Introduction

Civilized societies are characterized by the widespread use of a range of materials to construct the artefacts on which that society depends. However, within any such society there will always be an intelligentsia of some sort — priests, teachers and philosophers and so on — who will ponder about the nature of matter, the stuff that constitutes our world, and the individual materials that are the manifestation of that matter. The first ideas about matter in some of the more sophisticated earlier civilizations, such as that of ancient Greece, is that there were just a few simple substances from which all material was constituted. The Greeks, and others, chose the substances air, earth, fire and water as a basic set having a range of properties that would be possessed by all other material. If a material, say a metal, had rigidity then a major part of it would have to be earth, since the other three substances had no rigidity whatsoever. Again, something like honey would have a large component of water since it flows like water but, unlike air and fire, it maintains a fixed volume within a container.

One of the earliest drivers that stimulated the systematic investigation of matter was alchemy, the desire to make gold from base metals and to find the means of extending life — to eternity if possible. Although we now know that these activities were futile in terms of achieving their desired ends, they did nevertheless achieve something quite important. From the ranks of the alchemists there arose a class of individuals now called scientists, the seekers after knowledge for its own sake, and they created the first science — chemistry. From the 17th century onwards knowledge about the nature of matter grew apace and chemists gradually built up an inventory of elements, the atoms that are the constituents of all materials. At first there seemed to be very little relationship between the individual elements they discovered but then a pattern of relationships emerged, connecting elements with similar properties, connections which came to be represented in a tabular form — the Periodic Table.

This neat chemists' world of a fairly large, but finite, number of elements with indivisible atoms started to crumble at the end of the 19th century when physicists began to explore the nature of atoms. This was not actually the goal that they were initially pursuing. The physicists were interested in the way that electricity was conducted through gasses at very low pressure and the phenomenon of radioactivity. Starting with this seemingly unrelated work, step by step they built up a picture of an atom, not as something indivisible but as something with structure that could break down, either spontaneously or by being bombarded in some way. All atoms were now seen as structures consisting of protons, neutrons and electrons, so seeming — with only three components — to return to the simplicity of the early Greeks.

However, having apparently reintroduced straightforwardness into the description of the material world, the physicists, with further work, soon disturbed that simple picture. Isaac Newton (1642–1727) had described the behaviour of material bodies in terms of the laws of mechanics that accurately described the behaviour of bodies as disparate as billiard balls and spacecraft. It turned out that Newton's laws were inadequate for very tiny particles such as electrons; a new mechanics, wave mechanics, was discovered that could deal with the behaviour of such tiny particles. In this new mechanics the particles are described as though they have wave-like properties, similar to that of light, and there arose a new concept — wave-particle duality — where, sometimes, material particles could behave like waves and where radiation, usually described in terms of waves, could occasionally behave like particles. To add to this complication, in their high-energy collision experiments physicists discovered large numbers of short-lived exotic particles that seem to have little relevance to the material world in which we live. Fortunately it turned out that not all these exotic particles were basic and many of them, together with protons and neutrons, were composed of even more fundamental particles — quarks. It is just possible that we may not yet have reached the end of the story about what constitutes the fundamental particles of matter!

From the very earliest times humankind has exploited materials in a great variety of ways. This includes naturally occurring materials such as stone or wood but quite early it was found that metals could be extracted from particular rocks and that some mixtures of metals had better properties than the component metals themselves. In more recent times great industries have been built on the creation of new materials — textiles, plastics, pharmaceuticals and semiconductors, for example. New knowledge concerning the chemical basis of life and living materials — the structures of deoxyribonucleic acid (DNA) and proteins — have given prospects of great medical advances through gene therapy and possible benefits from genetically modified plants, either for food or for other uses.

The final topic of this book is the most fundamental of all and that is how all this material came into existence in the first place. That goes back to the Big Bang, the beginning of time, of space and of all the material in the Universe, including the infinitesimal part of it that constitutes our world.