population-based studies of melanoma patients in which family histories were collected," Bale says.

However, in the well-documented melanoma families, it now appears that the presence of dysplastic nevi is the single strongest predictor of melanoma risk factor. And the melanomas that do occur arise directly from these moles. This means that the investigators can advise family members who have these moles that they are at high risk for melanoma. These people are told, says Margaret Tucker of the NCI, to avoid sun exposure and, in particular, to avoid blistering sunburns. They also are taught to carefully examine the entire surface of their skin at frequent intervals.

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The NCI investigators have so far picked up about 70 malignant melanomas in melanoma family members. "The vast majority were very early, very thin lesions that should be cured by surgery," Tucker says. There still are failures, however. Even the most vigilant surveillance cannot prevent some cancer deaths. "We had two bad failures lately," says Bale. "One was a 32-year-old woman who had never had melanoma. She developed metastatic disease with no identifiable primary tumor site and died 2 weeks ago. The other is a woman in her 30's who is pregnant and just had a diagnosis of metastatic melanoma."

In order to assess the risk to melanoma family members, NCI geneticists looked at the pattern of inheritance of dysplastic nevi and malignant melanoma. Bale reports that dysplastic nevi and the susceptibility to the cancer are inherited as though they are caused by an autosomal dominant gene with greater than 90% penetrance, meaning that those who inherit the gene have a greater than 90% chance of having the nevi and, possibly developing malignant melanoma.

If nearly everyone who inherits the gene develops the disease, it is not clear whether measures such as avoiding sun exposure will make much difference. But Greene and his colleagues find that fibroblasts and lymphocytes from members of melanoma families who have dysplastic nevi are unusually sensitive to the mutagenic effects of ultraviolet light. When cells from these persons were exposed to ultraviolet light or to chemicals that mimic the effects of ultraviolet light, they had an unusually large number of chromosomal breaks and other abnormalities. The melanoma gene, Greene and his colleagues suggest, may act by making skin cells unusually prone to mutate when they are exposed to the sun.

The next step is to look for the melanoma gene itself. Dean Mann of the NCI, Armead Johnson of Georgetown University, and Christine Murray of the Uniformed Services University of the Health Sciences, in collaboration with Bale and her associates, began by looking for an association between the HLA genes, which code for the transplantation antigens that cause rejection of grafted skin or transplanted organs, and the melanoma gene. Several researchers have reported that melanoma patients have particular HLA antigens. In addition, it is known that the HLA gene complex includes immunoregulatory genes and that melanoma occurs frequently in patients with compromised immmune systems. For these reasons, it seemed possible that the melanoma gene is very near the HLA genes and is inherited with them. However, says Bale, "we proved *conclusively* that the melanoma gene is not in the region of HLA."

Furthermore, the NCI investigators, working with David Housman and Danila Gerhard of the Massachusetts Institute of Technology, have not found evidence that the melanoma gene is near any of several oncogenes nor near several other marker genes that could help them pin down the chromosomal location of the melanoma gene.

But the work has just begun. Once they isolate the gene, researchers will be better able to address the question of whether dysplastic nevi in the general population are actually risk factors. If a person in the general population has dysplastic nevi and the melanoma gene, he probably is at high risk of getting the cancer. And, finally, it would be fascinating to know just what the melanoma gene does. How does a single gene cause cancer? And if it is not an oncogene, what is it? ■ GINA KOLATA

This is the fourth and last of a series of articles on the development of genetic tests to determine susceptibility to disease. The first three articles appeared in the 18 and 27 April and 2 May issues.

ADDITIONAL READING

M. H. Greene *et al.*, "High risk of malignant melanoma in melanoma-prone families with dysplastic nevi," *Ann. Intern. Med.* **102**, 458 (1985).

Briefing:

Venus Is Looking More Like Earth Than Mars

For a while it seemed the surface of Venus might be as fixed and immobile as that of Mercury, Mars, or the moon, those tectonically dead, alien-looking spheres that so sharply contrast with Earth and its churning plate tectonics. But Venus looks a good deal more familiar now that closer radar views, from Earth-based and Soviet Venera 15 and 16 spacecraft observations, have revealed the crumpled and torn surface typical of the jostling of segments of crust.

At the recent Lunar and Planetary Science Conference,* the Soviet Venera spacecraft team, headed by Valery Barsukov and Alexander Basilevsky of the Vernadsky Institute in Moscow, presented a summary of the geologic features mapped from the Venera imaging radars that clearly sets Venus apart from the smaller rocky planets. Horizontal motion of the venusian crust had obviously compressed it into ridges and grooves unlike anything seen even on Mars. The motion of the surface of Venus "can be compared only to that of Earth," they reported.

James Head and his colleagues at Brown University have now taken the next step in the study of venusian geology and assembled geologic features created by horizontal motion into a sequence of events. This step is controversial because it involves making sense of a surface that is tectonically more complex than the minutely photographed surface of Mars but is glimpsed imprecisely through radar. Head and his group combined radar data from the American Pioneer Venus, the Soviet Venera 15 and 16, and the Arecibo radar in Puerto Rico and discerned two episodes of crustal compression that they believe created Ishtar Terra, a continent-like highlands high in Venus's northern hemisphere.

The first episode, operating in an east-northeast direction, squeezed the crust into a series of folds in the way that a rug can bunch up on a slippery floor. That formed the predecessor of the 500,000-square-kilometer Maxwell Montes, at an altitude of up to 11 kilometers the highest area on the planet. This compression also formed a region of folded and broken crust to the east. That arrangement of folds would bear a considerable resemblance in a radar image to the Appalachians that were formed by the

*Seventeenth Lunar and Planetary Science Conference, 17–21 March 1986, Houston, Texas. Abstracts are available from the Lunar and Planetary Institute, 3303 NASA Road One, Houston, TX 77058–4399.

collision of Europe and North America.

