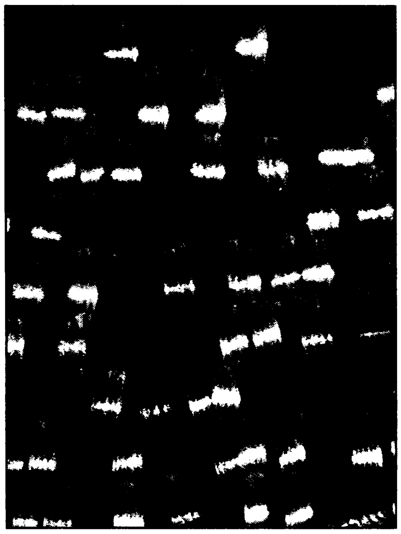
BUTTERFLY BIOMECHANICS

Wing Scales May Help Beat the Heat

Like a Day-Glo mohawk, the iridescent blue-green colors adorning the wings of some butterflies and moths get a lot of notice. And that's just how entomologists have viewed them: as eye-catching patterns designed to attract a mate or warn off a predator. But it's possible the jewellike scales that form these patterns may serve another, more mundane, function as well: Measurements by engineers at Tufts University in Medford, Massachusetts, suggest that the scales can reflect or absorb sunlight to regulate the cold-blooded insects' body temperatures.


GEORGE ELLMORE

Hot patterns. The optics of iridescent scales on the wings of the butterfly *Urania fulgans*, magnified 125 times, may help the insect regulate body heat.

The scales are made of stacked layers of a shell-like material, and the Tufts researchers—in work to be reported at a meeting in November—have shown that tiny changes in the thickness of these stacks can have large effects on the amount of absorbed solar energy. Although scientists have not tested these effects in living insects, specialists are intrigued. Joel Kingsolver, a zoologist at the University of Washington, Seattle, who has found that pigments in butterfly wings play an important heat-gathering role, says the changes "appear to affect absorptivities in such a big way that they could have important thermoregulatory consequences."

The project took off, not on a wing, but a chip. In 1991, Ioannis Miaoulis, dean of the school of engineering at Tufts, and engineering graduate students Peter Wong and Bradley Heilman were trying to understand defects in computer chips made of silicon films. Computer models indicated that tiny variations in film thickness could magnify the amount of heat the chips absorb during manufacturing, sometimes to the point of ruining them. Miaoulis, who also directs Tufts's Comparative Biomechanics Laboratory, wondered whether certain insects, whose scales are constructed in layers roughly analogous to the films, had evolved a way to control radiation absorption.

A literature search led the researchers to iridescent butterfly scales. Electron-microscope images of the scales (taken in the early 1970s by Helen Ghiradella, a biologist at the State University of New York) showed that the scales' alternating layers of air and chitin—the shell material—are close in thickness to the silicon films the Tufts group had simulated.

The Tufts team took a closer look at the scales' optics. In experiments to be reported at the annual meeting of the American Society of Mechanical Engineers in San Francisco in November, they showed that scales from one iridescent species, *Papilio palinurus*, absorbed significantly more light than did scales from another iridescent butterfly, *Urania fulgans*—although the chitin layers in *P. palinurus* are only 1/100th of a micron thinner. The reason: Chitin layers in *P. palinurus* are close to one quarter of the length of a typical light wave, says Wong. So waves reflected off the top and bottom of the layer will be half a wavelength out of phase (the peak of one will meet the trough of the other), cancel one another out, and dissipate their energy within the layer. A slightly thicker layer will move such waves back into phase, and they will reflect away from the scale. Over the whole range of wavelengths in sunlight, such differences add up, with cancellation winning out over reflection more consistently in *P. palinurus* than in *U. fulgans*.

The idea that iridescence has a thermoregulatory effect "shouldn't be in the least bit controversial," says Michael Locke, a biologist at the University of Western Ontario in London who has studied the development of insect cuticles. "Everybody accepts the notion that wing colors are important for thermoregulation in butterflies," he says. The novel feature of the Tufts work, he points out, is the suggestion that the effect is caused by optical interference rather than pigmentation.

Other scientists, however, note that no one has yet shown that the amount of heat absorbed through the scales makes an appreciable difference. "Just because a feature would seem to serve a given function well doesn't mean it's something that matters to the organism," cautions Thomas Schultz, a behavioral ecologist at Denison University in Granville, Ohio. Schultz has conducted absorption experiments—with negative results—on iridescent tiger beetles.

