a hot topic of research and debate.

Like dietary restriction, resveratrol has long been known to have interesting properties. During the 1990s it was extensively studied as a potential link between improvements in a variety of health indicators and moderate consumption of red wine[2]. The antioxidant properties of resveratrol, in particular, have been suggested to account for many of its beneficial properties, including putative cardioprotective and anticancer activities, as well as providing protection against liver failure. Here it is noteworthy that Baur *et al.*[1] show that resveratrol has a profound ability to prevent liver damage associated with the high-fat diet.

Resveratrol became of particular interest to gerontologists with the report[3] that it can increase lifespan in yeast by activating particular enzymes (protein deacetylases) of the Sir2 family of proteins (sirtuins). Sirtuins are evolutionarily conserved mediators of longevity that might also play a role in lifespan extension through dietary restriction[4]. Although the results from the initial study of resveratrol in yeast remain controversial[5], subsequent work has suggested that resveratrol has modest effects on lifespan in both worms and flies[6], and a more substantial effect on lifespan in a short-lived fish[7]. Based on these findings, it has been proposed that resveratrol increases lifespan in several different organisms by a mechanism similar to dietary restriction[8].

Baur *et al.*[1] favour the view that many (perhaps all) of the beneficial properties of resveratrol are the result of increased sirtuin activity, and various studies have supported the idea that sirtuins underlie the effects attributed to resveratrol *in vivo*[8]. However, there is a surprising lack of biochemical evidence that resveratrol directly increases sirtuin-mediated deacetylation of biologically relevant substrates, and some evidence that it may not[5,9]. Resveratrol is also known to interact with numerous proteins and pathways, including mitochondrial ATP synthase and complex III, fatty-acid synthase, protein kinase C, p53, MEK1, TNF-α and NF-κB, all of which are candidates for mediating its *in vivo* effects. In particular, activation of AMP kinase by resveratrol protects against atherosclerosis and liver damage in diabetic mice[10], suggesting a likely mechanism for the observations reported by Baur and colleagues.

Given the available data, it is difficult to predict the answers to a few key questions. Will resveratrol have an effect on health and longevity in mice fed a standard diet, rather than a high-calorie diet? Will it be effective in mice with genetic backgrounds other than the inbred strain used in the current report? Will it be effective in humans? Studies addressing these questions are under way: the answers will go some way towards determining whether or not resveratrol is a bona fide dietary-restriction mimetic.

Many people will wonder whether they should start supplementing their diets with resveratrol. After all, it is generally regarded as safe, and can be purchased over the Internet with promises of improved health and longevity. Our advice is to exercise caution. The safety of resveratrol at the high doses in humans comparable to those used by Baur *et al.*[1] is unknown, especially over the course of years or even decades, when relatively modest side effects could have dramatic consequences. A logical next step would be to initiate controlled studies to find out whether resveratrol can safely reduce the ill-effects associated with diabetes or obesity in humans.

In the most optimistic assessment, a true mimetic of dietary restriction could be effective against many age-associated human diseases, including heart disease, diabetes, cancer and neurological disorders such as Alzheimer's disease. Even if resveratrol doesn't make the grade, it is not the last hope of gerontologists, or necessarily even the best. Studies of several other compounds are under way in multicentre studies of mouse ageing sponsored by the National Institute on Aging[11]. These include potent antioxidants and compounds targeting other pathways thought to influence lifespan extension through dietary restriction.

For now, we counsel patience. Just sit back and relax with a glass of red wine — which, alas, has only 0.3% of the relative resveratrol dose given to the gluttonous mice (note also that increasing the dose via wine will not be healthy). But if you must have a Big Mac, fries and apple pie, we may soon know if you should supersize that resveratrol shake. ■

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FLUID DYNAMICS

Spinning discs in the lab

Steven A. Balbus

What causes gas to be drawn in towards black holes, rather than remain in a stable orbit as planets do around the Sun? A laboratory result indicates that something more than just hydrodynamics must be at work.

On page 343 of this issue, Ji *et al.*[1] describe a meticulous experiment in which they confined water between two independently turning cylinders. Through artful experimental design, the authors were able to reduce viscous effects in the resulting 'Couette' flow to a level of one part in two million. They chose the velocities of the cylinders so that they would mimic — and so compel the confined fluid to mimic — so-called keplerian rotation, which is typical of astrophysical disks around black holes. Here, velocity is inversely proportional to the square-root of the distance from the centre of the rotation.

The result was that nothing happened at all: the fluid continued to rotate stably. But why exactly do astrophysicists and fluid dynamicists find this apparently harmless result so surprising?

In the early 1970s, astrophysicists were struggling with the exciting and controversial question of whether black holes — objects whose gravity is so great that nothing, not even light, can escape once captured — were real[2]. Only slightly earlier, a series of compact sources of X-ray radiation had been discovered. One model held that this radiation originated from gas disks surrounding black holes in binary systems of close stars[3] and galactic nuclei[4]. This gas would dissipate its energy as heat, and ultimately X-ray radiation. Its angular momentum would be transported outward, and the gas would spiral inward towards the hole. By understanding these 'accretion disks', astronomers hoped that they would, in one fell swoop, both explain the mysterious X-ray sources and prove that black holes exist.

The existence of black holes and their accretion disks is now widely accepted by both theorists and observers. But understanding the dynamics of accretion disks, in black holes and in other types of system, has turned out to be an extremely knotty problem. Why do disks accrete at all? Why does gas in motion around a massive centre not remain in a stable, planet-like orbit?

