vertebrates (Fig. 1c). Moreover, they argue that amphioxus is not a close relative of either vertebrates or tunicates, but is more akin to echinoderms. This conclusion is not nearly as robust as the tunicate–vertebrate link. It does, however, seem to be a persistent feature of the analysis, and is worth careful consideration. After all, the close hemichordate–echinoderm link seemed unorthodox when it was first revived, and few would have expected that the tunicate–vertebrate link would receive such strong support.

So, if lancelets really are close relatives of echinoderms, what are the implications for our picture of deuterostome evolution? The short answer is that the textbook scheme is turned on its head. Rather than the steady acquisition of progressively more chordate-like (and, by implication, human-like) features from an ancestor with nothing much to recommend it, the story becomes one of persistent loss. The last common ancestor of extant deuterostomes would have been a free-living, bilaterally symmetrical creature with a distinct throat region perforated by gill slits, segmented body-wall musculature and possibly a reasonably sophisticated brain and central nervous system. In a sentence, the ancestor would have looked like a cross between an amphioxus and a larger, brainier, tunicate tadpole larva. Crazy? Possibly. But possibly not.

Most modern tunicates seem to be immobile relatives of motile ancestors, but some, such as the appendicularian tunicate *Oikopleura*, do move about. So in this group the proposed ancestral deuterostome portrait has not so much been erased as extensively modified by changes in the evolution of tunicate development. Fossil evidence fills in more details, with the discovery of the strange Cambrian vetulicolians[5], which look strikingly like the hypothetical ancestral deuterostome form — and, like the 'somatico-visceral animal', a model for a chordate ancestor described in one of the last and most prescient papers by the late great palaeontologist A. S. Romer[6].

Echinoderms have lost all these features to the extent that the ancestral portrait cannot be recognized at all in modern forms. However, some members of a group of fossil echinoderms called stylophora may have had gill slits (an interpretation made more likely by the reaffirmed hemichordate–echinoderm link) and, according to R. P. S. Jefferies' controversial calcichordate theory, an internal organization similar to that of tunicates[7]. Jefferies proposes that each kind of stylophoran should rather be assigned to the groups containing modern tunicates, vertebrates or cephalochordates, respectively, and that the characteristic echinoderm calcite skeleton has been lost in each case. However, a simpler alternative is that the calcite skeleton was acquired just once in the ancestry of echinoderms, when this creature still looked much like the proposed deuterostome ancestor. The irony is that even with this shift in perspective, many of Jefferies' detailed anatomical interpretations of stylophoran anatomy, particularly as regards the anatomy of the pharynx[8], could still be correct (but see ref. 9).

Much remains to be found. As Delsuc *et al.*[1] acknowledge, adequate tests of these ideas require the sequenced genomes of hemichordates, of more echinoderms and — especially — of amphioxus. This last is particularly important: for generations, amphioxus has been viewed as a model organism, representing a picture of the first stirrings of vertebrate evolution. But if this radical and certainly controversial new view is supported by further evidence, amphioxus could occupy a far more significant and inclusive position — the closest extant organism we yet have to the ancestor of all deuterostomes. ■

Henry Gee is a senior editor at *Nature*.


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PLANETARY SCIENCE

# Pluto's expanding brood

Richard P. Binzel

**Pluto is no lone ranger in the farthest expanses of the Solar System — its travelling companions now number three. And if Pluto can have so many, why shouldn't other objects in the distant, icy Kuiper belt?**

Once thought to be a solitary denizen of the outer reaches of the Solar System, Pluto — which piqued our curiosity in 1978 with the discovery of its large satellite, Charon[1] — is becoming ever more intriguing. In fact, the relative sizes of Pluto and Charon (Charon's diameter of around 1,200 kilometres is just over half that of Pluto's) means they are a 'double planet', orbiting a mutual centre of gravity, or barycentre, outside the surface of Pluto. But the story does not stop there. On page 943 of this issue, Weaver *et al.*[2] present Hubble Space Telescope images showing that the Pluto system is at least quadruple. And as Stern *et al.* indicate in a companion paper[3] on page 946, this complexity portends further discoveries: more small satellites may be lurking out there, and cratering impacts on them may have liberated rings or arcs of matter. Propitiously, NASA's New Horizons mission[4,5] is now successfully launched (Fig. 1) and on its way to a flying visit to Pluto and its companions in 2015.

Following Clyde Tombaugh's discovery of Pluto in 1930, searching for satellites was an obvious first task. But none was found until Pluto's march towards its point of closest approach to the Sun, coupled with the exquisite optics of a ground-based telescope, finally allowed Charon to be pinpointed[1]. Since then, ground-based surveys[6,7] have yielded

NASA

**Figure 1 | Destination Pluto.** The New Horizons spacecraft took off from Cape Canaveral on 19 January 2006 aboard an Atlas V rocket, bound for the Pluto system. Speedy results are not to be expected: the half-tonne, piano-sized spacecraft must cover a distance of just under five billion kilometres, and will reach a point of closest approach some 10,000 kilometres from Pluto on 14 July 2015.

