ABSTRACT. Much apprehension has been expressed by philosophers about the method of renormalisation in quantum field theory, as it apparently requires illegitimate procedure of infinite cancellation. This has led to various speculations, in particular in Teller (1989). We examine Teller’s discussion of perturbative renormalisation of quantum fields, and show why it is inadequate. To really approach the matter one needs to understand the ideas and results of the ‘renormalisation group’, so we give a simple but comprehensive account of this topic. With this in hand, we explain how renormalisation can and should be understood. One thing that is revealed is that apparently very successful theories such as quantum electro-dynamics cannot be universally true; resolving the tension between success and falsity leads to a picture in which any theory may be viewed as irreducibly phenomenological. We explain how, and argue that the support for this view is tenuous at best.

INTRODUCTION

Paul Teller (1989) discusses the question of infinite renormalisation in ‘Quantum Field Theory’ (QFT), tentatively proposing some ways of understanding it. As we shall explain, he considers the issue solely in terms of perturbative renormalisation; we feel that at this level the matter is just too opaque for any real understanding, one must take into account the results of the ‘Renormalisation Group’ (RG) developed since the 1970s. In particular, they reveal that certain theories, such as Quantum Electro-dynamics (QED) and $\phi^4$, which are perturbatively renormalisable, are in fact not renormalisable when considered exactly. Thus we sketch the important ideas and principles of this approach, and show how it explains renormalisation and renormalisability.

The RG also reveals constraints on the possible kinds of physical theory, in a way that should be of interest to philosophers, and which is certainly arousing interest in the physics community. The point is broadly this: imagine that you have a QFT with lots of different particles with widely varying masses. In situations where there isn’t enough energy to create a certain particle, parts of the theory which make reference to that particle can be ignored. Thus at such low energies,
physics is described by an ‘Effective Field Theory’ (EFT) which ‘effectively’ captures everything relevant.

Physicists such as H. M. Georgi (1989b), and philosophers and historians such as Tian Yu Cao and Silvan Schweber have suggested that this result opens up a new research programme in high energy physics. Any theory constructed at any energy scale can be taken as an EFT – as a theory which effectively describes the low energy consequences of another EFT describing energy scales great enough to make the next heaviest particle appear. In this way there never is an ‘actual’ theory which contains all the fields that make up the world, and of which lower energy EFTs are effective versions. This is the exact opposite of the dominant research programme in high energy physics since the 1960s – the Grand Unified Theory (GUT) approach. A central argument for a shift to the EFT programme is that renormalisation as employed in the GUT approach is ‘formalistic’; in some way obnoxiously uninterpretable. We shall use our account of renormalisation to undercut this claim.

There are at least three reasons why these matters should be of interest to philosophers of science: first, the apparently inexplicable and ad hoc nature of perturbative renormalisation has troubled many who have considered QFT. We feel that the RG relieves these worries. Second, it appears that physics is entering a period of revolution over this matter – insofar as we are interested in the opposing ideologies involved in theory changes we need to understand the EFT and GUT approaches. Finally: rather grandiosely we might describe the GUT programme as ‘neo-Pythagorian’, or at least we can view it in the Laplacian tradition. The QFT SU(5), say, could be a ‘once-for-all’ theory, capturing all physics (apart from gravity naturally) in a few elegant principles. Contrasted in this way, the EFT view says that there is new physics every time you turn up the energy enough – forget simplicity and unity, things get more and more complicated. The issue of whether there is a deep underlying simplicity in the complexity of phenomena is, we think, philosophical. Our aim is to sketch the physical models behind these positions so that philosophers can see exactly what ontological and methodological commitments are contained or implied by them.

This note is in three parts; the first is a brief summary of Teller’s results, the second is an account of the RG and the implications it has