days of testing. They also used a 'longitudinal' experimental design in which they tested the same mice every four weeks for roughly three months. They could therefore track changes in performance over time — much as would be done in human clinical studies. Given these differences, it is remarkable that both groups find that immunization with β-amyloid peptide offered significant protection from the age- and amyloid-dependent performance deficits seen in non-immunized controls.

Janus *et al.*[4] also show that when the mice are immunized with the β-amyloid peptide in the so-called 'β-pleated sheet' form that will eventually be deposited, they produce antibodies that seem to be specific to this form. The result is a significant reduction in plaque formation and the number of amyloid 'fibrils', but there is no great difference in the overall level of β-amyloid peptide. This suggests that β-amyloid in its more soluble form does not contribute to Alzheimer's dementia. But, although Morgan *et al.*[5] used the more soluble form of β-amyloid peptide for vaccination, they find modest but significant reductions in the proportion of the brain's neocortical and hippocampal regions that is covered by amyloid plaques. Both groups suggest that either a small or a selective reduction in β-amyloid deposition may be sufficient to protect against dementia.

The symptoms of Alzheimer's disease worsen with age, and so a valid animal model must also be age dependent. In the model used by Chen *et al.*[6], there is a correlation between age (and β-amyloid deposition) and the impairment of some forms of learning, such as episodic-like memory. But some other learning defects in these mice are independent of both age and β-amyloid deposition. For example, some aspects of the episodic-like task are impaired in mice that are too young to show plaques, and object-recognition memory seems unaffected at any age[6]. The tasks used by Morgan *et al.* appear to be age related, but it is more difficult to assess those of Janus *et al.* because the mice were retested over several months. Further investigations of correlations among different behavioural measures and different pathological features will be important to strengthen the validity of the mouse models.

All in all, though, these three papers[4–6] give cause for optimism. But the range of behaviours tested was rather narrow, and the mechanism of action of the β-amyloid vaccine is not yet fully understood. Other possible treatments, such as anti-inflammatory drugs[11] and inhibitors of enzymes that produce the β-amyloid peptide from its precursor protein[12,13], should be developed further and tested in these and other behavioural tasks, as should markers of other changes that accompany ageing and amyloid accumulation in mice[14]. The way will then be well prepared for clinical tests of treatments for Alzheimer's disease. ■

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Astronomy

The Big Bang is bang on

John Bahcall

Did the Universe really start in a hot Big Bang? New measurements of the temperature of the Universe when it was young provide exciting confirmation that it was indeed hotter in the past.

The Universe is filled with unimagined things of great beauty and enormous significance, just waiting to be discovered. On page 931 of this issue, for example, Srianand, Petitjean and Ledoux[1] report the discovery of a rare set of features (absorption lines) in the light from a distant quasar. These features make it possible to test rigorously the fundamental idea, underlying all of modern cosmology, that the Universe was hotter when it was younger. The results reported by Srianand and colleagues are a convincing test of this idea and represent a landmark result.

Two twentieth-century discoveries have shaped the way humans view their place in the Universe. First, Edwin Hubble[2] discovered that the Universe is expanding — all other galaxies are moving away from us at a speed that is approximately proportional to their distance from our Galaxy. Second, in 1965, Arno Penzias and Robert Wilson discovered[3] that the local part of the Universe is permeated with microwave radiation, called the cosmic microwave background (CMB).

Nearly all physicists and astronomers interpret the CMB as the leftover glow from a time when the Universe was very hot and very small. According to the popular Big Bang theory[4], the Universe expanded from a tiny volume to its present vast expanse over the past 10^{10} years. As the initial gas of photons expanded, it cooled until the average wavelength of the cosmic radiation fell into the microwave region that we observe today. This theory predicts that the CMB temperature is the same everywhere at a given universal time and that the temperature increases in a simple and specific way as we look back to earlier and earlier times.

