of operation at the Tevatron (known as 'Run II'), the experimental error on M_t will be reduced to 2–3 GeV/c^2; at the Large Hadron Collider[8], currently under construction at CERN, this accuracy will be improved further to 1–2 GeV/c^2.

The ultimate precision on M_t, however, will be achieved at a linear electron–positron collider. Such a machine is currently in the planning phase and could go into operation around the middle of the next decade. Data from the linear collider could improve the accuracy on the top-quark mass by about a factor of ten[9–11]. Only then will the uncertainty due to the experimental error of the top-quark mass be well enough under control for the information gleaned from the LHC in the next decade — on the Higgs boson (or bosons), supersymmetric partners or other new physics — to be fully exploited. ■

Georg Weiglein is at the Institute for Particle Physics Phenomenology, Department of Physics, University of Durham, Durham DH1 3LE, UK.
e-mail: georg.weiglein@durham.ac.uk

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Interstellar chemistry

Molecular nitrogen in space

Theodore P. Snow

Astronomers have found evidence of molecular nitrogen in the clouds of gas between the Earth and a distant star. The chemistry involved in the formation of these diffuse clouds might need to be rethought.

On page 636 of this issue, David C. Knauth and colleagues[1] claim the first detection of molecular nitrogen (N_2) in interstellar space. This simple diatomic molecule, made of one of the most abundant elements in the Universe, is the most common constituent of Earth's modern atmosphere. It is also a major component of the atmosphere of Saturn's moon Titan, and has been detected in trace amounts in the atmospheres of Venus and Mars. But it has proved surprisingly difficult to find N_2 in any environment beyond the Solar System.

Chemical models of dark interstellar clouds (whose densities are usually in the range of 10^3 to 10^5 particles per cm^3) suggest that N_2 should be the most abundant form of nitrogen in these regions. This leads to the prediction[2–4] that the ratio of N_2 to hydrogen should be about 10^{-5}. In contrast, models for diffuse interstellar clouds, which are transparent and have densities of about 10^2 particles per cm^3, predict a much lower N_2 abundance, in the range between 10^{-9} and 10^{-8} that of hydrogen[2,5].

Both predictions suggest that N_2 might be observable, but searches for this molecule in interstellar space had been fruitless until now. One of the difficulties in detecting interstellar N_2 arises from the fact that the symmetric diatomic molecule has no allowed rotational or vibrational (dipole) transitions. Thus, N_2 — unlike most of the 120 or more species now detected in dark interstellar clouds — cannot be detected either through millimetre-wavelength observations of rotational emission lines or through infrared spectroscopic detection of vibrational bands (absorption or emission).

The only viable approach to finding interstellar N_2 is to search for the spectral lines created by electronic transitions in the molecule. These lines are found exclusively at far-ultraviolet wavelengths (shorter than 100 nm), for which space-based telescopes are required because the Earth's atmosphere blocks such radiation. For technical reasons, however, most ultraviolet telescopes have not covered the far-ultraviolet spectral region where the N_2 bands lie. For example, the Hubble Space Telescope cuts off at about 115 nm, well above the wavelength needed for an N_2 search. The Copernicus satellite — a small mission that was developed and led by the late Lyman Spitzer and operated from 1972 until 1980 — was the first orbiting spectroscopic observatory capable of far-ultraviolet searches for N_2 in interstellar space, but no detection was achieved[6].

The best chance for astronomers to search for interstellar N_2 has been afforded by the Far Ultraviolet Spectroscopic Explorer (FUSE) mission, now in its fifth year of operation. FUSE was designed specifically to extend ultraviolet spectroscopy to the shorter wavelengths that are not accessible to the Hubble Space Telescope, including the spectral region where the electronic bands of N_2 lie. Knauth *et al.*[1] have taken advantage of FUSE's far-ultraviolet sensitivity to search for N_2 — and apparently they have found it.

