

typically slower than 1 km s^{-1}) might differ significantly from what is assumed by current modelling efforts²⁷. The expected equation-of-state differences among small bodies (ice versus rock, for instance) presents another dimension of study; having recently adapted our code for massively parallel architectures (K. M. Olson and E.A, manuscript in preparation), we are now ready to perform a more comprehensive analysis.

The exploratory simulations presented here suggest that when a young, non-porous asteroid (if such exist) suffers extensive impact damage, the resulting fracture pattern largely defines the asteroid's response to future impacts. The stochastic nature of collisions implies that small asteroid interiors may be as diverse as their shapes and spin states. Detailed numerical simulations of impacts, using accurate shape models and rheologies, could shed light on

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removed from a clustered neighbourhood to make a short cut has, at most, a linear effect on C ; hence $C(p)$ remains practically unchanged for small p even though $L(p)$ drops rapidly. The important implication here is that at the local level (as reflected by $C(p)$), the transition to a small world is almost undetectable. To check the robustness of these results, we have tested many different types of initial regular graphs, as well as different algorithms for random rewiring, and all give qualitatively similar results. The only requirement is that the rewired edges must typically connect vertices that would otherwise be much farther apart than L_{random} .

The idealized construction above reveals the key role of short cuts. It suggests that the small-world phenomenon might be common in sparse networks with many vertices, as even a tiny fraction of short cuts would suffice. To test this idea, we have computed L and C for the collaboration graph of actors in feature films (generated from data available at <http://us.imdb.com>), the electrical power grid of the western United States, and the neural network of the nematode worm *C. elegans*¹⁷. All three graphs are of scientific interest. The graph of film actors is a surrogate for a social network¹⁸, with the advantage of being much more easily specified. It is also akin to the graph of mathematical collaborations centred, traditionally, on P. Erdős (partial data available at <http://www.acs.oakland.edu/~grossman/erdoshp.html>). The graph of the power grid is relevant to the efficiency and robustness of power networks¹⁹. And *C. elegans* is the sole example of a completely mapped neural network.

Table 1 shows that all three graphs are small-world networks. These examples were not hand-picked; they were chosen because of their inherent interest and because complete wiring diagrams were available. Thus the small-world phenomenon is not merely a curiosity of social networks^{13,14} nor an artefact of an idealized

model—it is probably generic for many large, sparse networks found in nature.

We now investigate the functional significance of small-world connectivity for dynamical systems. Our test case is a deliberately simplified model for the spread of an infectious disease. The population structure is modelled by the family of graphs described in Fig. 1. At time $t = 0$, a single infective individual is introduced into an otherwise healthy population. Infective individuals are removed permanently (by immunity or death) after a period of sickness that lasts one unit of dimensionless time. During this time, each infective individual can infect each of its healthy neighbours with probability r . On subsequent time steps, the disease spreads along the edges of the graph until it either infects the entire population, or it dies out, having infected some fraction of the population in the process.

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