medicine at MICHIGAN

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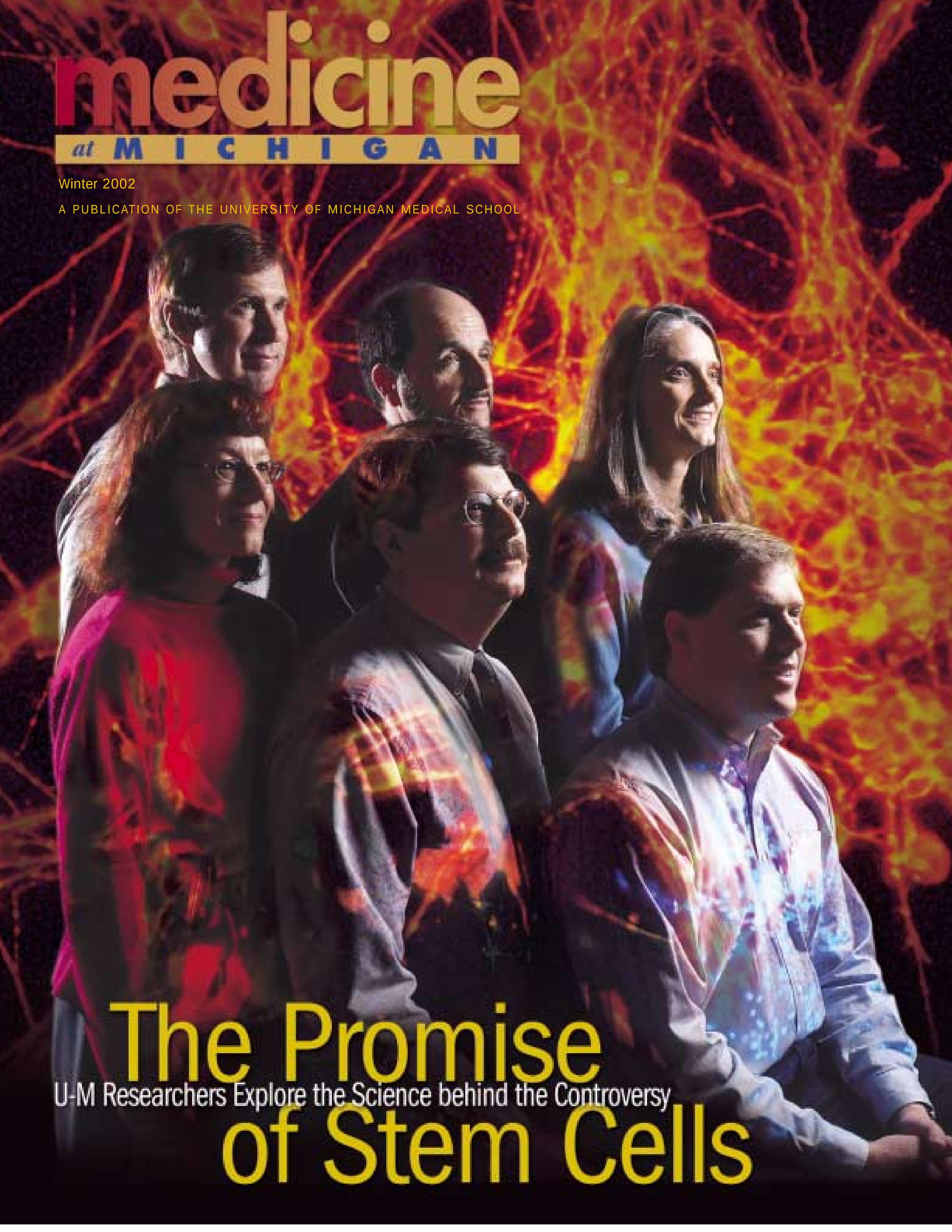

