d level and that the conductance should be a universal function of T/T_K.

Experimental data should, however, not be expected to show perfect quantitative agreement with predictions based on the AM, because the latter, having only one localized level, is too simple to fully capture the properties of a real QD, which has many levels. Rather, the challenge now is to extend our understanding of Anderson-type models in novel directions.

Recent and ongoing research investigates nonequilibrium effects due to finite bias voltage, time-dependent effects due to an AC driving field or sudden changes in system parameters, phase-coherent transport through a tunable Kondo impurity, the effect of additional levels in the QD, two or more coupled Kondo QDs, and more exotic Kondo effects that can arise, for example, when two orbital levels are tuned to be degenerate using a magnetic field.

For the first time in years, experiment is ahead of theory on several of these fronts, which not long ago were inaccessible to experiment. The field has been reinvigorated by the advent of artificial, tunable Kondo impurities. Stay tuned!

References

1. A. C. Hewson, *The Kondo Problem to Heavy Fermions* (Cambridge Univ. Press, Cambridge, 1993).
2. D. Goldhaber-Gordon *et al.*, *Nature* **391**, 156 (1998).
3. D. Goldhaber-Gordon *et al.*, *Phys. Rev. Lett.* **81**, 5225 (1998).
4. S. M. Cronenwett, T. H. Oosterkamp, L. Kouwenhoven, *Science* **281**, 540 (1998).
5. J. Schmid *et al.*, *Physica B* **256**, 182 (1998).
6. F. Simmel *et al.*, *Phys. Rev. Lett.* **83**, 804 (1999).
7. W. G. van der Wiel *et al.*, *Science* **289**, 2105 (2000).
8. L. I. Glazman and M. E. Raikh, *JETP Lett.* **47**, 452 (1988).
9. T. K. Ng and P. A. Lee, *Phys. Rev. Lett.* **61**, 1768 (1988).
10. Y. Meir, N. S. Wingreen, P. A. Lee, *Phys. Rev. Lett.* **66**, 3048 (1991).
11. ______, *Phys. Rev. Lett.* **70**, 2601 (1993).

PERSPECTIVES: PLANETARY SCIENCE

Asteroids Come of Age

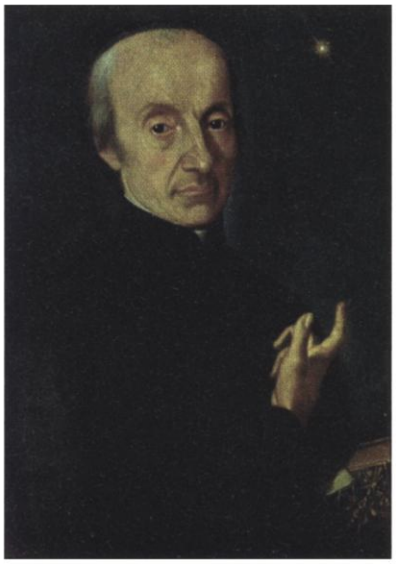
Richard P. Binzel

Just a few months shy of the bicentennial of the discovery of the first asteroid, four reports in this issue on pages 2088, 2085, 2101, and 2097 (*1*) present results from the first ever rendezvous mission with an asteroid. No longer just "star-like" points in the sky, asteroids have become the focus of dedicated geological and geophysical studies aimed at gaining insights into planetary formation and addressing practical concerns for the long-term safety of our planet. These studies are yielding new links to meteorites and planetary origins.

At the dawn of the 19th century, a Hungarian baron, Franz von Zach, was organizing a group of "Celestial Police" astronomers to search the sky for the "missing planet" predicted to exist between Mars and Jupiter by the Titius-Bode relationship for planetary distances (*2*). Meanwhile, an Italian monk in Palermo, Giuseppe Piazzi (see the figure, this page), was systematically revising an existing star catalog when on 1 January 1801 he came upon an object that "might be something better than a comet" (*3*) moving slowly north and west in the evening sky. Astronomers, aided by the eminent mathematician Karl Friedrich Gauss, calculated an orbit for the new object, named Ceres (*4*), and showed that it fit the location for von Zach's planet. Surprise and dismay greeted the discovery of a second object, Pallas, in 1802, followed by Juno (1804) and Vesta (1807), leading astronomers to conclude that the "missing planet" was in pieces. On the basis of "star-like" telescopic appearance, William Herschel coined the term "asteroids" for these newest members of the solar system.

One century after their discovery, astronomers generally considered asteroids the "vermin of the sky," because their trails on photographic plates exposed for studying nebulae were a nuisance. Tracking them required laborious manual computing of their orbits and ephemerides (*5*). Yet insights into their nature were emerging. In 1867, the American astronomer Daniel Kirkwood noted gaps in asteroid orbital distances from the sun that corresponded to the locations of jovian resonances (*6*), presaging our current understanding that Jupiter's gravity was responsible for interrupting the formation of a sizable planet. Kiyotsugu Hirayama's realization in 1918 that many asteroids orbit together as "families" formed by the catastrophic breakup of larger parent bodies uncovered the role of collisions for controlling their sizes, shapes, spins, and surfaces.

