



Figure 1 Would RHIC wreck the world? Fears that the Relativistic Heavy Ion Collider at Brookhaven in the United States could trigger an unforeseen disaster have been allayed by new calculations^{1,2} that show the risk of a worldwide catastrophe to be truly negligible.

have been a comment by theorist Frank Wilczek in the July issue of *Scientific American*³, which was picked up by a British newspaper. Later that month, the director of Brookhaven got together a panel of independent experts (including Wilczek) to investigate the reality behind the headlines. The report from Buzna *et al.*¹ identifies three conceivable disaster scenarios at RHIC: in which experiments produce 'black holes' that could gradually consume the Earth; a 'vacuum instability' that could expand catastrophically in all directions at the speed of light; or 'strangelets' — a stable kind of 'strange matter' — that would grow to incorporate ordinary matter, perhaps transforming the entire Earth into its form.

The first two issues have been raised, and dismissed, each time a new particle accelerator opens. Using similar arguments, Buzna *et al.* were able to conclude that neither poses any threat at RHIC. There is no chance at all that RHIC could manufacture a black hole or a gravitational singularity. Even if the RHIC (or its higher-energy successors) could create a black hole, it would be so tiny that it would evaporate instantly. Previous studies also argue against a vacuum instability, but cannot quite rule it out. In the natural world, relativistic heavy ions in the form of cosmic rays have been making RHIC-like collisions with one another in space for aeons (more, in fact, than will ever take place at RHIC). These distant collisions do not make RHIC experiments any less useful because they cannot be directly studied, but one fact is clear: cosmic-ray collisions in space have not led to the creation of a new vacuum, so we can breathe easily.

The third possibility is a new concern raised by the fact that RHIC accelerates

heavy ions rather than individual elementary particles, and must be considered more carefully. This was done by Buzna *et al.*¹ and also by Dar *et al.*² at CERN in Geneva. Both groups include theorists who were among the first to speculate that lumps of strange matter called strangelets — which contain many strange quarks as well as the usual up and down quarks that make up atomic nuclei — might be more stable than ordinary matter. If strangelets exist (which is conceivable), and if they form reasonably stable lumps (which is unlikely), and if they are negatively charged (although the theory strongly favours positive charges), and if tiny strangelets can be created at RHIC (which is exceedingly unlikely), then there just might be a problem. A newborn strangelet could engulf atomic nuclei, growing relentlessly and ultimately consuming the Earth. The word 'unlikely', however many times it is repeated, just isn't enough to assuage our fears of this total disaster.

Neurobiology

The topography of memory

Howard Eichenbaum

For more than 40 years neuroscientists have explored the cerebral cortex with microelectrodes, recording the electrical activity of single neurons while 'tickling' them with different stimuli. Early investigators found that the cortical areas responsible for initial processing of sensory information yielded their secrets relatively easily^{1,2} — for each area, a small set of simple sensory fea-

tures that activate the neurons could be identified. Many of these features have since been found to have a systematic anatomical organization; they are mapped onto the surface of the cortex, and the topographies for different sensory features are interleaved within each cortical area.

Since those early successes, the feature-coding properties of other cortical areas,

Once again, Mother Nature's own experiments with energetic cosmic rays have much to teach us. These natural processes produce collisions similar to those to be studied at RHIC, and in much greater numbers. Using different, but decisive, cosmic-ray arguments, the two groups^{1,2} make a compelling case that RHIC will not produce dangerous strangelets. Buzna *et al.* use the Moon as their canary. Lacking a protective atmosphere, with a surface rich in mid-sized atoms such as iron, it is a plausible target on which incident cosmic rays of iron (or larger) nuclei with RHIC energies could produce strangelets. Yet countless collisions over billions of years have left the Moon intact. In contrast, Dar *et al.* consider heavy-ion collisions in space that are virtually identical to those at RHIC. Strangelets produced in this way would be swept up into stars where they could instigate supernova explosions or create ultra-bright stars (such as have never been seen). The low rate of supernovae — a few per millennium per galaxy — also makes this extremely unlikely.

