Wilmut says, it loses the proteins that came attached to it and takes up others from the cytoplasm. At the same time, it apparently becomes "reprogrammed" so that the embryo can develop normally.

Those multiple replications, and the several days it takes for them to occur, may be the reason nuclear transfer works in sheep but not very well in mice, suggests Richard Schultz of the University of Pennsylvania, whose own work focuses on gene expression in early development. In mice, all DNA remodeling takes place in the first cell division and the new DNA takes over by the two-cell stage, rather than in the eight-cell stage as in sheep. "Maybe in rodents there's just not enough time [for reprogramming]," he says. (In humans embryos, the new DNA apparently takes charge after the four-cell stage, in between mice and sheep or cows.)

Or it may be that Dolly's DNA didn't require much reprogramming. Her DNA came from cultured mammary cells, which are normally capable of developing into lactating tissue. Wilmut and his colleagues acknowledge that the collection of cells may have included a stem cell—an undifferentiated progenitor cell of many different tissue types—which has a higher developmental potential than an ordinary epithelial cell from the mammary gland. "The udder cells are a mixed population, and we don't know which are able to be totipotent," comments human geneticist Nick Hastie of the MRC's Human Genetics Unit in Edinburgh, U.K.

But assuming reprogramming did occur, its efficiency was low. The sole successful transfer out of 277 attempts "may say this is still a very difficult task in terms of successfully completing the reprogramming," Schultz points out.

Efforts to increase that success rate may run into another barrier, he adds: "We don't really know" how programming occurs normally during development. This makes understanding deprogramming difficult, although it likely involves reversal of chemical modifications, such as methylation and acetylation, that the DNA and its associated proteins undergo as cells take on specialized functions. Also, some reprogramming may occur when DNA is stripped of its old packaging proteins and repacked with new ones in the egg's cytoplasm—a process that also occurs with the DNA of a fertilizing sperm. "We need to spend a significant amount of effort in the near future in understanding that mechanism [of how the egg interacts with its new DNA]," says James Robl, a developmental biologist at the University of Massachusetts, Amherst. However, it may now be possible to study how that programming occurs by examining the molecular conversation that goes on between the egg and the transferred nuclei.

And the reprogramming is just one aspect of cloning that can go wrong. Many subtle differences exist between mammalian species in how they develop during those first few days. Not only do they differ in how quickly the new DNA takes charge, but they also vary in how they decide to implant in the uterus and develop a placental connection. These differences could make nuclear transfer from adult cells harder, if not impossible, in animals other than cows or sheep, suggests Zena Werb, a developmental cell biologist at the University of California, San Francisco. Also, in livestock, past efforts to clone embryonic cells have tended to produce oversized, delicate young that required extra care if they were to survive, notes embryologist George Seidel of Colorado State University in Fort Collins. The same may prove true of the new procedure.

But the tantalizing possibility of making identical copies of prized livestock, or even of animals used for research, will be too exciting to pass up, says Robl, who helped form a company 3 years ago to take advantage of these advances in cloning technology. Add to that the prospect of cloning genetically modified animals that can produce drugs or better milk, meat, or wool, Robl says, and "tomorrow, next year, this field is going to be so crowded."

Yet, even if few or none of the potential applications come to pass, Dolly will forever have her place in history. As Werb points out, this lamb's creation "is the category of experiment that bends your mind."

