An Octet in Flushing Meadows

The Fountain of the Atom *at the 1939 New York World's Fair married art deco design with one of chemistry's most enduring conceptual tools.*

Roald Hoffmann and Dasari L. V. K. Prasad

In the spring of 1939, as the world emerged from the Great Depression and braced itself against the threat of impending war, the United States hosted an optimistic exhibition of a brighter future. The 1939 New York World's Fair was a showcase of economic might, nationalism, culture, and modernist and art deco design. Visitors arriving in Flushing, Queens, by subway entered the fairgrounds through the Community Interests zone. To their right was the Hall of Fashion, to their left was the Town of Tomorrow, and straight ahead, the Home Furnishing building. In the center of this area stood the *Fountain of the Atom*.

The *Fountain of the Atom* had distinct tiers resembling a wedding cake. On the upper terrace were four figures signifying each of the classical elements: earth, air, water, and fire. On the lower tier were eight ceramic sculptures, each representing an electron. Eight is not merely a lucky number, nor just the number of right practices on the Eightfold Path of Buddhism, it's also the number of electrons associated with a stable atom.

Life magazine, then at the height of its popularity, ran a 17-page photo-essay on the World's Fair just prior to its opening and gave a prominent place to the terra-cotta statues on the lower terrace in the fountain. They are electrons, but they are surely not your usual electrons. Nonetheless, the *Life* feature had no doubts of their significance, describing the electrons as "symbolizing the modern atomic theory of matter."

A Precocious Sculptor

The fountain's statues are a high point of the ceramic art of American sculptor Waylande De Santis Gregory (1905–1971). Gregory collaborated on the fountain with architect Nembhard Culin (1908–1990), who designed the steel-framed structure, which also featured water running in columns and a flame burning from the top tier.

It is unclear whether Gregory had any exposure to chemistry or physics in his education, but he certainly lived through the atomic age. He was a precocious, talented young sculptor who had mastered a variety of techniques but concentrated on the ceramic arts. Ceramics requires knowledge of practical chemistry, from the properties of different clay mixtures to the complex chemistry of glazes, as well as the engineering of precarious three-dimensional objects (the elements on the *Fountain of the Atom*'s upper tier were nearly 2 meters tall). Gregory mastered these many techniques, and he taught them in his years at the Cranbrook Academy of Art, a modernist school in Bloomfield Hills, Michigan.