The next step will be to conduct such heat tests on butterflies. Biophysical ecologist Warren Porter of the University of Wisconsin says he is interested in performing them. If they pan out, says Kingsolver, it would be interesting to survey iridescent scales in wing regions that affect body temperature on butterflies from colder environments, to see whether they are of different thicknesses and have greater absorption than those on butterflies from warmer climes. Tiny variance in the chitin could, Kingsolver says, turn out to be a way that butterflies adapt to different latitudes.

–Wade Roush

CANCER BIOLOGY

Another Blow Weakens EMF-Cancer Link

Perhaps the most plausible piece of laboratory evidence linking electromagnetic field (EMF) exposure to cancers has just become much less plausible. This area is rife with tenuous connections, but work suggesting that low-level EMF exposure can dramatically affect the workings of the *Myc* gene, an oncogene implicated in a host of human cancers, has stood out as stronger than most. Now, however, two elaborate attempts to replicate the findings have failed completely.

The two papers, both to be published in the October issue of the *Journal of Radiation Research*, rebut the decade-long work, begun in 1982, of Columbia University cell biologist Reba Goodman and Hunter College molecular biologist Ann Henderson. The two had reported that the *Myc* gene in immature human blood cells had a two- to threefold increase in expressed RNA when the cells were exposed to low-level EMF. These large effects impressed Jeff Saffer, an author of one of the new papers and head of the department of biology and chemistry at the Pacific Northwest Laboratories (PNL). But when he completed his own study, he says, he was less than overwhelmed: "There was no observable effect."

Saffer's study, which was conducted with his colleague Sarah Thurston, was funded by a program run jointly by the Department of Energy (DOE) and the National Institute of Environmental Health Sciences (NIEHS). The program's goal "is to try to take the most important and most relevant findings, those driving the science in the EMF controversy, and try to validate and replicate them under very, very carefully controlled conditions," says Gary Boorman, who runs the NIEHS side of the effort.

In the United Kingdom, the National Grid PLC, a major power distribution company, funded a similar replication study by biologist Robin Hesketh of Cambridge University in England, an author of the other paper. Hesketh, too, had found the Goodman-Henderson work initially compelling: "First of all the effects were large, and they had been recording the effects for 10 years and had found very similar effects for a whole variety of cell systems. ... It was a general phenomena, and if it affected a gene like *Myc*, it was clearly of great importance."

While the two teams set out to duplicate the Goodman-Henderson experiments, they also tried to improve on the methodology, which, says Saffer, had some potentially serious flaws. In particular, he noted a lack of controls and internal calibrations. As Saffer explains the protocol, cells are exposed to EMF, and then the RNA is purified. A small amount of that RNA is then sampled and run on a filter, and the amount of *Myc* RNA in that sample is then measured. But Goodman and Henderson's technique didn't allow them to check whether they sampled identical amounts of RNA each time, he says. "So you would get a larger signal if the amount of *Myc* RNA was in fact greater in cells exposed to the magnetic fields. But you would also get a larger signal if in fact you had unknowingly [taken a larger sample of total RNA] to begin with." (Goodman admits this was true in her original experiments, but says her more recent work controls for this problem: "We started using internal controls about a year before they started pointing it out. Some of their criticisms were justified. When we started in 1982, things weren't so sophisticated.")

Both the Cambridge and PNL groups used methods that allowed them to compare the amount of RNA from *Myc* to another type of RNA from the cells known to be remarkably invariant under a variety of conditions. That gave them a yardstick against which they could measure the size of their *Myc* RNA sample. To enhance the replication attempt further, both groups played host and guest with Goodman and Henderson. Saffer and Thurston spent 2 weeks at Goodman and Henderson's lab running experiments there. "We used their exposure system," he says, "their cells, their methods." Goodman, meanwhile, visited the Cambridge group and briefed them on both her data and her methodology. Then Hesketh and his colleagues purchased the identical exposure system, as well as building a second exposure system that eliminated a potential flaw they spotted in the Goodman-Henderson protocol: The cells were manipulated for short periods outside a rigorously controlled magnetic field environment. They then did two sets of experiments, one with the Goodman-Henderson system and one with their own.

No matter how and where they ran the experiments, however, both groups came up empty. "We did not find any evidence for a magnetic field effect, even using their cells and their exposure system," Saffer says. EMF did not increase the amount of *Myc* RNA at all. And Hesketh concurs.