NASA/ESA/HST

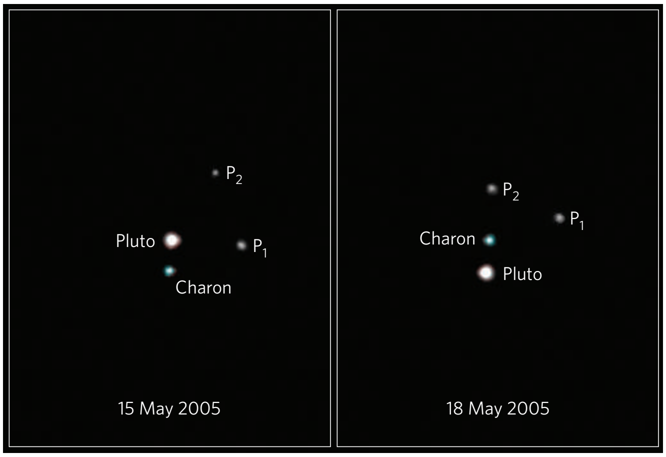


**Figure 2 | A remote quartet.** Two Hubble Space Telescope images of the Pluto system taken three days apart, revealing the existence of two smaller satellites, P1 and P2, in addition to Charon (discovered in 1978). P1 is the farther of the two newcomers from the system's centre of gravity, which lies just above the surface of Pluto. It completes just one orbit for every six of Charon's; P2 completes about one-and-a-half in the same time.

no evidence for other satellites larger than about 160 kilometres in diameter. Motivated by the impending launch of New Horizons, Weaver and colleagues[2] secured Hubble Space Telescope time in May 2005 to search for satellites as small as around 25 kilometres across[8]. Sure enough, two objects were found travelling through space with Pluto that had motions consistent with orbits around the Pluto–Charon barycentre (Fig. 2).

This discovery[2] prompted a fresh look at Hubble images from 2002 taken to map Pluto's surface. Although these images were not optimized for the identification of satellites, when preliminary orbital calculations gleaned from the 2005 images were added in, the presence of two additional companions was confirmed. The diameters of the satellites, creatively dubbed 'P1' and 'P2' (they will receive their official names later this year), are respectively around 60 and 50 kilometres, assuming surface reflectivities similar to that of Charon. (They are larger if their reflectivities are lower.)

Satisfying as discovery for discovery's sake is, it is the intriguing orbits of the newly spotted satellites that is creating the most scientific excitement. The present, limited data show that P1 and P2 are in circular orbits in the same plane as Charon. Moreover, the radii of their orbits place them in a resonant dance with Charon: for every twelve orbits Charon makes, P1 completes almost exactly two; in the same time, P2 (which is closer in) completes nearly three. Such consonance is not likely if P1 and P2 are captured objects that just happened, once upon a time, to have ventured too close to Pluto: tidal forces from Pluto and Charon are not great enough to coerce captured objects into co-planar resonances over the age of the Solar System[3]. The most plausible explanation is that Charon, P1 and P2 are all Pluto's progeny, and split off from it through a giant impact[3,9]. The disk of material ejected by this collision into orbit around Pluto allowed these satellites — and perhaps others yet unseen — to condense in co-planar, circular orbits[3]. The resonant niches occupied by P1 and P2 may have been particularly fertile locations for coalescing material, or for maintaining long-term orbital stability.

As Stern and colleagues point out[3], implications abound for Pluto's brethren in the Kuiper belt, the disk-shaped region of small, icy bodies found outside the orbit of Neptune. Within current detection limits, up to a fifth of all Kuiper-belt objects seem to have satellites or to be part of a binary system[10]. Pluto is the first known quadruple system, but multiple companions may be just the tip of the iceberg for the complexities of gravity's play on small bodies far from the perturbative forces of the Sun and giant planets. For example, most ejected debris from cratering impacts on P1 and P2 can easily escape the satellites' surfaces, but not the gravitational hold of the Pluto system. So tenuous rings or ring arcs may be the rule, rather than the exception, for Pluto and other multiple-bodied congregations in the Kuiper belt[3]. Even quadruple systems may become *passé* as investigations become increasingly percipient.

Those planning NASA's New Horizons mission, now en route first to a gravity assist from Jupiter in February 2007 and then its July 2015 appointment with Pluto, are now adding to their to-do list highly resolved imaging and spectroscopy of the newly discovered satellites. Refining these satellites' sizes and their orbital positions in nine years' time will also be a priority for observations to follow those currently being reported[2]. Both on its way in and out of the Pluto system, New Horizons' instruments will canvass the orbit plane for more satellites, rings and other telltale signs that might reveal the origin and evolution of this close-knit family. Pluto is a lonely place no more. ■

Richard P. Binzel is in the Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA.
e-mail: rpb@mit.edu

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# 50 & 100 YEARS AGO

## 50 YEARS AGO

In his Stephen Paget Memorial Lecture, "Humanity's Rising Debt to Medical Research",...Sir Henry Dale referred to the convincing evidence of the success of inoculation against diphtheria... Systematic inoculation began in Hamilton, Ontario, in 1925, and the death-rate from diphtheria fell so steeply that after 1930 there were no more deaths and after 1933 no more cases. In Great Britain a full-scale preventive inoculation campaign was not inaugurated by the Ministry of Health until 1940 and was not fully under way until 1942. In 1940 there were still in England more than 45,000 cases of diphtheria, and more than 2,400 of these were fatal. As inoculation became effective, in spite of a counter-campaign, the numbers fell steeply and steadily until in 1954 there were only 173 cases; of the nine deaths, six were in children less than fifteen years old, and all in the minority who had not been inoculated.

From *Nature* 25 February 1956.

## 100 YEARS AGO

The traditional scientific man has disappeared almost as completely as the traditional Yankee of the stage. The change came gradually, but the proof that it had come was brought before us suddenly. In 1902 there was called in New York a meeting of those who were designated by the picturesque expression captains of industry. To that meeting representatives of science were invited, not as lions to be stared at, but to sit with the leaders of the industrial and commercial world as representatives of science, and not only of applied science, but of pure science. As the captains of industry were supposed to be men of force in organising and to have a keen insight into men and things, we had a right to feel that science had been honoured, perhaps not more than ever before, but for a reason for which it had not been honoured before in the United States... The conception of a scientific man as a captain of industry means simply the acknowledgement that science has a practical relation to the world.

From *Nature* 22 February 1906.