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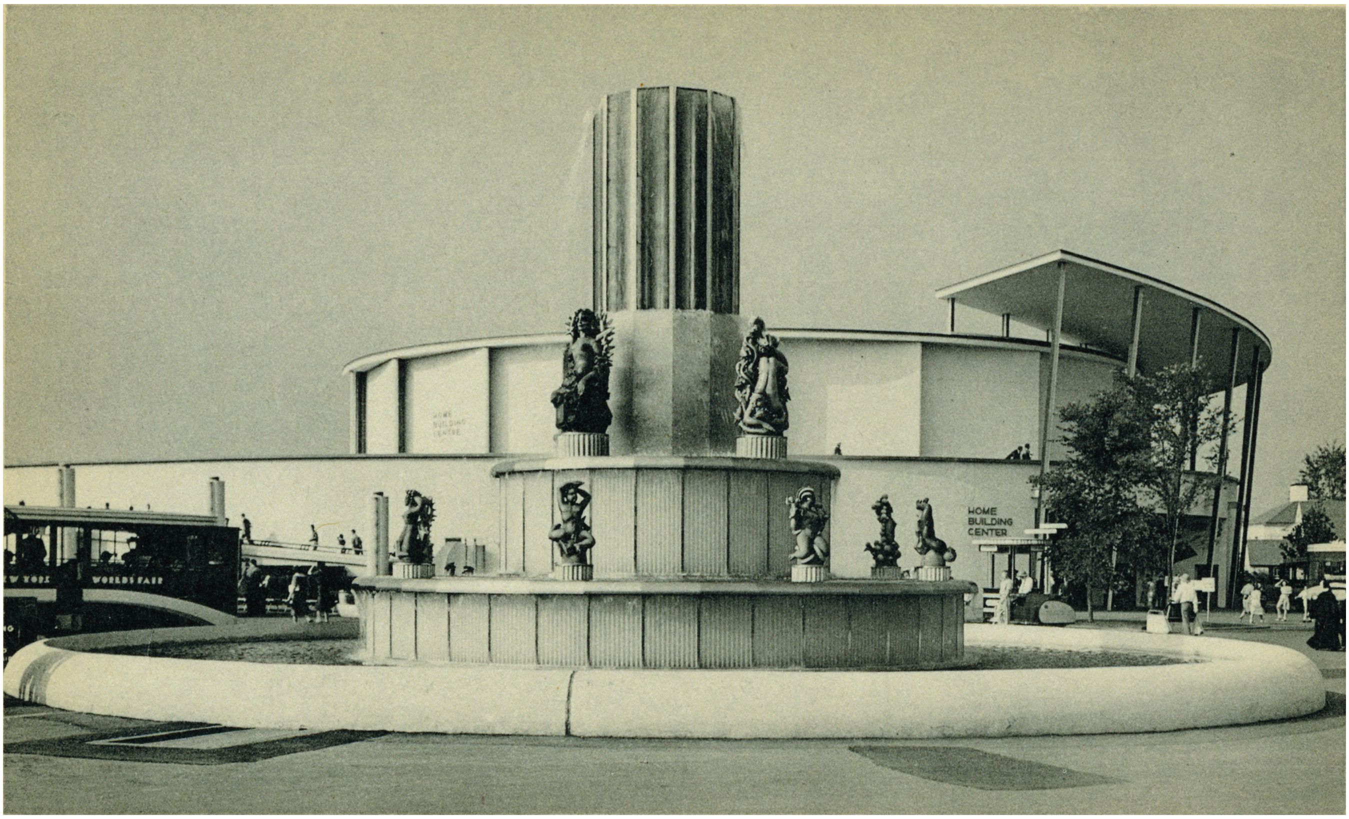
There is no sign in Gregory's previous work that he was familiar with the theory of atoms; however, he had shown a previous interest in scientific innovation. A year before the World's Fair, Gregory created a fountain dedicated to Thomas Edison titled *Light Dispelling Darkness*, which you can still visit at Roosevelt Park in Edison, New Jersey. On one side of the fountain is a sculptural group titled *Science and Achievement*, which portrays people working with electrical equipment (including one holding a dynamo), as well as the medical sciences. But no chemists. So how did Gregory learn about the Lewis octet, the theory that eight electrons make for a strong and stable bonded atom?

The Octet

In an interview with the *Illustrated London News* published April 29, 1939—one day before the opening of the New York World's Fair—Gregory says, "I based [the fountain's] general design on the octet theory of the atom." The vast majority of chemical compounds, including those that make up living organisms, testify to the special stability of the octet: eight electrons unshared or shared around carbon or other elements in the periodic table's so-called main groups (columns 1–2 and 13–18). The fountain's architectural design (the circular plan, several terraces, and the fixed number of figures on each terrace) is consistent with what a perceptive artist such as Gregory could have known at the time about the structure of the atom, and about the central role of electrons.

The octet rule is attributed to Gilbert N. Lewis (1875–1946), one of the



Donald G. Larson Collection on International Expositions and Fairs, Special Collections Research Center, Henry Madden Library, California State University, Fresno

Visitors arriving at the 1939 New York World's Fair were greeted by the *Fountain of the Atom*, an art deco celebration of chemistry. Ceramicist Waylande Gregory created 12 terra-cotta figures for the structure. The top tier featured representations of the four classical elements (earth, air, water, fire), and the lower tier displayed eight colorful, playful electrons. The octet of electrons represented a strong and stable bonded atom.

greatest American chemists, who laid the foundation for the electronic theory of chemical bonding. But the story of the octet is in fact a complex one, involving along the way independent discoveries by Richard Abegg, J. J. Thomson, Walther Kossel, and Irving Langmuir, and a dance between chemistry and physics in the first quarter of the 20th century.

