

# PRESERVING PLASTICS

## An Evolving Material, a Maturing Profession

BY ODILE MADDEN AND TOM LEARNER

There is always a temptation to make some quip about the film *The Graduate* at the beginning of any article about plastics. It is surprising how often the subject of the movie is raised when someone outside the profession hears about our work, as if conservation scientists would never make the connection between plastics research and a memorable line from an iconic movie.

Megan Geckler's *Every Move You Make, Every Step You Take*, ©2010 megangeckler.com. This work—created with flagging tape, a mass-produced colorful plastic ribbon—was an installation at the Pasadena Museum of California Art in 2010. Photo: Courtesy of Megan Geckler.

"Yes, yes, you've got one word for us! Yes, we do know that scene. Yes, it IS priceless!" The truth is, as Mr. McGuire in the film declares, "There's a great future in plastics," and there clearly is much more to come. McGuire is a poolside prophet in a navy blazer who captures the vision and irony of plastics in one sentence.

Of course, the term *plastics* describes an extraordinary range of materials that emerged relatively recently, spread incredibly quickly, and continue to develop at a lightning pace. They are a stunningly versatile group of products entering most, if not all, museum collections as artifacts or as the materials used to preserve, store, and exhibit them.

Creations in plastic have shaped our culture, values, and abilities. We have turned various forms of natural and synthetic polymer goo into paints, coatings, adhesives, moldable sheets, cars, boats, airplanes, movie films, billiard balls, dice, chairs, tables, combs, telephones, screwdriver handles, Kewpie dolls, Barbie dolls, eyeglass lenses, contact lenses, clock radios, computers, plastic wrap, soda bottles, and takeout containers. There are many surprising uses of plastics in materials that would not initially appear to be part of this club, such as laminate structures created by combining natural and synthetic polymers with wood, glass, paper, and textiles: plywood, windshields, cell phone screens, countertops, and waterproof bedding, all of which can be found in museum collections. And now we face another big stage of development with new plastics engineered at the molecular level, which use new feedstocks or are intended to biodegrade. Others are designed for rapid prototyping, 3-D printing, and nanotechnology.

Listing innumerable examples is futile. Plastics are everywhere, and it is nearly impossible to imagine life without them.

Plastics have been used in truly ingenious ways. The first artificial heart implanted in a human patient, by Denton Cooley in 1969, was a pump developed by Domingo Liotta that incorporated textiles of Dacron, a polyester fiber created by DuPont, and embedded in Silastic, a silicone elastomer from Dow Corning.<sup>1</sup> Today the Liotta-Cooley heart is in the

Smithsonian's National Museum of American History, and, while to some people it might look like an old sneaker, it clearly is one of the most important artifacts of human achievement. Later in 1969, astronauts Neil Armstrong and Buzz Aldrin walked on the moon in self-contained, life-sustaining suits mainly constructed of synthetic polymers: polyamides, polyester, neoprene, polytetrafluoroethylene, polyimide, heavily plasticized polyvinyl chloride (PVC), polyurethane, polycarbonate, and silicone rubber; these were used as textiles, coatings, sheets, tubing, and foam.<sup>2</sup> The development of artificial organs and the exploration of space are feats of human ingenuity that were almost unimaginable until they were achieved; they became possible in large part because of synthetic polymers. Plastic artifacts associated with these triumphs are valuable historical objects, and we want to preserve them for posterity.

Unfortunately, the news on longevity has not been great for many plastics. Some synthetic polymers deteriorate rapidly in ways that fall nothing short of catastrophic, and these problems have driven conservators (and journalists) to sound the alarm that all plastics are unstable—and to tremble at how to cope. For certain categories of plastics—in particular, the cellulose esters, polyurethane, and plasticized PVC—the alarm bells undoubtedly are justified. Objects made of these compounds often quickly exhibit severe symptoms of degradation, such as discoloration, embrittlement, distortion, cracking, stickiness, or the reek of vinegar or vomit. On the other hand, many plastics seem to age just fine—although in the large scheme of history, there hasn't really been enough time to know for sure.

