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Epilogue

Almost no one doubts that the Standard Model is only an effective theory that has to be incorporated into a larger framework. What this framework will ultimately look like, we do not know. Empirical facts that we cannot account for in the Standard Model, such as neutrino masses, dark matter, and dark energy, provide some guidance. Aesthetic considerations such as the desire for unification of interactions and for an understanding of the patterns of matter fermion masses and mixing angles also guide our thinking. Although this seems rather removed from particle physics today, we also hope that one day we will have a framework that consistently incorporates gravity.

It was, however, efforts to resolve the fine-tuning problem of the Standard Model that led us to arrive at the exciting conclusion that there must be new physics at the TeV scale that can be probed at high energy colliders such as the LHC or a TeV electron–positron linear collider. Weak scale supersymmetry provides an attractive resolution of this problem, and continues to hold promise also for several other reasons, detailed at the end of Chapter 2. Indeed, many of these positive aspects of supersymmetric models have become evident only in the last 10–15 years – many years after the discovery of supersymmetry, and well after the effort to explore its phenomenological implications had begun in earnest. We believe that the motivations for seriously examining supersymmetry remain as strong as ever.

These promising features notwithstanding, SUSY is not a panacea. By itself, it has nothing to say about the choice of gauge group or particle multiplets, the replication of generations, or the patterns of matter fermion masses and mixing angles (though specific SUSY models that incorporate these patterns have been constructed). In fact, *generic* SUSY models lead to new problems *not present* in the Standard Model.

1. Why do baryon and lepton numbers appear to be conserved when we can write down renormalizable $SU(3)_C \times SU(2)_L \times U(1)_Y$ invariant interactions that violate their conservation?
2. What is the origin of SUSY breaking, and what makes the SUSY breaking scale required to avoid fine tuning so much smaller than the Planck or GUT scales?
3. Why is the supersymmetric parameter μ so much smaller than the Planck scale?
4. What makes the flavor-violating interactions of scalar quarks and leptons so small when we can write gauge invariant renormalizable flavor-violating couplings for these?
5. What makes the potentially large CP-violating effects in supersymmetry so small?

We stress that these are problems only of a generic SUSY theory, that can with suitable (but seemingly ad hoc) assumptions be overcome in specific models. Indeed, we have studied such models in the text. The point, however, is that while none of these were issues in the Standard Model, they appear to be so in the supersymmetric context. We speculate that once the mechanism of supersymmetry breaking is understood, the answers to these questions will appear evident; in the meantime, these should serve to guide our thinking about how supersymmetry is broken.

If nature turns out to be supersymmetric, it will change the physicist's view of the Universe. Indeed, the wide range of issues that might be addressed by the inclusion of supersymmetry in particle physics has led many physicists to expect that supersymmetry is realized in nature. While we know that supersymmetry – if it exists – must be broken, the scale of supersymmetry breaking is not known. However, if supersymmetry is the new physics that stabilizes the scalar electroweak symmetry breaking sector, supersymmetric matter will ultimately be revealed at or near the weak scale. With the LHC set to begin operation in 2007, and with the high energy physics community seriously considering the possibility of a TeV scale e^+e^- linear collider, this is an exciting prospect.

Only experiments can tell whether weak scale supersymmetry is realized in nature. The important thing is that the idea of weak scale supersymmetry can be directly tested in experiments at various collider and non-accelerator facilities. The fact that supersymmetric theories can sensibly be extrapolated to much higher energy scales suggests that if superpartners are discovered and their properties measured, we may be able to learn about physics at energy scales not directly accessible to experiment. Whether or not supersymmetric particles are discovered soon, it is clear that the exploration of the TeV scale will provide clues for unravelling the nature of electroweak symmetry breaking interactions. We must look to see what we find.