Unraveling Life's Building Blocks: Sculpture Inspired by Proteins

Julian Voss-Andreae

ABSTRACT

Inspired by proteins, the molecular building blocks of life, the author's presented work re-creates the first step of the emergence of three-dimensional bodies from one-dimensional DNA. Utilizing an algorithmic approach as his point of departure, the artist follows his vision freely, creating sculptures that bring life's isolated components emotionally back to life. In this sequel to an earlier *Leonardo* article on the inception of his protein-inspired sculptures, the author presents the unfolding of his vision: Large-scale works of increasing formal and conceptual complexity display the emergence of an organic aesthetic from geometric elements and inspire a more holistic view of nature than that provided by reductionist science alone.

There are a number of common themes woven through the fabric of my sculptural work. One such theme is the idea of the fundamental building block, the smallest unit that, upon assembly, displays an extraordinary transformation from geometric simplicity to organic complexity. Some of my recent work was inspired by quantum physics, the study of the building blocks of the physical world [1,2]. A larger body of work, begun in 2001 after I switched careers from quantum physics to art, is concerned with the structure and conceptual potential of proteins, the molecular building blocks of all life forms. This article presents a selection of these works, complementing others that I have described earlier [3]. The article's final section places the work in the context of contemporary efforts that aim at expanding the current paradigm beyond the confines of scientific reductionism.

Protein Sculptures

When we cut an organism into parts small enough to be handled intellectually, we both literally and emotionally lose its essential property of being alive. Perceiving the parts of a living being as inanimate often lets us presume that the "aliveness" of the whole being is just an illusion. But perhaps the opposite is true: Because the whole is alive, all its parts are in the same sense alive and should therefore be worthy of an equal emotional attachment. Among the smallest molecular parts specific to life are the proteins. It is through proteins that life accomplishes the transition from one-dimensional DNA, the carrier of genetic information, to three-dimensional organisms [4]. Proteins are chains of amino acids arranged in a specific sequence that is encoded in the DNA's sequence of base-pairs, the "rungs" on the DNA "ladder." The structure of a protein is largely determined by its sequence of amino acids. Inherently still one-dimensional, the linear molecular chain folds into an often well-defined, three-dimensional object. I use the application of compound mitered cuts, the rotation of every other part, and subsequent reconnection as an elegant way to re-create the structure of proteins from the ubiquitous one-dimensional building materials, such as lumber or steel tubing. My process is to search for proteins with determined structures that have aesthetic as well as conceptual appeal. After downloading the structural data, I run a custom-developed computer algorithm to generate the cutting instructions that provide the starting point for my sculptures (see Fig. 1). The basic ideas and processes are described in detail elsewhere [5,6].

Due to the inherent properties of the miter-cut representation, sculptures based on smaller proteins evoke the impersonal aesthetic language of modernist sculpture [7]. A good example is *Alpha Helix for Linus Pauling* [8] (Color Plate C [d] and Fig. 1[d]) based on a 15-amino-acid sequence. As the number of amino acids increases to several hundreds or even thousands, an exciting transition takes place: The cold and crystalline feel of a small number of polyhedral faces gives way to something that feels "warmer," and the much more complex aesthetics of the organic world starts to emerge.

Light-Harvesting Complex

Plants and photobacteria (bacteria capable of photosynthesis) absorb sunlight, thereby providing us and virtually all other creatures with the energy and low entropy we need to maintain life. Photobacteria possess a beautiful and well-understood photosynthetic apparatus embedded in their cell membranes. Instrumental to the initial absorption of the light is a structure known as the light-harvesting complex, an array of two concentric rings of proteins. Coiled protein segments traverse the cell membrane and hold light-absorbing pigments in between the rings. Intrigued by both its structure and its function, I created a sculpture based on the light-harvesting complex. Each of the two protein rings is made up of nine identical subunits, which I portrayed using ½-in-diameter (13-mm) wooden dowels. The whole complex consists of 850 amino acids, corresponding to the same number of one-inch-long (25 mm) pieces of wood. Each protein subunit is anchored in position

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Article Frontispiece. *Birth of an Idea*, steel, colored glass, and wood, 60 × 32 × 32 in (150 × 80 × 80 cm), 2007. (© Julian Voss-Andreae. Photo © Dan Kvitka. Collection of Roderick MacKinnon, Rockefeller University, New York City, N.Y.) This sculpture is based on the structure of the potassium channel protein. Roderick MacKinnon, who commissioned *Birth of an Idea,* won the 2003 Nobel Prize in Chemistry for his work on this structure and provided the experimental data that were used as a starting point to create this sculpture. For a color image see the artist's website [30].