In terms of the prospects for advancing conservation of plastic, the news remains mixed. We are faced with the challenge of learning about a diverse, rapidly evolving category of materials with which we have limited experience. How, for example, can we expect to have the same level of knowledge and experience we have with oil paint, bronze, or stone? Not only are there hundreds of types of plastic, each is rarely composed of a single compound. For each polymer, countless modifications are possible;



*Torso* (1924–26) by Antoine Pevsner (1886–1962). Plastic and copper, 29 1/2 x 11 5/8 x 15 1/4 in. (74.9 x 29.5 x 38.7 cm). Katherine S. Dreier Bequest. The Museum of Modern Art, New York. For Antoine Pevsner © 2014 Artists Rights Society (ARS), New York / ADAGP, Paris. Photo: Digital Image © The Museum of Modern Art/Licensed by Scala / Art Resource, New York.

polymers frequently are blended as mixtures or copolymers in different proportions, with different microstructures. Any number of additives can then be compounded into their formulations to facilitate manufacture, alter flexibility, or provide flame resistance, stability, color, or texture (to name just a few)—and each addition can significantly alter the overall material properties and stability of the final product. Manufacturers can suddenly substitute additives with completely different chemicals; for example, the current development of alternatives for phthalates (a ubiquitous family of plasticizers) can result in plastics that have the same trade name but that are likely to age quite differently.

Many processing technologies produce different materials from the same ingredients, such as sheets, fibers, and other extrusions; molded objects; foams; and printed objects. There is the added complication of many processes changing over time and becoming obsolete and forgotten. Beyond mass-produced items, particular processes of individual artists and designers kick in a whole new set of variables, as the possibilities of these extraordinary materials are explored and their performance is pushed in ways rarely imagined by their manufacturers. Will this intricate landscape be simplified any time soon? For the time being, developments in plastics technology will likely outpace advances in conservation research.



Space suits worn by Neil Armstrong and Edwin Aldrin when they climbed down from their lunar module “Eagle” in July 1969 to become the first humans to walk on the moon. These suits are mainly constructed of synthetic polymers. Photo: Eric Long, National Air and Space Museum, Smithsonian Institution.

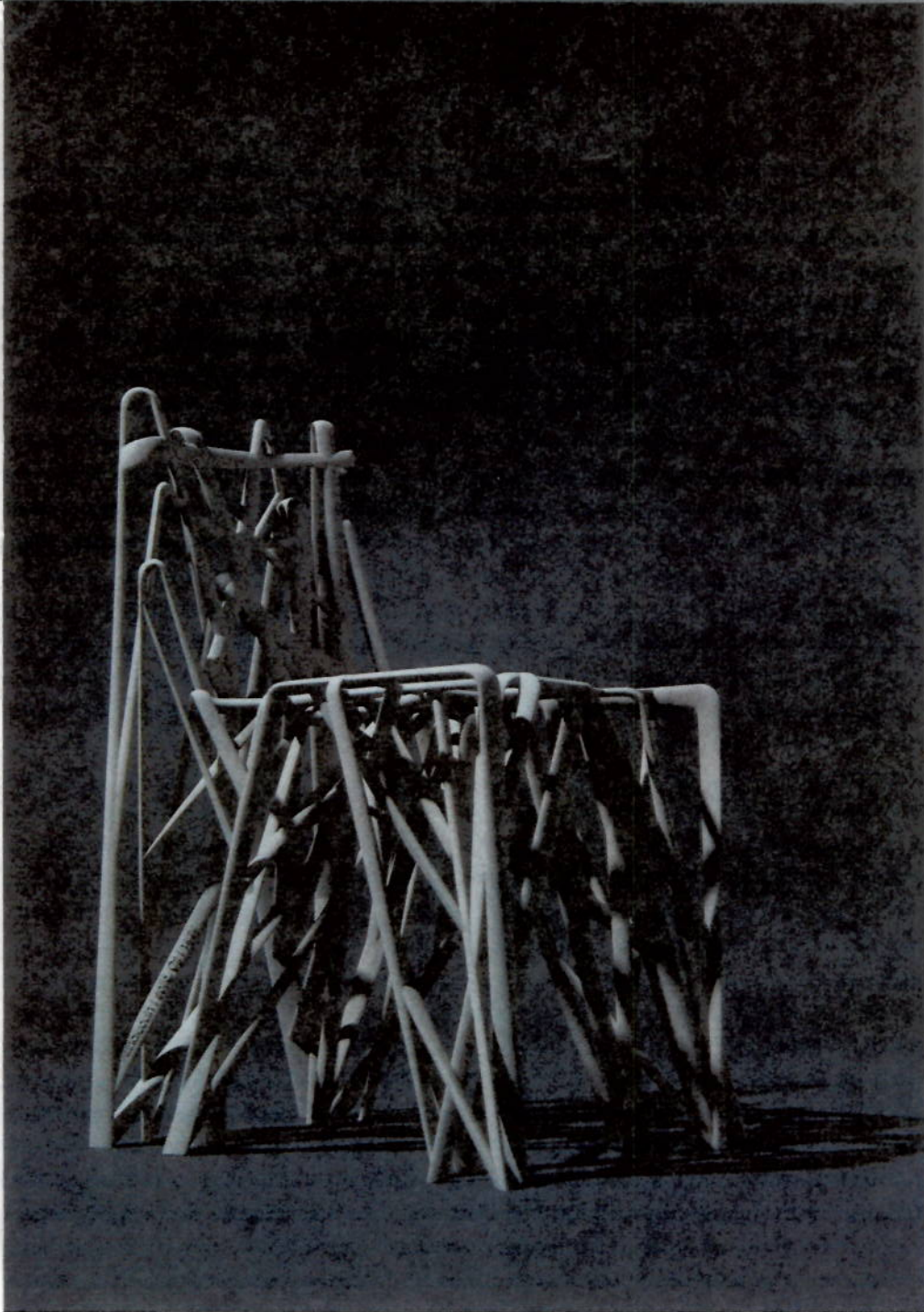
Why do plastics seem inherently less secure than other materials we encounter as artifacts? One reason is that their technology is relatively immature. For most traditional cultural heritage artifact materials, such as stone, wood, bone, ceramics, glass, metals, oil paint, and paper, the technologies used to modify them developed over a long period of time. Generations of practitioners have worked by trial and error and weeded out the processes that resulted in inferior products. Slowly and through repetition, these technologies have tended to evolve toward those that favor stability. Moreover, older artifacts fashioned from traditional materials seem to be durable because they are the ones that survived. In essence, time has selected the sound examples while the unsound have returned to the earth. We also have had plenty of time to observe these survivors under a range of stressors and have experienced how variations in their makeup can affect longevity. We have figured out environmental conditions that can slow change and have come up with methods to address deterioration when it occurs.

