



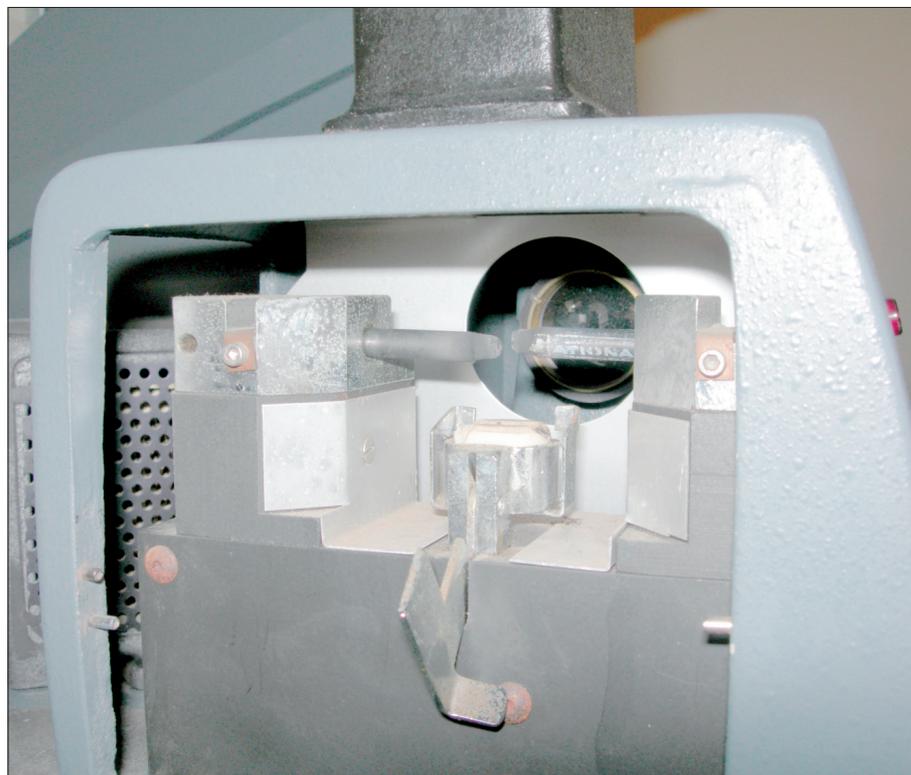
1

Spectroscopy

Pierre Laszlo and James Elkins

The large photograph is a spectrum. It records the wavelengths of light, from the deep violet near the end of the visible spectrum (at the top) down into the warmer colors that lead to infrared (at the bottom). The machine that made this is a Vreeland spectroscope, a fairly ugly machine that works very simply.





The sample, usually powdered rock, is put on a small ceramic plate; the plate is just visible beneath the dark opening. Above the plate are two carbon rods, which are arranged so they do not quite touch. When the machine is turned on, an arc of electricity sparks between the plates, creating a rasping noise and a blinding light (far brighter than sunlight). The arc melts and vaporizes the rock sample; the spectrum is produced when light is reflected off a diffraction grating inside the machine.

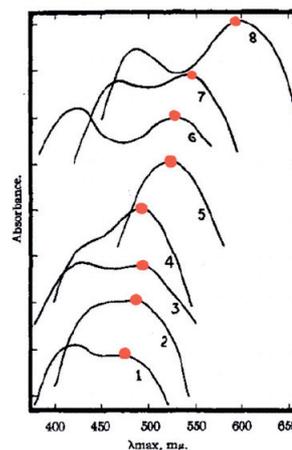
When a viewer looks in the eyepiece, he or she sees the spectrum in brilliant colors. The Vreeland spectroscope has two film reels that can run on either side of the spectrum. They can be rolled along using the two black handles visible in the first photograph. The left-hand film reel, in this case, has the wavelengths of light on it, for reference. The right-hand reel has the spectral lines that are characteristic of different elements. Here the large “Sn” indicates this is the portion of the film that shows the typical lines of Tin. The green line and the blue line match lines in the spectrum, and in fact the powder on the crucible in this case was pure tin from a chemical supplier.