The Promise of Stem Cells

U-M Researchers Explore the Science behind the Controversy

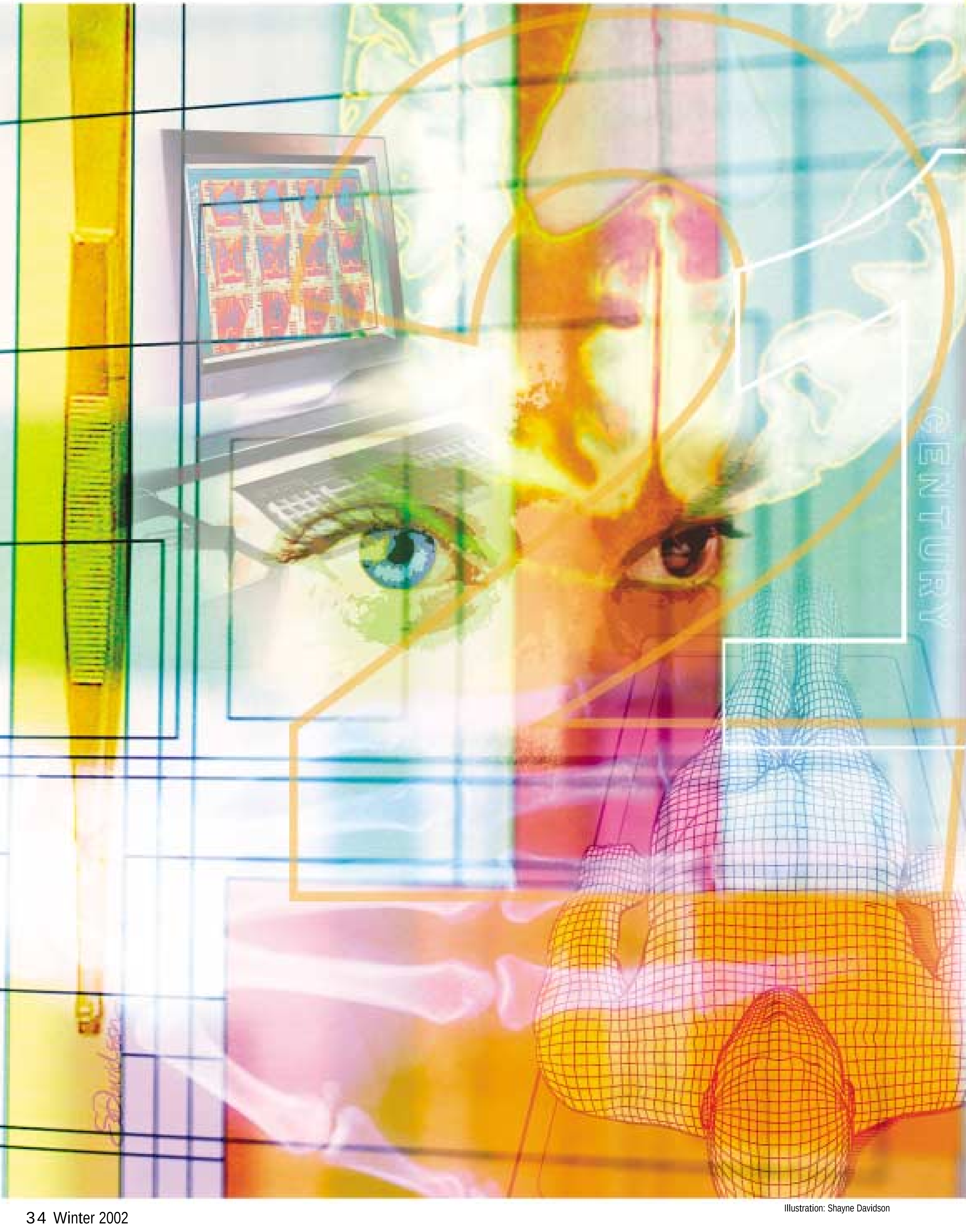

Illustration: Shayne Davidson

Technology contributes stunning new ways to see inside the human body

LEARNING ANATOMY

IN THE TWENTY-FIRST CENTURY

by Rick Krupinski

In the152 years since Moses Gunn arrived in Ann Arbor by stagecoach, accompanied by a long wooden crate carrying the first cadaver for study at the new University of Michigan Medical School — indeed for centuries before the School and its peer institutions were even founded — dissection, of animals and of humans, has been the foremost way of teaching and learning anatomy.

As an autopsy instructs in the specifics of death by allowing the medical examiner to "look inside" (the literal meaning of the word), so has dissection enlightened students of anatomy throughout history by providing three-dimensional, palpable experience with the muscles, bones, organs and tissues that comprise and enable human life.

