INTRODUCTION

At the time of the publication of this volume, more than fifty years have passed since the appearance in *The Physical Review* of Philip W. Anderson's landmark paper titled *Absence of Diffusion in Certain Random Lattices.*[1] During the decades since, the phenomenon predicted and explained in that paper became known as "Anderson localization" and has been widely recognized as one of the fundamental concepts in the physics of condensed matter and disordered systems. Anderson's 1977 Nobel Prize, shared with Nevill Mott and John Van Vleck, is based in part on that seminal paper.

Anderson was initially motivated to understand the influence of disorder on spin diffusion and on electron transport. In the years since, the concepts and results that he created have found their way across a wide range of other topics. Among them are nano– and meso–scale technology, seismology, acoustic waves, quantum optics, ultracold atomic gases, localization of light.

The chapters contributed by Phil Anderson, David Thouless and T. V. Ramakrishnan explain clearly some of the early history of the understanding of the localization phenomenon. Earlier discussions of the background and content of Anderson's 1958 paper may be found in Thouless' 1970 review[2] and in Anderson's 1977 Nobel Lecture.[3]

In the area of electron transport, not much was done on the localization problem for more than a decade after the 1958 paper. What might be called the modern era of localization began in the 1970s, with the introduction of scaling ideas by Licciardello and Thouless,[4] Wegner[5] and Schuster.[6] As a matter of fact, it was the Schuster paper that set Phil Anderson, Don Licciardello, T. V. Ramakrishnan, and I thinking about the statistical mechanics analogy, one–parameter scaling and the beta function of scaling theory. The consequence was our 1979 Physical Review Letter,[7] often called the "gang of four" paper ("G4"). As is well known, we concluded that the metal–insulator transition is continuous, i.e. there is no minimum metallic conductivity and that all states in two dimensions are localized. The history of these developments is beautifully reviewed by David Thouless in his contribution to this volume.

There are a number of papers that are not often quoted now, although they made significant impact when they appeared. Here, I take this opportunity to mention some of them and to place them in historical context. The functional integral formulation for correlation functions of a disordered electron system and disorder averaging by means of the $n \to 0$ replica trick was developed by several people, notably Amnon Aharony and Yoseph Imry.[8] John Cardy, in 1978,[9] reformulated the functional integral representation and the n-replica method. He showed how to control the saddle point of the equivalent Ginzburg–Landau action and obtained power laws for the energy dependence of the density of states.

Following upon G4, Shinobu Hikami, Anatoly Larkin and Yosuke Nagaoka[10] incorporated scattering mechanisms with different symmetries (spin–orbit scattering, magnetic impurities), inelastic scattering, and crucially, magnetic field into the treatment of the crossed graphs of Langer and Neal,[11] which are the basis of the scaling behavior derived in G4. Here, the magnetoresistance was derived and this became, and remains, the diagnostic of choice for all subsequent experiments. In this connection, see the chapters of Bergmann, Dynes and Giordano in this book.

Around 1980, there were a number of discussions[12] of the equivalence of the localization problem and the matrix nonlinear σ model. An especially transparent derivation was given by Shinobu Hikami in 1981.[13] He showed how the systematic perturbative treatment of the relevant diffusion propagators in the particle–hole ("diffuson") and particle–particle ("cooperon") channels leads to an effective Hamiltonian of the nonlinear σ model. His analysis of the propagators and their interaction vertices became the standard basis for subsequent perturbative treatments of various effects, including in particular early analyses[14] of the effect of electron–electron interactions. The development of matrix nonlinear σ model methods is reviewed by several contributors to this volume: Efetov, Mirlin *et al.*, Pruisken.

The physics of Anderson localization has had a pervasive influence on a broad variety of fundamental concepts and phenomena, including the quantum Hall effect, quantum criticality, symmetry and random matrix theory, multifractality, electron–electron interaction in disordered metals. These and other issues are explored in many of the chapters of this book.

Some of the pioneers in the field of disordered systems, both theorists and experimentalists, have contributed to this volume. It is a mark of the vitality of Anderson localization physics (and indeed of the contributors) that while a few chapters are essentially historical, the others report results of current research. Unfortunately, space constraints have prevented a comprehensive survey of all the past and current developments. In spite of this limitation the hope is that the reader will acquire an appreciation of the history of the physics of localization and its current manifestations.

References

1. P. W. Anderson, *Phys. Rev.* **109**, 1492 (1958).
2. D. J. Thouless, *J. Phys. C: Solid State Phys.* **4**, 1559 (1970).
3. P. W. Anderson, *Rev. Mod. Phys.* **50**, 191 (1978).
4. D. C. Licciardello and D. J. Thouless, *Phys. Rev. Lett.* **35**, 1475 (1974).
5. F. J. Wegner, *Z. Physik B* **25**, 327 (1976).
6. H. G. Schuster, *Z. Physik B* **31**, 99 (1978).
7. E. Abrahams, P. W. Anderson, D. C. Licciardello and T. V. Ramakrishnan, *Phys. Rev. Lett.* **42**, 673 (1979).
8. A. Aharony and Y. Imry, *J. Phys. C: Solid State Phys.* **10**, L487 (1977).
9. J. L. Cardy, *J. Phys. C: Solid State Phys.* **11**, L321 (1978).
10. S. Hikami, A. I. Larkin and Y. Nagaoka, *Prog. Theor. Phys.* **63**, 707 (1980).
11. J. S. Langer and T. Neal, *Phys. Rev. Lett.* **16**, 984 (1966).
12. F. J Wegner, *Z. Phys. B* **35**, 207 (1979) and for example, K. B. Efetov, A. I. Larkin and D. E. Khmelnitskii, *JETP* **52**, 568 (1980); A. J. McKane and M. Stone, *Annals of Physics* **131**, 36 (1981); A. B. Harris and T. C. Lubensky, *Solid State Comm.* **34**, 343 (1980).
13. S. Hikami, *Phys. Rev. B* **24**, 2671 (1981).
14. See the review of P. A. Lee and T. V. Ramakrishnan, *Rev. Mod. Phys.* **57**, 287 (1985).