# To probe a core

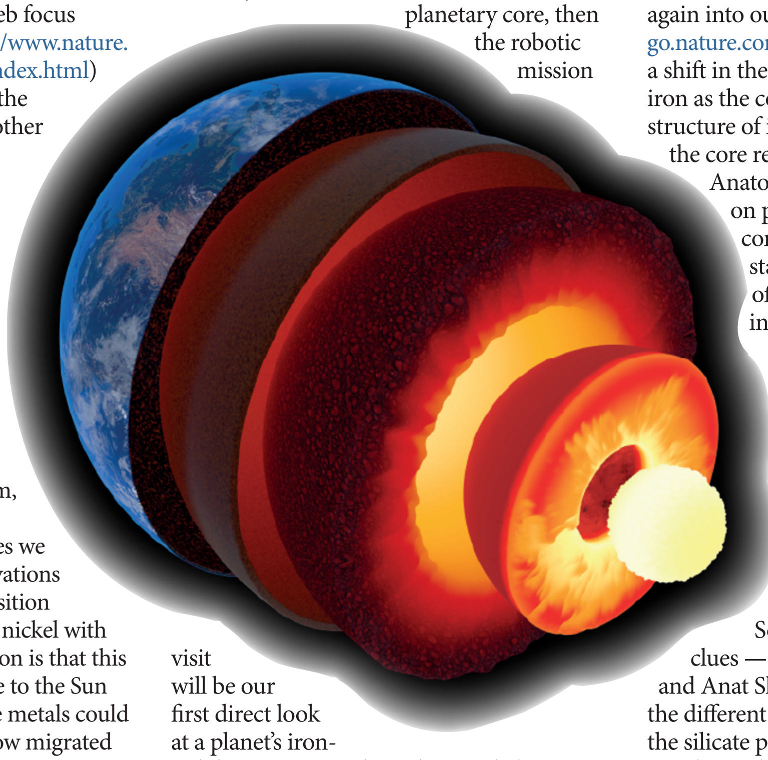
Hidden under many kilometres of silicate mantle material, the cores of Earth and other planets are hard to investigate. The Psyche spacecraft, designed to visit a metal body that may be a core stripped of its mantle, could bring a close-up view.

The make-up and properties of the centre of our planet remain a mystery. As there is no way of accessing core material directly, we only have circumstantial information such as geophysical measurements of seismic wave velocities, first-principles calculations, and laboratory experiments under conditions thought to resemble those in the core. The Psyche mission, scheduled for lift-off in 2023, is set to complement these insights. Its target, a strange metal world in the asteroid belt, is thought to be an exposed core of an early planet and could yield direct observations of planetary core material. A web focus published with this issue (http://www.nature.com/ngeo/focus/core-science/index.html) discusses what we know about the Earth's interior and that of the other terrestrial planets, and why the core is key to understanding the formation and evolution of many bodies in our Solar System.

In January, NASA announced that the Psyche mission had survived the cut for the next class of spacecraft. Psyche is currently scheduled to arrive at its target — an asteroid of the same name — in 2030. With a diameter of about 200 km, the asteroid Psyche is seemingly unique amongst planetary bodies we have surveyed. Telescope observations have revealed its surface composition to be extremely rich in iron and nickel with very little silicate. One explanation is that this metal-rich asteroid formed close to the Sun where it was so hot that only the metals could condense, before it then somehow migrated outward to the asteroid belt. But based on what we know from telescopes observations, Psyche seems intriguingly similar to the iron- and nickel-rich cores of Earth and the other terrestrial planets. These comparisons suggest that it too could be a planetary core.

The early Solar System was violent and large collisions between growing planetesimals frequent. Such collisions eventually led to the accretion of the planets. But not all collisions lead to perfect accretion. For example, in some impacts the outer part of a planetesimal can be stripped away by the impactor, rather that the two bodies combining. Such a so-called hit-and-run collision has been proposed to explain why the planet Mercury has a relatively large core for a planet of its size (http://go.nature.com/2nvjFvN), and the same explanation has been suggested for Psyche. But whereas Mercury lost only some of its silicate mantle, the differentiated planetesimal that formed Psyche is believed to have been stripped of its mantle completely by impacts, leaving behind a naked core.

If Psyche is indeed the remnant of a planetary core, then the robotic mission visit will be our first direct look at a planet's iron-rich heart. Previously we have only been able to directly analyse the silicate portions of planets. For inferences about the core, we have had to rely on observations of the propagation of seismic waves, compared against mineral physics experiments and calculations and geodynamical simulations.



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These endeavours have both delivered important insights and opened more questions. They have revealed constraints on core composition. Density estimates indicate the presence of a lighter element in Earth's core, along with its main constituent, iron. For example, the alloying of iron with carbon may explain the core's observed elastic properties (http://go.nature.com/2mQlznN), and partitioning experiments continue to yield information about how readily the different candidate light elements may have been incorporated into the core during core formation.

The core's internal structure is another focus of research. It is well established that the core has a liquid outer layer and a solid inner layer, but seismic data indicate that the inner core can be subdivided yet again into outer and inner zones (http://go.nature.com/2mQIzTL), perhaps reflecting a shift in the crystallographic structure of iron as the core grew. The crystallographic structure of iron in the inner portion of the core remains an open debate, but Anatoly B. Belonoshko *et al.* show on page 312 that there is new computational support for the stability of a cubic structure of iron minerals under inner-core conditions.

Despite these advances, outstanding questions remain about the composition of the Earth's core, how and when it formed, and how it operates today (http://go.nature.com/2maftBH) — including in the generation and longevity of the geodynamo that generates Earth's magnetic field. Our Solar System neighbours lend clues — for example, Stephen M. Elardo and Anat Shahar argue on page 317 that the different iron isotope compositions of the silicate portions of planetary bodies may be explained by differing conditions of core formation inducing different degrees of isotopic fractionation. Understanding the interiors and interior evolution of other differentiated planetary bodies may tell us how Earth's interior ended up like it is today.

Psyche may look like an oddball, but probing the hearts of planets is a long-running avenue of research in the Earth and planetary sciences. We look forward to what the Psyche mission will tell us about core formation in differentiated bodies and early terrestrial planet formation. ❐