We start now our study of some topical problems in the philosophy of factual or empirical science. As we saw in Ch. 1, factual science is semantically and methodologically quite different from mathematics. Unlike mathematics, factual science seeks truths of fact - i.e. propositions representing reality - and it employs not only mathematical reasoning but also empirical procedures. However, factual science and mathematics share a number of traits, and this is why both are rightfully called 'sciences': both employ the general scientific method, both attempt to maximize exactness and systemicity, both justify their assertions, and both change relentlessly as a result of research rather than in obedience to dogma or social pressure. (Recall the general definition of a scientific research field in Ch. 1, Sect. 1)

We begin with the philosophy of physics for the following rather obvious reasons. Firstly, physics is the most basic and universal of all factual sciences, because (a) every real thing is either a physical entity or is composed of physical entities, and (b) the laws of physics are not place or time bound. Secondly, physics (including astronomy) was the first discipline to attain a scientific status and, as a consequence, it showed the way of science to all the other research fields. Thirdly, the philosophy of physics (including astronomy) is the oldest, most firmly established and most flourishing of all the philosophies of science. (Ptolemy was one of its founding fathers, and Galilei its first modern practitioner.) For this reason the philosophy of physics showed the way to the other regional philosophies of science. This has been both a blessing - because of the high standards it required - and a misfortune - because we have tended to overlook the specific differences between the physical sciences and the others. (Biologists often complain that philosophers of science treat their science as if it were a mere extension or application of physics. See Ch. 3, Sect. 1.1.)

Although the philosophy of physics is the most advanced branch of the philosophy of science, it is still underdeveloped in a number of respects. For one thing much of it is based on secondary literature. Secondly, philosophers of physics are often overspecialized - e.g. in the philosophy of space
and time, or of quantum mechanics. Consequently they tend to take problems out of their general scientific setting, which prevents them from controlling the proposed solutions by checking their compatibility with the bulk of physics. Thirdly, philosophers of physics seldom attack problems in the light of an explicit semantics, epistemology, methodology, and ontology. Consequently they often come to conclusions that are at variance with the marrow of physics – witness the views that the world is a system of mathematical equations, that there are no laws but only conventions, that there is a general and a priori theory of measurement, that change is illusory, or that physics does not study autonomously existing things. Fourthly, although many workers in the philosophy of physics master some of the mathematics of physics, they seldom make use of the mathematics of philosophy. As a consequence their assertions about exact formulas are often inexact for including unanalyzed key philosophical or methodological concepts, such as those of matter, event, causation, physical quantity, factual meaning, factual truth, and measurement.

There is, then, much to be done in the philosophy of physics. In this chapter we shall grapple with a handful of open problems, and shall do so by availing ourselves of some of the tools wrought in previous volumes of this Treatise. On occasion we shall also make use of results, in physics and its philosophy, obtained by the author or his coworkers. The first Section will be a pot pourri devoted to elucidating half a dozen key concepts of physical science. These concepts are so familiar that they are seldom analyzed – a sure sign of their scientific importance and philosophical complexity.

1. Preliminaries

1.1. Physical Quantity, Convention, Measurement

Physical science studies physical things such as bodies and fields. (This platitude is of course denied by subjectivists, operationists and conventionalists.) Physical things can be simple – i.e. without separable components – though possibly extended; electrons and photons seem to be both simple and extended. Or they can be complex, i.e. systems proper such as atoms and clouds. All things other than physical things are systems, and they exist only in special environments. For example, chemical systems are confined within rather narrow temperature and pressure bounds, biosystems