But is this really the story of our Universe? Did it really go from hot to cold? All of the widely discussed recent measurements[5,6] of the CMB have been made locally, on properties of the microwave radiation near the Earth. Astronomers and physicists are optimistic that they will be able to use these local measurements to determine the parameters that characterize the history of the Universe. They hope, for example, to determine whether the Universe will expand forever and to find out how much matter it contains.

In the late nineteenth century, physicists had a similarly grand concept of the cosmos. They supposed that the Universe was filled with an unseen quantity that they called the 'ether', a hypothesis that bears some resemblance to present-day ideas of dark matter. All radiation was supposed to propagate in the ether. But when Michelson and Morley searched experimentally for the ether, they couldn't find it. Physics had to be revised and the result was Einstein's special theory of relativity, which revolutionized our ideas about space and time. Would something similar happen when astronomers searched for data on the CMB in distant clouds?

Srianand and colleagues[1] analyse light from a distant quasar, one of the most luminous objects in the Universe. The light they studied was absorbed by carbon atoms and hydrogen molecules in a remote cloud of gas and dust when the Universe was only about one-sixth of its present age. Fortunately, the absorbed light provides several clues to what was happening at this early time. The astronomers used the ultraviolet and visible spectrograph (UVES) on the European Southern Observatory's 8.2-metre telescope at the Paranal observatory in Chile, and have obtained some wonderful results.

The cloud discovered by Srianand *et al.* is unique among the many hundreds of thousands of distant clouds whose absorption of light has been analysed so far. It is almost as if nature planted an abundance of clues in this anonymous cloud in order to allow some lucky researchers to infer the temperature of the CMB when the Universe was young. The absorption of quasar light by neutral and once-ionized carbon atoms shows that some of the cloud's atoms are in atomic states called 'fine-structure states', which are only slightly more energetic than the lowest energy states of carbon. The difference in energy between a typical fine-structure state and the lowest energy state of carbon is comparable to the CMB temperature predicted by Big Bang theory in the vicinity of the distant cloud.

The different atoms and molecules that absorbed light in this remote cloud enable the astronomers to demonstrate that there is only one reasonable explanation for the number of atoms that are observed to be in fine-structure states. Srianand *et al.* conclude that there must be an ambient radiation field around the cloud corresponding to a temperature of between 6 K and 14 K. Bingo! This value agrees with the temperature of 9 K predicted by the Big Bang theory to be the CMB temperature at the position of the cloud. This is three times as high as its temperature near Earth (2.7 K), as expected.

The idea of using atomic fine-structure lines to test Big Bang cosmology was first suggested[7] in 1968, only three years after the discovery of the CMB. Over the past three decades, a series of ever more precise measurements, or upper-limit determinations of the CMB temperature in distant clouds, were made using fine-structure lines[8]. Generations of sensitive telescopes and spectroscopic instruments had to be developed before the latest robust test was possible. It also took good luck to find a cloud that contained the necessary clues — carbon atoms in fine-structure states, hydrogen molecules in various excitation states, and light absorption by iron, silicon and magnesium atoms.

In future, astronomers will be able to use the latest 8- and 10-metre telescopes to look for other rare absorbing clouds at different distances from us (that is, at different ages of the Universe) and in different directions (to check that the CMB is the same in every direction). Tests of the Big Bang theory using fine-structure lines will become more precise and more numerous in the next few years as larger telescopes and better instrumentation become widely available.

The Big Bang theory has survived a crucial test. The theory would have been abandoned if astronomers had found that clouds at earlier times had lower temperatures than predicted. So while the result reported by Srianand and colleagues is a tremendous achievement, I confess to feeling a little disappointed, and I am sure that some of my more rebellious colleagues will secretly feel the same way. I am happy that the Big Bang theory passed this test, but it would have been more exciting if the theory had failed and we had to start looking for a new model of the evolution of the Universe. ■

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Evolutionary biology

Cooperation can be dangerous

Richard H. Kessin

In social situations, opportunities arise for some individuals to take advantage of others. This happens in wild populations of the social amoeba *Dictyostelium discoideum.*

Most of the organisms studied by developmental biologists — the fruitfly *Drosophila*, for instance — arise from a fertilized egg. So, apart from the mature reproductive cells, the cells from which these organisms are made are genetically identical. No cell has a genetic advantage over the others, and any variants that do arise are excluded from the germ line. Because of the lack of genetic diversity among their cells and the presence of a germ line, cheating by individual cells is restricted in most multicellular organisms.