Whether witnessed from a distance in an amphitheater as instructors like the legendary Corydon Ford — a U-M anatomist renowned in the early days of the School for meticulous, even elegant, dissection — demonstrated techniques and presented the internal structures of the human body, or whether performed firsthand by students themselves, as has been the case in gross anatomy labs since the late 19th century, "looking inside" has been an essential experience fundamental to the study of medicine, even as the medicine we study has evolved, changed, and grown more complex. Today, whole fields like ➤

Photo: Bill Wood

Photo: D.C. Goings

Left to right: **Tom Gest with medical students Parrish Balcena and Igor Siniakov**

Below: **Bill Burkel**

bioinformatics have emerged to effectively unravel and compile the explosion of new information coming from the ever-expanding frontiers of medical science.

In just the last 20 years, technological advances have revolutionized ways of not just looking inside the human body, but also relating what is seen to physiological function, diagnosis of disease and subsequent treatment. The evolution of radiological imagery into precise and dynamic pictures of human structures; the ever-changing and pervasive presence of computer technology; and new processes that can preserve anatomical specimens virtually forever have all contributed significantly to the study of anatomy today.

Relating anatomy to physiology and the actual practice of medicine is not coincidental, nor is the shift in focus to learning rather than teaching. As the Medical School undertakes a major curriculum review, context and methods of learning are helping shape the future of medical instruction at Michigan. "Our goal is to create a learning environment centered upon helping students excel as they prepare to care for patients and develop their professional careers," explains Joseph Fantone, M.D., associate dean for medical education.

"Anatomical knowledge underlies physicians' ability to provide quality care, and providing the 'why' about what students are learning in context of the patient and of patient care helps them to become more effective physicians," he says. "Linking physiologic function and clinical findings with anatomical structure and the pathology of tissues and organs helps bring relevancy — and greater retention — to the study of anatomy overall. Learning effectiveness is driving medical instruction and revisions to our curriculum.

"The lecture is an efficient way of delivering information," Fantone says, "but what do you as the student do with all that information? How do you know what's relevant, what facts you really need to know and how they need to be organized to be effectively applied in the future? Active learning environments that offer students the chance to apply and test new knowledge have been shown to be highly effective in promoting student learning and integration of information, especially when organized around a specific medical or patient care issue."

Learning Anatomy in the Age of Technology

It's a point reinforced by Tom Gest, Ph.D., associate professor of anatomical sciences and the new Gross Anatomy course director after Bill Burkel, Ph.D., professor of anatomical sciences, recently concluded 17 years as course director. With about 170 student contact hours, Medical Gross Anatomy is the largest course in the Medical School's offerings. "We try to keep students focused on what they have to know and on the clinical applications of anatomy. As faculty, we have to look deeply at every fact we teach. Why are we teaching it? Is it relevant? If not, we don't encumber students with it," Gest says. "It's our obligation to help students cut through the enormous volume of information so they understand what is important."

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—TOM GEST

Gest is largely credited with maximizing use of technology in gross anatomy, especially digital technology, since he came to U-M from the University of Arkansas more than three years ago and began building upon the efforts of Burkel and others. A lanky, laid-back man with a bushy mustache and traces of a southern drawl from his Arkansas days, Gest has a varied background in archeology, anthropology, math and statistics. It is this unique background combined with his utter love of anatomy that makes him comfortable with the concept of multiple contextual bases for learning — biomedical, social, cultural and developmental. He points to the change in educational philosophy to focus on learning rather than teaching as an important means of encouraging students to be self-reliant and self-paced in their studies, a goal very much facilitated by technology.

U-M medical students have ready access to an array of computer-based learning tools that allow for individual paces of learning from their home computers, the Computer Assisted Instruction Lab and the Learning Resource Center within the Medical School, and even right alongside dissection tables in the Gross Anatomy Lab.

"We have one computer terminal for every two dissection tables," Gest says. "If students have questions or need to review material or dissection technique, they can access that material right then and there." From the computer, students can refer to the Medical Gross Anatomy course pages, find detailed information in the lab manual on the area being dissected, watch dissection movies, and reference three-dimensional anatomical models that can be rotated and examined from all angles, bringing a wealth of information to the dissection experience. Such learning tools augment rather than replace faculty-student interaction; Gest and other faculty members work directly with students in the Gross Anatomy Lab, explaining and discussing items related to dissection procedures and anatomical structures.

Other Web-based resources available to students of gross anatomy at Michigan include anonymous medical histories of the cadavers to bring clinical relevance to anatomical learning (as well as personal relevance to the cadaver as a unique human individual), clinical cases related to each dissection component, anatomy tables and labeled images, practice quizzes — even anatomical crossword puzzles, all as interactive as possible to engage the students.

