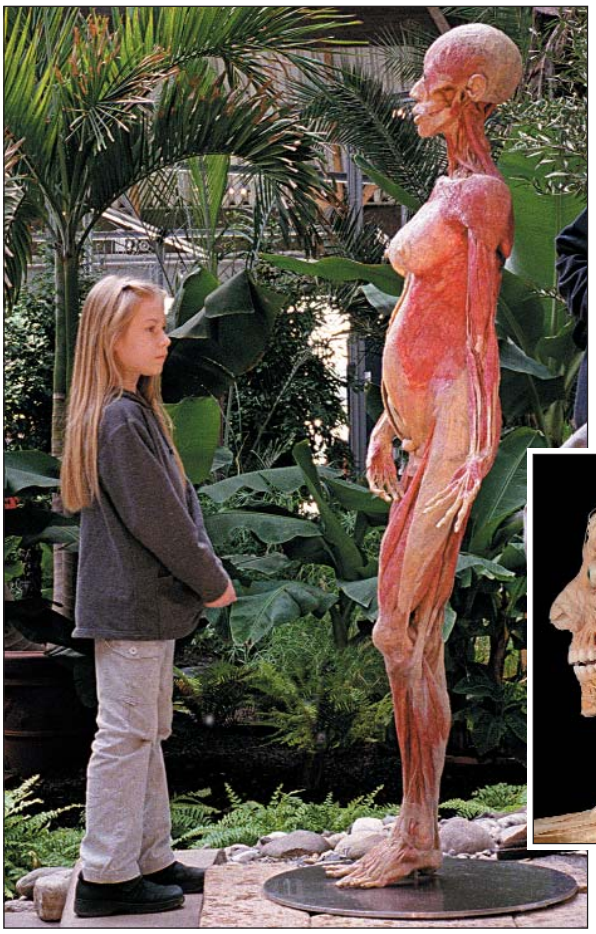
Gunther von Hagens developed a way to preserve tissue by replacing fluids with polymers. His "plastinated" body exhibits are drawing vast crowds. Is he the savior of anatomy, the "Disney of Death," or both?

Anatomy's Full Monty

DALIAN, CHINA—The cavernous chamber is as chilly as a morgue. Its enormous garage door has been left ajar to allow chemical fumes to escape into the frigid winter air. Within the fluorescently lit space, four Chinese technicians wearing teal smocks and rubber gloves huddle around the torso of a figure lying on a long steel trolley. A fifth technician, a young woman perched on a stool next to the trolley, cradles a pasty hand in hers and delicately peels away the skin of the palm with tweezers. She looks up from her work and smiles shyly. Flaying the skin from a human body without damaging the underlying tissues demands hours of painstaking work. The team makes steady progress, centimeter by centimeter, without a whisper. There is extra impetus today because, as everyone has heard, "Gunther is coming."

At least every 6 weeks, their German boss, anatomist-entrepreneur Gunther von Hagens, makes a rush tour and convenes a meeting of all employees. Perhaps the remaining skin can be stripped from this cadaver before his arrival. But before the glossy tendons of the hand can be exposed, the bunker is echoing with greetings as Von Hagens appears, zipping from table to table with his Chinese translator in tow. Approaching the trolley with a toothy grin, Von Hagens nods approvingly.



Face to face. Some 12.6 million people have visited exhibits of Gunther von Hagens's work, getting a close-up view of the human body, including the inside of the head (*inset*).

Like the dozens of plastic-wrapped bodies stacked by forklift on metal shelves along the walls, this corpse is destined not for the grave but for the public gaze. Through a process invented by Von Hagens called plastination (see sidebar), the body's decay-prone juices will be replaced by resilient plastics and its limbs permanently fixed in a position of his choosing for display in the traveling anatomy exhibit called Body Worlds (*Science*, 29 March 2002, p. 2359). So far, 50 whole plastinated bodies and 400 body parts—ranging in size from a torso to the anvil of the inner ear—have been viewed up close by 12.6 million people at exhibits in seven countries in Europe and Asia.

Von Hagens sees himself as the savior of anatomy, a science he claims has lost touch with a public frightened by limp body parts floating in jars. Plastination, he believes, can restore "the beauty beneath the skin." But many academics accuse Von Hagens of trampling on human dignity and damaging the public perception of medical science. "Von Hagens's exhibition raises some very grave concerns about consent," says Sandy Thomas, director of the Nuffield Council on Bioethics in London, because some body parts on display in Body Worlds were plastinated without consent. Von Hagens is a "showman who uses the cover of science to reap millions from voyeuristic audiences," seethes Tom Shakespeare, a sociologist at the University of Newcastle upon Tyne, U.K.