For all these reasons, extant traditional artifacts tend to behave more predictably and cause fewer problems. Plastics are different. Our experience with them is much shorter, and the objects being nominated for cultural heritage status were made only recently. We have limited understanding of how they will behave, and, in contrast to antiquities, we are tasked with stewarding the unstable and stable alike.

## ACHIEVEMENTS

Research into plastics has received significant attention in recent years, and despite a continued cloudy outlook, it is important not to lose sight of the fact that much has been achieved. Plastics are now taken seriously by the cultural heritage field, and this advance is important. Gone are the not-so-distant days when a few die-hards sat in small meeting rooms discussing sticky PVC tubing or crumbling cellulose acetate film, occasionally joined by conservators working on more traditional materials who wandered in for a bit of light relief. The Modern Materials and Contemporary Art working group of ICOM-CC (International Council of Museums—Committee for Conservation), for example, has expanded more than any other of the twenty-one ICOM-CC working groups over the last ten years, and it is now one of the largest in the organization, up there with the long-established groups of Paintings, Preventive Conservation, and Scientific Research. There is now genuine interest in the conservation issues of plastics within the cultural and scientific fields; this attention can only bring more resources for much-needed research.

Our understanding of plastics behavior has been enriched through the transfer of knowledge from other fields. Conservation scientists have followed the evolution of synthetic polymers since their creation in order to advise about and improve upon the range of adhesives, coatings, and paints that conservators select for treatments. Our research into the technologies and stability of artifacts is no longer driven only by reaction to failures of materials



A plastic chair, designed by Patrick Jouin (Solid C2, 2004) and in the collection of Die Neue Sammlung, The International Design Museum Munich. Photo: Die Neue Sammlung, The International Design Museum Munich (A. Lorenzo).

like cellulose nitrate and sticky PVC. Nowadays research is also driven by interest in the technology of an artifact per se. We have learned about a set of degradation processes to which particular polymers are prone (hydrolysis and oxidation, for example) and about the factors that drive them (light, temperature, moisture, and oxygen). The degradation of certain artifacts has been attributed to specific processes, and attempts have been made to demonstrate the connection analytically. As a consequence of this knowledge transfer process, we have identified environmental conditions that we believe slow deterioration of certain unstable plastics. We use this information for basic storage strategies: to segregate certain classes of plastic and rubber artifacts (particularly if they are degrading); to understand which absorbents will work better on certain classes; and to decrease temperature and remove light (and, in some cases, oxygen).

