# 4

# Mercury's size, mass, and density

## 4.1 MERCURY'S SIZE

Mercury is the smallest planet in the Solar System (4878 km diameter). Even three outer planet satellites are equal to or larger than Mercury – Callisto (4818 km diameter) is a satellite of Jupiter and almost the same size as Mercury, Ganymede (another satellite of Jupiter) at 5,468 km diameter is significantly larger and the Saturnian satellite Titan (5,150 km diameter) is also larger. Mercury is only 4,878 km in diameter, or about one-third the diameter of Earth (Figure 4.1). Its volume is only about 6% that of the Earth, so it would take almost 18 Mercurys to make one Earth (Figure 4.2).

## 4.2 MASS AND SURFACE GRAVITY

Although Mercury is small, it is very massive for its size ($3.3 \times 10^{23}$ kg). Therefore, Mercury has almost the same surface gravity as the larger planet Mars. A planet's surface gravity is a measure of how fast an object is accelerated by its gravity, and is usually measured in $cm/sec^2$. On Earth, a dropped object will increase its speed by 980 cm/sec per second. The amount by which an object accelerates is determined by the mass and radius of the planet. Although Mercury is 30% smaller than Mars, the combination of its large mass and small size results in a similar surface gravity (370 $cm/sec^2$). For the same reason, Mercury's gravity field is more than twice as great as the Moon's, although its size is only 40% larger. Because it contains so much mass in relation to its size Mercury possesses an unusually high density, only slightly exceeded by the density of Earth.