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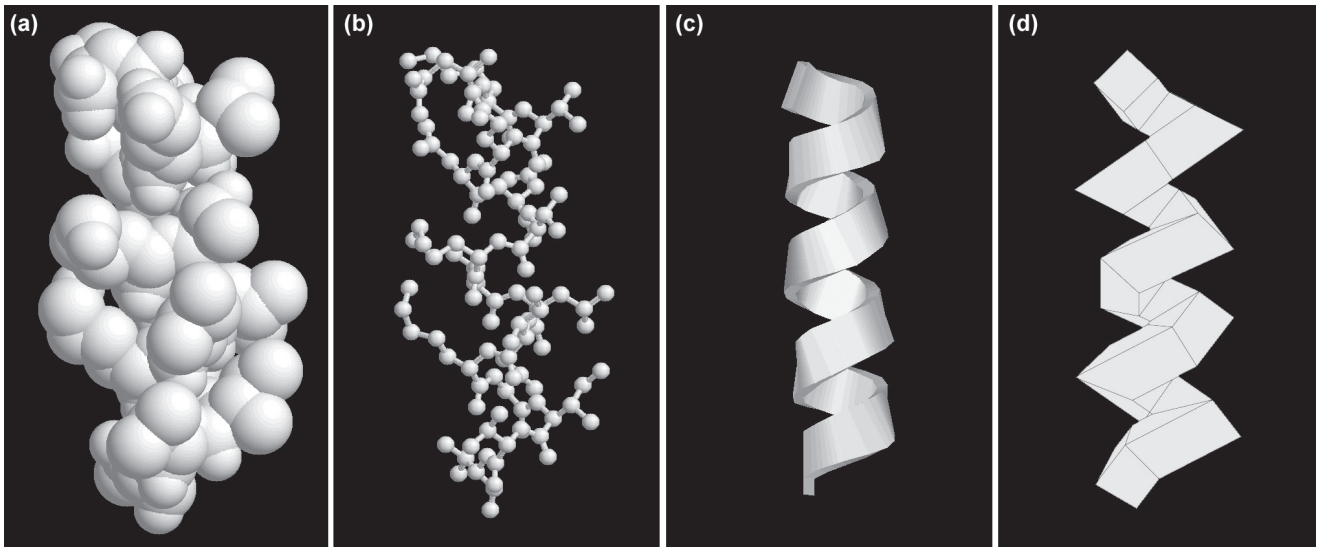

Fig. 1. One protein depicted in four different ways. (© Julian Voss-Andreae) The figure shows a coiled amino acid sequence known as an alpha helix, commonly found in many proteins. Panel (a) depicts the alpha helix as a "space fill" model: All (non-hydrogen) atoms of the molecule are drawn as intersecting spheres. Panel (b), a "ball-and-stick" model, has smaller atoms that are connected by rods to indicate the chemical bonds. Panel (c), the "ribbon" model, reduces the protein to its backbone, which is depicted as a smoothened ribbon in space. Panel (d) shows the alpha helix as a miter-cut object; this technique was used for the sculptures presented here. Instead of being presented with the backbone smoothed into a curve, each amino acid corresponds to a straight miter-cut piece. Compare this image to Color Plate C(d), a photo of an actual sculpture created after the same computer model. Panels (a–c) were generated using the molecular graphics visualization software RasMol [31] and panel (d) was generated using my own software.

in a layer of transparent casting resin on a wooden disc. The sculpture is placed on the floor of a dimly lit room so that the structure casts moving shadows on the wall (see Fig. 2). The shadows evoke plants moving in the wind. It seems as if the macroscopic plants of our world have become ephemeral shadows, while the microscopic, and ordinarily not perceivable, basis for their existence has become the tangible object [9–11].

