Electricity storage

Ne plus ultra

A new version of an old idea is threatening the battery industry

PUT the pedal to the metal in the XH-150 – a souped-up Saturn Vue – and watch the instruments. Sure enough, the speedometer shoots up in a satisfactory way. But an adjacent dial shows something else: the amount of charge in the car's capacitors is decreasing. Ease off the accelerator and as the speedo winds down the capacitors charge up again.

Such a capacitor gauge could become a common sight on the dashboards of the future. A capacitor can discharge and recharge far faster than a battery, making it ideal both for generating bursts of speed and for soaking up the energy collected by regenerative braking. AFS Trinity, a company based in Washington state, has turned that insight into a piece of equipment that it has fitted into an otherwise standard production model as an experiment. The result – the XH-150 – was unveiled at this year's Detroit motor show.

In fact the XH-150 is a three-way hybrid, employing a petrol engine and conventional lithium-ion batteries as well as its special capacitors. An overnight charge gives it an all-electric range of 40 miles (60km), after which the petrol engine needs to come into play. AFS Trinity says the vehicle is capable of more than 80mph and returns the equivalent of 150 miles per gallon (more than 60km/litre) in normal use. Edward Furia, the firm's chief executive, reckons the extra kit would add around $8,700 to the price of a petrol-only vehicle were it put into mass production.

This, however, may be only the start. Eventually, the so-called ultracapacitors on which the XH-150 is based may supplant rather than merely supplement a car's batteries. And if that happens, a lot of other batteries may be for the chop, too. For it is possible that the long and expensive search for a better battery to power the brave, new, emission-free electrical world has been following the wrong trail.

Full capacity

A traditional capacitor stores electricity as static charges, positive and negative, on two electrodes that are separated by an insulator. This works best when the electrodes are parallel with each other, which means they need to have smooth surfaces. The amount of charge that can be stored depends on the surface area of the electrodes, the strength and composition of the insulation between them, and how close they are together. If the electrodes are then connected by a wire, a current will flow from one to the other. A battery, by contrast, stores what is known as an electrochemical potential. Its two electrodes are made of different chemicals—ones that will release energy when they react. But because the electrodes are physically separated from one another their chemical constituents can react only by remote control.

This is able to happen because the space between the electrodes is filled with a material called an electrolyte which allows ions (electrically charged atoms, or groups of atoms) to pass from one electrode to the other and thus combine with their chemical complements. To compensate for this movement of ions, electrons have to move in the opposite direction—and if the electrodes are connected by a conducting wire running through a useful circuit, that is the route they will take. Chemical electrodes of this sort can store a lot more energy than the static electricity of a capacitor. But the whole process of ion movement and chemical reaction is slower than the movement of electrons in a capacitor. Hence the different advantages of the two storage systems: capacitors give speed; batteries, endurance.

The reason ultracapacitors may be able to bridge the gap between speed and endurance is that, like batteries, they use ions and an electrolyte rather than simply relying on the static charges. In an ultracapacitor, positively charged ions gather on the surface of the negatively charged electrode and negative ions on the surface of the positive electrode. Since the ions do not actually combine with the atoms of the electrodes, no chemical reaction is involved. The ionic layers are also very close indeed to the surfaces of the electrodes, and obviously run parallel with them whatever their shape. This, in turn, means clever engineering can increase the surface area (and thus the storage capacity) without increasing the volume. And that gives endurance without sacrificing speed.

Existing ultracapacitors get their extra surface area by using electrodes coated with carbon and etched to produce holes, rather like a sponge. This gives about 5% of the storage capacity of a battery. But Joel Schindall and his colleagues at the Massachusetts Institute of Technology think they can do better than that using nanoengineering. Instead of digging holes in the electrodes, they are coating them with a forest of carbon nanotubes, each five nanometres (billionths of a metre) wide. This, they hope, will push capacitors to 50% of a battery's storage capacity.

A different approach has been taken by EEStor, a Texan firm that has developed a capacitor it claims can store “very high” levels of energy using a special insulator called barium titanate rather than an electrolyte. Its “Electrical Energy Storage Units” will go into production later this year. EEStor recently signed a deal to supply Lockheed Martin, a big defence contractor, which wants to use the storage units in rugged packs that will power a variety of military and security equipment.