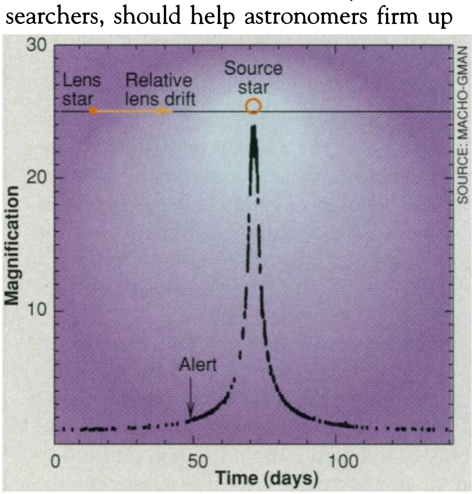
–Elizabeth Pennisi and Nigel Williams

ASTRONOMY

Farsighted Gravity Lens Sees Stars

Almost all stars are so distant that, even with the largest conventional telescopes, they appear as unresolved points of light, as featureless as the twinkling dots seen by an unaided observer on a clear night. Now, by using the gravity of one star as a huge magnifying glass, a team of astronomers has been able to make out features on the face of a second star located 30,000 light-years from Earth. The team found that the gravitational lens, which bends light rays as predicted by Einstein's theory of relativity, was aimed so precisely that it scanned across the face of the distant star, revealing details of its structure. "We have, in essence, obtained more than 8000 times better spatial resolution than the Hubble Space Telescope [HST]," says Andrew Becker of the University of Washington, Seattle, one of 57 astronomers from nine countries who collaborated in the study. The team announced its findings at a conference this week at the University of Notre Dame in Indiana.

Becker quickly adds that gravitational lensing requires the chance, near-perfect alignment of Earth and two stars, and so is much less versatile than the orbiting HST or conventional ground-based telescopes, which can be pointed anywhere in the sky. Still, says astronomer Virginia Trimble of the University of California, Irvine, who is not part of the collaboration, this use of gravity to peer at an object so far away "is obviously enormously exciting." The detail it reveals on distant stars, say other researchers, should help astronomers firm up computer models of how stars grow old and die.



A gravitational spyglass. A source star's brightness shoots up, then drops again as the gravity of a second star magnifies the signal through gravitational lensing.

The multinational collaboration that first noticed the event goes by the acronym MACHO, for Massive Compact Halo Object. MACHO's principal aim is to use gravitational lensing to search for dark blobs of matter, such as burnt-out stars or black holes, that might be swarming in a shadowy halo around our galaxy and making up most of its overall mass, as some theories predict. The project does this by constantly monitoring stars in a nearby galaxy called the Large Magellanic Cloud with a telescope at the Mount Stromlo Observatory in Australia, seeking sudden brightenings—a signal that a star has been magnified by the gravity of an unseen object in the halo. By keeping track of these events, MACHO hopes to estimate the overall amount of this kind of dark matter.

So far, MACHO has reported eight such brightenings, and is sitting on "a few" new ones for which the analysis hasn't been completed, says David Bennett, a team member at the University of Notre Dame. Settling the dark matter issue could take years, but while that program inches forward, the team also monitors stars near the Milky Way's more crowded central bulge. Here, the chance alignment of two stars and Earth in a straight line—the prerequisite for observing a gravitational lens—is more common. Becker says the team has collected roughly 120 of these events, gathering statistics on how matter is distributed in the bulge and therefore on its shape.

Most of those brightenings follow a standard "light curve" of increasing and then decreasing brightness with time. Such a curve suggests that the degree of alignment—and of magnification—was slight, causing a modest jump in the star's apparent brightness, but not enough to resolve it beyond a point source. But in the case of the event called MACHO Alert 95-30, says Becker, deviations from that curve showed that the alignment was so perfect that "the lens passed across the face of the star," like a detective scanning a body with a magnifying glass.

As the brightness started increasing and MACHO issued the worldwide alert, says Bohdan Paczynski of Princeton University, a "spectacular and successful" coordination of telescopic observations came into play. Called the Global Microlensing Alert Network, or GMAN, the program, whose astronomers were co-authors on the paper, collected spectra and light curves (see graphic) of the days-long brightening almost 24 hours a day. The result was a kind of transect, indicating how the spectrum of the starlight—a clue to composition and structure—changed from point to point across the star, which had been identified as a bloated red giant.

In this case, the MACHO team found that although the orientation of the stars was nearly perfect, the lens's focus passed along a line closer to the edge than the center of the red giant's face. But that was enough to make the first-ever comparisons between the calculated structure of an old, bloated star and actual observations, says Dimitar Sasselov of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts. Calculations by Sasselov and CfA's Abraham Loeb showed how the spectral signatures of stellar constituents like hydrogen and titanium oxide should vary from the center of the star to its visible edge, where the line of sight passes through more of the star's atmosphere, "and that's exactly what's observed," says Sasselov. Gravitational lensing, he says, "is giving us a fairly cheap and amazing way of studying the surfaces of distant stars"—and in greater detail than possible even for nearby stars with lengthy exposures on ordinary telescopes.