From color to monochrome

This is simple spectroscopy, done with a rough-and-ready machine that was designed to be used in the field, by geologists. Machines like this are rare in laboratories now; they have been replaced by massive, and massively expensive, machines that produce very accurate quantitative results.

It may come as a surprise that spectroscopy, in science, does not often involve any color reproductions. This is a series of ultraviolet spectra, numbered 1-8, illustrating an experiment carried out in an organic chemistry laboratory during the 1950s — that is, almost exactly a full century after Bunsen and Kirchhoff invented spectroscopy.

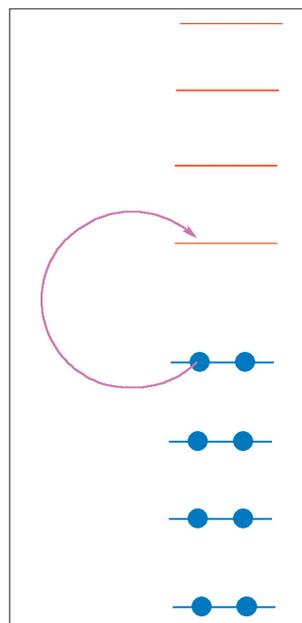
The curves show how the molecules absorb light of different wavelengths. Note that there are no spectral colors here, and really no colors at all; the original publication had no red dots, and this was its only illustration.

*What are we looking at?*

The picture on the top depicts a stack of spectrograms — spectra for short. Each spectrum is that of a different molecule, numbered 1-8. The underlying physical phenomenon is absorption of light, in the UV-visible part of the range of electromagnetic radiation, that is, from 400 to 800 m μ (a micron, μ , is a millionth of a meter, or a thousandth of a millimeter).

Why do certain molecules absorb light in that range? Because absorption of a photon lifts an electron — hence the name “electronic spectroscopy” — from a doubly occupied energy level (blue) into a vacant energy level (red).

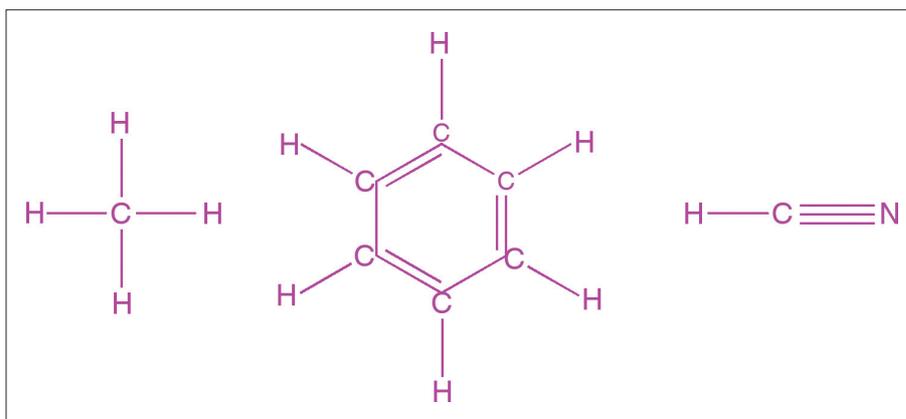
As the light excitation sweeps through the accessible range, in this case from 400 to 650 m μ , it probes various electronic energy levels within a given molecule. The manifold of such light absorptions, across the whole range monitored, is termed the “spectrum.”



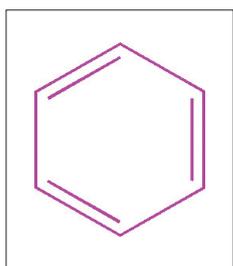
The iconic language of chemical formulas

The simplest formulas, termed berzelian formulas, provide information only about composition. For instance, the methane molecule (natural gas) is CH_4 , benzene C_6H_6 and hydrocyanic acid is HCN . In these, C stands for carbon, H for hydrogen and N for nitrogen.