Another achievement has been the development of analytical techniques to identify and characterize plastics. Theoretical models of degradation mean little if we do not know the materials composing the artifact. Identifying and even quantifying the main constituents are now routine procedures in some larger analytical laboratories. Optical spectroscopy (Fourier transform infrared spectroscopy, Raman, and near-infrared spectroscopy), separation techniques (gas chromatography and evolved gas analysis), mass spectrometry, elemental analysis, thermal analysis (thermogravimetric analysis and differential scanning calorimetry), and mechanical testing—all have been applied to plastics with great success. One of the most comprehensive assessments of the information that can be gleaned about plastics with specific analytical methods was carried out during the POPART project by a consortium of European research institutions and the GCI (see sidebar). The field certainly can benefit from further collaborations in which expertise and resources are shared, but such projects require considerable effort and management to maximize their efficiency.

An extraordinary amount of quality information can be gained from instrumental techniques. In addition to identifying the polymer(s) and a host of additives, certain analyses can elucidate how components are structured and how they interact. These analyses can also measure chemical and physical changes (including oxidation, hydrolysis, fragmentation, increase in molecular weight, change in volatility, loss of components, and phase changes). In-depth, highly resolved analyses can be noninvasively performed in laboratories or executed on micro-

scopic samples, and mobile instruments allow for rapid on-site surveys of large collections.

Just as significant has been a shift in our approach to research—to tackle the issue of plastic stability in a broad way. An excellent example is the Smithsonian Museum Conservation Institute's 2012 symposium, "The Age of Plastic: Ingenuity + Responsibility," which took the position that scientific studies benefit from cross-disciplinary approaches.<sup>3</sup> Presentations concerning remarkable and ingenious productions like the space suit were juxtaposed with more mundane topics like the rise of plastic packaging, which has transformed commerce, our eating habits, and even our garbage. Unlike some art, neither space suits nor Styrofoam clamshell hamburger boxes were designed to last in perpetuity, but now these products have become icons for us to preserve. Concepts in material innovation were explored through

examples of successful and failed ventures in “bioplastics”—materials derived from agricultural feedstocks, including cellulose, soy, latex, milk, and animal body parts, rather than materials derived from fossil fuels. The complex relationship between plastics and the environment was probed further, and perspectives were gained on pollution, the value of plastics for living zoological collections, and recycling. The symposium made clear that plastics are now integral to the artifact record as markers of achievement and of the innovation process. But their materials, processing methods, intended service life, and conservation treatments make their preservation complex.

## CHALLENGES

Despite advances that the conservation profession has made with plastics over the past twenty years, considerable challenges remain for research, conservation, and the allocation of resources. What effort should we expend on preserving objects that are inherently unstable? One could take the long view and see these unsound objects as examples of experimentation in an ongoing innovation process that could take decades or centuries before we hit stasis. Collecting archetypal examples and masterpieces that mark important milestones, and often come with inspiring creation stories, certainly is key. (John Wesley Hyatt’s nineteenth-century development of a celluloid billiard ball is one example.) However, a balance must be struck between preserving important examples and keeping a record of the technologies that failed. Should we also focus on documenting some of the mutating objects, letting them degrade, and learning from the process how their materials behave over time? Would that improve our understanding of and ability to preserve them?

Even with knowledge transfer and recent advances in material characterization, our understanding of plastics stability remains rudimentary. We have a menu of mechanisms that potentially explain degradation, but there is a tendency to default to them and recite them, rather than investigate skeptically what is actually going on. We also need to study the complex systems that result when several degradation mechanisms occur simultaneously. This challenge includes understanding the chemical mechanisms involved,

the conditions under which they occur, the rates at which they transpire, and their interplay. Similarly, we must continue to generate data about the environmental conditions that favor (and hurt) plastics—particularly in storage (see page 13)—and we need to explore best practices for stabilization, cleaning, and repair.

And now, with the proliferation of plastic pollution, the value of longevity is being questioned. Biodegradable and recyclable plastics that may help reduce our waste stream are engineered to fail. Biodegradable plastics are deliberately manufactured to be susceptible to heat, light, moisture, and microorganisms; recycled plastics are prone to weakness, increased oxidation and diversity in polymer weights, and contamination. As opposed to the desired stability of traditional artifact materials, here we may be moving toward enhanced instability, a property that will have interesting consequences for cultural heritage preservation. Some of these materials are already entering collections.