But there is another route to multicellularity, taken by organisms such as *Dictyostelium* and *Myxococcus*, a group of social bacteria. As they describe on page 965 of this issue[1], Strassmann and colleagues have studied the curious cooperative behaviour of *Dictyostelium*, and find that some genetic

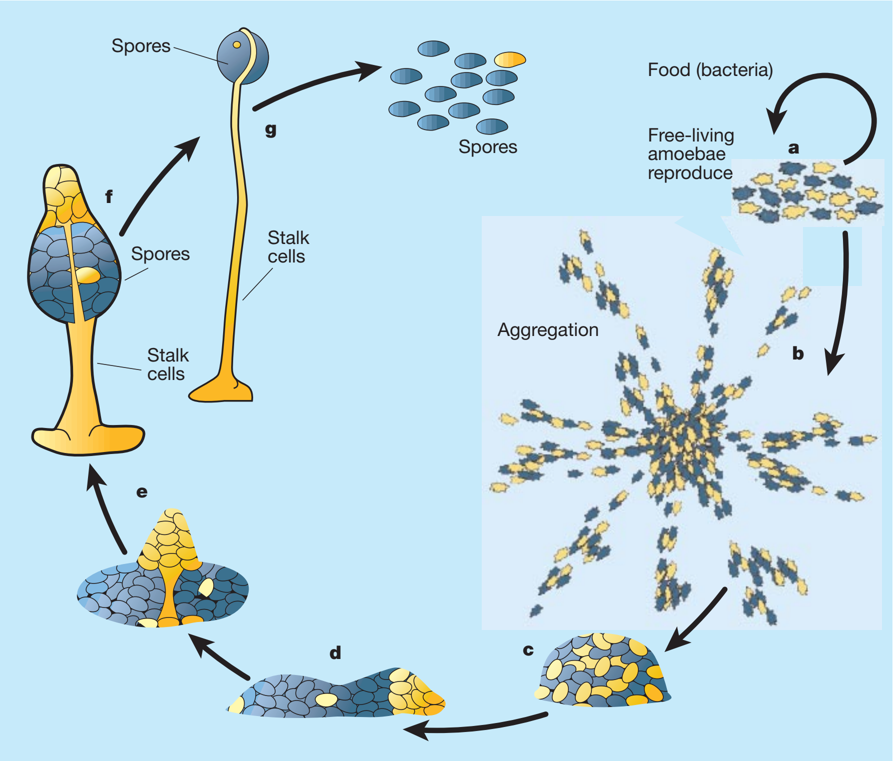

Figure 1 **Cheaters in the *Dictyostelium* life cycle.** a, ***Dictyostelium* amoebae live off bacteria in the soil.** b, **When the bacteria are consumed and starvation is imminent, the amoebae stop dividing and activate several genes that allow them to aggregate by chemotaxis towards cyclic AMP diffusing from centrally located cells. These aggregates, which can contain up to 100,000 cells, transform into motile slugs** (c, d) **and finally into fruiting bodies** (e–g). **The fruiting bodies contain 80,000 viable spores supported by 20,000 dead stalk cells. If the cells of two natural isolates are mixed, they will aggregate. But in some combinations, as Strassmann *et al.*[1] show, one isolate predominates in the spore population. Here, equal numbers of yellow and blue cells aggregate, but eventually the blue cells dominate the spore mass. How this advantage is achieved is not known, but it could involve manipulation of the signals that control the 80:20 ratio of spore and stalk cells. For a dynamic view of *Dictyostelium* development see ref. 10. Graphic modified from ref. 11.**