In a classic example of spectroscopic sleuth work, Knauth *et al.* have detected absorption by N_2 in the line of sight towards the star HD 124314 by sorting through and eliminating other features that are blended into the spectrum. These other features arise through the absorption of radiation by the star's own atmosphere, by foreground interstellar gas (mostly molecular hydrogen) and by N_2 in the outer vestiges of Earth's atmosphere. The detection of interstellar N_2 was aided by the fact that several individual N_2 lines are accessible to FUSE and also because FUSE covers the N_2 wavelength region with two separate detectors, which means that instrumental artefacts in the data can be eliminated.

The line of sight towards HD 124314 does not intersect a dark molecular cloud; rather, this is a long pathlength, probing one or more diffuse clouds. So, according to model calculations, the ratio of N_2 to hydrogen should be closer to the 10^{-9} to 10^{-8} level that is predicted for diffuse clouds than to the 10^{-5} level predicted for dense clouds. Knauth *et al.* have found an intermediate value, with N_2 representing about 10^{-7} of the total hydrogen abundance in their observed line of sight. This abundance of N_2 does not fit either the dense-cloud or diffuse-cloud models.

Among the possible explanations is that the line of sight towards this star contains one or more 'translucent' clouds, which are reckoned by astronomers to be intermediate (or possibly transitional) between dense and diffuse clouds[7]. Alternatively, the models for diffuse clouds might be incorrect, or the detection claimed by Knauth *et al.* is wrong. The first and third of these options can probably be eliminated, as the line-of-sight dust extinction to this particular star is too small to include a translucent cloud, and the claimed detection of N_2 seems secure. So we must surmise that the chemical models for N_2 in diffuse clouds are inadequate.

Normally it is assumed that, with the exception of hydrogen, molecules in diffuse clouds form through gas-phase chemical reactions[2,5]. But in dense clouds an additional process, that of molecule formation on grain surfaces, is probably important[8,9]. The detection of N_2 by Knauth *et al.*[1] suggests that grain-surface reactions might contribute more to diffuse-cloud chemistry than previously thought. This conclusion is consistent with earlier searches in diffuse clouds for NH, another simple diatomic molecule found to be more abundant than expected from gas-phase chemistry alone[10,11]. If grain-surface reactions are required to explain the measured abundances of N_2 and NH, it is possible that other surface reactions should also be incorporated into models of the chemistry inside these diffuse clouds. ■

Theodore P. Snow is at the Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, Colorado 80309-0389, USA.
e-mail: tsnow@casa.colorado.edu

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Economics

The wealth of nations

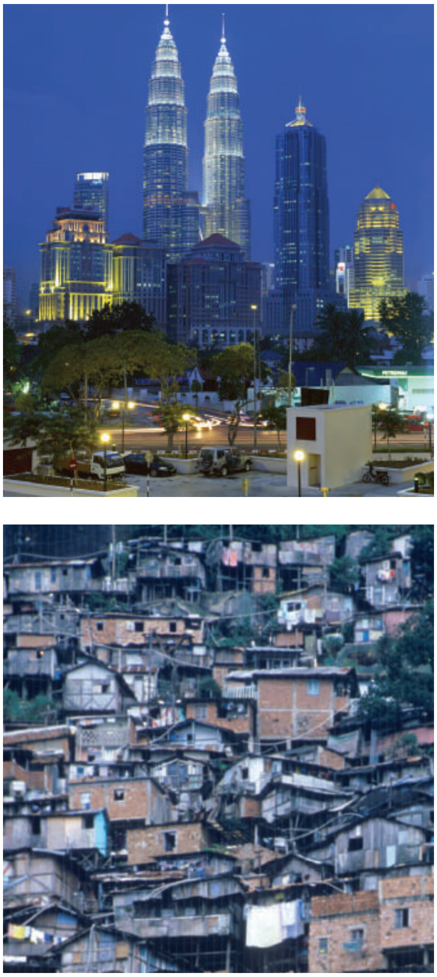
Jared Diamond

A country's affluence depends partly on its institutions. Geographic and other factors yield a fuller explanation, illuminate the origins of 'good' institutions, and suggest targets for foreign aid.