"We have the equivalent of several full books of information on the Web," Gest says. Students also have access to *ATLAS-plus*, a CD-ROM photo atlas presentation (it stands for Advanced Tools for Learning Anatomical Structures) developed in the early 1990s by Burkel, Associate Professor of Anatomical Sciences Ted Fischer, Ph.D., their colleagues and students, using images made during 45 dissections over a three-year period.

And in an exciting technological initiative, the U-M Medical School is home to a team working on the National Library of Medicine's Visible Human Project, a massive effort to create complete, anatomically-detailed, three-dimensional, digital representations of the normal male and female human bodies to be distributed via high-speed computer networks for application to a wide range of educational, diagnostic, treatment planning, virtual reality, artistic, mathematical and industrial uses around the world. Directed by Brian Athey, Ph.D., assistant professor in the Department of Cell and Developmental Biology, the benefits of the Visible Human Project will be enormous for students and teachers of anatomy, physicians and other health professionals, and the future direction of gross anatomy learning methods.

The Medical Gross Anatomy course is based upon educational principles which hold that traditional methods of learning, often passive, have the lowest rates of retention: lectures, for instance, carry only a five percent retention rate; reading, just 10 percent. Active methods, such as teaching others and practice by doing, result in retention rates of 75-80%. The active methods are the focus in gross anatomy instruction at Michigan today, and it's not just computer technology that contributes to active learning and greater retention.

Peer teaching is a concept implemented by Burkel and continued by Gest. "While half a dissection team of six students dissects," Gest says, "the other half is free to study, then the dissection half presents to the study half, with one member responsible for presenting the clinical application." The roles rotate, and Gest has on-hand eight video cameras so students can tape themselves presenting for ➤

“Radiology is at the center of medicine. It will be used by virtually all physicians over the course of their careers. **THE LANGUAGE OF ANATOMY IS THE LANGUAGE OF RADIOLOGY.”**

–REED DUNNICK

later self-critique. Presenting medical information — to patients and their families, to colleagues, and to students of the future — is a fundamental skill required of physicians and researchers, so the taping activity develops communication skills even as it strengthens retention of gross anatomy material.

“We really owe a lot to Bruce Carlson,” Burkel says. “As department chair, he supported innovative ideas that allowed us to move forward, particularly with technology. Without that support, anatomy instruction at Michigan would have fallen way behind.”

Burkel speaks from a desk that carries the same impeccable, neatly-ordered organization characteristic of the gross anatomists. He retrieves files on a variety of topics with ease, as if the elegant order of component parts of the human body he studied and taught for years extends into the external world. Original airbrush and carbon pencil illustrations of the internal and external aspects of the human skull hang on the wall next to him, drawn by medical illustrator William L. Brudon for the much-respected anatomy textbook, *Essentials of Human Anatomy,* which Burkel co-authored with former Chair of Anatomy Russell Woodburne. Burkel points out that while technology has greatly aided learning, it’s also made teaching more difficult, and he speaks from the perspective of his 35 years at U-M.

“Twenty years ago,” he says, “Gross Anatomy consisted of about 45 lectures divided among six or seven faculty members. Lectures changed little from year to year, so there wasn’t a lot of preparation involved. Now we’re constantly struggling to keep information current and preparation is ongoing. I just spent six weeks on four anatomy movies for four days of the Gross Anatomy course.

“When I studied anatomy,” Burkel reflects, “the field of molecular biology didn’t exist. We knew much less of biochemistry than we know now. Anatomy becomes smaller in light of explosions of progress in other areas.” As a result, what was at the beginning of the 20th century a two-year course has now been distilled to the first semester of medical training. One begins to understand why helping students figure out what they need to know has become so crucial over the course of the revolution in teaching and learning strategies for gross anatomy.

“Overall,” Gest adds, “we have one of the strongest programs in gross anatomy, with a long tradition of innovative teaching. There are lots of anatomy Web sites and instruc-

Photo: Martin Vloet

Photo: Gregory Fox

Marilyn Roubidoux *(left)* **and Reed Dunnick** *(right)* tional software, to be sure, but what distinguishes Michigan is that focused learning takes place in the most advanced way possible, with maximum use of technology. You can have a thousand links in your Web site, but are they providing what students need to know? At Michigan, we're focused tightly on what students need to know to become the best physicians and researchers possible.

"Last year we experienced the highest grade point average in Gross Anatomy in 10 years and student satisfaction was the third highest it's been in 10 years." In characteristic understatement Gest concludes, "This seems to indicate that we're effective and not going in the wrong direction."