A major step forward was taken during the 1860s when structural formulas were devised. They show in how atoms are connected. The very same examples are shown below:



Chemists soon realized that rather strict rules governed these formulas. Notice, for instance, how each carbon atom bears a total of four lines (bonds) to neighboring atoms? Accordingly, a shorthand was quickly established: one would display only the framework of interconnected carbon atoms without showing explicitly the attached hydrogen atoms. Thus, the benzene molecule is written, in this simplified manner as shown at the lower left.



In a benzene ring, all twelve atoms are in one and the same plane. To distort a benzene ring from such coplanarity demands considerable energy.

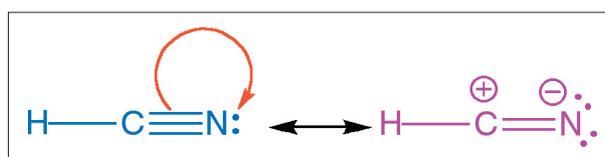
During World War I, Gilbert N. Lewis (1875-1946), a professor of chemistry at the University of California, proposed to integrate the then newly discovered electron into the structural formulas. Each line (bond) is equivalent to a pair of electrons. For instance, there are three such pairs between the C and N atoms in HCN . Moreover, there exist also pairs of electrons which remain uninvolved

in bonding atoms. In the same HCN molecule, one such pair sits on nitrogen:





It remained for Linus Pauling (1901-1994) to perfect this iconic language by making the representation somewhat more involved. Consider again the HCN example. The three pairs of electrons in between C and N are drawn towards the atom on the right (N) since its nucleus has an additional proton. Protons have a positive electric charge, electrons are negatively charged. Thus, protons attract electrons. To account for such a polarization, Pauling wrote the HCN structural formula as a *hybrid* of two limiting forms:



The red curved arrow shows transfer of an electron pair, from in-between C and N, to the N atom only. In the purple limiting form on the right, N has gained negative charge, from now bearing two instead of just one lone pair of electrons. Carbon, having lost negative charge, has become positively-charged. The HCN molecule is best conceived of as a hybrid (indicated by the black double arrow) of the two formulas in blue and purple.



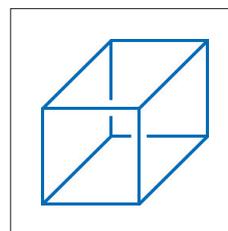
What “physical organic chemistry” consists of



In chemical history, physical organic chemistry, which appeared during the 1920s and 1930s, was another hybrid. Organic chemistry studies molecules derived from hydrocarbons such as methane or benzene. Physical chemistry, a close relative of physics, studies the equilibria between molecules and the rate of the chemical reactions which interconvert them. Physical organic chemistry is thus physical chemistry applied to organic structures.

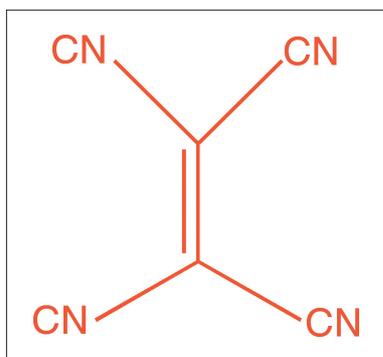
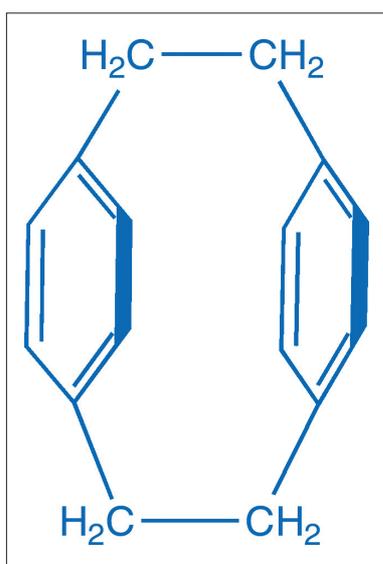
A defining trait of physical organic chemistry is the synthesis of novel molecular architectures in order to test theories of chemical structure. For instance, about the time Cram and Bauer published their paper, Philip E. Eaton, from the University of Chicago synthesized cubane.