Von Hagens's bravado may be put to the test next year with his plans to tour Body Worlds through the United States, in part because of laws governing the use of human bodies. He explored the option of bringing his bodies to Florida in 1998, but the state's anatomy board voted to block the entry of his cadavers. But Von Hagens remains unfazed. He is confident that people will come around to his point of view sooner or later.

Fantastic plastic

Becoming the "Walt Disney of Death," as a commentator on a BBC documentary called him, is a relatively recent twist in the life of Gunther von Hagens. Once upon a time in the communist East Germany of the 1960s, he was just another hard-working medical student. Along with many of his fellow students at the University of Jena, Von Hagens was arrested for protesting against the invasion of Prague by Warsaw Pact troops in 1968, and soon after he was locked away for trying to escape to West Germany.

By a stroke of luck, 2 years later Von Hagens was among a group of political prisoners whose freedom was bought by the West, allowing him to finish his medical doctorate at the University of Heidelberg in 1975. The young and restless Von Hagens then became the research assistant of Wilhelm Kriz, a specialist in kidney pathology and now the director of the university's Institute for Anatomy and Cell Biology.

CREDIT: G. VON HAGENS/INSTITUTE FOR PLASTINATION, HEIDELBERG, GERMANY

While preparing thin slices of kidney, Von Hagens began innovating. The standard protocol of embedding the organ within a block of paraffin and then carefully cutting it into smaller sections seemed like "too much wasted effort" to him. A moment of inspiration in the local butcher shop, he says, led to a method to impregnate organs with polymers from within and then cut them with a deli meat slicer—and plastination, as he dubbed it, was born. Although those early specimens looked "anything but promising," he was hooked.

For Von Hagens, who names Thomas Edison as his archetype, plastination became not just his academic passion but also a business venture. Convinced of its potential, he obtained a handful of patents related to plastination and sank a sizable chunk of his own money into starting up a company in 1980 to sell the polymers. The risk paid off. After describing the technique in a few papers and at conferences, Von Hagens generated a flurry of enthusiasm among anatomical technicians. By 1982, biennial conferences were being organized by the International Society for Plastination, which began publishing its own peer-reviewed journal in 1987.

In those early days, says Ronald Wade, one of the first Americans to become licensed by Von Hagens's company as a plastinator and who is now director of the Anatomical Services Division at the University of Maryland School of Medicine in Baltimore, "it was kind of a Von Hagens admiration society."

The creative awakening for Von Hagens came one late night in 1988 when he encountered an awestruck janitor staring at some plastinated body parts. Until then, plastination had been a purely academic pursuit; it had hardly occurred to him that the public might be fascinated by plastinated anatomy. But a modest exhibit of plastinated specimens in the small German city of Pforzheim that year proved to be a minor hit.

Why stop at body parts, wondered Von Hagens? Why not plastinate an entire human body so it can stand upright and stare back at eye level? By 1993, he had overcome the technical hurdles to making whole-body specimens and was selling them to medical institutions as teaching aids. But he found it difficult to convince universities and museums that the general public would not simply be repulsed. Then Tatsuo Sakai, an anatomist at Juntendo University in Japan, invited Von Hagens to stage an ensemble of plastinated bodies in Tokyo in 1996. To their amazement, more than 400,000 people squeezed through the doors in 2 months.

"Everything changed for me after Japan," says Von Hagens. His 1997 exhibit at a science museum in Mannheim, Germany, became so popular that the city allowed the doors to remain open 24 hours a day to reduce the enormous queues outside. Von Hagens returned twice to Japan before touring his plastinated bodies through Austria, Switzerland, and back through Germany. He then jumped the English Channel to London, where the long-extended exhibition finally closed its doors in February after 11 months. An exhibit that has been going on since April 2002 in Seoul, South Korea, has been the most successful yet, with over 2 million visitors so far. And since March of this year, Von Hagens has been running a simultaneous exhibition in Munich, Germany.

Against the tide. Von Hagens, wearing his trademark hat and waistcoat, puts the finishing touches on plastinated bodies posed as swimmers.