Both of these groups, using worst-case arguments and sound empirical data, find the chances of a catastrophe at RHIC to be truly negligible: "Cosmic ray collisions provide ample reassurance that we are safe from a strangelet-initiated catastrophe at RHIC"¹, and "Beyond reasonable doubt, heavy-ion experiments at RHIC will not endanger our planet"². Amen. Even though the risks were always minimal, it is reassuring to know that someone has bothered to calculate them. Now, the only conceivable disaster at RHIC would be a costly failure to detect the fabled quark-gluon plasma. ■

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including late stages of sensory³ and cognitive⁴ processing, have also been characterized. Yet there has been limited success in describing a topography for those cortical areas⁵, suggesting that higher and more complex aspects of perception and cognition might not be systematically mapped. On page 610 of this issue, however, Hampson and colleagues⁶ reveal a functional organization for the hippocampus, one of the highest cortical-processing areas in the brain.

Although the hippocampus is crucial for memory, the nature of its contribution is controversial. Human studies point to critical hippocampal function in 'declarative memory'⁷ (our ability to record personal experiences and weave these episodic memories into our knowledge of the world about us). By contrast, animal studies indicate that the hippocampus is dedicated to 'spatial mapping'. Animals with hippocampal damage show severe and selective impairments in spatial memory⁸ (their ability to learn and

express knowledge of spatial relations among cues in the environment). Animal studies have also revealed the existence of hippocampal 'place cells' — neurons that fire when the animal is at a particular location, as though signalling occupancy of a coordinate in a spatial map⁹.

Recent studies offer the beginnings of a reconciliation between the 'declarative' and 'spatial' views of hippocampal processing. For example, rats with hippocampal damage have impaired learning, and they cannot express knowledge about relations between distinct experiences in nonspatial memory¹⁰. It has also become clear that hippocampal neurons are activated in association with specific nonspatial cues, as well as with cognitive events and behaviours that occur at different times in many places¹¹. These observations suggest the hippocampus is fundamental in registering and linking episodic memories into larger networks for both spatial and nonspatial memory¹². In a

network of spatial memories, the critical links may be remembered places that a person visited at different times. In a nonspatial memory network, the links may be particular objects, people or events that are common to (and hence can bridge) distinct episodic memories that include those items. But how would such memory networks be organized within the architecture of the hippocampus?

Hampson *et al.*⁶ now outline, for the first time, a functional organization of the hippocampus — a sketch of a memory network on the surface of the hippocampus. The authors monitored the activity of hippocampal neurons in rats, first when they performed a simple task, and then when they remembered the episode in a subsequent test. On each trial the animal initially pressed a 'sample' lever, presented in one of two positions in a chamber. The rat maintained this memory for several seconds, then demonstrated it by choosing the other lever when both were presented in a 'nonmatch' phase of the trial.

To make these recordings, Hampson *et al.* used a unique electrode array that allowed them to monitor many cells at known distances apart in the hippocampus (Fig. 1). In each animal the activity of some neurons was associated with the position of the lever being pressed, regardless of whether this occurred during the sample or nonmatch trial phase. Other cells fired during just one of the trial phases, independently of the lever's position. Yet other cells fired in association with the various combinations of lever position and trial phase (for example, left-match), or with several events that made up a specific type of trial (for example, right-sample then left-nonmatch). All of which means that hippocampal neuronal activity represents both the relevant aspects of space and the relevant nonspatial features of the task, consistent with the mixture of spatial and nonspatial coding observed in other situations¹¹.

