1992 March Meeting of the American Physical Society
16-20 March 1992, Indianapolis, IN

March 10, 1992

When Did Dirty Solids Become Different From Clean Solids?

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Most of the materials you encounter in your daily life—liquids, glass, plastics, gels, alloys, colloids—are highly irregular in structure. Even the properties of the true solids of technology are controlled primarily by defects in their structure—e.g. dislocations in metals, flux lines in superconductors, domain walls in magnets. Yet 30–40 years ago, when the previous lectures left off, solid state physics—now known as condensed matter—was overwhelmingly the study of the pure crystalline state or of as good an approximation as could be managed, or of certain very simple types of defects such as color centers or shallow impurity centers.

I looked in the two major textbooks as written or revised even as late as 1976, and found no reference in one under "disorder"'—Kittel's 5th edition—and in the other (Ashcroft and Mermin) the following dismissal in a footnote: "The problem of electronic structure in disordered potentials......is the subject of lively discussion". True enough.

The very next year a Nobel Prize was awarded in just this area, and this year's prize, awarded to Pierre Gilles de Gennes for work on almost everything but regular solids, represents perhaps the full maturation of a new field, involving complexly irregular materials, as part of the mainstream of physics. Clearly, at some time a revolution must have happened: some landmarks to mark the time scale being the first session on localization at the major semiconductor meeting in 1980, and mention—and a picture—in Kittel's '86 edition. But the existence of this new field of physics has yet to catch the attention of the world outside CM: for instance, a visitor at one of the country's oldest and most prestigious physics departments, Berkeley, was told of some bewilderment at the Nobel choice of de Gennes in 1991. And in an otherwise excellent book called "The New Physics" dedicated to postwar developments, the field was completely ignored by Paul Davies.

A book which summarizes this revolution as it was taking place was produced as the lectures from a Les Houches summer school in 1978 called "Ill-Condensed Matter"'—"La Matiére Mal Condensée"— which would have been a much better title for my talk here—and in the introduction to these lectures I wrote some words which may serve as the manifesto for this revolution.

"Multiple scattering is the paradigm of the old attitude; localization and percolation of the new. These are phenomena which are specific to disordered systems ...... closely related is the concept of non-(or broken) ergodicity... This revolution has left us asking a whole new set of questions...... 'How do disordered systems differ from regular ones?', not, 'How can they be reduced to them?'...... "

To cover even a fraction of the history related to that book is far beyond my capacity, even given indefinite time, which I'm not.. I will focus on what I see to be a few characteristic, and/or seminal bits of history, and of course I can only talk authoritatively about things I was more or less involved with so I apologize in advance for a self-centered point of view.

But first I am going to give you an overall map of some of this territory, much of which may be unfamiliar to you.

I will borrow Davies' phrase and essentially lay out for you a "Table of Contents" of a possible history of The New Physics of Ill – Condensed Matter. The table, is, hopefully, to a great extent self-explanatory; it reveals an enormous burgeoning of activity, involving the generation of many very active new fields of physics, some of which, such as mesoscopics, spin glass, esoteric phases, and defect-dominated phase transitions, are very active today; while the problem of glass itself remains, to my mind, the most profound problem, which is both well-posed and unsolved, in modern physics.

After guiding you through the general structure of this table, I'd like to focus on what I see as important and seminal events. Most of these I shall just list in Table II, and then finally try to discuss one or two of them in a truly historical manner in the sense of "how and why did they happen?"

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III. SELF-ORGANIZED CRITICALITY ('88)???

So let's see how many of these seminal events we have time for. Clearly the earliest, and the most interesting historically, was localization.

TABLE II:

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~'80 CONFIRMATION: BOUCHIAT + OTHERS, Non-linear χ

(3) FIRST SUCCESSFUL DEFECT TH. OF PHASE TRANS :

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