version of normal (if premature) ageing than does dyskeratosis congenita. In people with dyskeratosis congenita and in telomerase-deficient mice, it is tissues that normally express telomerase that one would predict to suffer most from its loss, and this proves to be the case.

People with dyskeratosis congenita, as well as late-generation telomerase-deficient mice, also suffer from a higher rate of cancer. This can likewise be explained by the lack of telomerase, which results in unstable chromosomes — in dyskeratosis congenita sufferers and the mutant mice, many chromosomes fuse end-to-end[8,9], probably because their telomeres are terminally eroded (discussed in ref. 10).

In short, the symptoms of this disease provide a glimpse of the effects of telomerase defects on the maintenance of human tissues. Cells in rapidly dividing tissues, with progenitors that usually express telomerase, are more strongly affected. It will be interesting to see whether Werner's syndrome and related premature-ageing disorders affect the maintenance of telomeres in tissues that do not have telomerase-expressing progenitors. ■

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Statistical physics

The salesman and the tourist

H. Eugene Stanley and Sergey V. Buldyrev

Solutions to optimization problems, such as that faced by the travelling salesman, have many practical applications. Might a related problem offer insight into the behaviour of foraging animals?

The travelling salesman problem is of fundamental interest to mathematicians and physicists, and has a number of practical applications, such as computer design. At first sight, the related travelling tourist problem might seem to be of little interest to anyone except perhaps quarrelling travelling companions.

What are these two problems? The travelling salesman problem is the question of what is the shortest possible route followed by a salesman assigned to visit N clients spread across a huge territory; it is a classic example of a class of problems called global optimization problems. Because the salesman's next step depends on his knowledge of the location of every client yet to be visited, the solution to the travelling salesman problem is far from trivial, and has attracted some of the best minds[1–3].

In *Physical Review Letters*, Lima *et al.*[4] introduce a new example from a class of problems known as local optimization problems, and name it the travelling tourist problem. This is the question of what is the best path to be followed by a tourist not constrained to only one visit per city, but constrained — say by his budget — to visit the nearest city. Note that the tourist wants to minimize only the distance to the next city, a local optimization, not the sum of all the distances along the trajectory as in the travelling salesman problem. So, at first sight, the travelling tourist problem would seem to be trivial.

Nonetheless, even a trivial-sounding problem can yield rich behaviour. For example, the random-walk problem considers a walker limited to the vertices of a square grid. At each step the walker moves to the neighbouring north, south, east or west vertex depending on the throw of a four-sided die. Clearly the walker does not need to know more than his immediate environment. Even so, his behaviour cannot be predicted in many cases, such as when he cannot revisit a vertex, or if the grid has some randomly scattered sites that can trap the walker.

Similarly, the travelling tourist problem exhibits some surprising behaviour. For example, after visiting a few cities the tourist will visit city A, whose nearest neighbour, city B, has no other neighbour closer than A. So as soon as the tourist visits either A or B, he will thereafter simply oscillate between them, in what is called a two-city limit cycle. Such two-cycles act as effective 'tourist traps' with the tourist going back and forth, like Sisyphus, for eternity.

Lima *et al.*[4] enrich the travelling tourist problem by assuming that the idealized tourist is more like a real tourist and does not wish to visit the city he went to last, so they introduce a rule that prevents this. The same sort of logic applies as before, except that now the tourist can be trapped in a three-cycle (three cities that form a triangle A-B-C such that a tourist starting at A will pass to B and then to C, before returning to A). Surprisingly, in addition to three-cycle traps, there are also p-cycle traps, where p is as large as desired.

This simple rule can be further generalized if the tourist cannot visit a city already visited in the previous V visits (in the two previous cases, $V=0$ and 1, respectively). Remarkably, after a trip exploring several cities, the tourist is always trapped into repeatedly revisiting a subset of them. Indeed, the entire set of N cities can be partitioned into a large number of 'free cities' that the tourist can enter and then leave, and a number of tourist traps, in which he is condemned to revisit repeatedly the same subset of p cities (Fig. 1).

So, at first sight, the travelling tourist confronts a landscape not so different from that confronted in the random-walk problem with traps. But in the random-walk problem, the traps are typically assumed to have sizes that follow a normal distribution centred around a typical size. In the travelling tourist problem, the p-cycle traps can have a range of p-values, so the number of

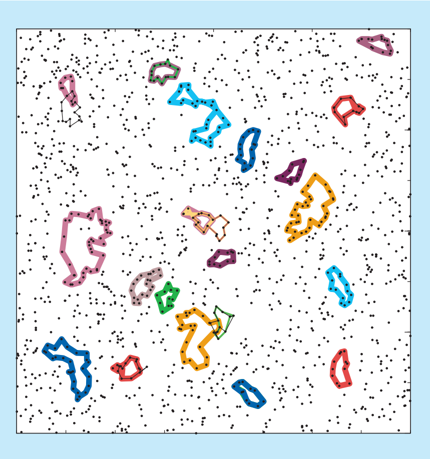

Figure 1 **The travelling tourist problem. An example in which the tourist is allowed to visit any one of 1,600 random 'cities', subject only to the condition that he does not revisit a city visited in the previous V visits, where $V=10$. As well as a great number of free-standing cities to which the tourist can come and go, there are 378 cities that belong to one or more p-cycles, which serve as 'tourist traps' by constraining the tourist to visit the same set of cities over and over again. The 29 traps shown here occur in a range of sizes and shapes. Lima *et al.*[4] show that the distribution of these p-cycles follows a power-law function. Such a distribution is normally associated with random processes, rather than the completely deterministic walk followed by the tourist.**