Unraveling Collagen

One of the many helical structures of vital importance to us is collagen, our bodies' most abundant protein. In collagen, three amino acid spirals, reminiscent of a rope, wind around each other to create a meta-spiral. Collagen mainly provides our bodies with structural support [12]. In a sculpture inspired by collagen, I emphasized its structural function by reducing each of the sculpture's faces to a cross-braced outline to reveal the dominant force lines in a way that resembles many modern steel buildings, utilitarian structures and bridges. For aesthetic and conceptual reasons, I departed from the actual molecular structure by opening up the intertwining helices toward the top (Fig. 3). In this way, the sculpture also becomes a metaphor for aging [13,14]: It is the degradation of collagen that famously leads to the wrinkles that accompany aging. At the same time, the playful upward movement of the sculpture imparts a sense of aging as growth, a journey toward completion, where "unraveling" becomes "unfolding": the fulfillment from innate potential into reality.

Heart of Steel

Hemoglobin, the oxygen-carrying molecule that gives our blood its red color, is another well-known protein of vital importance to our existence. Its color stems from iron atoms, which are essential in capturing oxygen from the air and distributing it to the whole body. I created a sculpture based on the hemoglobin structure and alluded to the basis of our body's ability to breathe by letting a similar reaction occur on the artwork's surface: Initially sanded to a bright, silvery sheen, the steel sculpture started forming a reddish oxide layer soon after its unveiling at an outdoor gallery. As the sculpture's entire body became successively saturated with oxygen, it acquired an increasingly deeper coloration [15,16] (Color Plate C[a–c]). The intricately shaped steel piece is complemented by a large, blood-red glass sphere in its center, evoking the image of a drop of blood [17]. The sculpture reacts sensitively to wind and touch, answering each push with an unexpected shiver, echoing the complex vibrational dynamics of large biomolecules [18].

Nanos

The small protein microcin, synthesized by a certain strand of the common intestinal bacterium E. coli, features a most unusual structure, resembling a lasso whose tail folds over and enters the noose. It is this knotted structure that kills off other bacteria by interfering with its victims' protein synthesis machinery [19]. *Nanos*, named after the Greek word for "dwarf," is a 6-ft-tall (1.80 m) sculpture based on microcin's structure. In addition to referring to the nanoscale these molecules inhabit, the name hints at the anthropomorphic character of the sculpture, with the noose on top evoking an oversized head (Fig. 4). It is remarkable how much the sculpture resembles abstract modernist sculpture, even though it is, strictly speaking, representational. I emphasized this resemblance by giving the stainless steel the irregular sander finish pioneered by American abstract expressionist sculptor David Smith, which has influenced subsequent generations of artists and designers and has since become associated with the look of modernist sculpture.

Birth of an Idea

In 2007 I completed a sculpture (Article Frontispiece) based on the structure of an ion channel protein for Roderick MacKinnon, who received the 2003 Nobel Prize in Chemistry for his seminal work on such a molecule. Found in the nerve cells that make up our brain and its nervous connections to the rest of our body, ion channels control the passage of specific atoms through the nerve cells'

Fig. 2. ***Light-Harvesting Complex*****, wood, casting resin, and candle, 22 × 25 × 25 in (56 × 64 × 64 cm), 2003. (© Julian Voss-Andreae) The left panel is a top view showing the two concentric rings of alpha helical proteins. A candle placed in the center of the structure serves as the only light source. The right panel shows a side view, with the helical structures casting moving shadows on the wall of the small chamber where the piece is displayed.**

membranes. Intimately connected to our intellectual and emotional responses to the world, this mechanism is at the very foundation of the living nerve cells' characteristic activity, the filtering and relaying of information through selective firing. When I was commissioned to create this sculpture, I was inspired by the ion channel's potential to symbolize the "spark," the small but all-important idea at the beginning of everything we do. Although we will probably never be able to point at one structure in our brain where that proverbial spark emerges, the ion channel provides a beautiful metaphor for it because it functions as the smallest logical unit in the vast network of our brain. Inspired by depictions of the potassium channel's interior [20], I created an object welded from steel wire to represent the pore's cavity. This pore object, surrounded by a protein scaffold made from blackened steel, is lacquered in a translucent blue. Like an isodensity plot of a molecule's electron density [21], the pore object features bulges at the locations the ions populate during their single-file passage through the protein. The largest bulge corresponds to the channel's main cavity, where the ion's surrounding water molecules are stripped off to be replaced by specific protein atoms. The main cavity contains a yellow blown-glass bubble, evocative of a rising balloon. The sculptural pedestal is fabricated from hand-planed, one-inch-thick (2.5 cm) wooden boards connected by the ancient technique of finger joints, mirroring the fourfold rotational symmetry of the protein.

