

east Asia in the late 1970s and early 1980s, which proved to be bee faeces².

Pine pollen is known to traverse great distances, and is often found as a component of both pollen rain and stratigraphic pollen assemblages well beyond the tree line³. Spruce pollen, being much larger, does not transport as readily but can nevertheless form a significant proportion of the tundra pollen assemblage³. Typically, boreal forest pollen deposit in the high Arctic at a rate of less than 1 grain per species per cm² per year¹. The influx rate in Repulse Bay during this event was not measured, but must have been of the order of hundreds of grains per cm² in only a few hours.

The timing of the deposit and its geographic coverage indicate that the event was the result of an unusually strong low-pressure system that developed over Repulse Bay on 5 June. A three-dimensional back-trajectory analysis indicates that winds arriving at Repulse Bay on 6 June would have been near ground level in central Quebec on 1 June. Pine, spruce and alder may all be in flower at this time of year, depending on weather conditions⁴. High surface winds (up to 24 km h⁻¹) lofted the pollen into the air, and this pollen-laden air mass travelled at approximately the 850 hPa level

(~1,300 m) northeast over Labrador, north over the Labrador Sea, and west over southern Baffin Island, arriving at Repulse Bay late on 5 June and in the morning of 6 June. The wind speed dropped to less than 20 km h⁻¹, allowing the pollen to settle out. This event lasted an unusually long time (turbulence in the airflow causes most grains to remain airborne for less than a day⁵) and covered a remarkable distance (nearly 3,000 km).

That lifetime residents of the area have never seen anything similar demonstrates the rarity of this type of pollen transport event. As stratigraphic pollen data often integrate several decades in a single sample, however, such rare events may account for some of the variability often seen in the records of high Arctic regions. Similar rare transport events may account for some of the noise in ice-core records of pollen, dust, charcoal and other particulates and aerosols.

Ian D. Campbell*, **Karen McDonald†**, **Michael D. Flannigan***, **Joanni Kringayark‡**

*Canadian Forest Service, 5320-122 Street, Edmonton, Alberta, T6H 3S5, Canada
e-mail: icampbel@nrcan.gc.ca

†Environment Canada, Edmonton, Alberta, T6B 2X3, Canada

‡Government of the Northwest Territories, P.O. Box 59, Repulse Bay, Northwest Territories, X0C 0H0, Canada

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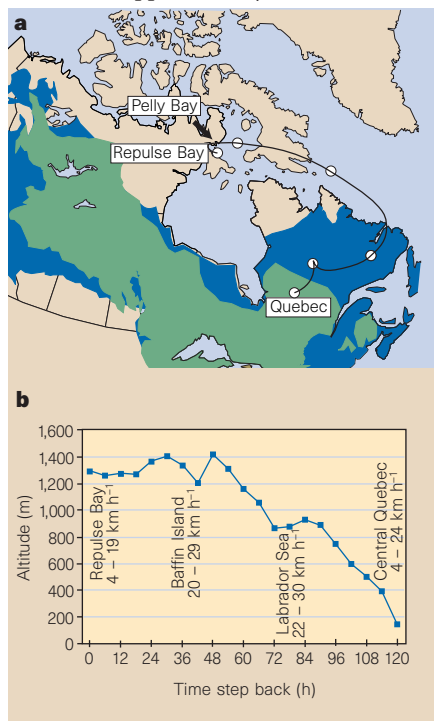


Figure 1 Movement of pollen. Back-trajectory analysis indicates that the pollen was picked up by strong surface winds on 1 June in central Quebec and lifted to and transported at the 850-hPa level to Repulse Bay, where it was deposited in calmer air developed by a low-pressure system on the night of 5 June and early morning of 6 June. **a**, Shading indicates ranges of *Pinus banksiana* (green) and *Picea glauca* (dark blue). The solid line is the 850-hPa trajectory; symbols on the trajectory line mark 24-hour intervals. **b**, Altitude of trajectory from 1 to 6 June.

Cause and effect in evolution

The need to see ‘purpose’ in evolution, or at least some internal drive to help the blind processes of random variation and natural selection, is remarkably resilient¹. Recent manifestations in the scientific literature imagine evolved mechanisms that actively promote further evolution or that facilitate rapid response to changed conditions. For example, Rutherford and Lindquist² (and the authors of related commentaries^{3,4}) suggest that the heat-shock protein Hsp90, by stabilizing developmental pathways, fosters the accumulation of hidden variants that can be exposed by environmental challenges and subsequently fixed by selection.

This is interpreted as “an explicit molecular mechanism that assists the process of evolutionary change”² (or even “a way of saving up mutations for a rainy day”⁴). Similarly, it is widely believed that organisms

increase mutation rates under stressful conditions to improve their chances of hitting on appropriate adaptations⁵.

Such interpretations seem to call for the evolution of properties that anticipate future needs. But selection lacks foresight, and no one has described a plausible way to provide it. In principle, group selection might produce results that seem to escape this limitation. For example, increased mutation rates may indeed allow populations to adapt more quickly to changed conditions, even though they harm most individuals. The evolutionary problem is that such group benefits are usually weaker than individual costs, in a well-defined sense that makes group selection effective only under very restrictive conditions⁶. So, in general, we need explanations that are based on individual fitness differences⁷.

From this perspective, the obvious function of Hsp90 is to prevent abnormalities of the kinds that appear when it is compromised. Up to a few per cent of adults heterozygous for a mutation that inactivates Hsp90 display significant morphological abnormality, so clearly there is selection to maintain its function. Likewise, increased mutation under stress might plausibly arise from trade-offs affecting individual fitness: stressed cells may simply be unable to maintain normal DNA repair without sacrificing other vital functions.

In the natural world, only living things (and their artefacts) have ‘purposes’, and natural selection is the ultimate source of all such ‘purposeful’ design⁸. When speaking of the function or purpose of some feature of an organism, we are therefore referring to the selective advantages that brought the feature into being and that maintain it in the face of recurrent damaging mutations. It is especially important, in any discussion of evolutionary processes, to observe the distinction between function or purpose on the one hand, and effect or consequence on the other. This is not a semantic quibble. Cosmic rays affect evolution by causing mutations, but we would not claim that they exist for that purpose. Similarly, developmental buffering and variable mutation rates may influence the course of evolution, but this does not mean that they evolved to that end.

W. Joe Dickinson, Jon Seger

Department of Biology, University of Utah, Salt Lake City, Utah 84112-0840, USA
e-mail: dickinson@bioscience.utah.edu

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