**The Liotta–Cooley heart—the first artificial heart to be implanted in a human body.** It included plastic components and kept the recipient alive for sixty-four hours until a human heart was available for transplant. Photo: Division of Medicine and Science, National Museum of American History, Smithsonian Institution.

## IMPROVING STEWARDSHIP

Practical conservation concerns will no doubt continue to dominate our attitude toward plastics, as we strive to make significant advances in understanding them. Perhaps we as a profession are also growing up a little and expanding our philosophy of the plastics paradigm. Of course we will bemoan the things that turn yellow and sticky, but we also should embrace the excitement of being in the midst of plastic’s invention period. It began in the mid-nineteenth century and will continue for the foreseeable future. If we accept that this is a time of evolution and experimentation, we might acknowledge the inherent instability of some artifact compositions and their obsolescence. If we also become more willing to make tough decisions about objects that just will not survive, resources can be

reallocated for investigation and documentation of the technologies these objects represent and of their paths to failure. Compiling these histories, tracking stability, and figuring out causes of and remedies for entropy are valuable contributions that our profession can make to the Plastics Age. These efforts, of course, take time and require taking action under conditions of uncertainty. There will be many failed attempts along the way, but slowly and iteratively we will improve our stewardship.

So maybe Mr. McGuire's prophecy still holds true. Despite all the conservation headaches that are bound to continue and despite the seemingly thankless task of trying to preserve a class of material that almost defies preservation—there really is a great future in plastics. Shhh! Enough said.<sup>4</sup>

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1. Denton A. Cooley, Domingo Liotta, Grady L. Hallman, Robert D. Bloodwell, Robert D. Leachman, and John D. Milam, "Orthotopic Cardiac Prosthesis for Two-Stage Cardiac Replacement," *American Journal of Cardiology* 24, no. 5 (November 1969): 723–30.
2. Bill Ayrey and Linda Hughes, paper presented at "The Age of Plastic: Ingenuity + Responsibility," June 7–8, 2012, Smithsonian Museum Conservation Institute, Washington, DC.
3. Papers presented at the symposium are intended for publication by Smithsonian Institution Scholarly Press.
4. [www.youtube.com/watch?v=PSxihhBzCjk](http://www.youtube.com/watch?v=PSxihhBzCjk)



**A model of a British Airspeed Horsa.** Models like this were used to teach aircraft recognition during World War II. Seven decades later, many of these early examples of injection-molded cellulose acetate plastic are disintegrating spontaneously in the National Air and Space Museum collection. Photo: E. Keats Webb, Museum Conservation Institute, Smithsonian Institution.