The problem is that energy dissipation and angular-momentum transport are properties of a viscous fluid, and the viscosity of the disk gas is far too small to account for the angular-momentum loss that leads to accretion. This problem might be solved if a keplerian gas were turbulent. A turbulent fluid can have a small particulate viscosity, yet behave in some ways as though it were viscous: correlations between different components of the fluid's velocity fluctuations cause both substantial energy dissipation and enhanced momentum transport.

The importance of viscosity in fluid flow is measured by a dimensionless quantity known as the Reynolds number; a high Reynolds number indicates a small viscosity. Shear flows (those with regions moving at different velocities) of high Reynolds number are generally exquisitely unstable to any small perturbation[5]. But astrophysical disks both shear and rotate; the rotation introduces Coriolis forces, which can sometimes stabilize an otherwise turbulent fluid.

Starting in the late nineteenth century, the British physicist Lord Rayleigh investigated fluids similar to the gas in an astrophysical disk that rotate differentially (at different speeds according to radial distance) and have a very small viscosity. He found that such fluids would become unstable (and possibly turbulent) only where the specific angular momentum of the flow decreases as one moves to greater radii. In a keplerian disk, however, the specific angular momentum increases with radius. According to the Rayleigh criterion, such a flow is stable.

Because the Rayleigh criterion applies only to infinitesimal disturbances, not those of finite amplitude, and only to perturbations that are symmetrical about the axis of rotation, the formal stability of keplerian disks did not immediately embarrass the theorists. Indeed, although Couette experiments[6] persistently failed to reveal instability for keplerian profiles, it was widely believed that differentially rotating flows would ultimately prove to be unstable; it was simply a matter of reaching large enough Reynolds numbers in the laboratory[7].

For many, this 'faith-based' approach to turbulent hydrodynamical accretion was less than satisfying. The discovery[8] in 1991 that even very weak magnetic fields profoundly alter the stability of rotating gases improved matters. A rotating magnetized gas becomes unstable when its angular velocity decreases as one moves away from the centre, a condition nearly universally satisfied in astrophysical disks. Computer simulations have since shown that this 'magnetorotational instability' leads to precisely the sort of turbulence that disk theorists are seeking[9].

Not all disks are ionized throughout to an extent that would allow magnetic fields the necessary influence to seed instability. Only a very small electron component is needed to couple the field and the gas, but accretion disks associated with the formation of stars, known as protostellar disks, seem to contain an extended region that is cold, dense and dusty. In such a region, free electrons are suppressed, and gas and field are decoupled. For this reason and others, many disk theorists continued to believe that a fluid of large Reynolds number undergoing keplerian shear would ultimately prove to be turbulent. In 2001, a laboratory Couette-flow experiment at large Reynolds number seemed to find just that[10].

One of the great difficulties in working with Couette flows is that the rotating cylinders have end-caps that rotate uniformly, whereas in the adjacent fluid the rotation is a function of distance from the rotation axis. This mismatch creates a boundary layer near the end-cap and a secondary axial velocity flow known as an Ekman circulation in addition to the purely rotational flow that one wishes to study. This effect can be controlled to some extent by making the cylinders very long, distancing the end-caps from the bulk of the flow.

Ji and colleagues, however, wish to use their apparatus[1] in investigations of the magnetorotational instability. These require a very uniform magnetic field that would be difficult to maintain over a long cylinder. So the authors overcame the Ekman circulation problem by splitting the end-caps into two parts that rotate at different speeds. This was sufficient to control the Ekman circulation and to attain an exceptionally high Reynolds number of around 2×10^6.

The authors' finding that, at such a high Reynolds number, the rotation profile of a keplerian fluid is as stable as the rotation of a solid body should lay to rest the notion that any rotating flow (in general) or an accretion disk (in particular) is nonlinearly unstable simply if its viscosity is sufficiently small. The implication, for which there is now growing astrophysical evidence[11], would seem to be that accretion is magnetically, not hydrodynamically, driven.

Ji and colleagues' primary goal for their apparatus was to find evidence for the magnetorotational instability in liquid gallium, and the results of these experiments are yet to come. The researchers might thus be poised for a double coup: tolling the death knell for hydrodynamical shear turbulence in accretion disks, and capturing magnetic instability in a cylindrical flow for the first time. ■

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ENVIRONMENTAL CHEMISTRY

Browning the waters

Nigel Roulet and Tim R. Moore

Levels of dissolved organic carbon in British streams and lakes have risen over the past two decades. It might be a downstream effect of decreased acid rain — but isolating single factors is notoriously difficult.

It may be small, but dissolved organic carbon (DOC) — operationally defined as organic compounds in water that can pass through a 0.45-μm filter — is of great interest. The export of DOC from land to aquatic ecosystems and the oceans is a significant mover of carbon through continents and local landscapes (Fig. 1, overleaf). In some ecosystems, loss of DOC can be as great as long-term accumulation of carbon in the form of dead organic material, for example as peat in peatlands. Then there is its role in the metabolism of lake ecosystems and the protection of aquatic organisms: DOC-rich waters are light brown, and so absorb ultraviolet radiation. On the other hand, DOC-rich water can produce carcinogens when chlorinated. Last — but for the bibulous not least — DOC content is even believed to help determine differences in the flavours of malt whiskies.

This is the context in which Evans *et al.*, writing in *Global Change Biology*[1], supply evidence that median DOC concentrations in eight streams and ten lakes in the United Kingdom have almost doubled from 1988 to 2003. It is important to distinguish between DOC export and concentration here: whereas increased export can result from an increase in runoff with no change in concentration, increased concentrations can occur with no change in hydrology, but with altered production or retention of DOC in the landscape. Increased export of DOC through streams and rivers in the Northern Hemisphere has been observed before, specifically in western Siberia as a result of increased release of DOC from peatlands[2]. But decreased DOC export has also been observed, in the Yukon river system of