By combining the data from several animals, Hampson *et al.* found a set of regular anatomical patterns (Fig. 1). Lever-position codings are segregated, such that alternating 0.6–0.8-mm cross-sectional segments of the hippocampus contain clusters of 'left' or 'right' lever-position codings. Trial-phase codings are also segregated in alternating 0.2–0.4-mm cross-sectional clusters of 'sample' and 'nonmatch' responses. The two topographies are interleaved, such that each position cluster contains clusters for both trial phases. Furthermore, in this mapping, function follows form — the clusterings of position and trial-phase specificity follow the known anatomical organization in which neurons are more closely interconnected within cross-sectional segments (called lamellae) than they are across them¹³. This correlation between anatomical and

Molecular motors

Spotting the goods trains

The organization of membranous structures in the cell, such as the Golgi body or endoplasmic reticulum, depends on motor proteins and the microtubules along which they move. Of the two major protein families involved, the dyneins move towards the 'minus' end of the microtubules, generally clustered close to the nucleus, whereas the kinesins chiefly move towards the 'plus' ends of the microtubules, distributed about the periphery of the cell.

Although organelle transport is a central function of microtubule-based motors, these motor proteins were originally identified for other reasons, such as their ability to make microtubules glide over glass coverslips. Now, however, Ron Vale and colleagues present a more direct approach (*J. Cell Biol.* 147, 493–505; 1999). By specifically assaying organelle transport they have identified two new kinesin-like motors from the slime mould



Dictyostelium discoideum.

To do this, the authors mixed *Dictyostelium* cell extracts with organelles and assembled microtubules. Then, using video-enhanced differential interference microscopy, Vale and colleagues assessed the extracts' ability to reconstitute organelle movement, and also determined the direction of that movement. An example of this assay is shown in the picture. Video stills separated by half a second are overlaid and colour-coded to show the direction of motion (purple–cyan).

Using a number of chromatography steps, two plus-end-directed activities were purified associated with proteins of relative molecular masses

(*M_r*) 245,000 and 170,000. Peptide analysis allowed the identification, cloning and sequencing of the *M_r* 245,000 protein. It proved to be homologous to known kinesins from mice and nematode worms, and was named DdUnc104 after the worm homologue. When Vale and colleagues knocked out the *DdUnc104* gene, the mutant mould had disrupted organelle transport, confirming the *in vivo* role of DdUnc104 in this process.

The importance of this work is not so much in the identification of two previously unknown kinesins, but in the establishment of a system for dissecting the mechanics of organelle transport. Because *Dictyostelium* is so amenable to genetic manipulation, it should be possible to investigate not only the motors involved, but also the accessory proteins and receptors that allow them to identify and transport specific organelles.