EEStor also envisages employing its devices to build an “energy bank” to store off-peak power and release it when demand is high. One use of such a bank, the firm suggests, could be the rapid charging of electric cars—which would, of course, also be fitted with capacitors.

That would remove a big obstacle to the adoption of electric vehicles in general —that it takes so long to refuel them. If a driver could pull into an electrical filling station and top up his capacitors as rapidly as he can now replenish his petrol tank it would both increase the effective range of all-electric vehicles and decrease resistance to buying them in the first place.

At least one firm is backing the logic of this argument in its showrooms rather than just in prototypes. Ian Clifford, the chief executive of the Zenn Motor Company in Toronto, has done a deal with EEStor to replace the lead-acid batteries in the small, low-speed electric cars that his firm sells for urban use. Mr Clifford reckons that ultracapacitors will transform his vehicles and enable them to be used on motorways as well as city streets.

Whether ultracapacitors really will take over the market now dominated by batteries, rather than merely supplementing them in it, remains to be seen — for batteries themselves are also getting better. They do have a chance, though, of being one of the 21st century's disruptive technologies. And even if they do not replace batteries entirely, the world will surely be seeing more of them in applications which need that little bit of extra oomph from time to time. After all, as Dr Schindall points out, animals use two types of muscle fibre: one for endurance and one for rapid movements. So it could make sense for machines to do the same.

Diet and behaviour

Eat it up and be a good boy

Prisoners benefit from dietary supplements; prisons might benefit, too

SUPPLEMENTS are all the rage: evening primrose oil; St John's wort; fish oils; glucosamine; selenium; zinc; iron; molybdenum; probiotics. And don't forget those old standbys, multivitamin tablets. It is hard to walk through a pharmacy without seeing a promise of clearer skin, a stronger immune system or less squeaky joints. But what about a pill or potion to make you better behaved?

That is exactly the intention of a study led by John Stein, a professor of neuroscience at Oxford University, that is about to start in three British prisons. Not only is there a growing body of evidence that good nutrition can improve behaviour, there is also a theoretical basis for supposing that a lack of essential nutrients has an impact on the way the brain works.

Dr Stein believes that the proper functioning of nerve-cell membranes and signalling molecules depends on adequate supplies of minerals, vitamins and fatty acids. To test the idea, his team will recruit 1,000 prisoners. Half of them will receive these supplements, while the others receive a placebo. Neither prisoners nor experimenters will know who got what until the trial is over.

The trial will replicate, on a larger scale, a study carried out by Natural Justice, a British charity, and published in the British Journal of Psychiatry in 2002. Then, 231 volunteers were given either capsules containing their official daily requirements of vitamins, minerals and essential fatty acids (such as omega-3s) or placebos. The trial lasted for nine months and during that time the number of offences committed by each prisoner was recorded. Those who received the extra nutrients committed an average of 26.3% fewer offences than those who got the placebo. For violent offences, the reduction was 37%.

Two years later a study in the Netherlands reached similar conclusions. Indeed, the number of disciplinary offences fell by almost half. Supplements were deemed so cost-effective that they would allow prison services to be improved at the same time as saving money.

Dr Stein's study will attempt to find out more details about how the supplements work. Blood samples will be taken and the levels of nutrients in these samples correlated with prisoners' “impulsivity” and the variability of their heart rates. Heart-rate variability, says Dr Stein, is a good index of the degree of control an individual has over his autonomic nervous system (which controls many of the internal organs). This in turn is a predictor of anti-social behaviour.

Although nobody is suggesting that diet is the only factor that determines whether someone will behave badly in prison, it is increasingly clear that a poor diet can make behaviour worse. Although nutritionists are often a little sniffy about dietary supplements, pointing out instead how important it is to eat the right food in the first place, there are corners of society in which people lack either the knowledge or the means to do so, or simply choose to eat poorly.

In British prisons, serving time in jail used to be known as “doing porridge”, because a bowl of oatmeal was an inmate's regulation breakfast. These days British prisoners have access to a far wider range of foods but nevertheless often make poor choices and consume diets that are far from ideal. So although prisoners, like anyone else, are well advised to choose a balanced diet, they may not pay much heed. Unless, of course, being forced to eat your greens becomes a standard part of a custodial sentence.

