common switching effects (twisted nematic, supertwisted nematic and vertically aligned nematic) are not appropriate. Moreover, it is not clear that satisfactory alignment across the entire liquid crystal layer can be generated from a single aligned substrate. The authors also hint that controlling the thickness of the liquid crystal layer may be an issue; in normal LCDs, the thickness of this layer is controlled to a tolerance of 1%.

Most of all, if PES is to be adopted as a production technique, the challenge of device lifetime must also be overcome. One of the main reasons that plastic substrates have not yet replaced glass in the conventional LCD sandwich is their reduced lifetime, owing to the permeability of plastics to atmospheric contaminants such as water and oxygen. This would be particularly important if active devices such as thin-film transistors are used on the substrate. Thin-film transistors are used to drive most high-information-content LCDs and they require liquid crystal of very low conductivity. If the liquid crystal is contaminated it becomes too conducting.

However, any new technique has problems to be solved and challenges to be met before it can be widely adopted. The history of LCDs shows that industry has been highly successful in overcoming such challenges. The idea of being able to paint an LCD onto a substrate of arbitrary size and shape is so attractive that one suspects that the underlying problems will be solved. We can look forward to the day when we will be able to put displays on almost anything. ■

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Neurobiology

The amazing astrocyte

Clive N. Svendsen

Two regions of the brain in adult mammals contain stem cells that can generate new neurons. It seems that astrocytes — cells once viewed merely as padding in the brain — can stimulate the neuron-generating process.

The cells that make up our brains come in two main flavours: neurons and glia. Neurons conduct action potentials and have traditionally held centre stage in neurobiological research. By contrast, glia have often been seen as the poor relatives. With their name originating from the Greek word for glue, they were for many years viewed simply as the brain's packing material, holding neurons in place. But this view is changing rapidly. One dominant type of glial cell is the astrocyte, and studies of its functions continue to take intriguing twists and turns. As well as providing structural support for nerve cells, astrocytes are now known to modulate the environment around neurons, release a range of neuronal growth factors and help to maintain the cellular barrier between blood and brain. They may also control neuronal life more directly by regulating the production of synapses, the brain's chemical junctions[1]. On page 39 of this issue Song *et al.*[2] add to this impressive list, showing that astrocytes can also instruct unspecialized cells to become neurons — a process termed neurogenesis. It seems that, in the cellular hierarchy of the nervous system, astrocytes are upwardly mobile.

At first glance, the idea that astrocytes control neurogenesis appears very unlikely — during brain development, most neurons are created much earlier than these glial cells. But matters are different in adult brains, which contain neural 'stem cells' that constantly produce new neurons in the presence of existing astrocytes. Neural stem cells, by definition, must renew themselves and produce both neuronal and glial lineages (Fig. 1, overleaf). In adult brains, this process is controlled by a combination of the stem cells' intrinsic properties and their local environment, so the exact location of adult neural stem cells is a topic of intense investigation.

In this context, the two best-studied brain regions are the hippocampus and the areas immediately surrounding the walls of the fluid-filled ventricles found in the centre of the brain and spinal cord. The 'subventricular zone' in forebrain ventricles is probably the most dynamic of the brain's neurogenic regions, daily producing thousands of new neurons that migrate into the olfactory bulb. The hippocampus likewise produces new neurons. But in most brain regions and within the spinal cord in adults, neurogenesis is very limited. If it could be enhanced and better controlled in neurogenic regions, or triggered elsewhere, it might prove possible to repair brain tissue that has been damaged through trauma

Systematics

Old insects in new order

It's a once-in-a-lifetime event. The creatures pictured here are members of the first new order of insects to be discovered since before the First World War. The Mantophasmatodea, as they have been christened, take their place alongside the other 30-odd insect orders such as beetles, flies and termites.

Writing in *Science* (online 19 April 2002; DOI 10.1126/science.1069397), Klaus Klass and colleagues have described the first two species of the order from museum specimens. Collected in Tanzania and Namibia in the early years of the last century, the specimens had languished unidentified in Lund, Sweden, and Berlin.

Most exciting of all, an expedition to Namibia earlier this year found living mantophasmatodid species in the tall grass atop the country's Brandberg Mountains. All specimens found so far are about two centimetres long. Analysis of stomach contents shows that they eat other insects. Three or four more species await description.