Christopher Surridge

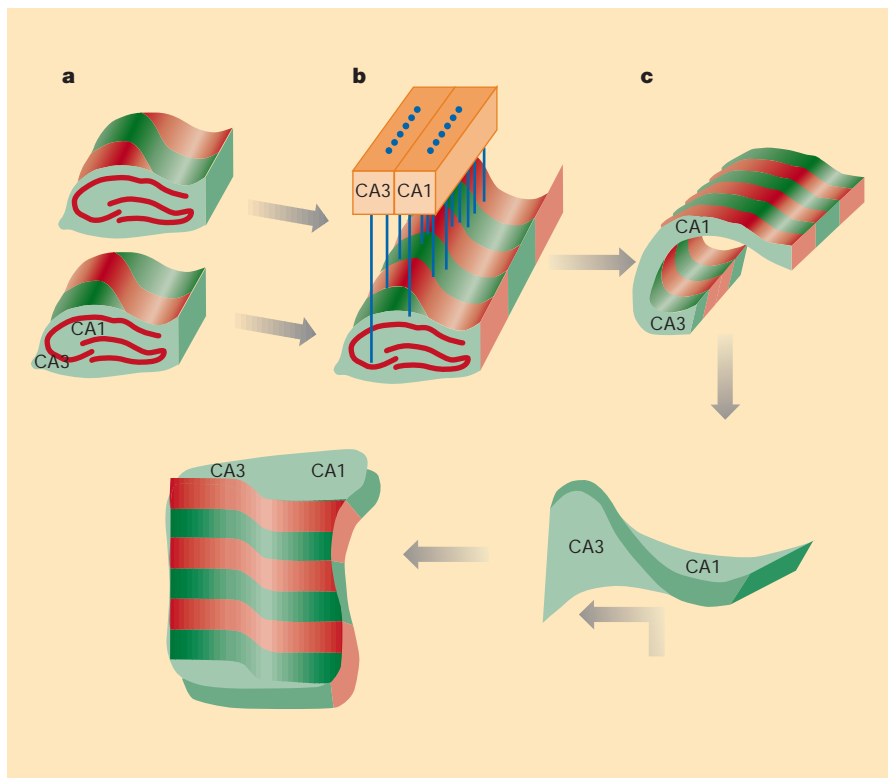


Figure 1 ‘Unfolding’ of a functional organization in the hippocampus. **a**, Pairs of hippocampal lamellae — anatomical segments within which CA3 and CA1 are closely connected. Each pair of lamellae represents a single lever position (black or white for left or right) and a set of trial phases (sample and nonmatch). **b**, Normal appearance of the dorsal hippocampal regions CA1 and CA3, and the sites where Hampson *et al.*⁶ made recordings with the electrode array. **c**, Unfolding of the hippocampus, revealing the systematic functional architecture. (Figure provided by R. E Hampson and S. A. Deadwyler.)

functional organization resembles the common anatomical and functional ‘columns’ of well-connected, like-responsive cells in most areas of the cerebral cortex^{1,2}.

Two other aspects of Hampson and colleagues’ observations should be emphasized. First, the representation of space in this functional organization is not a detailed Cartesian mapping, as envisaged within the dedicated spatial-mapping view of hippocampal function⁹. The authors’ code involves only two positions — not a continuous set of spatial coordinates. Perhaps the hippocampus discriminates space only at the resolution required to remember where important events occurred.

Second, the full scope of declarative memory probably cannot be reduced to features of working memory such as ‘position’ and ‘trial phase’. Yet the topographies for these features fill the hippocampus, and there are no empty slots for other features of memory. The same hippocampal cells can encode different — and seemingly unrelated — features when an animal is exposed to different situations, even in the same environment, and the scope of hippocampal coding¹² goes beyond the memory task studied by Hampson *et al.* So functional organization of the hippocampus probably contains a different set of interleaved topographies for

each of several memory networks.

Finally, the authors offer a further clue that may relate the organization of these networks to their operation. Hippocampal neu-

rons encoding combinations of the position and trial phases are found on the borders of the position and trial-phase codings. Perhaps these cells represent events unique to particular types of trial episode. The lever-position and trial-phase cells, by contrast, encode events that are common to, and might link, the representations of different episodes. A memory network based on these linked episodic codings could mediate a rat’s ability to remember previous trials based on current events. Of course, this is the critical memory demand in the task. But the same kind of functional organization could mediate the linking of episodic memories — and access to them through current cues — across many domains of memory in humans as well as in animals. ■

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Astrophysics

Chaotic planet formation

Renu Malhotra

Our understanding of how planets formed around the Sun is far from complete, and is increasingly challenged by new discoveries of unusual planetary-mass companions around other stars. The idea that chaotic dynamics — or extreme sensitivity to initial conditions — plays a large role in the formation, evolution and survival of planetary systems has gained popularity in recent years. This is in contrast to earlier ideas that solar systems similar to our own are an inevitable by-product of the formation of Sun-like stars.

On page 635 of this issue, Thommes *et al.*¹ propose that all of the giant planets in our Solar System formed in a narrow region of the disk-like solar nebula that surrounded the young Sun: they ended up in their present

widely spaced orbits as a result of violent and chaotic scattering. Also, on page 633, Armitage and Hansen² propose that the early formation of a Jupiter-mass planet in a nebular disk could ‘trigger’ the formation of other giant planets. Such protoplanets would also form in a narrow region, and would be expected to evolve chaotically into systems that might resemble some of the putative extrasolar planetary systems.

Both groups have used computer simulations to advance these ideas. In our Solar System there are two ‘gas giants’ (Jupiter and Saturn), having a small rocky core surrounded by a large hydrogen and helium atmosphere, and two ‘ice giants’ (Uranus and Neptune), which have icy mantles around their cores and only a thin atmosphere. Theorists