Angel of the West

When I was doing research for a sculpture based on the structure of our immune system's key molecule, the antibody, I noticed an interesting similarity between this molecule and the human body, in both proportion and function: Shaped like a "Y," the antibody features a pair of identical protrusions, resembling arms, that are able to move by means of a flexible region in the molecule's center. These "arms" end in "hands," highly spe-

Fig. 3. ***Unraveling Collagen*****, stainless steel, height 11 ft 3 in (3.40 m), 2005. (© Julian Voss-Andreae) Inspired by the most abundant protein in our bodies,** ***Unraveling Collagen*** **is based on the collagen structure. In contrast to the tightly coiled molecular structure, the sculpture's three strands unravel toward the top.**

Fig. 4. ***Nanos*****, stainless steel, height 6 ft (1.80 m), 2006. (© Julian Voss-Andreae. Collection of Shari and Alan Newman, Lake Oswego, OR.) While resembling an abstract modernist sculpture,** ***Nanos*****, like all other sculptures presented in this article, is actually representational. Its shape is based on the unusual structure of a small antibacterial protein.**

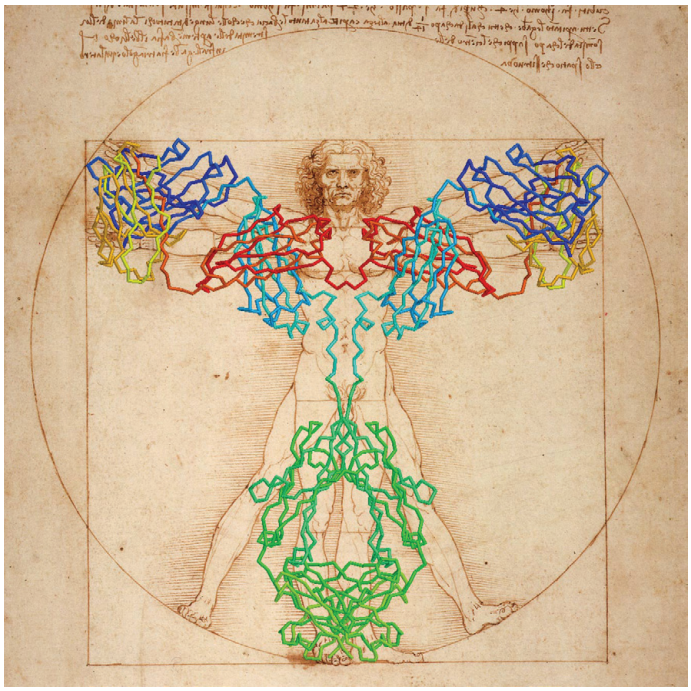

Fig. 5. ***Antibody Structure Superimposed on Leonardo's Vitruvian Man*****, computer sketch of the idea for** ***Angel of the West*****, 2006. (© Julian Voss-Andreae) Eduardo Padlan's 1994 composite model of the antibody molecule was superimposed on Leonardo's 1490** ***Vitruvian Man*****, revealing a striking resemblance between man's body and his antibody, in proportions as well as function.**

cific regions that hold on to an intruder, for example a virus particle, thereby tagging it for destruction through the immune system. In order to allude to the similarity between man's body and his antibody, I designed the sculpture to subtly evoke a Renaissance icon deeply anchored in popular culture: Leonardo da Vinci's 1490 study of the human proportions, *Vitruvian Man*. When I superimposed the frontal view of the antibody's 1,336-amino-acid structure, as provided by Eduardo Padlan [22], onto the *Vitruvian Man*, I was struck by the fact that the two images coincide perfectly (Fig. 5). For my design, I decided to utilize this powerful similarity and let the antibody molecule stand in place of Leonardo's man while turning the surrounding circle into a tapered ring. I then added thin rods under the arms radiating out from the position where the center of the head was located in the drawing. This set of rays emanating from a central source makes the design reminiscent of spiritual imagery [23]. With the wing-shaped "arms" added, the image is evocative of an angel (Color Plate C[e]) [24]. Our antibodies can, in fact, be viewed as legions of tiny guardian angels, constantly protecting us from disease. Their ability to bind very specifically to certain molecules is also the reason the antibody molecule has become an indispensable tool in biomedical research, crucial for understanding the machinery of life [25]. I chose the name *Angel of the West* as a play on Antony Gormley's monumental sculpture *Angel of the North* (1998), in Gateshead, U.K. The "West" in my sculpture is a reference to the Western approach to healing through the tools of Western science. The fabrication of the sculpture resembled a gigantic three-dimensional puzzle with about 1,400 pieces, laser-cut from steel sheet of varying thicknesses to fit the structural requirements [26].