In that structure with berzelian formula C_8H_8 , the angles at the eight carbon atoms are constrained as 90° instead of the “natural” angle of 109.5° found in methane. What would be consequences of such a huge internal strain in the cubane molecule, Eaton wondered. We now know that one such consequence is the feasibility of manufacturing much more powerful explosives than previously known.



What are paracyclophanes, and why make them?

Donald Cram, in an early line of research, chose to synthesize paracyclophanes for similar reasons as Eaton's in making cubane. Paracyclophanes are molecules in which two benzene rings are bridged at positions diametrically-opposed, by a number of hydrogen-bearing carbon atoms. This is, for example, the formula of [2.2]paracyclophane (shown below, in blue).



but on the outside (it is too bulky for the internal space of the paracyclophane).

An electronic interaction is thus set: the TCNE moiety (red) pulls electrons away from the paracyclophane moiety (blue). Each of the two benzene rings donates electrons, as shown by the horizontal arrows, which the TCNE avidly pulls:

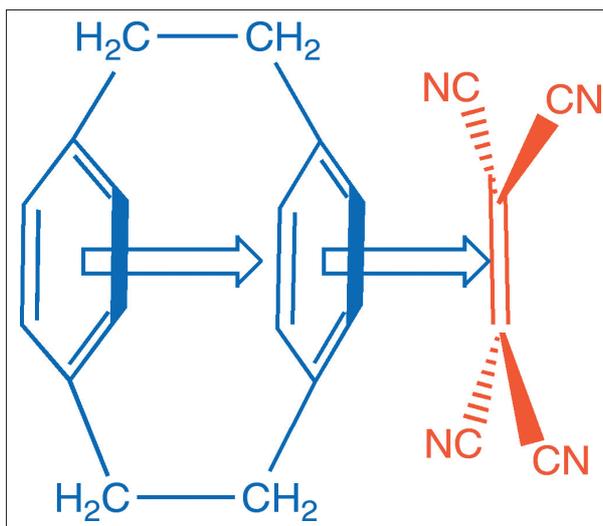
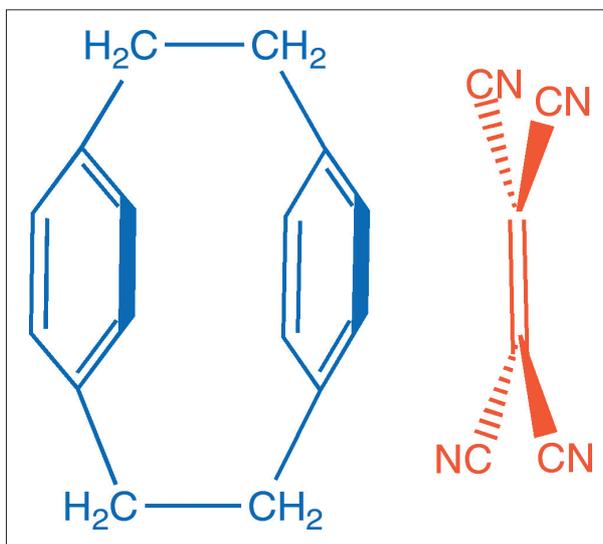
Why become interested in such a molecule? Its internal strain. The presence of the two bridges, each made of two mutually-bonded carbons, pulls on the benzene rings. Such double bridging tends to distort the benzene rings from their coplanarity. Would this, besides the geometry, affect the ability of the benzene rings to either accept or donate some of their electrons to another entity?

When Cram and Bauer did this work, chemists at the Central Experimental station, of DuPont de Nemours in Wilmington, Delaware had just made tetracyanoethylene (TCNE) in quantity (shown at bottom).