This doesn't quite lay the matter to rest. Goodman says that both the PNL and Cambridge groups still failed to replicate her protocol exactly. "Deviations, even in the guise of 'improvements,' can produce different results," she says. Moreover, she and Henderson have been working separately now, and yet both are still reporting *Myc* RNA increases of 50% to 60% due to EMF. "I'm not worried," she says. "I was a hell of a lot more worried before we started repeating our own experiments."

Yet another check should come soon: Although Boorman says the new work seems solid, the DOE-NIEHS program is still funding one more attempt to replicate the Goodman-Henderson results, this one at a Food and Drug Administration lab.

–Gary Taubes

ASTRONOMY

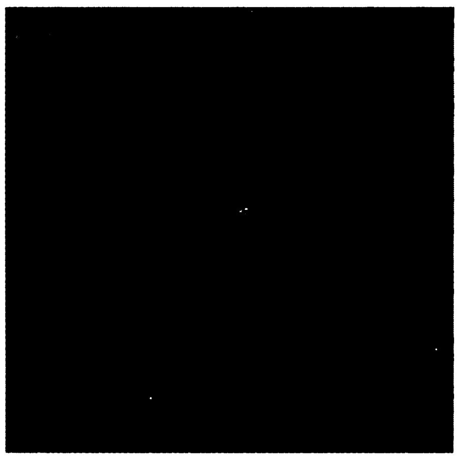
Is the Most Distant Galaxy a Star Factory?

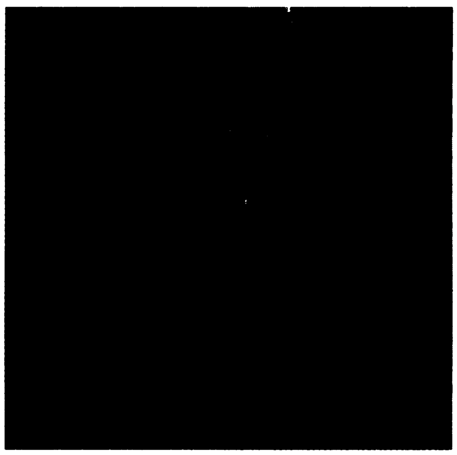
Astronomers, like everyone else, love to set records, and a team of European astronomers has just announced a new one: the most distant galaxy yet identified. Using the European Southern Observatory's (ESO's) New Technology Telescope at La Silla Observatory in Chile, the team has obtained images of a galaxy with a redshift of 4.4. Redshift is a measure of the extent to which light from distant objects is stretched out to longer wavelengths by the expanding universe: The farther the object, the faster it is moving away, and the more the light is shifted to the red end of the spectrum. This new galaxy, which appears to have a spiral or irregular structure, beats the 4.25 redshift of the previous record-holder, known as 8C1435+635 (*Science*, 11 November 1994, p. 974).

But astronomers are excited about this new discovery not just because it provides another entry in the record books. Although the light we see from it set out when the universe was only 10% of its current age, the galaxy shows evidence that stars within it had already formed, lived out their full lifespan, and died, spilling their contents out into the interstellar gas. Sandro D'Odorico of ESO's headquarters at Garching, Germany, together with Stefano Cristiani at Padua University in Italy and Adriano Fontana and Emanuele Giallongo of the Astronomical Observatory at Rome, obtained the first images of the new galaxy, and it was quite a feat to detect its faint starlight.

The first hint of the far-off galaxy came with the discovery in 1993 of a new quasar, one of the extremely bright but mysterious objects that often have redshifts even greater than those of the most distant galaxies. A British-American group led by Cyril Hazard of the University of Pittsburgh made a search for high-redshift quasars using the Anglo-Australian Schmidt Telescope at the Siding Spring Observatory in New South Wales, Australia. Most quasars have spectra with few features, but one of the quasars they found, known as QSO 1202-07—with a redshift of 4.7, making it one of the most distant objects known—caught their attention.

Its spectrum had dark absorption lines in it, indicating that some of the light was being absorbed by a cloud of gas between the quasar and Earth. "In 1993 we observed in the spectrum of the quasar many absorption lines ... due to clouds, mainly of hydrogen, and metal





PHOTOS BY ESO

Blinded by the light. Galaxy with redshift 4.4 is barely visible on the rim of the quasar QSO 1202-07 at the center of upper image. When astronomers summed 12 charge-coupled device images, with a total integration time of 120 minutes, and processed the image to subtract light from the quasar and a nearby star, the galaxy stands out more clearly (*lower image*). Among some of the other objects in this picture may be galaxies with even higher redshifts.