Art and Scientific Reductionism

Despite our increasingly heavy reliance on science-derived technology, only a minority of people today recognize science as a vital part of human culture or have experienced feelings of wonder from scientific observations in the same way as they would from, say, a beautiful sunset. After an era of relative faith in science, culminating in the immediate post–World War II era, the public's attitude toward the natural sciences began to shift, starting around 1970 [27]. My generation, born during that time, grew up with a new sense of mistrust that was triggered by the growing suspicion that the reductionist approach inherent in science and technology, and its profound effects on our lifestyle, could not be separated from the global environmental and spiritual crisis that was then becoming increasingly apparent.

Scientific reductionism, the assumption that complex systems can be completely understood through an under-

standing of their components, is deeply ingrained in the very structure of the natural sciences and has been an extraordinarily successful guiding principle in the West since the Age of Enlightenment [28]. Art, by contrast, is non-reductionist in its very nature: The profound effect of a great work of art cannot be comprehended by adding up the effects the work's separated parts would have. Nor can that artwork's impact be reduced to the intellectual knowledge of specific interpretations of it. True appreciation of art seems impossible in a frame of mind that clings to the object-subject dichotomy that has become so deeply entrenched in Western thinking for the past few centuries. According to Einstein, in art, "We show [what we behold and experience] in forms whose interrelationships are not accessible to our conscious thought but are intuitively recognized as meaningful" [29]. The presented works take the notion of artistic counter-reductionism to another level: Departing from a mere structural representation of proteins, the exemplary specimens of reductionist biology, these works take living beings' components, typically considered inanimate, and bring them metaphorically back to life. In this way, these sculptures, born from scientific data, are capable of imparting an artistic experience of life that complements the understanding provided by reductionist science alone and thereby inspire a more holistic view of nature.

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References and Notes

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2. P. Ball, "Quantum Objects on Show," Nature **462** (2009) p. 416 <www.JulianVossAndreae.com/Artist/resume/articles/2009_11_26_Nature.pdf>.

3. J. Voss-Andreae, "Protein Sculptures: Life's Building Blocks Inspire Art," Leonardo **38** 1 (2005) pp. 41–45.

4. I use the term "*n*-dimensional" (where $n = 1, 2, 3$) in this article as it is commonly used to describe objects of the real world (as opposed to mathematical entities): An object is *n*-dimensional if it extends significantly only into *n* of the 3 dimensions of physical space. Its extent into the remaining $3-n$ dimensions is negligible compared to its extent into the other *n* dimensions, i.e. smaller by some orders of magnitude.

5. J. Voss-Andreae [3].

6. J. Voss-Andreae, BFA thesis paper: Protein Sculptures (Saarbrücken: Lambert Academic Publishing, 2010) <http://julianvossandreae.com/Work/Thesis/Thesis.pdf>.

7. Voss-Andreae [6], chapter 5.1.

8. J. Voss-Andreae [3].

9. A. Chugunov, "Изваяние Невидимого (Invisible Monuments)," *Computerra* **45** 713 (2007) pp. 26–28 <http://julianvossandreae.com/Artist/resume/articles/2007_12_05_Computerra.pdf>.

10. "Julian Voss-Andreae, Protein Sculptor (interview)," *PDB Newsletter* **32** (2007) <http://julianvossandreae.com/Artist/resume/articles/2007_01_PDBnewsletter.pdf>.

11. Voss-Andreae [6] chapter 4.3.

12. The symptoms of scurvy drastically illustrate what happens to our bodies if, due to a lack of Vitamin C, we fail to keep up the regular synthesis of new collagen.

13. J. Wallace, "Protein Sculptures for the People," *AWIS Magazine* (Spring 2008) pp. 14–17 <http://julianvossandreae.com/Artist/resume/images/2008_AWIS.pdf>.

14. B. Wand, "'Unraveling Collagen' structure to be installed in Orange Memorial Park Sculpture Garden," *Expert Review of Proteomics* **3** 2 (2006) p. 174.

15. P. Ball, "The Crucible," *Chemistry World* **3** (2008) pp. 42–43 <www.rsc.org/chemistryworld/Issues/2008/March/ColumnThecrucible.asp>.