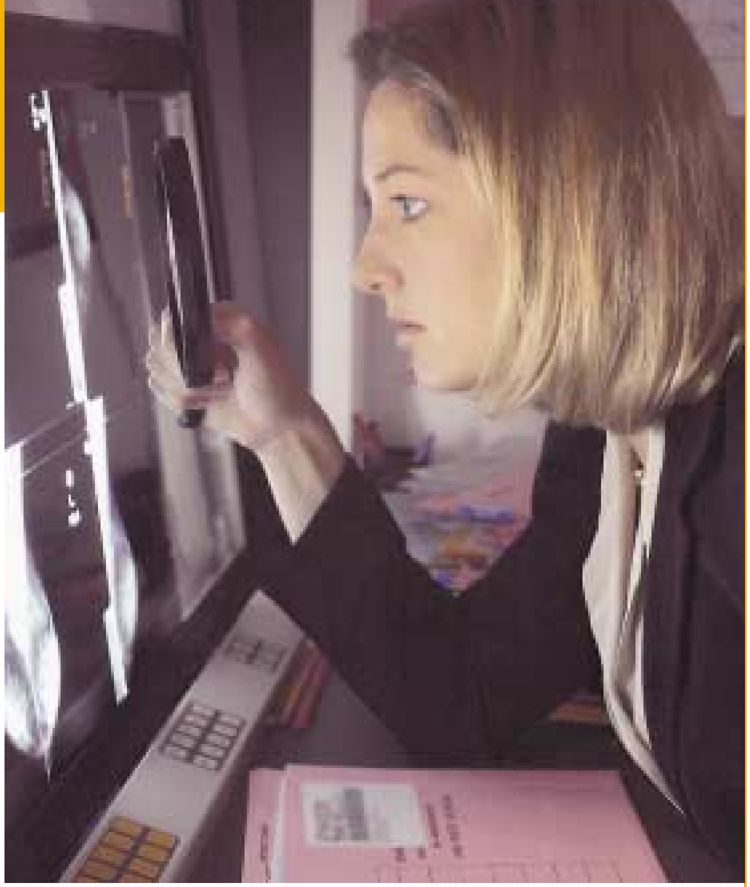


Photo: Martin Vloet

Katherine Klein

Radiological Views

"Radiology is at the center of medicine," says Reed Dunnick, M.D., the Fred Jenner Hodges Professor of Radiology and chair of the U-M Department of Radiology. "It will be used by virtually all physicians over the course of their careers. The language of anatomy is the language of radiology."

Dunnick oversees a busy department of more than 100 faculty, and he's proud of its participation in the gross anatomy curriculum. "We just don't learn well from flat, two-dimensional pictures. Radiological images show three-dimensional shape and form and relativity to other structures much more clearly and usefully."

The field of radiology has come far since Wilhelm Conrad Roentgen, a physics professor at the University of Wurzburg in Bavaria, took the world's first X-ray, of his wife's hand, in 1895, but most of the distance has been traveled since the 1960s. Until then, "fever of unknown origin" was a bedrock diagnosis for unsuspected tumors or chronic infections that plain X-rays simply weren't able to detect, and exploratory surgery was the best way of seeing for oneself inside a living patient. Contrast materials helped, as did stereoscopy (two images of the same structure from different perspectives) and fluoroscopy (continuous viewing of an internal structure by transmission of X-rays to evaluate dynamic events, like breathing, swallowing, and blood flow, akin to a movie in real time).

But all that began to change in the 1970s. Use of barium and barium-plus-air for contrast had already led to finer X-ray detail for the body's hollow organs (such as the esophagus, stomach, small bowel and colon), but it was the development of ultrasound, which uses high frequency sound waves instead of ionizing radiation, that was the first big leap forward. Ultrasound produces images that can be viewed on a television monitor, taped with a videocassette recorder, or recorded on radiographic film or photographic paper.

The 1980s saw the advent of computed tomography (CT) scans, which use thin X-ray beams that rotate around the patient to gather information that is collated by a computer to create an image of the internal structures of the patient's body, like a slice, showing the relative location of the structures in cross-sectional orientation. The resulting images can be stored on a computer disk or magnetic tape or printed on radiographic film. Magnetic resonance imaging came to the forefront in the 1990s; strong magnetic fields cause hydrogen atoms in the body to produce radio waves that make the MRI image. As with CT scans, computers create cross-sectional images of the patient's body that are particularly useful for examinations of the brain and spinal cord because of the images' detail.

