clude that the VSD alone forms the classical voltage-gated proton channel, the founding member of the new H_V channel family (*4*, *5*).

That is a satisfying conclusion. But here is a gentle caution from someone once burned by applying exactly the same criteria—similarity of electrophysiological properties, alteration of functional behavior by mutation, appropriate tissue distribution—to infer that a quirky K^+ channel protein, minK, is identical to a particular K^+ current of human cardiac tissue (*9*). That conclusion was later shown to be wrong: minK is an auxiliary subunit of a conventional K^+ channel (*10*). Nevertheless, the idea of an ion channel formed by a solitary VSD is so chemically intriguing, biologically rich, and aesthetically pleasing that I will refrain from demanding the tight proof normally expected for family founders: functional reconstitution of the purified protein.

With the arrival of the H_V family, I can almost hear the patch-pipettes pulling and PCR tubes popping as biophysicists rush to attack new questions. Why does the channel not have a pore domain? Maybe because protons, unlike metal cations, do not need an aqueous pathway to move through proteins (*3*). Where do the protons go? Probably not along the S4 helix itself, despite the fact that a proton leak can be engineered into a K^+ channel's S4 helix (*11*). How many VSDs associate to form the channel? Two or more, surely, because at least six charges move across the membrane upon opening (*3*). What does the VSD look like? Probably similar to the known structure of an isolated, though nonfunctional, VSD of a K^+ channel (*12*). And how will knocking out this gene affect the health of a mouse?

I reckon that I will be saving the many future papers addressing these questions as PDFs.

References

1. R. C. Thomas, R. W. Meech, *Nature* **299**, 826 (1982).
2. T. E. DeCoursey, *Biophys. J.* **60**, 1243 (1991).
3. T. E. DeCoursey, *Physiol. Rev.* **83**, 475 (2003).
4. M. Sasaki, M. Takagi, Y. Okamura, *Science* **312**, 589 (2006); published online 23 March 2006 (10.1126/science.1122352).
5. L. S. Ramsey, M. M. Moran, J. A. Chong, D. E. Clapham, *Nature*, 10.1038/nature.04700 (22 March 2006).
6. S. B. Long, E. B. Campbell, R. Mackinnon, *Science* **309**, 903 (2005).
7. Y. Murata, H. Iwasaki, M. Sasaki, K. Inaba, Y. Okamura, *Nature* **435**, 1239 (2005).
8. V. V. Cherny, T. E. DeCoursey, *J. Gen. Physiol.* **114**, 819 (1999).
9. S. A. N. Goldstein, C. Miller, *Neuron* **7**, 403 (1991).
10. M. C. Sanguinetti *et al.*, *Nature* **384**, 80 (1996).
11. D. M. Starace, F. Bezanilla, *Nature* **427**, 548 (2004).
12. Y. Jiang *et al.*, *Nature* **423**, 33 (2003).

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PLANETARY SCIENCE

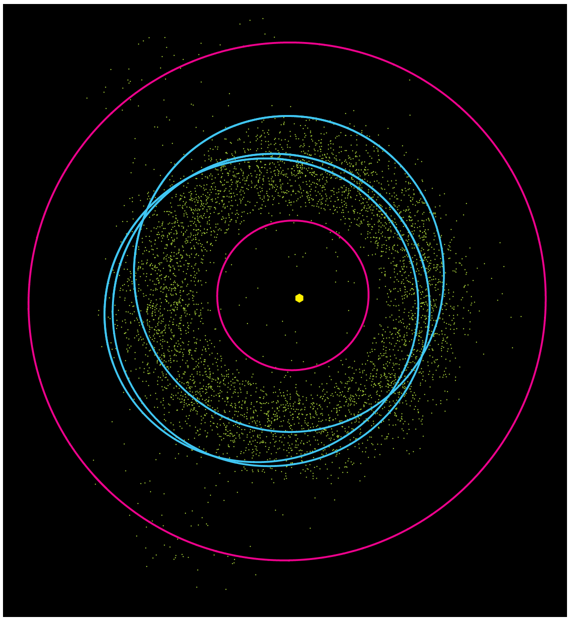
Ice Among the Rocks

Alan Fitzsimmons

Two groups of comets are known: those with orbital periods of hundreds of years or greater, and those with decade-long periods. A third class appears to be orbiting within the asteroid belt.