There are also fossil specimens. The species *Raptophasma*, described last year from an insect trapped in amber, shows that mantophasmatodids were present in Europe during the Eocene, about 45 million years ago. The living African species might be the remnants of a once-widespread group now perilously close to extinction, or they might still be widespread in Africa.

Klass *et al.* suggest that the new order is most closely related to the stick insects, and to a group called the Grylloblattodea, or ice-crawlers. This group, known from about 25 species found on mountaintops in North America and Asia, was the last new order, discovered in 1914. DNA sequencing now under way might help to pin down the Mantophasmatodea's exact position in the tree of life. **John Whitfield**

ANITA BHATTACHARYYA & CLIVE SVENDSEN

or neurodegeneration, as in Alzheimer's and Parkinson's diseases.

Song *et al.*'s discoveries[2] may lead to a better understanding of how neurogenesis could be stimulated. The authors isolated neural stem cells from the hippocampus of adult rats, and engineered the cells to express green fluorescent protein (GFP), allowing them and their progeny to be easily traced. After culturing the stem cells with astrocytes from the hippocampus of newborn rats, Song *et al.* found that the rate of neurogenesis increased more than eightfold. By contrast, GFP-labelled stem cells cultured with fibroblast cells or purified neurons did not change their rate of neurogenesis. Next, the authors showed that astrocytes derived from the adult hippocampus could also increase neurogenesis, albeit with less efficiency than hippocampal astrocytes from newborn rats. The astrocytes appeared to work by increasing the rate of proliferation of the stem cells and steering their progeny towards becoming neurons, rather than simply enhancing the survival of new neurons.

Is this feature common to all astrocytes? To find out, Song *et al.* purified astrocytes from the spinal cord of newborn and adult rats — a region that does not normally show neurogenesis *in vivo*. The spinal-cord astrocytes from newborns had only small effects on neurogenesis from hippocampal stem cells; adult spinal-cord astrocytes had no effect. So there is significant regional specificity in the ability of astrocytes to induce neurogenesis.

Song *et al.*'s demonstration that astrocytes can control the proliferation of hippocampal stem cells accords with previous studies that used stem cells from other brain regions. For example, astrocyte fragments can modulate the proliferation of stem cells from the cortex of developing rats[3], and astrocyte monolayers can increase neurogenesis from adult subventricular-zone stem cells[4]. What is new and fascinating about Song *et al.*'s work is that it shows that astrocytes can direct the fate, as well as the proliferation, of hippocampal stem cells, inducing their progeny to become neurons rather than glia — and that this depends on using astrocytes from neurogenic brain regions.

One rather simple explanation for Song *et al.*'s regional-specificity results is that the spinal cord contains older astrocytes than the hippocampus, which constantly renews at least some of its astrocytes. (In fact, the neuron-producing hippocampal stem cells may even be astrocytes[5].) In support of this idea, newly generated astrocytes can increase the growth of neuronal extensions (neurites), whereas older astrocytes cannot[6]. But whatever the explanation, it should be possible to dissect the mechanisms underlying the ability of astrocytes to control neurogenesis.

For example, researchers could use microarray technology to identify which genes are expressed differently in those astrocytes that can and cannot promote neurogenesis. Hot candidates might be genes encoding molecules similar to Noggin, which is known to be released from the ependymal cells lining the ventricles of the brain. Noggin can induce neurogenesis from subventricular-zone stem cells, both *in vitro* and following grafting into the brain, by inhibiting glial signalling pathways involving bone morphogenetic proteins (BMPs)[7]. As Song *et al.* mention, if neural stem cells are taken from the spinal cord and grown in culture, they can produce small numbers of neurons. This suggests that neurogenesis-inhibiting factors such as BMPs may be present in intact spinal cords. They may also be present in astrocyte cultures generated from the spinal cord, perhaps explaining why such astrocytes cannot promote the proliferation of hippocampal stem cells.

It is also interesting that stem cells generated from different regions of human and rodent embryonic brains retain their regional specificity. Those from the forebrain generate more neurons than those from the hindbrain and have distinct gene-expression patterns, even after long periods in culture[8,9]. It remains to be seen whether this regional specificity of stem cells is due to their control by regionally specific astrocytes, but Song *et al.*'s paper makes it an intriguing possibility.