Drug testing

The invisible man

A new way of using computers to test drugs gets its first outing

NINE years ago a group of enthusiasts who were looking for signs of alien life in the universe had a bright idea. They would farm the task out to thousands of owners of personal computers by sending them chunks of data from radio telescopes, along with the software needed to look for intelligent signals. That idea caught on, and is now applied to many other things, including the search for promising drugs. Researchers at University College, London, are taking it a bit further. Instead of farming out their drug-testing project to the world's PCs and Macintoshes, they have gone for the jugular: the world's supercomputers.

The drug in question is saquinavir, one of a class known as protease inhibitors, which revolutionised the treatment of AIDS when they were introduced in 1996. Protease is a protein crucial to the life cycle of HIV, the AIDS-causing virus. However, as often happens, evolution has got to work and generated drug-resistant strains of the virus by modifying its protease. As they report in the Journal of the American Chemical Society, Peter Coveney and his colleagues wanted to investigate resistance to saquinavir by using a computer model to predict how it binds to the particular forms of protease produced by different resistant strains of HIV.

This is an important problem in its own right. But Dr Coveney's study was also a test of what is known as the Virtual Physiological Human (VPH). This is a project designed to simulate the human body—a huge undertaking that has, perforce, to be spread over many supercomputers of the sort more usually used to forecast the weather and model nuclear explosions.

Dr Coveney recruited both Britain's national supercomputer grid and America's TeraGrid for the endeavour and, encouragingly, the project worked. The results from the model match those from the real world, which increases confidence that predictions made by the VPH about other processes will also be accurate.

The hope is that as the VPH becomes more comprehensive, and as the price of computing power falls, it might be possible to use it to design patient-specific treatment regimes “on the fly”. Distributed computing may or may not find aliens. But it looks a good way to investigate that most alien creature of all: man.

Linguistic evolution

Received pronunciation

Languages and species evolve in surprisingly similar ways

ONE of the unresolved—and rather bitter—disputes in evolutionary biology is between the creeps and the jerks. The creeps (so dubbed by the jerks) think that evolutionary change is gradual. The jerks (so dubbed by the creeps) think it happens in sudden jumps that are separated by long periods of stasis.

Probably, both are true. Work done a couple of years ago by Mark Pagel of Reading University, in England, suggests that about a fifth of evolutionary change happens jerkily at around the time new species form. The rest creeps in gradually over the millennia.

Species, however, are not the only things that evolve. Languages do too. And in the current edition of Science, Dr Pagel and his colleagues publish evidence that they do so in a way which looks intriguingly similar to what happens in species.

There was already some historical evidence for this. The English of Geoffrey Chaucer (born in the 14th century), for example, is incomprehensible to modern laymen, whereas that of William Shakespeare (born in the 16th) is not only comprehensible but held by some to be a model. Dr Pagel, however, wanted to examine the question systematically and to include languages with no literary history in his analysis.

To do so he looked at three well-studied parts of the linguistic family tree: the Bantu languages of Africa, the Indo-European group from Eurasia and the Austronesians of the Pacific. In all three cases it is pretty clear how the branches connect up, even if it is not always obvious when particular splits occurred.

Dr Pagel did not, however, need to know that. He only needed to know the shape of the tree. That was because his hypothesis was that if linguistic evolution is jerky, the jerks will happen at the points where languages split—the equivalent of species splits in biological evolution. The way to test that is to track back along the branches leading from each existing language, and count the number of splits on each path before you get to the common ancestor of all.

His hypothesis turned out to be correct. Languages are formed not, it seems, by a gradual drifting apart of two groups who no longer talk to each other, but by violent rupture. Around a third of the vocabulary differences between modern Bantu speakers arose this way, around a fifth of the differences between speakers of Indo-European languages, and around a tenth of the Austronesians. That compares with around a fifth for biological species.

All this suggests that the formation of both languages and species is an active process. For species, adaptations to novel environments and the need to avoid crossbreeding with those on the other side of the split are both plausible hypotheses. For languages, the explanation may be a cultural rather than biological need to distinguish populations. As Noah Webster, the compiler of the first American dictionary, put it: “as an independent nation, our honor [sic] requires us to have a system of our own, in language as well as government.” In other words, if you don't speak proper, you ain't one of us.