TCNE is a powerful attractor of electrons, because each CN group is polarized in the same manner as in HCN, with a positively-charged carbon. Moreover, TCNE is a planar molecule just like benzene.

Cram and Bauer thus studied the so-called charge-transfer complexes which occur when a paracyclophane comes together with a TCNE molecule. Such a complex is depicted below depicted in the top illustration on the next page.

The two benzene rings are in roughly planar and parallel vertical planes. The TCNE molecule, also in a vertical plane in this image, stacks next to one of the benzene rings,



But we are moving too quickly: this last image already translates into the iconic language of *chemistry* the information latent in the very first image as provided by *spectroscopy*.

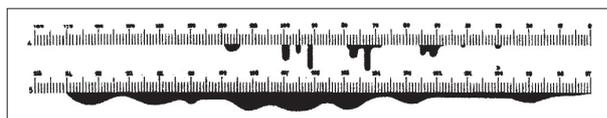
Extrapolating to a trend from discrete data points

At the time of the study by Cram and Bauer, the study of charge-transfer processes was in full bloom. A charge-transfer process occurs when, because of a

sticky collision between two different molecules, electron density flows from one molecule to the other. Each curve in the spectrum results from such an event.

A relevant question, left unanswered by these spectra is that of the geometry of the collision complex: is it a sandwich-type, with the TCNE inserted in-between the two benzene rings; or is it an outer complex, with the TCNE positioned on top of one of the benzene rings? Spectroscopy of other sorts can help answer such questions.

Spectroscopy was devised in mid-nineteenth century by Bunsen (1811-1899) and Kirchhoff (1824-1887). Art influenced science. The very first mode of representation chosen by Bunsen was to depict a spectrum in silhouette manner; it looked like a mountain range, shown upside-down (1864):



The lingering effect of this initial choice, now that spectra are shown as line drawings, is in the vocabulary, with its “peaks” and “valleys.” Each of the eight curves in the first diagram on page 61 — each on a different paracyclophane — has two peaks. They document a gradual shift of one of the peaks toward longer wavelengths (toward the right in this graph). It turned out that the more basic the paracyclophane hydrocarbon (that is, the better it is at electron donation), the more electron pumping into TCNE occurs. The attendant charge-transfer band shifts to longer wavelengths.

Looking at that diagram, a chemist’s eye immediately sees the trend for gradually greater basicity of the paracyclophanes. In an instant, then, a chemist can extrapolate from a set of separating pictures to a unifying hypothesis.

From simple to complex

This is the gist of this work, generalizing the notion of basicity (the converse of acidity) to these chemicals, called aromatic hydrocarbons. (And thus, to give it its technical explanation, to *pi* electrons instead of *n* electrons as is the case for traditional bases, such as nitrogen-containing molecules.) There is much more that spectroscopy can do with these molecules. The authors, Cram and Bauer, did not attempt to “deconvolute” each spectrum into its component absorptions. Thus it would be mistaken to equate the apparent absorption maxima (the red dots added to the figure) with the true maximum, as is often done. The “real” spectra are far more complex and spiky than these smooth curves suggest.

So spectroscopy is a signal example of a technology that began as a sensuous science, with all the colors of the rainbow, and gradually lost its visual content. We reproduce the one illustration from the 1950's experiment in a small size because it does not need to be any larger: it has no crucial visual details except the progression of peaks to the right. The Vreeland spectroscope is a survivor of the field's past. Today spectroscopic analyses do not even need to be given as graphs, although they often are. Numbers are all that is required in the end.