Another question is whether it might be possible to enhance brain repair simply by exposing stem cells that do not normally make neurons to 'neurogenic' astrocytes. An obvious way of finding out would be to transplant hippocampal astrocytes into a damaged spinal cord, and to see whether spinal-cord stem cells then produce neurons. Whatever the results, there will certainly be a complex interaction between the intrinsic gene-expression patterns of the stem cell, and environmental cues such as those produced by astrocytes. The 'nature versus nurture' debate has never been more interesting

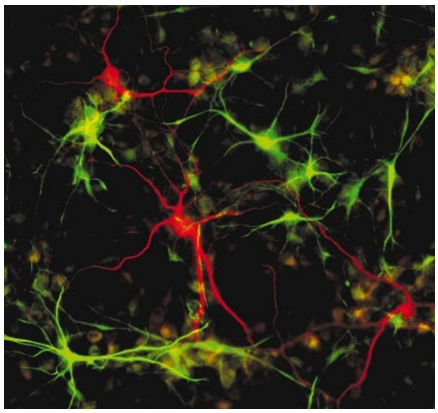

Figure 1 **More than just glue. Glial cells such as astrocytes (green) were once thought to have a purely supportive role in the brain. But more recent work, including the paper by Song *et al.*[2], tells a different story. The image shows neurons (red) and astrocytes, derived from mouse neural stem cells.**

100 YEARS AGO

In the *Proceedings* of the American Philosophical Society for December 1901 (vol. xl. No. 167), Mr. Percival Lowell refers at some length to the observations that led to the announcement in the Press that Mars had been signaling to the earth on a night in December 1900. It may be mentioned that the *original* dispatch read as follows:— "Projection observed last night over Icarium Mare, lasting seventy minutes." (Signed) "Douglas." In the present paper Mr. Lowell describes in detail some of the individual observations, and points out how the Flagstaff observations of 1894 showed that on general principles the Martian projections were most probably not due to the existence of mountain peaks. A close study of the surface markings led both Messrs. Lowell and Douglas to the result that these several projections were not caused by such permanent suface markings as mountains, but were the effect of clouds floating in the planet's atmosphere… Mr. Lowell, in his concluding remarks, says that the surface marking, Icarium Mare, is undoubtedly a great tract of vegetation, and the observation of December is completely explained if it be assumed that a cloud was formed over this region and rose to a height of thirteen miles, and then, traveling east by north at about twenty-seven miles an hour, passed over the desert of Aeria and there was dissipated.
From *Nature* 1 May 1902.

50 YEARS AGO

A new field of the application of television was opened up about a year ago when, at the request of the admiralty, Marconi's Wireless Telegraph Co., Ltd., hurriedly assembled a television camera chain in an attempt to find the lost submarine *Affray*. A great deal of development work has since been carried out in co-operation with Siebe, Gorman and Co., Ltd.; and recently (April 17) a demonstration of the newly designed equipment was given in an experimental tank at the works of this Company. Among the special features of the apparatus shown were the use of the extremely sensitive image-orthicon camera tube, the enclosure of this camera and its associated components in a chamber capable of withstanding the water pressure prevailing at great depths, and the provision of remote-control facilities whereby the camera may be focused and directed by the operator who remains on the ship above.
From *Nature* 3 May 1952.

— and is as complicated as ever. One thing, however, is clear. The humble astrocyte deserves a lot more attention. ■

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Plant population biology

How to be invasive

Wim H. Van der Putten

Few clear answers have emerged from studies of the factors determining abundance of plants in particular settings. A new idea invokes the differing susceptibility of plant roots to damage from pathogenic soil microorganisms.

Why, in any particular ecosystem, are some plant species rare and others common? And why are some species highly successful in invading new territories whereas others never make it outside their own specific habitat? In tackling these questions, ecologists are trying to identify the primary factors that determine plant abundance. On page 67 of this issue[1], Klironomos presents three elegant experiments which show that natural plant abundance is related to the different rates at which soil pathogens develop on the roots of various species.

In his first experiment, Klironomos grew plants that are rare in semi-natural grasslands, and plants — originating from Eurasia — that have successfully invaded grasslands in North America since they were introduced more than a hundred years ago. He cultured examples of each plant species in pots containing soil from a grassland near the University of Guelph in Canada. After ten weeks, he removed all of the plant matter and put in new individuals of the same species. Then, after another ten weeks, he collected the plants and split the soil into two halves. In one half, the same plant species was grown for a third run; in the other half, examples of one of the other grassland species were grown.