That kind of sleuthing could help firm up calculations of the age of the Milky Way's oldest stars, which seem to be paradoxically older than the universe itself. The MACHO group may eventually achieve its original goal of finding the galaxy's dark matter. Meanwhile, says Trimble, "it's impressive not only that the thing works, but that it's doing things it wasn't even designed for."

–James Glanz

WILDLIFE BIOLOGY

In Search of Africa's Forgotten Forest Elephant

Say "African elephant," and one pictures a vast savanna, where the largest land mammal mingles with lions, giraffes, gazelles, and zebras. In fact, about one-third of the continent's elephants live in its dark, often inaccessible rain forests, where the creatures are difficult for researchers to spot, let alone study. As biologist Claude Martin wrote in *The Rainforests of West Africa*, "Whoever is lucky enough to spy a forest elephant with his own eyes must satisfy himself with a few seconds of gray skin or a bit of white tusk shimmering behind the leaves."

But now a wealth of new studies is bringing these huge, elusive creatures out of the shadows. Scientists analyzing everything from elephant dung to DNA are piecing together the basics of forest elephant biology. With the forest elephant's rounder ears and thinner, straighter tusks, most taxonomists have long thought of it as a separate subspecies from its larger savanna cousin. But new analyses of mitochondrial DNA suggest that the two may be different species entirely (see sidebar). Studies of the forest elephant's diet suggest that the animal plays a crucial role in rain-forest ecology, dispersing the seeds of many fruiting trees. Ongoing research also is unraveling the secrets of their social behavior. Biologists have found, for instance, that unlike savanna elephants, the forest dwellers live in small groups. But like savanna elephants, they maintain dominance hierarchies and seem to mourn a family member's death, an event that scientists fear is becoming ever more common as an upsurge in commercial logging in Africa opens once-remote forests to poachers.

It's hard to blame scientists for overlooking the forest elephant. Why hike into an uncomfortably wet, hot habitat, when savanna elephants—one of the world's best studied mammals—can be easily observed from a jeep? The debate that preceded the 1990 ban on international ivory trade helped spark this new wave of research. Without knowing how many elephants were living in the forests of Africa, scientists found it hard to assess the overall impact of the trade. "Our ignorance of forest elephants was appalling," says Richard Barnes, a visiting scholar at the University of California, San Diego, and a member of the World Conservation Union's African Elephant Specialist Group.

Forest elephants range across more than a million square kilometers of dense forest and cannot be seen from airplanes, so estimating their numbers was a daunting task. But with support from the Bronx, New York–based Wildlife Conservation Society (WCS), Barnes and his wife, Karen Barnes, developed the first standardized method for gauging elephant populations by counting dung piles along transects and inserting the results into a mathematical formula that considers rates of defecation and dung decay.

The researchers first used the methodology in Gabon, where in 1993—after 2 years of hard, sweaty labor deep in the forest—they concluded that about 60,000 elephants lived.

A. K. TURKALO

Significant differences. Forest elephants are smaller and have rounder ears than their savanna relatives.

Over the next few years, WCS sponsored additional forest elephant surveys, and "today we have a pretty good idea where they live and of their relative abundance," says Richard Barnes. Of the continent's roughly half-a-million elephants, between a quarter and a third are forest elephants, the vast majority living in central Africa. The rest hang on in West Africa's very fragmented forests.

Elephant dung has also provided clues to what the animals eat and their role in forest ecology. Lee White, a WCS conservation scientist, says that unlike savanna elephants, which feed mostly on grass, forest elephants subsist on the leaves, twigs, bark, and fruit of rain-forest trees: "Their diet is much more like that of a gorilla than a savanna elephant." In Gabon's Lopé Reserve, White found that elephants eat 80 different kinds of fruit and will travel 50 kilometers or more to feed at a favored tree.

He and others contend that many fruiting trees depend on elephants to disperse their seeds. Seedlings of the makore (*Tieghemella heckelii*), for example—found only in Liberia, Côte d'Ivoire, and Ghana—were abundant along elephant trails in Ghana in the 1950s.