Why are per capita income and gross national product more than 100 times higher in some countries than in others? Why are resource-poor Iceland and Luxembourg among the ten richest countries, while resource-rich Bolivia and Nigeria are among the poorest? This question is of practical as well as academic interest: if we knew the answers, perhaps poor countries could use them to achieve wealth. But the question is controversial and complicated, as a burst of publications attests[1–9].

The usual view is that differences in national wealth arise from differences in the accumulation of physical and social capital and in the adoption of new technology, due in turn to differences in the quality of political and economic institutions[10–14]. Rich countries are rich because they have 'good' institutions promoting investment and accumulation of wealth. A conclusion from this view, embraced by many aid programmes, is that the best way to help poor countries is to assist them in developing good institutions — such as the rule of law, honest, efficient government, impartial enforcement of contracts, unimpeded flow of capital and goods across international borders, and protection of investors' property. The most convincing support for this view comes from four pairs of neighbouring countries sharing the same environment, one of them rich and with 'good' institutions, the other poor and with 'bad' institutions: South and North Korea, the former West and East Germany, Israel and its neighbours, and the Dominican Republic and Haiti.

This answer undoubtedly contains much truth. No one considers it wrong, and many commentators consider it a full answer (and disagree with the studies discussed below). However, increasing numbers of economists find it incomplete, for two reasons. First, the answer merely notes national differences in institutional quality, and says nothing about their origin. Why did Luxembourg, of all countries, end up with good institutions, whereas Nigeria didn't? Second, the answer neglects the non-institutional factors.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JOHN MAIER JR/STILL PICTURES

Figure 1 **Rich and poor: skyscrapers and a shanty town, icons of contrasting conditions among the world's nations.**

As regards origins, good institutions don't arise at random around the world. Instead, they are outcomes of a long history shaped by geography, which helps to explain why Luxembourg has them but Nigeria doesn't. The origins of complex institutions are linked inextricably with the origins of states, which unfolded over thousands of years as by-products of sedentary, populous agricultural societies. These arose independently in only a few areas of the world endowed with many domesticable wild plant and animal species, beginning around 8500 BC in the Fertile Crescent of the Middle East[15]. In particular, state societies gradually evolved national loyalty instead of clan loyalty, deep experience of centralized government, pools of trained administrators and educated, literate citizens, and enforcement of social norms through government-administered laws rather than through individuals taking matters into their own hands. It proves difficult to telescope those developments of millennia into a generation through imitation and foreign aid.

Two studies[1,2] by economists demonstrate this relevance of historical geography to institutional origins. In one study, Hibbs and Olsson[1] compared 112 nations' per capita wealth with the time since the local transition from hunting/gathering to agriculture. Two conclusions emerged: the larger the local biogeographic endowment of domesticable, large wild mammals and large-seeded wild cereals, the earlier was that transition locally; and the earlier that local transition, the richer is the country today. Part of the explanation is that some (but not all) countries with a long history of complex agricultural societies ended up with good institutions: geography and biogeography account for 40% of the explained variance in institutional quality.

In the other study[2], Bockstette *et al.* examined the growth rate of per capita wealth in the past 50 years, instead of current wealth itself. It turned out that countries with a long history of state societies have recently tended to enjoy high growth: countries that 50 years ago were still poor but had already developed complex institutions caught up quickly, once they added advanced technology to their institutional advantages.

For example, around 1950, when South Korea, Ghana and the Philippines were equally poor, most economists predicted that resource-rich Ghana and the Philippines were on the verge of wealth, whereas South Korea was doomed to remain mired in poverty. The result, of course, has been the opposite, because for 1,300 years South Korea has formed half of a unified, literate kingdom, and was strongly influenced by neighbouring China (one of the world's two oldest agricultural civilizations) long before that, whereas Ghana and the Philippines were exposed to rudimentary state government only within the past few centuries. As another example, Iceland, until a century ago Europe's poorest