Body Worlds has made Von Hagens a rich man. But he has much bigger plans. "I'm a monomaniac," he admits, with plans to keep expanding the number of specimens until he can tour three simultaneous exhibits around the world and eventually create a permanent Museum of Man, ideally in Germany. To achieve this, Von Hagens says he will need thousands of bodies. That's why he has plowed 90% of his profits into the facility in Dalian, a cluster of pink concrete buildings

CREDIT: G. VON HAGENS/INSTITUTE FOR PLASTINATION, HEIDELBERG, GERMANY

Plastination: Putting a Stopper in Death

For those who crave physical immortality, the main obstacle has always been the inevitable process of putrefaction. To preserve their nobility, the ancient Egyptians used mummification to stave off hungry bacteria and fungi. But after the brain is yanked out through the nose, the viscera scooped out, and the rest cured with potassium nitrate, the body does not look its best.

The pharaohs would have just loved a technique called plastination, invented by German anatomist-entrepreneur Gunther von Hagens, which not only permanently protects flesh from decay but preserves its original color and structure down to the cellular level. Whereas mainstream chemical preservation leaves the body's water in place and adds chemicals to fix the proteins of the tissue and to kill microbes, plastination replaces all the water with resilient polymers such as silicone rubber or polyester resin.

There are many variations on plastination, depending for example on what is to be emphasized or whether the body is to be sliced into layers or exhibited whole. But the first step is always freezing the body fast enough to prevent the formation of membrane-rupturing ice crystals. The frozen cadaver is then submerged in a bath of acetone at –25°C for up to 30 days until all its water has diffused off and been replaced by acetone. Most bodies then go into another acetone bath at room temperature to dissolve away fat. The body then goes into a bath of liquid silicone under vacuum for up to 14 days, during which the acetone slowly evaporates and is replaced with silicone.

At this point, the body is ready to be skinned, dissected, and articulated before being hardened by treatment with gas, heat, or ultraviolet light. Over 1000 hours of dedicated work and at least $30,000 go into the creation of a single whole-body specimen.

–J.B.

overlooking Xinghai Bay that he calls Plastination City. Here, 240 kilometers from the North Korean border, 200 fresh-faced Chinese technicians, most of them recent graduates of Dalian Medical University, can plastinate dozens of bodies at once with assembly-line efficiency.

Updating anatomy

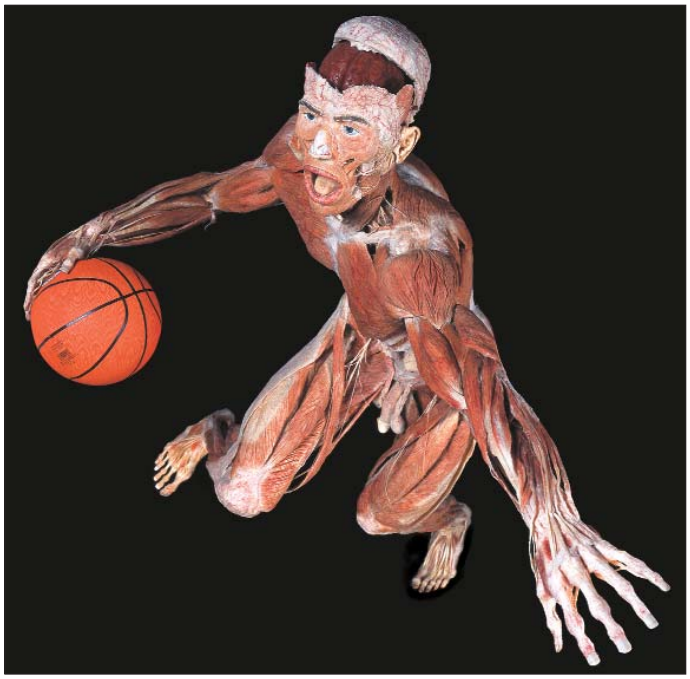
Before gathering the flock for a company meeting, Von Hagens wants to check on the progress of his latest bodily inventions. He trots in leather sandals with surprising speed through the underground corridors connecting the buildings of Plastination City, the regular pace of a man who is constantly on the move and keeps no office. "I like to wake up and not know which country I am in," he says.

The inside of Bunker-2 is like the studio of a Renaissance sculptor: Dozens of technicians tinker with human figures held in various poses, pausing periodically to consult anatomical illustrations. Von Hagens moves between groups of white-coated technicians, standing out like a raven over snow in his black leather vest and trademark dark fedora. Von Hagens relishes eccentricity, claiming that "an unusual outward appearance fosters nonconformist thinking," but he also dons the hat as a nod to the tradition of Renaissance anatomists who wore hats as a mark of their profession.