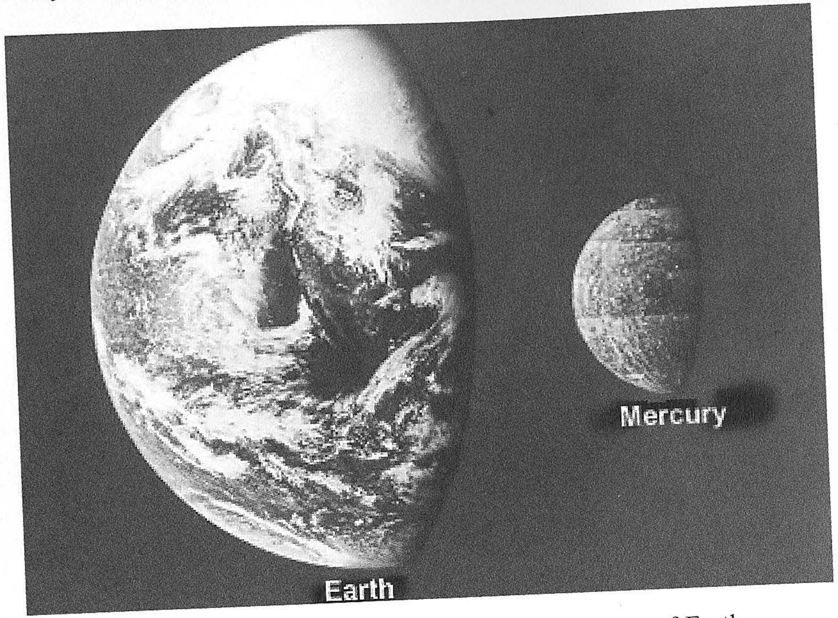


**Figure 4.1.** Mercury is about one-third the diameter of Earth.

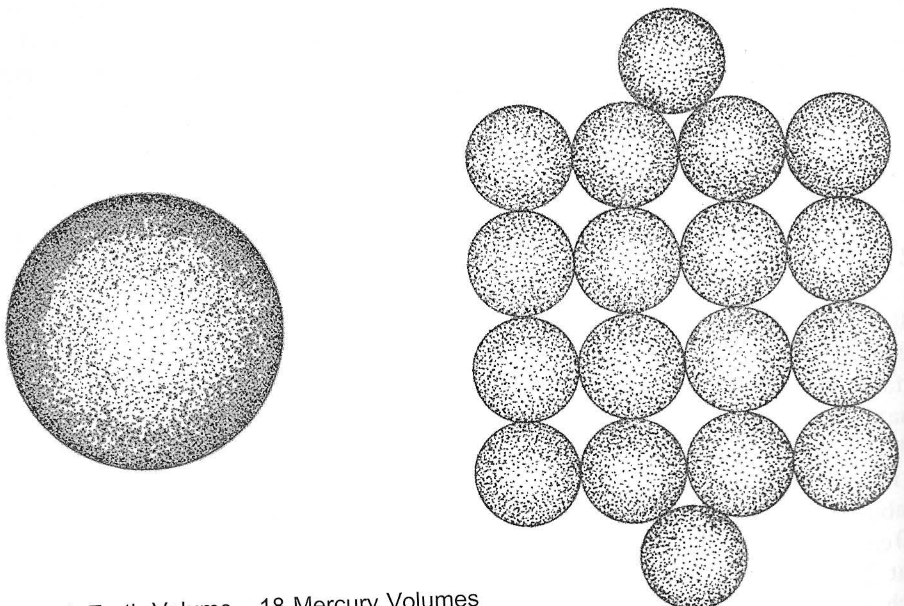


**Figure 4.2.** It would take about 18 Mercurys to equal the volume of Earth (from Strom, 1987).



## 4.3 DENSITY

The density of a planet or satellite reveals something about its gross composition and internal constitution. Density is determined by dividing the mass by the volume. It indicates how much mass is contained in a unit of volume. Density is measured in $g/cm^3$ or $kg/m^3$. We will use $g/cm^3$ throughout this book.

### 4.3.1 What are the important issues relating to density?

Planets and satellites are composed of material made up of elements with different atomic masses. Iron is a heavy element with a large atomic mass, while hydrogen and oxygen are relatively light elements with small atomic masses. Therefore, a cubic centimeter of iron has a much greater density than a cubic centimeter of water; iron has a density of $7\,g/cm^3$, and water has a density of $1\,g/cm^3$ (Figure 4.4). Igneous rocks are composed of various silicate and oxide minerals. They have densities ranging from about 2.6 to $3.3\,g/cm^3$ depending on their composition. For example, the Hawaiian Islands are composed mostly of a volcanic rock called basalt that is rich in minerals containing iron. Basalt, therefore, has a relatively high density of about $3.0\,g/cm^3$. Granite, on the other hand, is poor in iron-bearing minerals and thus has a relatively low density of about $2.7\,g/cm^3$.

Density can be increased by applying pressure. As a substance is compressed, the atoms of that substance are forced into a smaller volume, and the density increases (Figure 4.3). For instance, a cubic centimeter of basalt compressed to half its volume