The rising tide of planetary science in the 1960s and 1970s (*7*) brought an as yet unending wave of telescopic measurements that revealed the diversity of asteroids. For example, Ceres has a low albedo and colors matching primitive (unheated) carbonaceous chondrite meteorites, whereas its sister Vesta shows a bright variegated surface covered by lava flows, indicating a history of substantial heating with a compelling link to basaltic meteorites (*8*). A majority of asteroids hold the middle ground. These "S-class" asteroids display albedos and spectral colors that resemble the most common meteorites, the gently heated ordinary chondrites. This link is appealing, but not all pieces fit the puzzle (*9*): S-class asteroids display redder overall colors and subdued spectral absorption bands compared with their would-be meteorite mates. If S-class asteroids could be shown to match ordinary chondrites, this would place a wealth of laboratory data on meteorite chemistry and chronology into a planetary formation context (*10*).



Happy 200th birthday. Giuseppe Piazzi (1746–1826) inaugurated the 19th century with the discovery of the first asteroid, Ceres, on 1 January 1801.

CREDIT: OSSERVATORIO ASTRONOMICO DI PALERMO G.S. VAIANA

Heightening appreciation of asteroids and their meteorite manna as solar system building blocks turned the 1990s into a renaissance age. The first asteroid flybys courtesy of the Galileo Jupiter mission provided the first detailed look at their cratered and somewhat splotchy landscapes (*11*). Meanwhile, Hubble Space Telescope observations (*12*) and advances in ground-based planetary radar imaging (*13*) are providing a continuing series of views of their sometimes bizarre configurations.

The newfound respect for asteroids was won in large measure through the work of the late astrogeologist Eugene Shoemaker. When NASA moved toward focused low-cost missions, a near-Earth asteroid rendezvous (NEAR) mission was the first selection within the Discovery program. The target of the NEAR-Shoemaker mission is

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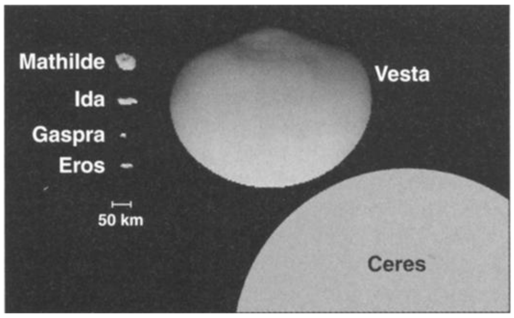
the 34-km-long asteroid cataloged as 433 Eros (see the figure, this page) (*14*). Now entering the second half of its year-long assignation, NEAR is returning a bounty of information about the asteroid's surface morphology, composition, topography, and internal structure (*1*). Eros is likely a fragment of a once larger parent; the collision that spawned Eros may have set its course for the inner solar system. Why Eros lacks small craters, why it has a remarkably uniform color, and how it maintains a seemingly homogeneous but porous interior remain to be resolved.



Off to asteroid worlds. A growing album of small asteroids have now been encountered by spacecraft (**left**). All of them are likely collision fragments from once larger parent bodies. The largest asteroids, such as the 900-km Ceres and 500-km Vesta (**right**), are sizable enough to be direct protoplanetary survivors that can give clues about the solar system's beginnings. These worlds are premier targets for exploring our planetary origins.

NEAR's long-term residence at Eros also provides the opportunity for performing the first ever in situ elemental abundance analysis of an S-class asteroid. Early results from the x-ray spectrometer reveal elemental ratios that are forging the first direct link between S asteroids and their long suspected ordinary chondrite analogs. These findings come at a time when other spacecraft (*15*), telescopic (*16*), and laboratory (*17, 18*) research has increasingly attributed the subtle reddening of spectral slopes and the muting of absorption bands for ordinary chondrite materials to a "space weathering" process. Confirmation awaits results from the complementary gamma-ray spectrometer, and many details of the space weathering mechanism and time scale remain to be worked out, but NEAR may be close to completing a long chapter on asteroid-meteorite relationships.

As asteroids start their third century, they are emerging from the astronomical realm into the domain of geology and geophysics. Key objectives for asteroid science will be to establish even stronger ties to the origin and geologic context of our meteorite samples and to probe farther back to the earliest stages of protoplanet formation and evolution.