One of the most promising recent developments in radiology is positron emission tomography (PET), which examines the metabolic activity in various structures of the body, such as the heart and blood vessels, and is becoming especially helpful in staging cancers and detecting Alzheimer's Disease.

"The primary benefit of using radiological images in gross anatomy study is that we can demonstrate anatomy in a living patient and directly relate that anatomy to physiological function and disease to ➤

THE VISIBLE HUMAN PROJECT

U-M is home to a team leading an ambitious national collaboration to implement a digital library of images of the human male and female for the education and training of future health professionals

When convicted murderer Joseph Paul Jernigan donated his body to science, he scarcely could have imagined the phenomenal use to which it would be put or the worldwide educational benefit it would have to countless students, teachers, physicians, nurses and others who would learn the intricacies of the human body from studying his own.

In 1993, Jernigan was executed by the state of Texas at the age of 39. His body was frozen and, at the University of Colorado, 'sliced' into one-millimeter increments that resulted in over 1,800 cross-sections. Two years later, the body of a 59-year-old Maryland woman who died of heart failure was likewise 'sliced,' in one-third-millimeter increments. The digitized data resulting from these two procedures show a myriad of views of the human body and form the basis of the National Library of Medicine's Visible Human Project. The Project uses photographs of the resulting cross-sections, as well as digital computed tomography (CT) and magnetic resonance images (MRIs) of the two cadavers.

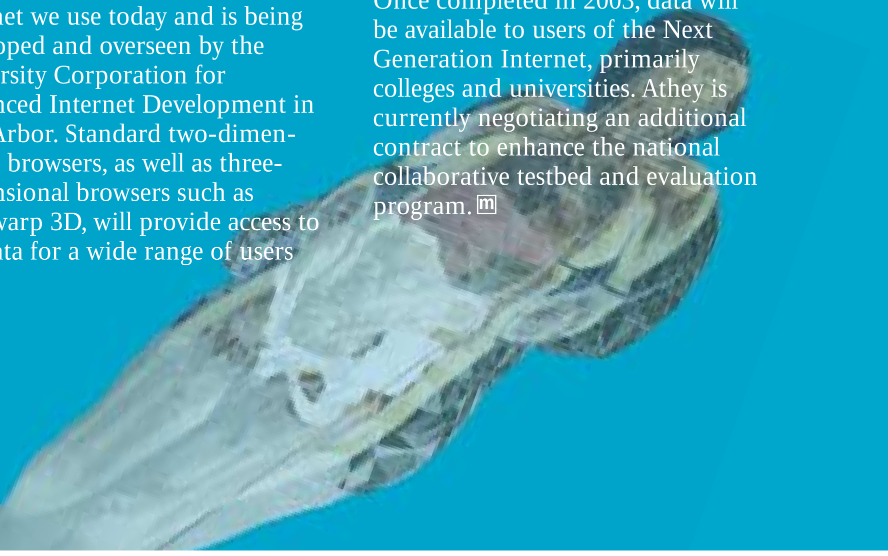
Perhaps no other combination of technology and medical knowledge exemplifies so completely the new directions the study of human anatomy is taking in the 21st century. The Visible Human Project will supplement the bibliographic and factual database services of the National Library of Medicine in Bethesda, Maryland — the world's largest medical library — with a detailed digital anatomical database of images representing a complete normal adult male and female, which can be distributed over high speed computer networks.

The University of Michigan is home to a team sponsored by the Library to continue development of the Visible Human Project. Led by Brian Athey, Ph.D., the U-M project team, in collaboration with the Pittsburgh Supercomputing Center, is working to put the Visible Human Project data on the federal government's Next Generation Internet. This system, known as Internet2, is projected to be 1,000 times faster than the Internet we use today and is being developed and overseen by the University Corporation for Advanced Internet Development in Ann Arbor. Standard two-dimensional browsers, as well as three-dimensional browsers such as Edgewarp 3D, will provide access to the data for a wide range of users around the world. Video, audio, text and graphics will be linked to interactive, three-dimensional representations to explain and expand upon the images.

The U-M team of 20 researchers is developing and evaluating these new virtual tools with input from users in 'testbed' groups from the Medical School, the School of Nursing, the School of Education and the School of Information. A collaborative partnership with Stanford University Medical School is also underway.