Astronomers have known for more than two centuries that comets can be split into two groups as defined by their orbits about the Sun. Long-period comets, so named because they have orbital periods of more than 200 years, originate from the Oort Cloud of comets surrounding the Sun and stretching at least 10% of the way to the nearest star (*1*). The second group are known as the Jupiter-family comets, with orbital periods near 20 years, whose dynamical evolution is controlled by gravitational encounters with the giant planet. Theoretical work pinpointed the source of this second group to a comet belt beyond the planet Neptune (*2*–*4*); this was dramatically proven by the discovery of the first such object in 1992 (*5*). Now, in a report on page 561 of this issue, Hsieh and Jewitt (*6*) have issued a shock to the system by demonstrating the existence of a third dynamical class of comets, orbiting much closer to the Sun and lying entirely within the main asteroid belt.

The story starts in 1996 with the discovery that an asteroid first seen 17 years earlier was in fact a comet, henceforth named 133P/Elst-Pizzaro (*7*). Observationally, all but the largest asteroids are optically unresolved and appear as point sources, whereas active comets are recognizable when near the Sun from the surrounding atmosphere of sublimated ices and dust particles. Each year, several objects classified as asteroids but lying in elongated comet-like orbits are found to exhibit a coma and/or tail and hence are reclassified as comets. The surprising fact about 133P/Elst-Pizarro was that its orbit was unlike that of any other comet, as it lay completely within the asteroid belt between Mars and Jupiter. Another comet on a similar orbit was discovered late last year, and Hsieh and Jewitt report finding a third in a dedicated survey for such objects. All three objects are relatively stable against strong gravitational perturbations from Jupiter, which implies that they exist where they formed.



Closer to home. Orbits of the three main-belt comets discussed by Hsieh and Jewitt (blue) and the planets Mars and Jupiter (red). The green points are the first 5000 asteroids numbered, showing the position of the main asteroid belt.

Hsieh and Jewitt show that the detected atmosphere of dust particles cannot be caused by weak processes such as electrostatic levitation, nor can it be the debris cloud from an impact by a smaller body, and hence it must result from the steady sublimation of ices as with other comets. In most walks of life, two is company but three is a crowd, and there is no escaping the recognition that we now have a third dynamical class of active comets identified in the solar system, which Hsieh and Jewitt have labeled main-belt comets.

Like all good discoveries, this throws up a number of questions. Perhaps the most important is how they can exist in the first place. Comets are ephemeral bodies, as each time they pass the Sun they lose a small fraction of their mass via sublimation of the surface ices. For example, the lifetime of Mark Twain's nemesis, Halley's comet, has been estimated as less than 100,000 years (*8*). The comets we see today disappear on these time scales, to be replenished by new comets from the Oort Cloud and the trans-Neptunian reservoirs. But the main-belt comets are still in their source regions, where continuous solar heating would have seen them vanish very soon after formation.

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Hsieh and Jewitt believe that the likely answer for main-belt comets is that they have suffered a small collision in the recent past, which has exposed subsurface ices to solar heating, and that these ices may sublimate on and off for at least several years before exhaustion. This is supported by observations showing that 133P/Elst-Pizarro has been only sporadically active over the past decade (*9*, *10*). Given that last year's spectacular Deep Impact mission (*11*) did not result in a new activity site on a normal Jupiter-family comet, our demonstrable lack of knowledge of how sublimation sites are activated implies that a better estimate of the sublimation lifetime is unlikely in the near future.

It is also unclear how many main-belt comets may exist. Hsieh and Jewitt estimate that there may be as many as 150 currently detectable in this new population, although they caution that true numbers will require a much larger systematic survey. The excitement for planetary scientists is that we now have a new direction in which to study the composition of the solar system. Current theories predict that both Jupiter-family comets and long-period comets formed in the outer solar system beyond Jupiter and were scattered into their present orbits via various gravitational perturbations. The main-belt comets are relatively immune to such effects and should be pretty close to their birthplace. Hence, by studying the ices in these comets, astronomers could look for changes in the ice composition in the protoplanetary disk. This makes main-belt comets a prime target for future space missions, but it may be possible to start such studies using the next generation of optical, infrared, and submillimeter telescopes currently being built or planned.

At the same time, Hsieh and Jewitt note that the outer asteroid belt has been proposed as a source of the water deposited on Earth after the end of the planet-building phase. This work should spur a closer assessment of recent dynamical models predicting delivery of large numbers of objects from this region into near-Earth space (*12*). It is interesting that many astronomers have pursued comets to greater and greater distances in their pursuit of understanding the evolution of comets and the early history of the solar system. All this time, it would have also been worthwhile to look a little closer to home.