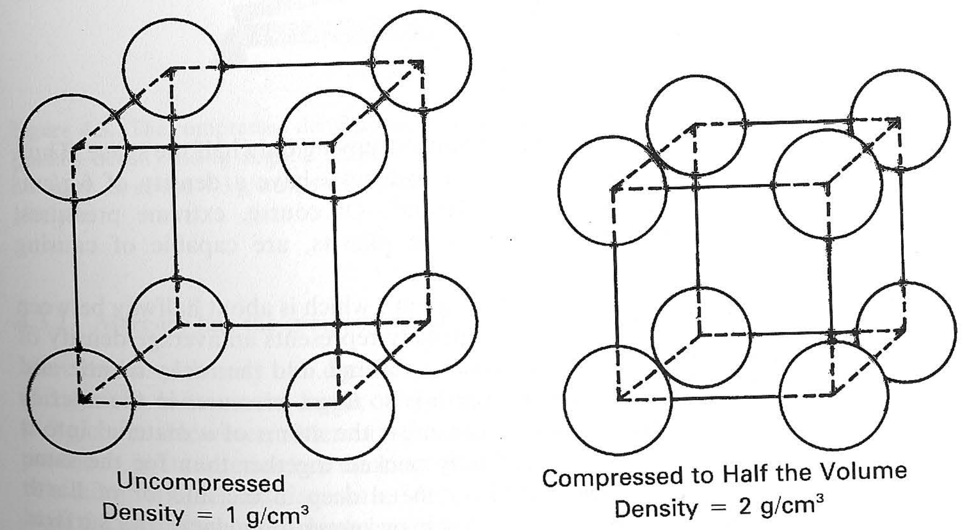


**Figure 4.3.** A large amount of pressure can cause the density of a substance to increase. If a material is compressed to half its volume, it will still have the same mass but its density will be twice that of its original uncompressed state (from Strom, 1987).

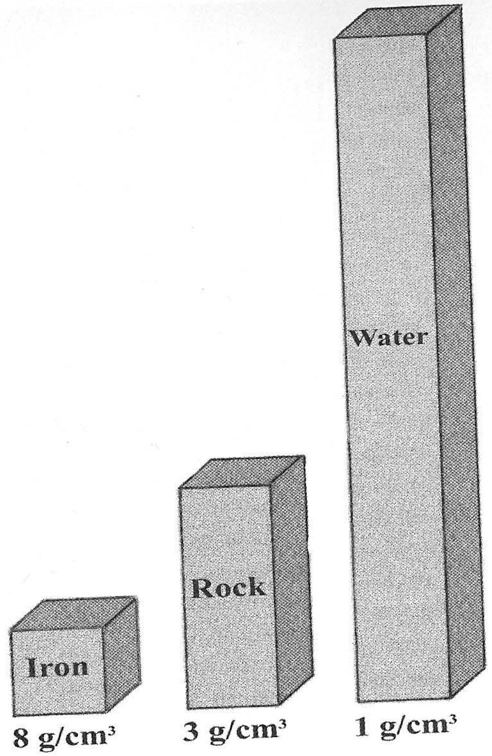


**Figure 4.4.** Each of these substances possesses the same amount of mass but different densities and therefore volumes (from Strom, 1987).

will contain the same number of atoms but now occupying only half the space. Thus, a cubic centimeter of this compressed basalt will now have a density of 6 g/cm$^3$ instead of its uncompressed density of 3 g/cm$^3$. Of course, extreme pressures, found only in the interior of relatively large planets, are capable of causing increases in density.

The Earth as a whole has a density of 5.5 g/cm$^3$, which is about halfway between the average density of rocks and iron. This density represents an average density of the iron core, consisting of 16% of the Earth's volume, and the rocky mantle and crust, which make up 84%. Because the Earth is so large, pressures in the interior are extremely high. These high pressures compress the atoms of a material into a smaller volume so that they are more closely packed together than for the same material nearer the surface. Thus, a rock or metal deep in the interior of Earth will have a higher density than the same rock or metal found near the surface. When these density or phase changes are taken into account and corrected for the Earth's pressure gradient, the Earth's uncompressed average density is only about 4.0 g/cm$^3$ (Figure 4.5).