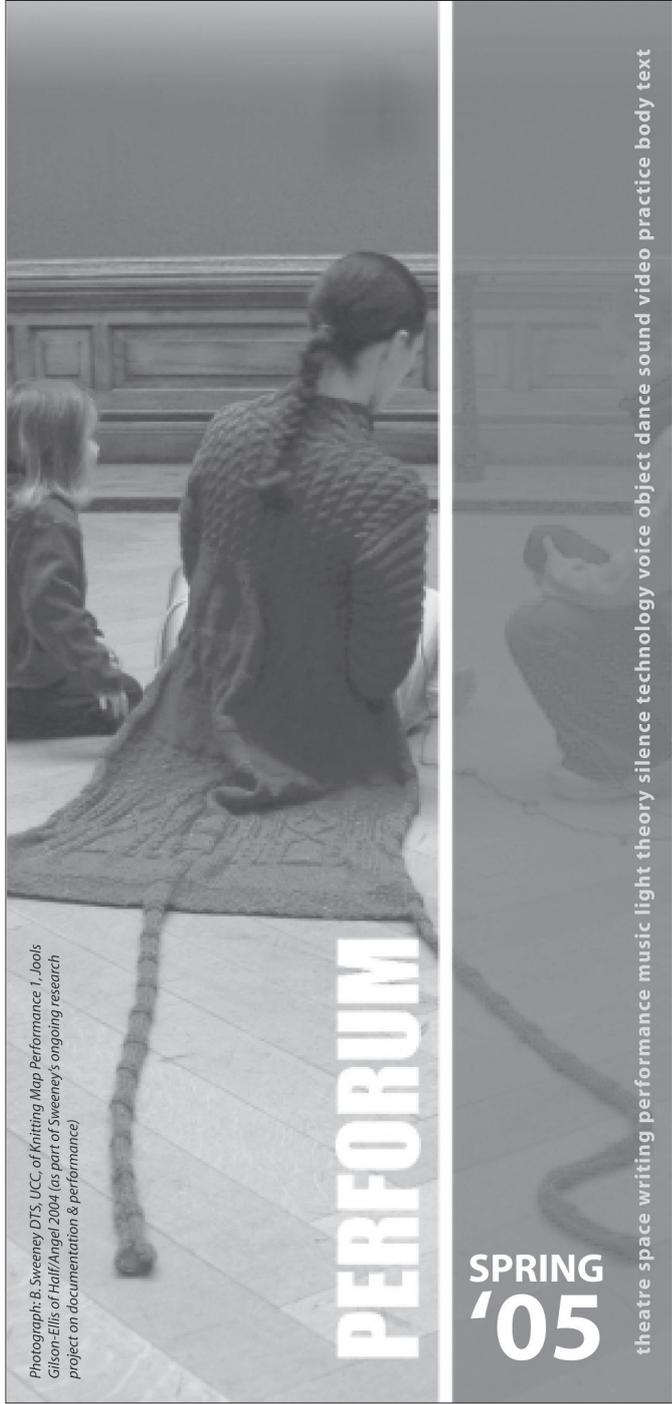
Resisting big science

More generally, spectroscopy is the handmaiden of chemistry. At the time when the work on paracyclophanes was carried out, research was on the rise on account of Vannevar Bush's report to the President of the United States, titled *Science: The Endless Frontier* (1945); chemistry laboratories were undergoing a qualitative and quantitative mutation. They were equipping themselves with extremely expensive commercial spectrometers. Within a few years, the cost of running a chemical laboratory increased between one and two orders of magnitude.

Chemists, who were following the lead set by physicists, were thus presented with the dilemma of embracing Big Science or sticking to their traditional, low-tech craft. For the most part, they opted for the latter. They went for the heavy equipment, but they managed to avoid it affecting the style of their research; chemistry continued to be done in small groups, with emphasis on manual dexterity, and on quick experiments which could be initiated in the morning and provide results in the afternoon. In a sense, spectroscopy retains the simple formats it once had.

For further reading

The report *Science: The Endless Frontier* is available at www.nsf.gov/od/lpa/nsf50/vbush1945.htm. For the early work on paracyclophanes, see D. J. Cram and S. H. Bauer's paper in the *Journal of the American Chemical Society* 81 (1959): 5971-77.