"To a large extent, this is the future of anatomy training," says Athey. Athey is among those who feel cadavers could be replaced by virtual methods of learning. "Virtual learning is safer from a health standpoint, with no worry of contagions, and it offers students the opportunity to perform dissections or practice surgical procedures again and again, something a cadaver simply can't do."

Currently, Visible Human Project data can be accessed only by high-speed, high-capacity computers. Once completed in 2003, data will be available to users of the Next Generation Internet, primarily colleges and universities. Athey is currently negotiating an additional contract to enhance the national collaborative testbed and evaluation program. ⓜ



With about 170 student contact hours,
MEDICAL GROSS ANATOMY IS THE LARGEST COURSE
in the Medical School's offerings.

show students why they need to know these things," says Katherine Klein, M.D., assistant professor of radiology, who participates in presenting the radiological content of the Gross Anatomy course. "That increases both motivation to learn and retention of what's studied."

Marilyn Roubidoux, M.D., associate professor of radiology, serves as course director for the radiology lectures in Gross Anatomy and also serves on the Medical School's curriculum review committee. She has worked, at Gest's behest, to build more radiological imagery and content into Gross Anatomy lectures and Web-based course materials. In the first week of the course, she and Klein present the radiology-anatomy correlation lecture, providing in-depth, highly visual information using multiple examples of anatomy and how they correlate to structures seen with plain films, CT, MRI, Ultrasound, PET scans and nuclear medicine. Included are descriptions of each radiological modality from the perspectives of history, physics and how each image is created.

"It's not just radiological technology that has improved gross anatomy instruction, it's technology in general," says Roubidoux. "Large screens for electronic presentations like PowerPoint mean we can share with a whole roomful of students images and movies that show, three-dimensionally and in living patients, physiological movement and function." A smaller form of the PowerPoint radiology lecture is placed on the Anatomy Web site where students can refer to it prior to the lecture, or later, for review.

With the entire field of radiology moving to digital technology — meaning electronic storage, use and transfer of images — "teaching and learning opportunities are not restricted to time and place," Dunnick says. "These changes truly are revolutionizing the field of radiology and its role in diagnosis, as well as its role in learning gross anatomy."

"It used to be that diagnosis had about 90 percent of its basis in the clinical history and physical examination of the patient," adds Klein. "Now radiological examination accounts for a large portion of diagnoses, and that portion continues to grow."

The next big development in radiological technology, according to Dunnick, is fusion imaging, a process that puts the best of two worlds into a single image more precise than ever before. "We've just purchased a CT/PET scanner, the combined technology of which will eliminate 'warping,' a problem that can occur with slight changes in position as successive images are taken. Positional changes can make it more difficult to pinpoint an area — it's as if the area has moved or migrated, which of course it has not. With a CT/PET scanner, both techniques simultaneously capture their images while the patient is in a single position, yielding a single three-dimensional view of the same area that is more comprehensive, thanks to two spectacular technologies, than anything we've seen before."

Preserving Anatomical Specimens — Virtually Forever

Beneath a large reproduction of the classic painting "Anatomy Lesson of Dr. Nicholaes Tulp" by Rembrandt van Rijn, and alongside models of the brain and a photograph of the Medical School's most beloved and illustrious neuroanatomist, Elizabeth Crosby, Roy Glover, Ph.D., associate professor of anatomical sciences, sits in scrubs and lab coat reviewing the history of establishing North America's largest plastination laboratory at the U-M Medical School. It is Glover, who came to U-M in 1968, who not only established the lab but has also directed it since its completion in 1989.

"Plastination," he explains, "is a method of preserving anatomical specimens so that they retain their flexibility and natural appearance and are at the same time protected during repeated handling and study." Invented in the late 1970s by German polymer chemist-turned-anatomist Gunther Von Hagens, the plastination process essentially removes tissue water from the specimens and replaces it with a liquid silicone polymer. Because the process uses acetone, a highly explosive and flammable chemical, Occupational Safety and Environmental Health regulations require that every laboratory be explosion-proof.

One of the most crucial steps in the plastination process, Glover explains, involves replacing the acetone within a specimen, under vacuum, with a curable silicone polymer; once the specimen is completely impregnated with the polymer, the polymer is hardened. Finally, after specimens are cured, trimmed, tagged and entered into the laboratory database, they are ready to be studied — by U-M medical and dental students as well as undergraduate health science students. Since the ➤

Where do these recent technological innovations leave that classical foundation of anatomical learning and teaching, the dissection of human cadavers?