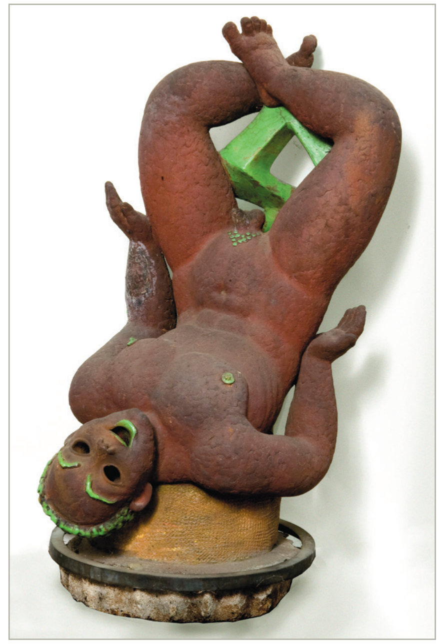
Gregory's circular orbit representation in the *Fountain of the Atom* may have been inspired by Lewis's theory, but it does not match with Lewis's cubical model of the atom—not that the latter is right, anyway, except as a heuristic device. From the beginning, the "real" whereabouts of the electrons have been points of intense debate. American experimental physicist Robert Andrews Millikan wrote in 1924:

> The chemist has in general been content with what I will call the "loafer" electron theory. He has imagined these electrons sitting around on dry goods boxes at every corner ready to shake hands with, or hold on to, similar loafer electrons in other atoms. The physicist, on the other hand, has preferred to think of them as leading more active lives, playing ring-around-the-rosy, crack-the-whip, and other interesting games. In other words, he has pictured them as rotating with enormous speeds *in orbits*, and as occasionally flying out of these orbits for one reason or another [*emphasis in the original*].

Try as one might, thus far no one has "seen" an electron. The reason for the quotes is that seeing is a nontrivial disturbance of the system. At this scale, one has to give it a quantum mechanical operational significance, which in turn means considering Heisenberg's uncertainty principle—that is, the moving electron does not exist at a perfectly defined location. Subject to those limitations, the electron cloud in an atom has been seen; it is certainly not cubical.

More broadly, the detailed structure of the atoms that John Dalton (1766–1844) postulated, the spectral lines that Robert Bunsen (1811–1899) discovered characteristic of the elements of the periodic table, and the nature of the radiant energy emitted from heated bodies all waited for their interpretations until the early 20th century, when Max Planck had his profound insight that the radiated energy will only be emitted in discrete quantities, called *quanta*. This quantum theory then set the stage for the work of Niels Bohr to propose the planetary model of electrons circulating around the nucleus of an atom, like tiny worlds orbiting a sun. This perspective on atoms could have been inspirational as well for Gregory as he contemplated the design of the *Fountain of the Atom*.

In 1927, German physicists Walter Heitler and Fritz London developed a quantum mechanical treatment of the chemical bond. Lewis's cube was replaced by electrons moving in indeterminate ways that we could only visualize on average, as an electron cloud attracted to the nuclei of the atoms involved in bonding. "Hybrid orbitals" pointing along the directions of the vertices of a tetrahedron came into play as a kind of housing assignment for the electrons. Linus Pauling's great experience in structural chemistry, for which he won his first Nobel Prize in 1954,



Electron sculpture photographs courtesy of University of Richmond Museums. From left: collection of Martin and Judy Stogniew; private collection; University of Richmond Museums, promised gift of Tom Folk; gift of the estate of Yolande Gregory

The *Fountain of the Atom* featured eight anthropomorphized electrons (*above and at top of facing page*). Gregory described the playful terra-cotta figures as participating in "a joyous, energetic dance around the nucleus."

allowed him to reinterpret the Lewis octet in quantum mechanical terms, and reconcile the chemical and quantum mechanical views of the atom.

Chemistry has a wonderful way of adapting productive chemical concepts to alternative understandings of the underlying reality. And so, despite knowing from quantum theory that the atom bears no resemblance to a hard, sculptural object, the octet remains the first of every chemist's conceptual tools with which one tries to understand which molecules are likely to be stable, and which very reactive. Just right for the *Fountain of the Atom*, which married the streamlined aesthetic of Art Deco with scientific ideas that, in retrospect, marked the birth of the "Atomic Age."

Elemental Beauty

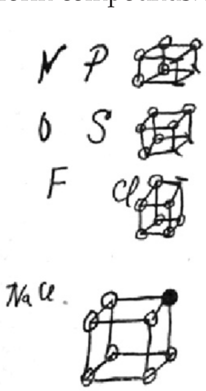
Although, at first glance, the larger sculptures of the four elements may seem out of place on the *Fountain of the Atom*, Gregory viewed them as integral to the creation of ceramics. In a 1935 article in the journal *Design*, Gregory wrote:

> Earth, Water, Air, and Fire are all companions in the creation of a ceramic sculpture. Nature's voice seems very near in the clay at one's feet, awaiting the release, the command to speak. The earth seems pregnant with potential sculpture and when commanded by the creative force, the surge is unrelenting until complete crystallization

The Evolution of Atomic Representations

The concept of atoms—the minuscule building blocks of matter—has been around at least since the 5th century BCE, when the Greek philosophers Leucippus and Democritus argued that there is a smallest possible component of matter. They called this fundamental unit *atomos*, meaning indivisible.