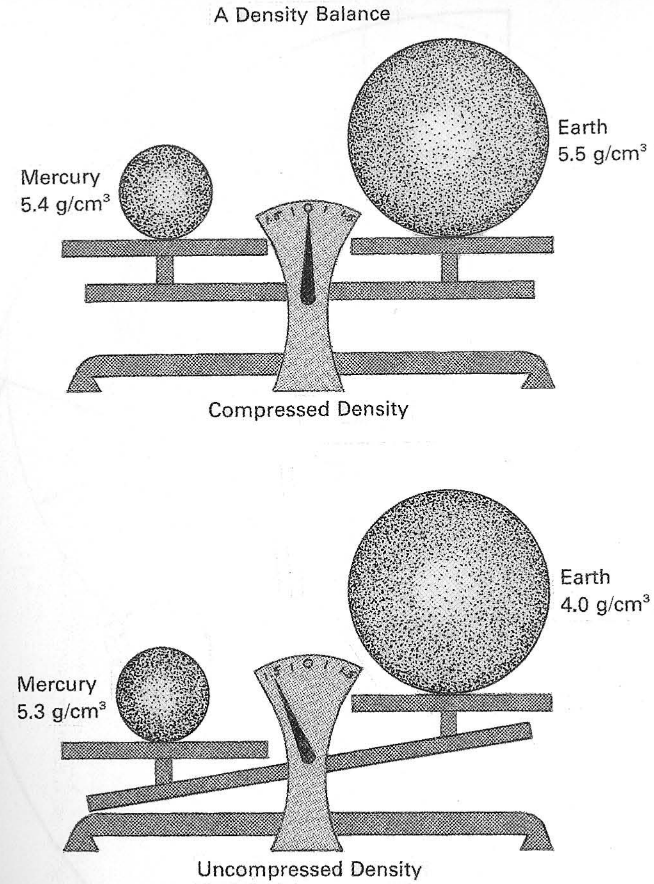


**Figure 4.5.** The compressed densities of the Earth and Mercury differ by only about 0.1 g/cm$^3$, Earth's density being slightly greater. The difference between the uncompressed densities, however, is about 1.3 g/cm$^3$, with Mercury's significantly greater than Earth's (from Strom, 1987).

### 4.3.2 Mercury has the greatest uncompressed density of any planet

Mercury has a density of 5.4 g/cm$^3$, which is comparable to that of Earth and Venus (5.2 g/cm$^3$) but much larger than that of the Moon (3.3 g/cm$^3$) or Mars (3.9 g/cm$^3$). However, Mercury is much smaller than Earth and, therefore, pressures in its interior are considerably less than those in Earth's interior. When this factor is taken into account, Mercury's uncompressed average density is still a high 5.3 g/cm$^3$, which is much larger than Earth's uncompressed density. This must mean that Mercury is composed to a large extent of heavy elements. Iron is the most abundant heavy element in the Solar System and is an important constituent of meteorites and terrestrial planet rocks. Seismic data for Earth also indicate that

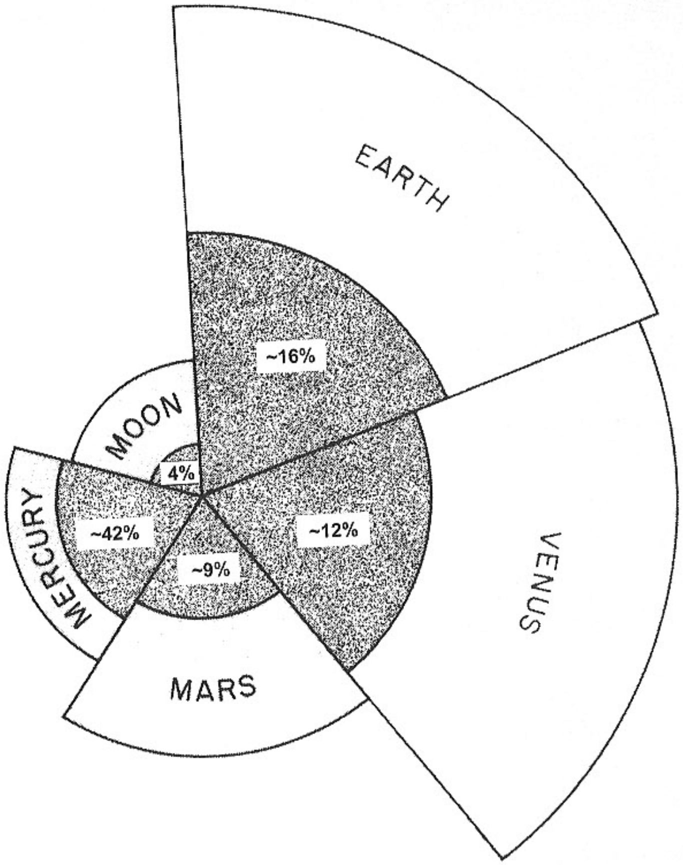


**Figure 4.6.** Relative sizes of the Moon and terrestrial planets and their cores. The % volume of the cores is also shown (from Strom, 1987).