OPINIONS ARE MIXED.

Plastination Laboratory is a cost-for-service facility, it also prepares specimens for other medical and dental schools, for museums, for hospital training programs, and for many other health-related organizations. The American Cancer Society, for example, has made effective use of slices of plastinated healthy, cancerous and emphysemic lungs in its anti-smoking campaign.

"Plastinated specimens are permanent, dry, odorless and non-toxic," Glover explains. "Specimens can be predissected to display underlying structures or, after processing, can be sliced to show a variety of different cross-sectional views. As with cadaver dissection, plastinated specimens afford the student the opportunity to examine important internal structures, with the added benefit of being reuseable and portable. They can be used for learning in many settings and passed around among students during classroom presentations — or even in the Gross Anatomy Lab to inform their own dissecting work." Most specimens come from the U-M Anatomical Donations Program and are harvested, with appropriate permission, from elderly donors.

Since the specimens are real, and because it is illegal to sell body parts, plastinated specimens are leased long-term by customers that request them, and the U-M Plastination Laboratory tracks and monitors the location and condition of specimens on loan throughout the world. Most of the specimens, however, remain right at U-M where they comprise a specimen library from which they can be made available to different groups of students, including graduate students in the School of Art and Design's Program in Biomedical Visualization, formerly known as Medical Illustration.

"Undergraduate anatomy students at U-M do not have the benefit of a laboratory experience," Glover says. "Now they are able to access module boxes which contain plastinated anatomical specimens, informational cards which include highlights about the specimens, and a self-test, which they can take to a quiet location in the library and study independently. These students can now see and appreciate things that they otherwise would be asked to understand either from textbook readings or from lecture notes.

"The use of plastinated specimens not only makes student learning more efficient but also can save teachers valuable curricular time. For example, the hand and the foot are usually not thoroughly dissected in Gross Anatomy Lab because the work is difficult and time-consuming. The study of plastinated dissected hands and feet presents an ideal solution to this problem. Specimens of both healthy and diseased organs can also be made available to students so that anatomy can be more readily related to pathology and diagnosis."

The U-M plastination library contains nearly 2,000 specimens that are catalogued and available for study. And recently, the laboratory designed and implemented the use of equipment that now allows for the plastination of entire cadavers. Seven such cadavers have already been plastinated and plans are underway to do many more, both for the U-M and for its customers. Work of this kind has been done in only one other laboratory in the world.

Photo: Bill Wood

Pharmacy student Jim Miller

Photo: Paul Jaronski

Roy Glover in the Plastination Laboratory

For more information:

U-M Medical School Division of Anatomical Sciences: www.med.umich.edu/anatomy

U-M Visible Human Project Team: http://vhp.med.umich.edu

National Library of Science Visible Human Project: www.nlm.nih.gov/research/visible/visible_human.html

U-M Department of Radiology: www.rad.med.umich.edu

What about dissection?

Where do these recent technological innovations leave that classical foundation of anatomical learning and teaching, the dissection of human cadavers?

Opinions are mixed. Ironically, two of the leaders of innovations in U-M's gross anatomy curriculum, Gest and Glover, believe that dissection will remain a crucial experience in learning anatomy. They believe that despite advances in technology, and though cadavers present tougher textures than do living tissues and in colors that aren't true, the first-hand, three-dimensional anatomical learning experience of dissection can't be duplicated as a learning tool even by the most sophisticated technology. The radiologists, on the other hand, predict the demise of dissection in gross anatomy courses, perhaps as soon as within a few years.

"People learn in different ways," Joe Fantone says. "There is something about the tactile experience for some learners, the three-dimensional *in situ* observation, that works very well for them.

"In many ways the cadaver also represents a student's first patient, a valuable dimension to learning that helps students gain respect and responsibility and provides opportunities for them to learn in the integrated biomedical, socio-behavioral and clinical contexts in which all patients live their lives."

In the debate, one thing is clear: Michigan's strength in gross anatomy is currently derived from its maximum combined use of all the learning methods currently available, with all the benefits they offer, as well as the expertise and technical support represented by the Visible Human Project and innovations in imaging technology. Beyond the educational opportunities such projects themselves present is the considerable ability of the people who make those projects happen — and the dedication and imagination that is brought to bear on students' day-to-day learning of the fundamentals of medicine and patient care en route to becoming the next generation of highly trained physicians and medical scientists. m