European composers began to experiment with a new invention, the tape recorder. Here was a medium in which an artist could actually hold sounds in her own hands. Chopping up a tape recording and reassembling the pieces in a different order opened up a new world of sounds for composers to explore. It also required artists to come to grips with the phenomenon of sound itself, and questions like what it was made of and how sounds differed from each other. These problems were eventually solved on paper but a real tool was required to give composers the ability to actually manipulate the building blocks of sound. In the 1950s, electronics technology had been developed to the point where it was finally able to meet this demand, leading ultimately to the development of the first music synthesizer by Harry Olson and Herbert Belar in the laboratories and studios of RCA.

The synthesizer is a device that creates sounds electronically and allows the user to change and manipulate the sounds. All sounds in nature consist of waves of varying air pressure. A synthesizer creates sounds by generating an electrical signal in the form of a waveform, usually either a sine wave or other simple mathematical wave, which is amplified and used to drive an acoustic speaker. Unfortunately, the sound quality of a simple waveform is somewhat raw and unmusical, at least to most people. The waveform is usually altered in numerous ways, using filters to create the interesting timbres, or colors, of sound that are usually associated with certain acoustical instruments. Changing the frequency of the waveform raises or lowers the pitch of the sound. A synthesizer can control and change the beginning attack of a sound, its duration, and its decay, in addition to controlling the waveform itself.

Synthesizers can receive information from numerous sources about how to set the different parameters of its output sound. Any electronic device, such as a computer program, or person can control the synthesizer. An obvious way to accomplish this is to build the synthesizer in such a manner that it resembles an already-existing musical instrument, such as a piano. A piano like keyboard is often used to generate signals that control the pitch of the synthesizer, although a keyboard is not required, or even necessarily desirable, to do the job. One of the first commercially available keyboard-based synthesizers marketed to the general public was built by Robert Moog in the 1960s. Other early competitors of the Moog Synthesizer were built by Don Buchla and Al Perlemon.

All of the early synthesizers were built using analog computer technology. Since the late 1970s, however, digital synthesis has developed as the premiere technology in synthesizer design. In the process of digitally recording a sound, called sampling, any sound recording can be converted into a series of numbers that a computer can analyze. The computer takes snapshots of the sampled sound in very short increments, about forty thousand times a second. Mathematical techniques, such as Fourier analysis, are then used to calculate the complex waveform of the original sound. The sound can then be easily reproduced in real-time from a synthesizer keyboard. This technique for creating sounds, and others, form the design basis of most digital synthesizers such as the New England Digital Synclavier and the Kurzweil music synthesizer. The same technique can be applied to synthesize drums, voices or any other kind of sound. Digital instruments can also receive input not just from a keyboard, but from the actual breath of the performer, for instance. Digital flutes and other wind-instrument synthesizers convert the force of the musicians breath into a signal that can modify any desired parameter of the output sound.

Synthesizers have shown themselves capable of creating a wide variety of new and interesting sounds. Their one limitation, of course, is that they sound only as good as the speaker that amplifies their signal. Most humans can hear sounds far beyond the range that even the best speakers can reproduce, sounds that acoustical instruments have always been capable of generating. Because of this limitation, and others, synthesizers are not viewed as replacements of traditional instruments, but rather as a creative tool that enhances the musician's already rich palette of musical possibilities.

See also Computer, digital; Synthesizer, voice.

Synthesizer, voice

The earliest known talking machine was developed in 1778 by Wolfgang von Kempelen. Eyewitnesses reported that it could speak several words in a timid, childlike voice. While the talking machine's success appears genuine, Baron von Kempelen's accomplishments are not above suspicion. Nine years earlier, he had built a chess-playing machine, which defeated many players, including Napoleon (who, incidentally, made several unsuccessful attempts to cheat). Eventually, it was discovered that the machine was a fraud—its cabinet concealed a hidden, human chess player, who controlled the game.

In 1830, Professor Joseph Faber of Vienna, Austria, produced his own speaking automaton. Faber's machine, dubbed Euphonia, had taken 25 years to construct. Designed to look like a bearded Turk, the creation could recite the alphabet, whisper, laugh, and ask "How do you do?" Speech was produced by its inner workings—double bellows, levers, gears, and keys located inside the mannequin. Strangely enough, Euphonia spoke English with a German accent.

The first talking machines employing electronic technology were developed in the 1930s. The Voice Operation Demonstrator, or Voder, invented by Homer Dudley in 1933, could imitate human speech and even utter complete sentences as its operator pressed keys on a board. Speech-synthesis technology evolved further with the rapid development of computer technology in the 1950s. During the late 1960s, the MITalk System was developed at the Massachusetts Institute of Technology. Although originally designed as a reading machine for the blind, once completed, the system could convert virtually any type of text into speech-synthesized output.

Raymond Kurzweil also developed speech-synthesis technology to aid the blind. In 1976, he produced the Kurzweil reading machine which could read everything from a phone bill to a full-length novel and provided unlimited-vocabulary synthesized output. Sometimes called a set of eyes for the blind, the reading machine has proved very popular.

Today, speech synthesis is a useful way to convey information in public places. Cars, appliances, and even games are being equipped with voice-synthesizer chips.

Syphilis *see* **Sexually transmitted diseases**

Systematics

In its broadest sense, systematics is where nomenclature and taxonomy intersect. Nomenclature is the assignment of accurate names to taxa. Taxonomy refers to the scientific method of classifying and organizing living organisms into specific groups according to their phylogenetic relationships. A single group is called a taxon; multiple groups are called taxa; the study of taxa is called taxonomy. Phylogeny is the study of the evolutionary relationships occurring among living organisms. Classification is the process of putting organisms together into categories based on their relationships to one another.

Carolus Linnaeus (1701–1778), a Swedish scientist and explorer, is considered the originator of the concept of systematics. He created enormous classifications of plants and animals, and published them as *Species Plantarum* (1753) and *Systema Naturae* (tenth edition published in 1758). In the nineteenth century (1800s), those reference volumes were used as the starting point for the modern systems of botanical and zoological nomenclature. One of the reasons that Linnaeus's work was so widely adopted was his use of simple and logical terminology, his hierarchical framework for grouping organisms (That is, a system in which organisms, such as plants or animals, are grouped in progressive order, from lowest to highest. This was generally done from least complex to most complex), and his use of binomial nomenclature, in which two-word names, consisting of a generic name and a descriptor, were created in combinations which were unique to a specific species. His naming system was based on observed physical similarities and differences between organisms; he called these "characters."

Systematics has developed into the science both of the diversity of living organisms and of their interrelationships. As conceptualized today, the biological science of phylogenetic systematics seeks to develop novel theories and means for classification that transcend the concepts of taxonomy, and consider not only the similarity of characteristics but also evolutionary processes that result in changes in the original gene pool. The English naturalist Charles Darwin (1809–1882) was the first scientist to state that systematic hierarchy should reflect similarities and differences in evolutionary history. In the 1950s, a German scientist named Willi Henning suggested the system that has come to be known as phylogenetic systematics; he reasoned that classification of organisms should closely reflect the evolutionary history of specific genetic lines.

On a molecular level and relative to forensic science, every organism has a genome that includes all of the biological materials necessary to replicate itself. The genome's information is encoded in the nucleotide sequence of DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) molecules and is subdivided into units called genes. The Human Genome Project, begun in 1990, was designed to identify each gene in