*Photograph: B. Sweeney DTS, UCC, of Knitting Map Performance 1, Jools
Gillon-Ellis of Half/Angel 2004 (as part of Sweeney's ongoing research
project on documentation & performance)*

PERFORUM

SPRING
'05

theatre space writing performance music light theory silence technology voice object dance sound video practice body text

2

How is Performance Documented?

Bernadette Sweeney

Performance is a notoriously ephemeral medium. Some artists make a virtue of that, but for others it presents a problem: how can a work whose meaning is in the making be preserved? The photos in this chapter record performances by the artist Jools Gilson-Ellis and others. In the nature of performance, these events varied hugely: one was a large outdoor event (held, as it happened, in a misting rain), and others were seen by fewer people.



*The idea*

Performance art, which has become increasingly important since its beginnings in the 1960s, continues to present difficult problems for historians and critics. Once the performance is over, what remains? Usually written descriptions, photographs, and sometimes also video.

Are those documents then the performance, as it will be known to future artists, historians, and critics? Or are they a kind of documentation that will always be inadequate? (And if so, how can we say how inadequate?)

Problems: the body

One crucial problem is that performance is about the body, and so it can never be put adequately into words. As Peggy Phelan has observed, performance moves from the “grammar of the word” to the “grammar of the body.” How, then, to do that justice in videos and photographs? Two of these images document a knitting project, in which the artist worked with people in many different settings; part of those events was a closeness between people. Photographs can only capture that by reminding us of what it might have been like: a mnemonic prod, as much as a realistic record.



Problems: time

A second problem is that performance is a “time art”: it cannot, by its nature, be documented in 2-D or 3-D. W.B. Worthen has noted that “all writing about performance must face its own impossibility: the event is gone, [and] the records are always partial and suspect.”

It is a difficult starting-point for any documentary project. In one photo at the top of the previous page, a man is slightly out of focus, giving a sense of his motion; in the photo below, two figures move across a dark field and are intentionally blurred to evoke their gestures and speed. In such ways photography translates bodily motions, and our perceptions of them, into conventional equivalents.

The uniqueness of performance art

Recently, Phelan and others have proposed that performance art is unique exactly because it cannot be documented. Irit Rogoff and Gavin Butt at Goldsmith’s in London have suggested that an entirely new kind of writing needs to be developed to adequately respond to performance. It is not enough, they say, to simply describe or document: the critic or historian has to enact the performance through writing. Journals like *Performance Research* and books such as *ReMembering the Body* try to embrace the new ideals.





In this way of thinking, performance demands not only sensitive and thorough documentation, but a new kind of documentation. The practice reflected in these documents is one of questioning: I ask about the relationship between the languages of the script, the stage, and the critic, and about what happens during the performance moment when “the word” is made flesh — or, in the end, what then happens when the performance is critiqued and the “flesh” is made word.

The place of the visual

Visual documentation, whether it is video or photography, brings with it an ideology and an aesthetic which prevent it from functioning simply as evidence. The visual becomes suspect: it is no longer evidential, but contentious. That is true, in varying degrees, of every image in this book: but here it can be perceived as a crippling defect. Performance art is, in this sense, immune from the danger of being reduced to documentary evidence.

For further reading

After Criticism: New Responses to Art and Performance, edited by Gavin Butt (Maiden MA: Blackwell, 2005); Peggy Phelan, *Unmarked: the Politics of Performance* (New York: Routledge, 1993), quotation on p. 150; *ReMembering the Body*, edited by Gabrielle Brandstetter and Hortensia Völckers, with contributions by Bruce Mau and André Lepecki (Ostfildern-Ruit: Hatje Cantz, 2000) (I thank Michelle Tupko for this reference – J.E.); W.B. Worthen, *Theorizing Practice: Redefining Theatre History* (New York: Palgrave Macmillan, 2003), quotation on p. 6; and Bernadette Sweeney, “Wordmadeflesh: Writing the Body in Irish Theatre,” *Modern Drama* 47 no. 4 (2004), quotations on p. 686.