References and Notes

1. J. Veverka *et al.*, *Science* **289**, 2088 (2000); D. K. Yeomans *et al.*, *Science* **289**, 2085 (2000); J. I. Trombka *et al.*, *Science* **289**, 2101 (2000); M. T. Zuber *et al.*, *Science* **289**, 2097 (2000).
2. A numerical relationship found by Johann Titius and popularized by Johann Bode in 1772 gives approximate distances to the planets as measured in astronomical units (AU). One AU is the average Earth-sun distance equal to 1.496×10^8 km. The sequence is $0.4 + 0, 0.3 \times 2^n$, where n = 0, 1, 2, 3, 4, 5, and 6, yielding 0.4, 0.7, 1.0, 1.6, 2.8, 5.2, 10.0, and 19.6 for Mercury through Uranus, with no 18th century planet known at 2.8 AU.
3. Letter from Piazzi to Barnaba Oriani in Milan, dated 24 January 1801. Modern historical account given by C. J. Cunningham, *Introduction to Asteroids* (Willmann-Bell, Richmond, VA, 1988).
4. Ceres was the Roman goddess of harvests.
5. An ephemeris (plural: ephemerides) is a table listing specific data for a moving object as a function of time. Ephemerides usually contain right ascension and declination, apparent angle of elongation from the sun, and brightness of the object; other quantities frequently included are the object's distances from the sun and Earth, phase angle, and moon phase.
6. Two planetary objects are in resonance if the ratio of their orbital periods can be expressed by integers. For example, the Kirkwood gap at 2.5 AU corresponds to the location where an object orbits the sun exactly three times faster than Jupiter, giving the integer ratio 3:1.
7. D. J. Stevenson, *Science* **287**, 997 (2000).
8. R. P. Binzel and S. Xu, *Science* **260**, 186 (1993).
9. R. A. Kerr, *Science* **247**, 527 (1990).
10. J. F. Kerridge and M. S. Mathews, Eds., *Meteorites and the Early Solar System* (Univ. Arizona Press, Tucson, AZ, 1998).
11. M. J. S. Belton *et al.*, *Science* **257**, 1647 (1992); M. J. S. Belton *et al.*, *Icarus* **120**, 1 (1996). NEAR also made a flyby of the asteroid 253 Mathilde [J. Veverka *et al.*, *Icarus* **140**, 3 (1999)].
12. P. C. Thomas *et al.*, *Science* **277**, 1492 (1997).
13. S. J. Ostro *et al.*, *Science* **288**, 836 (2000).
14. Eros was the Greek god of love, counterpart to the Roman Cupid.
15. C. R. Chapman, *Meteorit. Planet. Sci.* **31**, 699 (1996).
16. R. P. Binzel, S. J. Bus, T. H. Burbine, J. Sunshine, *Science* **273**, 946 (1996).
17. M. Yamada *et al.*, *Earth Planets Space* **51**, 1255 (1999).
18. C. M. Pieters *et al.*, *Meteorit. Planet. Sci.* **35**, 1101 (2000).

PERSPECTIVES: BIOMEDICINE

Staying Slim with Insulin in Mind

Michael W. Schwartz

When Banting and Best first administered insulin to patients with uncontrolled diabetes, they established its crucial importance in the regulation of blood glucose concentration. Secreted by the β-islet cells of the endocrine pancreas, insulin exerts its glucose-lowering effects by stimulating glucose uptake in tissues such as skeletal muscle, suppressing fatty acid release from adipose (fat) tissue, and inhibiting production of glucose by the liver (see the figure). Muscle, liver, and fat, therefore, are widely viewed as the principal "insulin-sensitive" tissues in the body. The brain, in contrast, has historically been considered "insulin-insensitive" because its ability to use glucose does not require insulin. Therefore, the notion that insulin participates in the central nervous system (CNS) control of food intake and body weight was received with a good deal of skepticism when it was first proposed by Woods and Porte more than 20 years ago (*1*). Since then, however, support for this hypothesis has steadily accumulated, including the demonstration that insulin is transported across the blood-brain barrier, that it is effective in suppressing food intake when given directly into the brain, and that insulin receptors are concentrated in brain areas involved in energy homeostasis (*2*). Now, Brüning and colleagues (*3*) provide important evidence to support this hypothesis with their report on page 2122 of this issue. They show that mice lacking insulin receptors in the brain have an increased body fat content (adiposity), demonstrating that insulin signaling in the brain is essential for normal regulation of adiposity.

Enhanced online at www.sciencemag.org/cgi/content/full/289/5487/2066

The hypothesis that body fat stores are subject to negative-feedback regulation was formally introduced by Kennedy in 1953 (*4*). He proposed that humoral signals, generated in proportion to body fat stores, act in the brain to lower food intake and body weight. Hence, weight loss induced, for example, by restricting food intake was suggested to decrease circulating "adiposity signals" and thereby to increase the drive to eat until the deficit in body adiposity is corrected. To qualify as an adiposity signal, candidate molecules should circulate and traverse the blood-brain barrier at levels proportionate to body fat content. Within the brain, they should influence the activity of key neurons to promote anorexia and weight loss, and a deficiency of such signals should stimulate feeding behavior. Insulin was the only known molecule to meet these criteria until the discovery in 1994 of leptin (*5*), a hormone secreted by fat cells (adipocytes)

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