Hale–Bopp with the European Space Agency's (ESA's) Infrared Space Observatory. More space missions to visit comets are in progress, such as Stardust, launched last year for a planned encounter with Comet Wild 2 in 2004. Others are in advanced preparation, including Rosetta, the ESA mission scheduled for launch in 2003 to meet periodic Comet P/Wirtanen in 2012–13, and the US space agency NASA's Deep Impact, scheduled for launch in 2004 and an encounter with Comet P/Tempel 1 in 2005.

Crovisier and Encrenaz describe the newly discovered Kuiper Belt and the more distant Oort Cloud, reservoirs respectively of the short-period and long-period comets — those with orbital periods of less or more than roughly 200 years. Dynamical studies are now telling us how comets are plucked from their distant orbits and drawn towards the inner Solar System, where the Sun's heat causes them to evaporate and glow in a brief but glorious passage through our field of view.

Comet Science is comprehensive yet brief, engaging yet authoritative, and fully accessible to a wide range of readers. It is well suited to student use and sufficiently detailed for astronomers wanting an overview of the state of the field, while remaining readable by the informed layperson. The translation from the original French is very smooth, and this edition is enhanced with colour pictures of comets and many technical diagrams.

The authors have captured the full panorama of the investigations of these primitive lumps of dirty ice, the messages they carry concerning the origins of the planets, and perhaps the origin of Earth's teeming veneer of organic matter, that includes the likes of us. ■

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More on the cosmos

Hubble Space Telescope: New Views of the Universe
by Mark Voit
Harry N. Abrams, in association with the Smithsonian Institution & the Space Telescope Science Institute, $19.95, £12.95 (pbk)

Unfolding Our Universe
by Iain Nicolson
Cambridge University Press, £24.95

Other Worlds: Images of the Cosmos from Earth and Space
by James Trefil
National Geographic Society, £22.50, $35

Science in culture

Nature's microscopic art forms

Radiolarians and diatoms drawn by Ernst Haeckel.

Philip Ball

Design in nature, a source of inspiration both to the artist and the engineer, has also solicited the attention of philosophers in the past. Where do the stunning beauty and elegance of the microscopic exoskeletons of radiolaria and diatoms come from? These works of natural micro-architecture were revealed for the first time to an astonished scientific community in the late nineteenth century, when the British research vessel *HMS Challenger* collected sediments from the seabed. The wonders of *Challenger's* booty were painstakingly drawn and catalogued by the German biologist Ernst Haeckel.

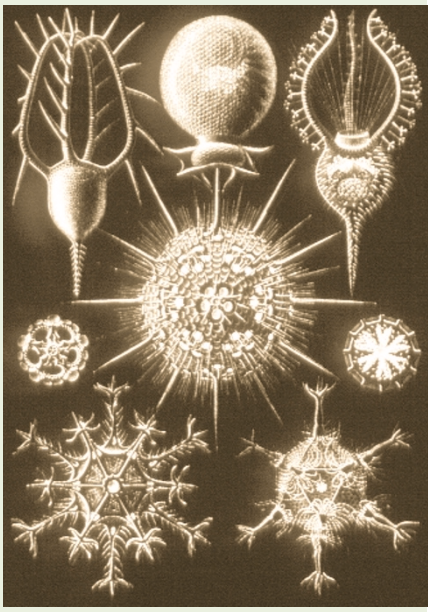
Haeckel's legacy to art, science and design is explored in the *More Than Meets the Eye* exhibition currently at the Victoria and Albert Museum in London (see *Nature* **407,** 20; 2000). The exhibition features a display that looks at biomimetic elements of art and engineering, ranging from art nouveau to the geodesic domes of US architect Richard Buckminster Fuller and the 'soap-film', tent-like structures of German architect Frei Otto.

Buckminster Fuller's domes are echoed in the spherical exoskeleton of the radiolarian *Aulonia hexagona*, one of those lovingly drawn by Haeckel for his portfolio *Art Forms in Nature*, published between 1899 and 1904. Haeckel's illustration shows the occasional pentagons in the web of hexagonal cells, necessary (as eighteenth-century Swiss mathematician Leonhard Euler showed) to produce curvature and close the sphere.

These radiolaria were not the first microscopic 'art forms' to be identified in nature. Christian Ehrenberg observed delicately patterned coccolithophore shells in chalk in 1836 — but concluded that they were inorganic formations. By that time, studies by biologists, including Thomas Huxley, had convinced most others that coccoliths were biogenic.

Yet the range and inventiveness of designs in radiolarians and diatoms were quite unprecedented. Such discoveries inspired a strong interest in natural form in the early twentieth century, most famously expressed in D'Arcy Wentworth Thompson's *On Growth and Form* (1917). Yet while the Scottish naturalist was busy showing in meticulous detail that these 'watches' needed no maker beyond the laws of physics and mechanics, his compatriot James Bell Pettigrew at the University of St Andrews was at work constructing a kind of theistic argument from design in his *Designs in Nature* (1908). Pettigrew saw the imprint of continual intervention from the divine in the geometric forms of nature.

Both men had to come to terms with what Haeckel himself had said on the matter. In Haeckel, science, art and philosophy combined to produce a heady brew, strongly flavoured by the German *Naturphilosophie* instigated by Johann Wolfgang von Goethe (whom Haeckel idolized). Haeckel is perhaps best regarded as a mystical atheist, sharing a Nietzschean belief that "Man creates God in his own image" and yet prepared to embrace the idea of a life-giving spirit that permeated matter even down to the atomic level.



SCOTT CAMAZINE/SPL

Computer-enhanced examples of Haeckel's painstaking work.

This outlook is encapsulated in Haeckel's book *Crystal Souls* (1917), in which he presciently attempts to link the geometry of radiolaria with the discovery of liquid crystals by Friedrich Reinitzer in 1888. Otto Lehmann, the German physicist who helped the botanist Reinitzer make sense of his discovery, suggested in 1904 that liquid crystals were intermediate between living and non-living matter. We now know that liquid crystals can indeed organize themselves spontaneously into ordered aggregates that provide templates for the formation of inorganic materials regularly patterned on the microscopic scale, and that this mimics some of the processes of biomineralization that occur in radiolaria.

Haeckel's contributions came at a time when Darwin's evolutionary theory was provoking debate both about the origin of life and about political theory: Marx and Engels were grappling with its implications. Blended with the nationalism that was in the air in Germany and with Haeckel's political ambitions, this lends some of Haeckel's views — such as those on eugenics — the taint of racial élitism from which *Naturphilosophie* has never been entirely free.

Yet his gorgeous illustrations had a wide impact, reaching the eyes of the art nouveau artists and their counterparts, the Jungenstil group, in Germany. Nature's ornamentation blossomed throughout Europe. ■

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