References

1. J. H. Oort, *Bull. Astron. Inst. Neth*. **11**, 91 (1950).
2. K. E. Edgeworth, *Mon. Not. R. Astron. Soc*. **109**, 600 (1949).
3. G. P. Kuiper, in *Astrophysics,* J. A. Jynek, Ed. (McGraw-Hill, New York, 1951), p. 357.
4. J. A. Fernandez, *Mon. Not. R. Astron. Soc*. **192**, 481 (1980).
5. D. Jewitt, J. Luu, *Nature* **362**, 730 (1993).
6. H. H. Hsieh, D. Jewitt, *Science* **312**, 561 (2006); published online 23 March 2006 (10.1126/science.1125150).
7. E. W. Elst *et al*., *IAU Circ. 6456* (1996).
8. F. L. Whipple, *Astron. Astrophys*. **187**, 852 (1987).
9. H. H. Hsieh *et al*., *Astron. J*. **127**, 2997 (2004).
10. I. Toth, *Astron. Astrophys*. **446**, 333 (2006).
11. K. J. Meech *et al*., *Science* **310**, 265 (2005); published online 8 September 2005 (10.1126/science.1118978).
12. R. Gomes *et al*., *Nature* **435**, 466 (2005).

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ATMOSPHERE

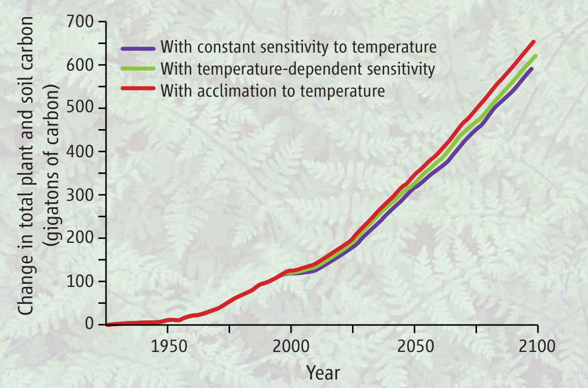
Plant Respiration in a Warmer World

Acclimation of plants to higher temperatures may reduce the extra warming caused by increased plant respiration in a future warmer world.

Anthony W. King, Carla A. Gunderson, Wilfred M. Post, David J. Weston, Stan D. Wullschleger

Plants release carbon dioxide as they metabolize carbon substrates for biosynthesis and maintenance of the biochemical machinery of life (*1*, *2*). This respiratory process globally transfers about 60 gigatons of carbon each year to the atmosphere (*3*). It has been predicted that plant respiration, and leaf respiration in particular, will increase in a future warmer world. But are these predictions consistent with observations from modern experimental studies?

Numerous studies have shown that respiration increases in response to an increase in temperature (*4*, *5*). Higher plant respiration at warmer global temperatures would release more CO_2 to the atmosphere, resulting in lower net ecosystem carbon uptake, even higher atmospheric CO_2 concentrations, and consequently more warming. Incorporating biotic feedbacks like this in coupled climate-carbon models results in an additional increase of simulated mean annual land-surface temperatures of as much as 2.5ºC by 2100 (*6*, *7*).



The effect of respiration. Cumulative change in global total terrestrial biosphere carbon simulated by the GTEC 2.0 model, using different temperature dependencies for leaf respiration. See the supporting online material.

However, many studies have shown that the increase in plant respiration in response to an increase in temperature is a short-term, largely transient response that is observed when plants grown at a controlled temperature are experimentally exposed to warmer temperatures. In the longer term, plant respiration may acclimate to warmer temperatures. Plants experimentally grown at higher temperatures often respire at nearly the same rate as plants grown at cooler temperatures, even though a short-term warming of either set of plants would produce a typical exponential response to temperature (*8*–*10*). In addition, plants from warmer climates often show a much-reduced sensitivity to temperature change when compared to plants from cooler climatic regions (*11*).The biochemical basis for acclimation is not yet known. Mechanistic synthesis, understanding, and modeling are thus problematic, and a mechanistic representation of the acclimation of plant respiration to temperature is generally absent from climate change analyses and carbon cycle models. An increasing number of physiological studies do, however, support the conclusion that the long-term response of respiration to temperature may be quite different from the more commonly measured and short-term response.

Acclimation of respiration to elevated temperatures has clear implications for predictions and expectations of higher plant respiration in a warmer world. For example, reduced sensitivity of respiration to temperature increase could reduce the magnitude of the positive feedback between climate and the carbon cycle in a warming world. Yet, though most coupled

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