The second episode of compression would have squeezed much the same region in a northwest-southeast direction. That formed two other mountain fold belts, Akna Montes and Freyja Montes, but it also sliced up Maxwell Montes along nine San Andreas–like faults, squashing the long, linear belt into its present roughly rectangular shape. Part of the compressed crust seems to have been squirted to the side, as has happened to parts of China caught between the colliding Indian and Asian plates.

"The exciting thing is that we are seeing features very similar to those on Earth that are not just randomly scattered," says Head, "but appear to be integrated in regional patterns. We're starting to see tectonics very different from that on the small terrestrial planets," whose surfaces cooled to form a single thick plate without horizontal motions developing.

Indeed, the Brown group sees indirect evidence of many plates or segments of crust moving about the surface of Venus. Crust seems to converge at Ishtar Terra and possibly at two other areas in mid- to high latitudes while extension and volcanism tend to dominate equatorial highland regions, in particular Aphrodite Terra. As at terrestrial mid-ocean ridges, most of the heat lost from the interior would escape in regions of extension by conduction through the thinned plate and increased volcanism. Head and his colleagues stress that they cannot say whether the crust is moving relatively rapidly and diving back into the mantle, as on Earth, moving just enough to form the extensional zones without plate recycling, or moving at rates between those two extremes in ways that are uniquely venusian.

Although other planetary geologists also now see abundant evidence on Venus of horizontal motions previously known only on Earth, they are still reluctant to construct such detailed geologic scenarios. "There seems to be horizontal tectonism," says Harold Masursky of the U.S. Geological Survey in Flagstaff, "but it is so complex. Perhaps the best approach now is to map geologic features, then make grand inferences." Geologists have a few more years in which to make inferences before the arrival of the next radar mapper at Venus, the U.S. spacecraft Magellan scheduled to arrive by the end of the decade. Everyone agrees that its resolution, the highest ever, will allow sequencing of events and assignment of tectonic mechanisms. Toward that end, Soviet scientists presented their American counterparts at the meeting with Venera 15 and 16 imaging radar data tapes and maps derived from them. ■ **RICHARD A. KERR**

Resolving the Star Wars Software Dilemma

A panel of computer scientists has concluded that computers will be able to manage a strategic defense system—but only if battle management is designed in from the beginning

SEVERAL months ago, a panel of computer scientists convened by the Pentagon's "Star Wars" Strategic Defense Initiative Organization (SDIO) quietly released a report concluding that the creation of battle management software for the Star Wars system will indeed be feasible.

Since most people would hardly expect an advisory panel handpicked by the SDIO to conclude anything else, the report seems to have aroused little public interest. In this case, however, the report is worth a closer look. Written by the nine-member Eastport Study Group, which is chaired by the Israeli-born computer scientist Danny Cohen of the University of Southern California, the report is in fact a scathing critique of the way the Pentagon handles high-technology weapons design in general and software development in particular. It challenges a number of tacit assumptions being made on all sides of the Star Wars debate. It deals with important questions about the limits of computing, the nature of reliability, the organization of large, complex systems, and the nature of strategic defense itself.

And in a striking paradox, it validates what the program's many critics have been saying about the *in*feasibility of Star Wars software.

This last conclusion is particularly ironic, because the software issue first gained widespread attention a year ago when David L. Parnas, a computer scientist from the University of Victoria, British Columbia, resigned from the panel on the grounds that Star Wars battle management software could never be made reliable. Since that time, Parnas and many other critics have continued to insist that software is the Achilles' heel of the entire strategic defense project.

Even if one assumes that space-based antimissile weaponry can be made to work, they argue—admittedly a big assumption—it will be computers that manage the battle. Human reaction times are simply too slow. Computers will process the raw data from the sensors. Computers will detect the missile firings, determine the source of the attack, and compute the attacking trajectories. Computers will discriminate between warheads and decoys. Computers will coordinate the activities of the battle stations. Computers will aim and fire the weapons. And computers will assess whether the warheads have been destroyed.

As a result, the Star Wars battle management system will be by far the most complex body of software ever devised. By one estimate it will require up to 100 million lines of computer code written by hundreds or thousands of individual programmers. Obviously, no one is going to be able to write that much software without making mistakes. But much more serious, say critics, no one will be able to trust the battle management system because no one will be able to test it under realistic conditions—realistic conditions being a full-scale nuclear war.

"It's not enough to put a bunch of killer satellites into space and call it a missile defense system," says Parnas. "We have to have confidence in that system. We have to *know* what it will do, because a weapon you can't trust is of no use to you. *We* will make decisions as if it was not there, and *they* will make decisions as if it might work. If we continue in that way, it's my fear that we will end up in a much weaker strategic position than ever before."

Judging from their report, the Eastport panelists are in complete agreement with that premise. Where they differ, however, is in their conclusions—or more specifically, in their assumptions about what strategic defense is supposed to be and how battle management is supposed to work. Parnas, like most members of the news media and the general public, explicitly takes the President at his word that Star Wars is supposed to make nuclear weapons impotent and obsolete. "I've taken my requirements from the very highest and most reliable source, Ronald Reagan," he says. And if that is the requirement, he adds, then the software clearly has to be perfect, or at least guaranteed free of catastrophic defects.

However, Cohen and his colleagues on the Eastport panel take the point of view held almost everywhere in the defense community outside the Oval Office: that Star