Modern-day anatomists are divided over Von Hagens's creations. Colin Stolkin, an anatomist at King's College London, notes that Body Worlds has had greater attendance than any human anatomical display in history. He himself took many groups of medical students to London's Body Worlds exhibit. "Von Hagens's dissections are outstanding," enthuses Stolkin. But Harold Ellis, a surgeon and celebrated medical lecturer at University College London, dismisses the specimens in Body Worlds as no better than "the excellent, anatomically correct models made of plastic" that he uses for teaching. Ellis criticizes the exhibition for being a "shock provider" rather than an educational effort, pointing out several careless errors in its anatomical labeling.

Others too are suspicious of Von Hagens's educational aims. "It's a wonderful opportunity to see what's under your hood," says Donald Jenkins, an anatomist at the Uniformed Services University of the Health Sciences in Bethesda, Maryland, but "I run into problems with the exhibitionist style." Jenkins was particularly turned off by a public autopsy Von Hagens performed in November 2002, parts of which were broadcast on British television (*Science*, 6 December 2002, p. 1881). It amounted to nothing but a "publicity stunt" for Body Worlds, he says.

"What's wrong with sensationalism?" counters Von Hagens. In today's media-saturated world, anatomy needs a little shock and awe, and some humor, just to get people to walk through the door and pay attention, he says. And besides, Body Worlds is a benefit to public health, Von Hagens argues, because it includes comparisons of healthy and diseased bodies. On the basis of polls of people before and after visiting Body Worlds—conducted independently by Ernst Lantermann, a psychologist at the University of Kassel in Germany—Von Hagens claims to have helped persuade millions of people to smoke less, eat better, and exercise more. What could be wrong with that?



Shock tactics. Von Hagens has been criticized for sensationalism by plastinating bodies in striking poses.

CREDIT: G. VON HAGENS/INSTITUTE FOR PLASTINATION, HEIDELBERG, GERMANY

A question of consent

Aside from questions of taste and educational value of the Body Worlds exhibits, the biggest question his critics have raised is, Where do all the bodies come from? Some have charged that Von Hagens established himself in Dalian to ensure a steady flow of cadavers from the Chinese government, the world's number one executor of criminals. But he vehemently denies the charge. "The opposite is true," he says. "In China there is an even greater taboo on dead bodies than in the West." Von Hagens, who was a visiting professor at Dalian Medical University between 1994 and 1995, insists that he set up here because he was invited to do so by the university. And it seemed a wise choice because of the skill of local anatomists. Von Hagens has been able to employ 200 "excellent" anatomists for the dissecting tables of Plastination City. Of course, their roughly $280 monthly salary—about twice that of typical Dalian medical graduates—means he can attract the talent for a bargain price.

Foreseeing that he would come under fire about the source of the bodies used for plastination, Von Hagens says he set up a body donation program in Germany as early as 1982. Von Hagens says that over 5000 donors have signed a contract—revocable at any time during life—which gives him consent to dissect, plastinate, and publicly display their bodily remains. "I now receive on average a body a day," he says. According to Von Hagens, some 90% of donated bodies are German, but he declines to name the national origin of the remainder.

This lack of transparency has prompted some to dig deeper. Last year a group of German journalists investigated the trail of bodies leading to his Heidelberg facility, from which bodies are transported to Dalian in shipping containers. The path took them to medical doctors at the University of Novosibirsk in Siberia, who have now been sued by the families of 56 people whose bodies were allegedly taken without consent. The Siberian bodies were part of the contract work that Von Hagens says constitutes about 20% of the plastination done in Dalian: specimens sent by educational institutions to be plastinated for a fee and then returned. None have appeared in his exhibitions, he says. Von Hagens, who was not charged, says he was given assurances that consent had been properly obtained. Since then, he says he has refused to accept fresh, whole bodies from other institutions.

Questions still hang over his operation, however. Officials at the Chinese Ministry of Health in Beijing, contacted by *Science*, said they were unaware of the work of Plastination City, which is officially listed as a "manikin company" in Dalian. Von Hagens says he did not know it was listed this way. He says he has obtained "a few" Chinese bodies through a nascent donor program he set up in Dalian. He admits to using "unclaimed" bodies provided by the Chinese government, but he says they are only for in-house "educational" purposes and that no Chinese bodies have appeared in Body Worlds.

Although Von Hagens says he follows

strict consent procedures for whole-body specimens, he maintains that "consent is not important for body parts." Others find this view unacceptable. The Nuffield Council on Bioethics has spent years drawing up standards and ethical requirements aimed at plugging such loopholes, explains Thomas, after the revelation that in the 1990s some British hospitals had taken body parts from dead infants without consent (*Science*, 6 December 2002, p. 1867). "Von Hagens's posturing indicates that he takes the view that he is exempt from observing these requirements or standards."

