extremely dependent on the sophistication of the method (and, especially, of the wavefunction) used for their calculation.

If this (important) reservation is borne in mind, Elser and Haddon's theoretical predictions on buckminsterfullerene give a genuine impetus to future experimental work on the magnetic properties of this remarkable molecule. □

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R.B. Mallion is Assistant Manager in Mathematics at The King's School, Canterbury CT1 2ES, UK.

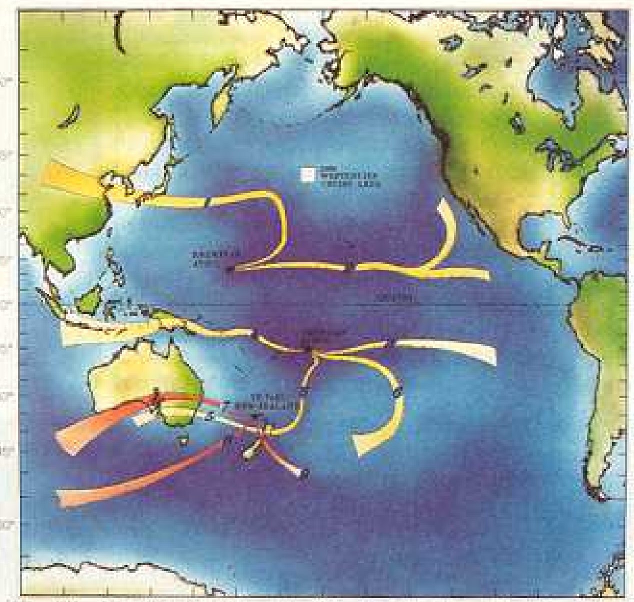
Air pollution

Tracers of atmospheric transport

Hiram Levy II

On page 800 of this issue[1], Gagosian and colleagues combine measurements of minute quantities of plant lipids present in organic aerosols collected over New Zealand with isentropic trajectory calculations to identify specific terrestrial source regions in the Southern Hemisphere and to determine transport paths over the southern oceans. Although the sensitivity of the chemical analysis and the ability to calculate believable 10-day trajectories are impressive, the key message of the paper is the value of using a combination of chemical and meteorological tracer techniques. Taken separately, neither approach would have produced conclusive results. In combination, the assignments of source regions and transport paths are quite powerful. Therefore, it is worth asking whether such techniques, which have been used successfully in relatively remote regions to identify distant sources, can provide quantitative information about global geochemical cycles and ultimately be applied to important local and regional environmental issues such as air pollution and acid rain in Europe and North America. Before discussing this question, an examination of some past developments may be useful.

Measurement techniques for radionuclides found on aerosols were first developed to assess movement of nuclear bomb debris and were found to provide valuable information on atmospheric transport. These techniques were then applied to ^{210}Pb and ^{7}Be, the naturally occurring tracers of surface and stratospheric air[2]. Next, filter measurements[3] in the supposedly pristine air over the Caribbean uncovered episodes of very high levels of mineral aerosol (dust). Extensive measurements[4] of dust over the remote oceans then identified large active continental sources for the material fraction of oceanic sediments. Trace metals, which were found in minute quantities on aerosols in clean air and were detected by neutron-activation analysis, as well as other sensitive analytical methods, provided another set of chemical tracers. These were used to identify the source types for background aerosols and metals such as cadmium and lead[5] and made very sensitive tracers of automobile exhaust[6]. The recent ability to measure small quantities of organic compounds found in aerosols[7] provided biomarkers that not only differentiate among terrestrial, oceanic and anthropogenic sources, but identify specific regions.



Map of the overall air mass trajectories at the major field sites of the SEAREX project, including the station used by Gagosian *et al.*[1].

