Questions and Answers

How are the sizes, temperatures, and compositions of planetary cores determined?
—S. O'Rourke,
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Determining the size, temperature, and composition of any planetary interior is, obviously, a challenging process—it's impossible to drill to core depths to take direct samples or measurements. Therefore, these characteristics must be determined using indirect methods.

The best approach to studying the physical properties of Earth's core is to measure seismic waves. These waves, generated predominantly by earthquakes, move at differing rates through various materials. By recording lots of seismic events and then cross-correlating the planet's seismic response at various depths, it is possible to build models that accurately demarcate the boundary between Earth's liquid metal core and its solid silicate mantle. These models show, for instance, that the core-mantle boundary is located about halfway to our planet's center. They also indicate that Earth's core appears to be consistent with the seismic properties of iron (with some lighter materials mixed in).

However, we have no operational seismometers on other planets at the present time. To estimate the interior structures of other planets, we must make inferences based on a planet's mass, size, and moment of inertia. The moment of inertia is a measure of how a body's mass is spatially distributed: the closer a body's mass is located to its rotation axis, the lower the moment of inertia. For example, if an ice skater (such as Brian Boitano) is in a spin, he would minimize his moment of inertia by pulling his arms in close to his sides. From measurements of mass and size, we can determine a planet's mean density. If the mean density of a terrestrial planet is far greater than that of typical mantle materials, we know that even denser materials exist in the planet's interior.

To determine how a planet's mass is distributed throughout its interior, we use estimates of its moment of inertia. These estimates are typically generated from measurements of perturbations in a planet's rotation, such as precession or libration (variations in the location of the planet's rotation axis—like the wobble of a spinning top). Such measurements are far more difficult to make than measurements of total mass or planetary radius but are necessary to characterize the planet's interior. For example, on Earth the moment of inertia is relatively low, indicating that high-density material is located near the planet's center. This makes sense: we know from seismology that Earth has a sizable metallic core.

It's not until we combine measurements of mass, size, and moment of inertia that we can build models of a planet's interior. In these models, we can vary the location of the core-mantle boundary and the densities (and, therefore, compositions) of the core and mantle materials. We are then able to map out the range of possible planetary interiors that reasonably support the measurements.

When it comes to estimating interior temperatures, we rely on other planetary attributes. These can include surface geology, measurements of heat flux, cratering dynamics, and planetary magnetic field generation, to name a few. Each of these can provide important constraints on the planet's interior.

Using such constraints, we build models of a planet's interior thermal state and its thermal evolution. Interior temperatures result from a balance between heat generation and heat loss. Planets are cold at their surfaces, where they radiate heat away to space, and then become hotter at increasing depths due to thermal blanketing and compressional effects from overlying material. In addition, long-lived radioactive elements in the mantle or core can strongly affect a planet's thermal evolution.

One goal of NASA's upcoming *MESSENGER* mission to Mercury is to provide detailed information about the size, temperature, and composition of that planet's core. *MESSENGER* will make precise measurements of Mercury's rotational properties and its magnetic field. With these findings, scientists will attempt to determine whether Mercury's large metallic core is still partially liquefied and whether the core hosts an active magnetic dynamo. Such information will provide tighter constraints for future models of Mercury's interior composition, temperature, and thermal evolution.

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A few dozen Moon and Mars meteorites have been found on Earth. Have any been found from Venus, Mercury, or any moons other than our own?
—William Laub,
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There are currently no known meteorites from Venus, Mercury, or moons of other planets. The working hypothesis for the class of meteorites known as *eucrites* is that they came from the asteroid Vesta. That hypothesis seems reasonable because eucrites are volcanic rocks, and it takes a large body, at least the size of Vesta (530 kilometers, or 330 miles, in diameter), to support volcanism. There is also some similarity in the spectral