Von Hagens will also have to overcome legal hurdles if he is to exhibit in the United States. The city of Munich asked him to show signed donor contracts for his plastinated cadavers, but he refused on grounds of privacy and the request was eventually dropped. But in the United States, says Wade, the Uniform Anatomical Gift Act can be used to force him to do so. And even if he does show that he has obtained informed consent, states' anatomy boards will have to give him the go-ahead based on their judgement of his intentions, says Lynn Romrell, chair of the anatomy board in Florida that blocked Von Hagens in 1998. "We decided that his intentions were not educational," says Romrell, and it will be up to Von Hagens to convince the anatomy boards in other states.

In spite of these barriers, Von Hagens says that his plans to conquer the United States in 2004 are "definite," although he is keeping his intended dates and venues under wraps. An American tour is bound to be controversial, says Wade, because "this country doesn't believe that anyone's death should be used for someone else's profit." But then again, Von Hagens is no stranger to controversy. He thrives on it. **–JOHN BOHANNON**

John Bohannon is a writer based in Paris. With reporting by Ding Yimin and Xiong Lei of *China Features* in Beijing.

Solar Physics

A Space Weather Aerie in the Caucasus?

The enterprising director of a cosmic ray observatory in Armenia is hoping to launch a global network of ground stations that would complement space-based forecasting

If you're in Armenia and want to catch some solar rays, try scaling the southern peak of Mount Aragats. There, 3200 meters up, an observatory run by the Cosmic Ray Division (CRD) of the Yerevan Physics Institute casts an unblinking eye on our star. Now the Soviet-era holdover is spearheading a bold new venture: a worldwide alert service that would warn of devastating solar storms approximately half an hour before their radiation blasts strike Earth's atmosphere.

During crests in its 11-year activity cycle, the sun occasionally unleashes a violent flare often accompanied by a billion-ton burst of plasma known as a coronal mass ejection. Such solar storms have knocked out several satellites in the past 2 decades and brought down Quebec's power grid in March 1989, and they could threaten astronauts by disrupting onboard instruments or walloping them with radiation.

To forecast space weather, scientists monitor the stream of ionized particles from the sun using Earth-orbiting satellites and two spacecraft—NASA's Advanced Composition Explorer (ACE) and the Solar and Heliospheric Observatory (SOHO), a joint NASA–European Space Agency mission—that pirouette in a part of our solar system where the gravitational fields of Earth and the sun roughly cancel each other out. ACE and SOHO pick up the deluge of particles that can wreak havoc on satellites and power grids.

But many experts argue that it is risky to rely solely on satellites to flag oncoming solar storms. For one, congressional appropriators are threatening the U.S.'s premier space weather forecasting service—the National Oceanic and Atmospheric Administration's Space Environment Center (SEC), a satellite-based alert and research unit—with a 40% cut to its proposed $8.3 million budget in 2004. And the space-based sensors themselves are not fail-safe, as the recent drama surrounding SOHO demonstrated (*Science*, 4 July, p. 31).

An alert system on terra firma could provide a safety net in case spaceborne sensors were to falter. "That's a valid paradigm," says Joseph Kunches, chief of SEC's space weather operations division. In a proposal to the International Science and Technology Center (ISTC), a Moscow-based outfit that funds nonproliferation activities across the former Soviet Union, CRD director Ashot Chilingarian has outlined a novel ground-based network that would rely on the detection of high-energy particles that pelt Earth roughly 30 minutes before the brunt of a solar storm arrives. "It's a fascinating project that promises to have critical applications," says physicist Alex Chao of the Stanford Linear Accelerator Center in Menlo Park, California.

With a unique combination of detectors and homespun analytical software, Chilingarian's team thinks it can spot the high-energy vanguard of an oncoming solar storm reliably enough to allow operators to take precautions such as flicking electronic switches to safe mode. In its ISTC proposal, now being vetted by the U.S. Department of State, CRD aims to construct a pair of prototypes of detectors that could be deployed at stations around the world. Chilingarian has launched negotiations with space weather centers in Greece, Israel, Russia, the United States, and elsewhere

Solar flair. Ashot Chilingarian hopes to secure his center's future by launching a space weather alert service.

Where the sun doesn't shine. In winter, underground tunnels are often the only way for technician Tigran Yepiscoposian and others to move between buildings.

CREDITS: (TOP TO BOTTOM) MKHITAR KHACHATRIAN/COURTESY OF THE SUPPORT COMMITTEE FOR ARMENIA'S COSMIC RAY DIVISION; CRD