The beginning of modern atomic theory is often credited to chemist John Dalton, who starting in 1803 proposed that each chemical element is composed of a single type of atom—an indestructible particle with a distinct mass and unique properties—which can combine with others to form compounds. Another century passed before physicist J. J. Thomson published his discovery of electrons, the first identified subatomic particles.



Understanding the nature of the components of the atom was one challenge, but getting a comprehensible picture of how these components bind, and how atoms interact with other atoms, was another. Although the quantum model of electrons in orbitals moving around a nucleus is widely accepted as an accurate and useful representation, Gilbert N. Lewis's dot structures appear to give a clearer description.

Lewis structures focus on atoms' *valence electrons*—the outer shell of electrons that can form chemical bonds. The main group of elements tends to form bonds that will create a stable shell of eight valence electrons, hence the octet of Gregory's *Fountain of the Atom*. Lewis conceived of the valence shell as a box with electrons at each corner (as shown in this 1902 sketch by Lewis, *top left*). Over the years, these cubes have been flattened and simplified into the chemical notations familiar to anyone who has taken Chemistry 101 (*bottom left*).

Courtesy of Alfred Ceramic Art Museum at Alfred University

To make ceramic sculptures, such as this representation of fire from the *Fountain of the Atom*, artists must harness all four of the classical elements. Gregory was a master at the medium and developed new techniques to create large-scale pieces.

> results in sculptured creatures of elemental beauty.

That aptly expressed appreciation of "elemental beauty" may have led to Gregory's interest in the atomic structures of elements. Around the lower tier of the fountain, four of the electrons are male and four are female. At least half of them have schematic lightning around them. One female electron is surrounded by bubbles, while a male electron sports fins. All are cavorting, in delight at their nudity, and seemingly able to defy gravity.

The electrons are certainly fun. There are no hints of them stealing or sharing another electron, but then the architectural constraints of the fountain do not allow them to interact. In the real world, they would most certainly be up to something. Gregory described the electrons as

> boys and girls dancing a joyous, energetic dance around the nucleus. I portray them as elemental little savages of boundless electrical energy, dancing to the rhythm of sculptured bolts of lightning-like flashes in brilliant colored glazes, their buoyant bodies of richly modeled terra cotta clays in warm colors.

Although the focus of the fountain was on the electrons and modernity, we cannot pass over the colonialist language. The headline of the *Life* article about the fountain paraphrased Gregory's description: "These Little Savages Are Electrons." Sadly, this was how the dominant powers in society at the time, without batting an eyelid, commonly depicted the "other"—as elemental primitives. These tropes were especially insidious at World's Fairs, which were explicitly promotional, nationalistic spectacles.

Honor to the Atom

Gregory's allegorical ceramic representation of the atom with the octet was noticed by Albert Einstein on April 30, 1939, when he visited the World's Fair. He is quoted as saying to Gregory, "Young man, I wanted to meet the artist who gave honor to the atom." Einstein was a great believer in visual and heuristic thinking, and we believe he is likely to have appreciated the sculptural solidity that Gregory crafted to "honor" the atom. It was also Einstein who gave us the quantum mechanics of light emission and absorption, and Lewis who invented the word "photon" (for what Einstein called light quanta, *lichtquanten*). The theory of how we see in absorption the radiant colors of the striking glazes that Gregory ground and mixed himself was formed by that other immigrant to New Jersey.

When the World's Fair was over, the *Fountain of the Atom* was disassembled, and its elements scattered. One can see individual pieces in the Cranbrook Academy collection, the Everson Museum of Art in Syracuse, New York, the University of Richmond Museums, and the Alfred Ceramic Art Museum at Alfred University. The dispersal of the *Fountain of the Atom* is itself a metaphor—the sculptural electrons moving off into the world, making new connections, bonding with new viewers. The electrons are still having fun.

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