16. C. Abad-Zapatero, "Escultor de proteínas (Protein sculptor)," *El País* (19 September 2007) p. 45 <http://julianvossandreae.com/Artist/resume/articles/2007_09_19_ElPais.pdf>.

17. I should note that this sculpture is not (nor is any of my work) intended to be a scientifically accurate model. For example, my placement of the red glass sphere in the center of the sculpture was a purely artistic decision and does not correspond to the location of the iron in the actual molecule.

18. J. Couzin, "Blood and Steel," *Science* **309** (2005) p. 2160.

19. Vivienne B. Gerritsen, "Entanglement," *Protein Spotlight* **72** (2006) <www.expasy.org/spotlight/pdf/sptlt072.pdf>.

20. See Fig. 5(B) in D. Doyle et al., "The Structure of the Potassium Channel: Molecular Basis of K+ Conduction and Selectivity," *Science* **280** (1998), p. 74; and Fig. 2 in Y. Zhou et al., "Chemistry of ion coordination and hydration revealed by a K+ channel-Fab complex at 2.0 Å resolution," *Nature* **414** (2001), p. 45.

21. Such structures' "shape," governed by quantum mechanics, is a spatial probability distribution of the likelihood of measuring an electron. In order to transform this kind of information into something we are accustomed to dealing with, scientists often visualize molecules through a pseudo-surface that is defined by a specific, constant likelihood of finding an electron, the "isodensity plot."

22. Eduardo A. Padlan, "Anatomy of the antibody molecule," *Molecular Immunology* **31** 3 (1994) pp. 169–217.

23. One of the images that guided my design was Gianlorenzo Bernini's famous 1666 alabaster window at St. Peter's Basilica, depicting the Holy Spirit as a dove.

24. Images of angels, winged humans, date far back into pre-Christian times. A well-known example is the Nike of Samothrace, from about 200 BC.

25. This makes the antibody an appropriate symbol for The Scripps Research Institute, which commissioned the sculpture as the signature piece for their new Florida campus.

26. The creation and installation of the *Angel of the West* was covered by Oregon Public Broadcasting Television's art series "Oregon Art Beat": V. Patton (producer), "Quantum Sculptures with Julian Voss-Andreae," Oregon Art Beat Oregon Public Broadcasting Television (18 December 2008) <www.youtube.com/watch?v=LqsQYVFAgPo>.

27. Tor Nørretranders, *Spüre die Welt.* Die Wissenschaft des Bewußtseins (Reinbek bei Hamburg: Rowohlt, 1997) Ch. 14.

28. John Cornwell (ed.), *Nature's Imagination* (Oxford, UK: Oxford Univ. Press, 1995) Ch. 6 by Gerald M. Edelman and Giulio Tononi.

29. Quoted in H.-O. Peitgen and P.H. Richter, *The Beauty of Fractals* (Berlin: Springer-Verlag, 1986) p. 1.

30. <www.JulianVossAndreae.com>.

31. <http://rasmol.org/>.

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Initially trained as an experimental physicist, Julian Voss-Andreae is a German-born sculptor based in Portland, Oregon. His sculpture is critically acclaimed and has been commissioned by multiple institutions and private collectors in the U.S.A. and abroad.

Julian Voss-Andreae, (a–c) *Heart of Steel*, weathering steel and glass, height 5 ft (1.60 m), 2005. (© Julian Voss-Andreae) The images show a time-sequence of the hemoglobin-based sculpture's metamorphosis: Photo (a) was taken right after unveiling, (b) after 10 days and (c) after several months of exposure to the elements. (d) *Alpha Helix for Linus Pauling*, powder-coated steel, 10 ft (3 m) high, 2004. (© Julian Voss-Andreae. Collection of The Linus Pauling Center for Science, Peace, and Health.) This memorial for Linus Pauling is located in front of Pauling's childhood home in Portland, OR. (e) *Angel of the West*, stainless steel, 12 × 12 × 4 ft (3.70 × 3.70 × 1.20 m), 2008. (© Julian Voss-Andreae. Photo by James McEntee, courtesy of The Scripps Research Institute.) Commissioned as the signature sculpture of The Scripps Research Institute's new campus in Jupiter, FL, this sculpture plays upon the striking similarity between the human body and our immune system's key molecule, the antibody.