In theory, the meteorological record of winds measured every 12 hours can be used to trace back in time the three-dimensional path of an air parcel, but in practice the normal meteorological data provide only the horizontal component of the wind and the record itself becomes very sparse in remote regions. Near the surface, the observed history of the horizontal component can be used to reconstruct the path of the parcel, but such trajectories are not appropriate for transport over long distances, particularly when rising and sinking motions are involved. The first successful calculations of realistic long-range trajectories circumvented the lack of measured vertical velocities by assuming that the atmospheric motions were adiabatic (no heat supplied to or withdrawn from the air parcel). Available meteorological soundings were used to construct isentropic (adiabatic) surfaces on which the air parcels moved. The resulting trajectories identified transport paths of radionuclides and ozone carried down from the stratosphere to the surface of the Earth[8]. This approximation to full three-dimensional trajectories is quite accurate for large-scale motions in relatively dry and stable air, but it does not work where there is strong mixing, such as in the boundary layer or during convection, or when there is significant latent heat release from the condensation of water. Isentropic trajectories have since been used to identify tropospheric sources; for example to track dust observed over the tropical Pacific back over 10 days to its source in arid central Asia[9] and, as reported in this issue[1], to track plant waxes observed over New Zealand.

Although previous studies have identified source regions and transport paths, they have produced little, if any, quantitative information. To do so, chemical transformations and physical processes such as aerosol coagulation and settling, dry deposition and precipitation removal must be included, either directly in the trajectory calculations or indirectly via an appropriate surrogate. Furthermore, it is not sufficient to do this for a single event. The detailed study of one or more representative transport events is important for testing a particular technique, be it chemical or meteorological, but a method is needed that integrates the results of all the events in a year or, given the year-to-year variability of weather, perhaps in a decade. As a first step, correlating surface wind direction, a primitive meteorological trajectory, with the deposition of acid rain in Bermuda clearly identifies North America as the primary source[10]. Without including chemical transformations and physical loss processes, however, the size of the North American export source cannot be determined.

The chemical tracer and isentropic trajectory methods of Gagosian and colleagues[1] seem to have some potential for quantitative studies of global geochemistry, particularly when there are a few well-separated sources and the background concentrations are low. But this type of approach is not adequate for studying regional phenomena, such as acid rain, which involve complex meteorology, chemical transformations, precipitation removal and several nearby large sources. Assigning the blame among all the neighbouring sources for acid deposition in one country or region is particularly difficult. A statistical approach using an array of chemical tracers with different signatures for different sources has been proposed by Rahn[11] and used, with some success, to apportion the sulphur fraction of acid rain in the northeastern United States among the different regional sources. However, this technique is not yet quantitative and does not work for the nitrogen fraction of acid rain. The most likely approach to pinpoint the sources of atmospheric pollution, although guided by chemical tracers, will require the development of high-resolution chemical transport models driven by realistic simulations of the meteorology of a region. □

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Hiram Levy II is at the Geophysical Fluid Dynamics Laboratory, Princeton University, Post Box 308, Princeton, New Jersey 08542, USA.

Developmental biology

Mechanism of fertilization

Brian Dale

RANKING high at present in the public eye is human *in vitro* fertilization. While politicians juggle with ethics on the use of human embryos in the laboratory, biologists have made some headway in understanding the mechanism of fertilization, using invertebrate gametes, that will help future clinical studies. Two problems of current interest are how the spermatozoon triggers the quiescent egg into metabolic activity; and why, of all the spermatozoa attached to the egg surface (Fig. 1), only one succeeds in penetrating the egg. Work recently published[1,2] in the journal *Developmental Biology*, using techniques of electrophysiology and fluorescence microscopy to study the initial events of sperm–egg interaction in the sea urchin, have produced some unexpected results that are changing present concepts about fertilization.