Figure 2 **A wandering albatross looking for food. This bird may follow a stable migratory route — it visits the same sites (typically feeding areas) over and over again in much the same way as the hapless tourist in Fig. 1. (Reproduced with permission of the British Antarctic Survey.)**

traps of a given size might be expected to follow a normal distribution. But Lima *et al.*[4] find that the number of *p*-cycles follows a monotonically decreasing power-law function of *p*, with an exponent of about 2.7. This is a surprising result because power laws are typically associated with systems dominated by random processes, but here the walk is completely deterministic. The power law must somehow arise from the initial random distribution of the cities, so it is intriguing to think there may be deep similarities between this problem and typical power-law systems[5].

There are many examples of trivial-sounding problems having unexpected applications; for example, random-walk problems can describe a rich range of diffusive motion[6], and are even used as a crude model of price movements on the stock market[7]. Accordingly, the travelling tourist problem could apply to some interesting questions. Some animals such as birds follow migratory routes in which they revisit an identical set of feeding spots in the same sequence (Fig. 2). These animals may not be altogether unlike the tourist, choosing deterministically the closest feeding ground to where they are, and conditioned by the fact that if they revisit the same feeding area without waiting a certain time the food supply will not have had the chance to rejuvenate itself. So the travelling tourist might provide new insights into the foraging behaviour of insects, mammals and birds, which can follow power-law functions[8,9].

Many humans tend, after some time, to fall into a rut — to revisit the same sequence of cities on their travels, to revisit the same sequence of restaurants in their social life, and even for some scientists to revisit the same set of ideas in their scholarship — all actions seemingly occurring as if by magic when in fact there may be a simple underlying reason. Indeed, this type of behaviour is more like the travelling tourist problem than the travelling salesman problem. Normally we think of our behaviour as emerging from free will. It is possible that some behaviour patterns are the result of applying deterministic rules to a stochastic (random) environment, perhaps not altogether unlike the rules governing the journey of the travelling tourist. ■

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Plant hormones

Transporters on the move

Mark Estelle

The hormone auxin is moved across plant cells by transporters called efflux carriers. It now looks as if these carriers behave much more dynamically than had been thought.

If you're a plant you cannot get by without auxin, for it regulates various essential aspects of growth and development. In their paper on page 425 of this issue[1], Geldner *et al.* provide a surprise for biologists studying auxin transport. But their results will also be of wider interest, for they bear more generally on the questions of how cell polarity is established and maintained, and on protein trafficking in plant cells.

Auxin is a hormone that operates through its effects on cell division and elongation. It is transported through files of cells by a process that is thought to depend on the asymmetric distribution of auxin 'efflux carriers' acting at a cell's plasma membrane. The importance of this transport system has been amply demonstrated using synthetic inhibitors of polar auxin transport, which were believed to interfere specifically with the action of the efflux carrier. Geldner *et al.* now show that the efflux carriers cycle rapidly between the plasma membrane and an as-yet-unspecified cellular compartment, and that the inhibitors prevent this cycling. Further, they find that auxin-transport inhibitors are not specific: they have a general effect on the transport of membrane proteins.

Auxin is produced in young organs, primarily near the plant apex. It is then transported to other parts of the plant by influx and efflux carriers, located at the plasma membrane, which move the hormone through files of cells by successive rounds of transport into and out of these cells[2]. The key to this mechanism is the asymmetric distribution of the efflux carrier. For example, auxin in the stem is transported in a highly directional fashion from the top towards the base of the plant. The PIN1 protein is a member of a large family of putative efflux carriers, and in the model plant *Arabidopsis* (and by implication all plants) it is required for this polar transport of auxins. Various studies in different plant organs found, in each case, that the efflux carrier is located on the downstream side of the transporting cell[3–5].

Our understanding of auxin transport comes largely from studies using artificial inhibitor compounds[2,6]. Two of the best-characterized are called TIBA and NPA. These compounds reduce polar auxin transport in stem segments by blocking cellular auxin efflux, implying that they specifically interfere with the efflux carriers. The biological effects of transport inhibition are diverse and dramatic. Treatment of developing embryos with NPA causes defects in pattern formation and behaviour of the meristems, the groups of stem cells that give rise to all postembyronic structures[7]. Later in development, the inhibitors prevent proper growth of roots and shoots in response to environmental cues such as light or gravity[8]. Bio-