After the third growth period, Klironomos weighed the plants and compared the results from 'home' soil with those from soil in which other plant species had been grown. The rare plants produced less mass when grown in their home soil than in soil used to grow other species, whereas most of the invasive plants performed best when grown in their own soil. This is a remarkable result. From his initial observations, it suggested to Klironomos that roots of rare plant species might be accumulating all sorts of soil microbes, including soil pathogens, whereas invasive plants predominantly accumulate mycorrhizal root symbionts — which, rather than hindering plant growth, actively promote it.

That possibility is supported by the results of a second experiment, where Klironomos used a special sieving technique to separate the mycorrhizal soil organisms, which are symbiotic fungi with relatively large spores, from smaller soil microbes that may include root pathogens. Adding mycorrhizal fungi to sterilized soil planted with each of the rare and invasive plant species resulted in an increase in the weight of most plant species. This was expected — mycorrhizal fungi not only promote growth but have a fairly wide range of hosts[2], so that even non-native plant species can form associations with them[3].

The more exciting result from this experiment is that Klironomos found that adding the remaining soil microbes had an adverse influence on the rare plant species, but no effect on any of the invasive plants. A supplementary experiment showed that dominant fungi present on the plant roots may contribute to this effect — rare plants rapidly accumulated soil pathogens, whereas invasive plants did not.

These results tell us a great deal about plant invasiveness. In their new territories, plants are liberated from their native soil community which results in two clear benefits. First, the invading plants escape from their soil pathogens but don't encounter new, species-specific ones. Second, mycorrhizal fungi can associate with a broad range of plant species[2], meaning that root symbionts are likely to be available to the invader. This makes any plant species, even those that are rare in their native area, a potential invader.

The many previous studies on invasive plants have produced all sorts of results, so few general conclusions about the factors promoting invasiveness have emerged[4]. Factors such as absence of above-ground natural enemies and genetic variation of the founding populations have been considered. But this is the first time that the effects of escape from natural soil pathogens have been looked at.

We do not know if the invasive plant species used by Klironomos are sensitive to soil pathogens in their area of origin. But we do know that some plants that are controlled by soil pathogens in their home territories, such as American cherry (*Prunus serotina*)[5], are highly invasive in new territories. We need further examples that include the responses of plant species in both their home and new territories to see how escape from specific soil pathogens may contribute to plant invasiveness.

In a final experiment, Klironomos grew a total of 61 species in a similar experimental set-up as before. By comparing the response of the plants to soils with different pre-growth histories, he found that rare plant species do better in the soil in which other species have grown than in their home soil, whereas it is the reverse for the more abundant plant species. The implication is that the rate at which plants accumulate soil pathogens can influence their potential abundance in the vegetation. Consequently, when plants escape from their soil pathogens, the patterns of abundance may drastically change. That happens in, for instance, the successional vegetation gradients of sand dunes[6], in which infestation of pioneer plant species by specific soil pathogens facilitates replacement of the pioneers by later species.

The response of grassland plants to soil organisms can also be analysed from other perspectives. How, for instance, does a plant's sensitivity to the accumulation of soil pathogens relate to the plant's life history —

BRIAN HUSBAND

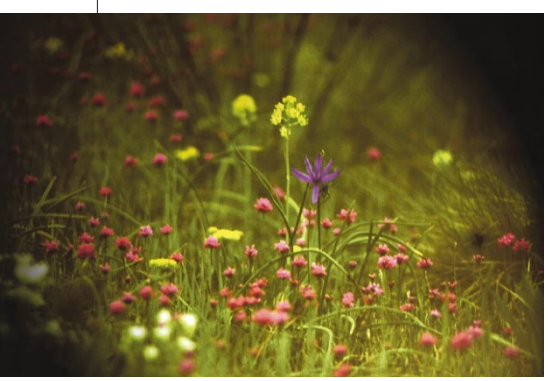

Figure 1 **Common as … this picture of a herbaceous plant community in the state of Washington shows an abundant species (*Plectritis congesta,* pink) and two rare ones (*Camassia* sp., violet; *Zigadenus* sp., yellow). Klironomos[1] digs into the reasons why some plants are abundant and others are not.**