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This Week's Citation Classic

Hubbard J. Electron correlations in narrow energy bands. *Proc. Roy. Soc. London Ser. A* **276**:238-57, 1963.
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It was pointed out that correlation phenomena could sometimes lead to atomic-like (as opposed to metallic) behavior in solids. A simple model was introduced to study such effects. An approximate solution of this model yielded a theory of Mott transitions. [The *SCI®* indicates that this paper has been cited over 855 times since 1963.]

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"In 1962 I was running a solid state theory group at Harwell. Amongst our concerns was the interpretation of the neutron scattering data generated there. In particular, the data on transition metals could be easily interpreted in terms of the Heisenberg model, drawing my attention to a controversy dating from the thirties over the question of whether the d-electrons of these metals were localized or itinerant.[1-6]

"Thinking about this I formed the opinion that the localized behavior resulted from electron correlation effects induced by the Coulomb interactions. Indeed, it seemed that here was something of importance for the whole of solid state physics, the nature of a solid might be determined not only by its band structure but also by these correlation effects. Apart from the theories of superconductivity and plasma oscillations, the application of many-body theory to solids had, up to that time, led to nothing striking; the correlations seemed merely to renormalize the band structures a little. But here we had something entirely different: the correlations might sometimes be determining the actual nature of the solid.

"The next question was how to turn these ideas into a proper theory. Walking back to my office from lunch one day the following strategy occurred to me. Since I knew the exact solution to the interacting electron problem in the zero bandwidth limit (the system behaved as a collection of atoms), I should be able to get this result by studying the many-body theory equations. I also knew the exact solution of these equations in the opposite limit of pure band theory, so I should be able to interpolate between these limits and obtain a general solution. Back in my office I set up the simplest possible model containing the necessary ingredients, what is now known as the 'Hubbard Hamiltonian' (the utility of this model is one of the main reasons for the frequent citation of the paper). Within a few hours I completed most of the calculations appearing in the paper.

"It is characteristic that genuinely new results are rather puzzling; one is at sea without any familiar landmarks. This is how I felt looking at my results. The band split in two! But this had to be so to interpolate correctly between the limits. I was not aware of the ideas Mott[7,8] had put forward many years before until after the manuscript was written, when Mott himself pointed out the connection. Of course today we recognize that I had come across a theory of Mott transitions although my attention was directed elsewhere. After digesting the results for a few months I wrote the manuscript. It presented for the first time a theory of circumstances in which the Coulomb correlations in a solid could be of dominant importance, a further reason for the interest in this paper. But, alas, the theory did not provide a solution to the original problem, that of localized versus itinerant behavior in metallic ferromagnets; this was to follow much later."

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