## THE POPART PROJECT

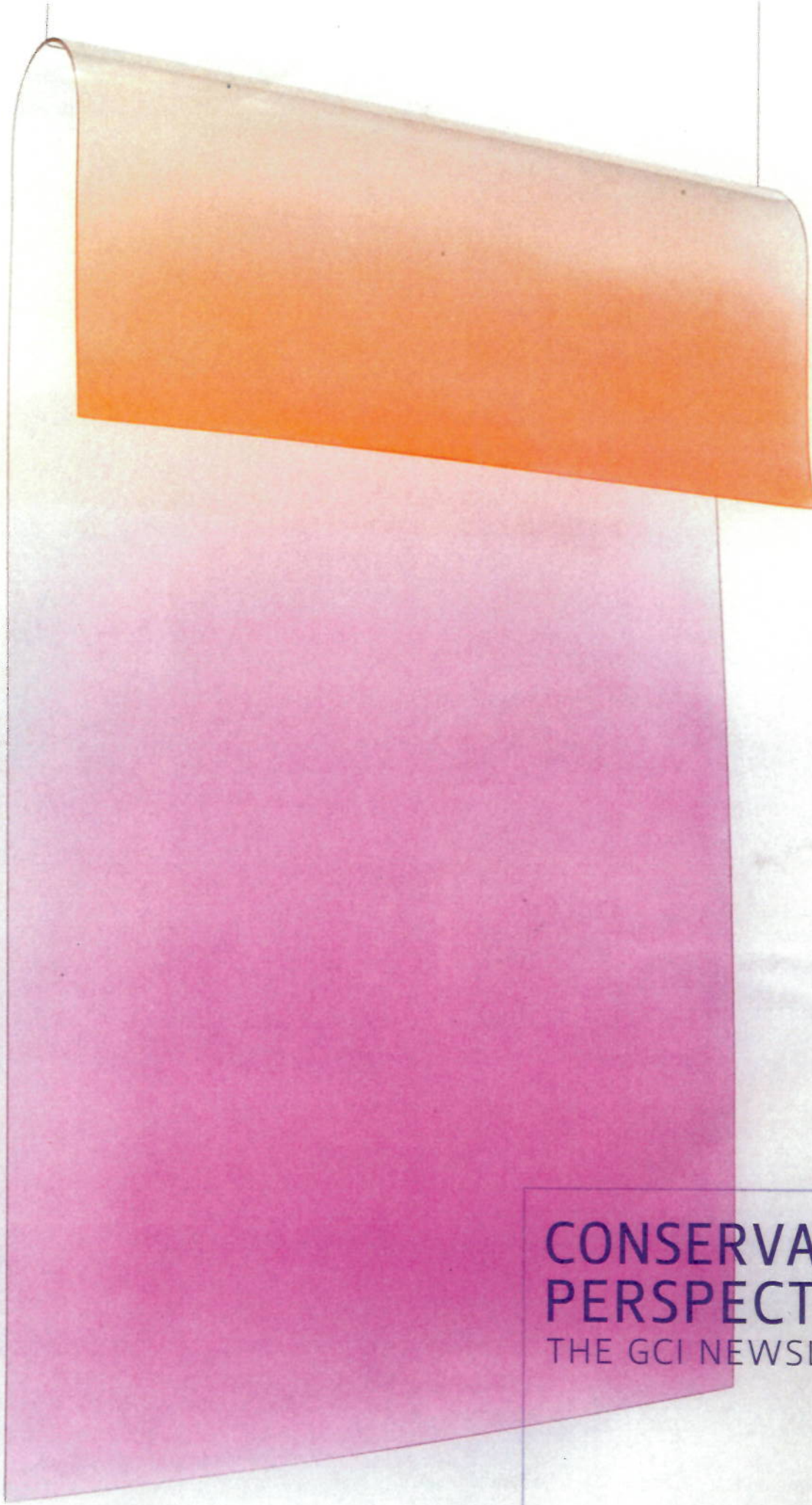
THE PRESERVATION OF PLASTIC ARTEFACTS IN MUSEUM COLLECTIONS (POPART) project was a major international research effort running from 2008 to 2012 and involving twelve research institutions. Collectively, they aimed to: (1) identify appropriate methods of analysis for plastics; (2) investigate plastics degradation; and (3) provide practical guidance for conservation issues and collections management of plastic cultural heritage objects. POPART remains the largest, most coordinated research effort in this area to date; it demonstrated the benefits of groups of professionals tackling conservation issues together. There were a number of salient results of the project:

- A variety of handheld analytical instruments were found to be particularly effective for rapid, on-site surveys of collections, but sampling was needed for a full characterization, including the detection of additives.
- A reference survey form was established and tested on different collections; it is available on the POPART website (<http://popart.mnhn.fr/>) and can be used as a template for plastics collection surveys.
- A reference plastic "doll"—made from a variety of different plastics—was placed in different museums to monitor environmental impact on natural aging; it was found to be an effective tool for monitoring dose-response functions.

- Cleaning techniques were evaluated for their effectiveness at removing dust, as well as for their effect on plastics. Consolidation of polyurethane foams with a number of new materials was also investigated.

One of the main achievements of the project was the publication of *Preservation of Plastic Artefacts in Museum Collections*, a 325-page overview of the main research areas (available at <http://popart.mnhn.fr/>). This book was published at the same time as an international conference held in Paris, where the key researchers presented their work; these presentations are viewable online (<http://popart-highlights.mnhn.fr/>).

The partners in POPART were Centre de Recherche sur la Conservation des Collections (France); Laboratoire du Centre de Recherche et de Restauration des Musées de France (France); Victoria and Albert Museum (UK); National Museum Denmark; Istituto di Fisica Applicata "Nello Carrara" (Italy); Cultural Heritage Agency of the Netherlands; Polymer Institute, Slovak Academy of Sciences (Slovakia); Atelier Régional de Conservation Nucléart (France); Morana RTD (Slovenia); SolMateS BV (Netherlands); University College London (UK); and the Getty Conservation Institute (US).



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The Getty Conservation Institute