The first of these papers, a collaborative effort between Frank Longo and Edward Chambers's group at Miami, correlates for the first time the sequence of ultrastructural events at fertilization with changes in the electrical properties of the egg plasma membrane. In a laborious study, the authors voltage-clamped eggs, fertilized them and then serially sectioned them to locate the fertilizing spermatozoon. The moment when sperm attach to the egg was called time 0, and the first electrical event was detected 2 seconds later. Gamete fusion occurred at 7 seconds and cortical exocytosis, which leads to the elevation of a protective extracellular coat (see Fig. 2), was seen at 9 seconds. A second, larger change in conductance, indicating the global transmission of the activating impulse, was detected at 13 seconds. Chambers and McCulloch have taken the work further[3], using the electrical measurement of capacitance to time sperm–egg fusion, thereby reducing the time delay inherent in the fixation of biological material. It now seems[4] that the initial electrical event occurs simultaneously with sperm–egg fusion and that in fact it may be the result of the ion channels in the sperm plasma membrane being incorporated into the egg plasma membrane.

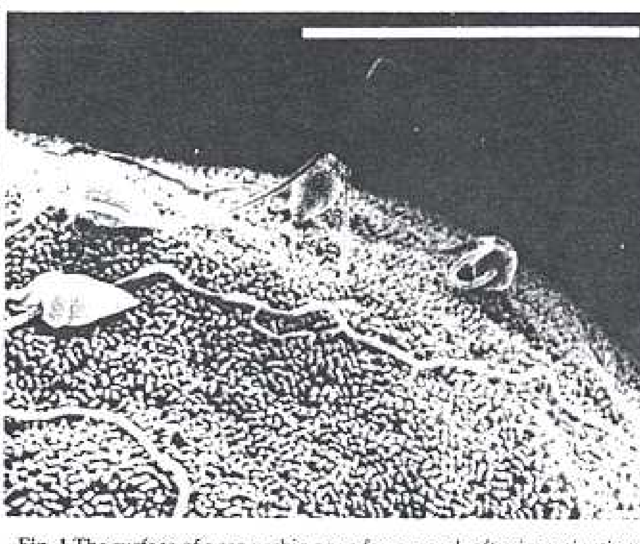

Fig. 1 The surface of a sea urchin egg a few seconds after insemination. Hundreds of spermatozoa can attach to the surface but only one succeeds in penetrating the egg. The successful spermatozoon dramatically alters the physiology of the egg within seconds. Bar, 10μm.

In the second of the two recent papers[2], a group at Miami, led by Robert Hinkley, loaded sea urchin eggs with a fluorochrome and then fertilized them. When cytoplasmic continuity between the two gametes is established the dye flows into the spermatozoon, which then fluoresces. This ingenious way of timing sperm–egg fusion not only supports the results of Chambers and colleagues, but shows that when the egg membrane potential is voltage-clamped at a negative potential, only one sperm fuses with the egg. This is unexpected, because it was thought by many that the positive shift in membrane potential at fertilization is a fast block to polyspermy[5]. Preventing voltage change by clamping should have resulted in multiple sperm fusions and entries.

There are two generally accepted ideas about how the spermatozoon triggers the dormant egg, a cell one million times its own volume, into metabolic activity. One[6] is that binding of the spermatozoon to externally located receptors on the egg surface is the primary signal, which is then transduced across the membrane to the cell interior, mobilizing second messengers such as inositol trisphosphate and calcium ions. The other[7] is that the spermatozoon contains a factor, soluble in the egg cytoplasm, that is released into the egg following gamete fusion, and which directly triggers the mobilization of secondary messengers. If the initial electrical event is the result of the spermatozoon fusing with the egg, as now suggested by Chambers and colleagues, it seems less likely that an externally located receptor mechanism is responsible for egg activation. The idea that spermatozoa contain a soluble activation factor is not new: it was popular more than 70 years ago, before the concepts of cell surface receptors were conceived. This is not to say, of course, that surface receptors are not important in fertilization, but rather their role is in the recognition and binding of the gametes, not in physiological activation of the egg.

One of the most astounding facts to an observer watching the process of fertilization for the first time is why only one spermatozoon, of potentially hundreds investing the egg surface, manages to enter the egg (Fig. 1). In many animals, including mammals, eggs *in situ* do not