Earth's core is mostly iron. Scientists strongly suspect, therefore, that iron is the principal heavy element responsible for Mercury's high density. From this high density we can infer that the planet is composed of about 70% by weight of metallic iron and only about 30% by weight of rocky material. Mercury thus contains more than twice as much iron per unit volume as any other planet or satellite in the Solar System. This iron is probably concentrated into a core like Earth's, but its size is enormous compared to the diameter of Mercury. The diameter of the core is about 75% of Mercury's total diameter and constitutes about 42% of its volume. In contrast, Earth's iron core is 54% of the total



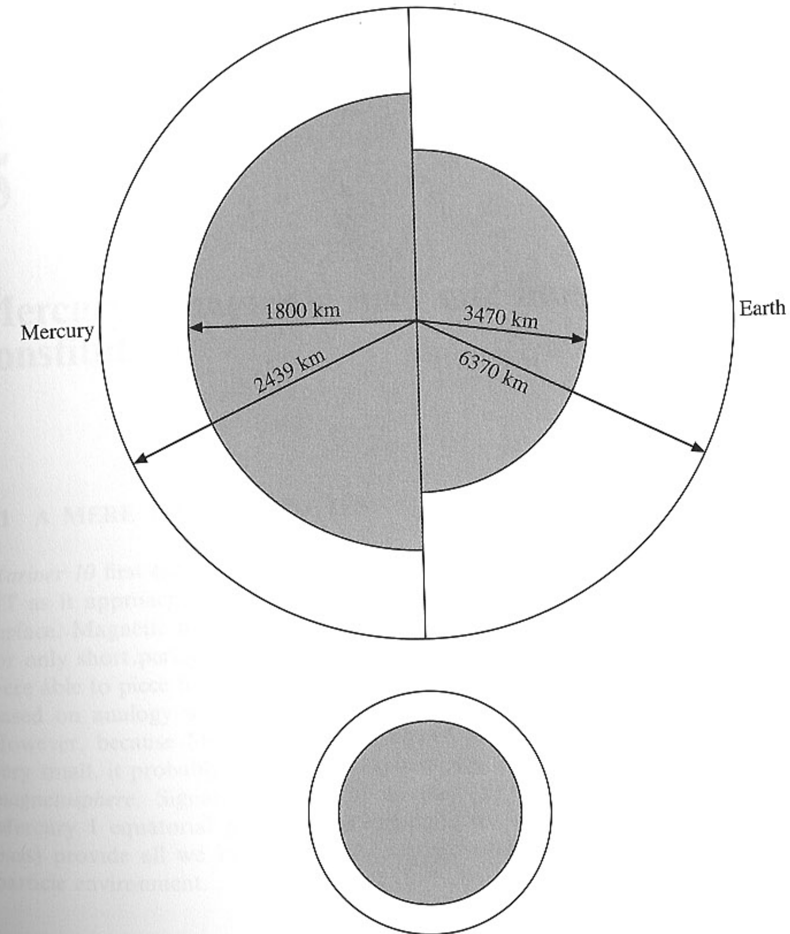


**Figure 4.7.** This diagram shows Mercury and Earth scaled to the same diameter. It illustrates how large Mercury's core is compared to the planet's total size. Mercury's actual size in relation to the Earth's is indicated by the smaller disc at the bottom (from Strom, 1987).

diameter but constitutes only 16% of the volume (Figures 4.6, 4.7 and [4.8, see colour plate section]). How Mercury obtained such an enormous iron core has important implications for Mercury's origin, which in turn sheds light on the origin of all the terrestrial planets. This will be discussed in the Chapter 12.