and aspects of arson investigations as examples. The reason for the wall, he adds, “is that people who practice the techniques don’t want them to be examined.”

Still, the NAS report is broad, says Bohan, and as this year’s president of the American Academy of Forensic Sciences, “I will push hard to have specific forensics techniques reviewed for reliability by an objective body such as the NAS so we can expel incompetent theories early in the legal process. One approach is to require expert witnesses to provide detailed written reports that can be peer reviewed.”

Science out the window

“What I’ve learned,” says Boise State University physicist Richard Reimann, “is that when you talk about injuries to children, science goes out the window, and emotions take over.” He adds that “equations mean nothing to the general public, so now I am at the stage where it’s got to be graphs or demonstrations.”

Typically, Reimann gets called to determine whether a baby was shaken or hit, or whether an injury or death might have been from a fall. He recalls his first case, about a decade ago, when “a lawyer came walking into our offices looking for someone who could help him with head injuries. I reluctantly agreed to take a look.” In that case a man reportedly woke up when he heard some thuds. He found the 11-month-old son of his girlfriend at the bottom of the stairway with a serious head injury. “The prosecutor’s case was that the boyfriend hadn’t been as quick [to call 911] as he said and that the injury couldn’t have occurred by falling down the stairs—it had to have been some violent act like holding him by his ankles and swinging him against the bathtub.”

But by Reimann’s calculations, “even if a child were to topple over and hit his head on the floor, a skull fracture or brain injury was possible.” And what really stuck with him, Reimann adds, “was the idea that the child had a low temperature when they took him to the hospital. I was able to get a couple of data points and to extrapolate back with Newton’s law of cooling. It looked right spot on that the event could have happened five minutes before his call, whereas the prosecutor had it maybe an hour before.” The judge threw Reimann’s testimony out “because I was not a medical doctor,” Reimann says. The man was convicted of murder in the first degree and sentenced to life without parole.

On other occasions, Reimann’s testimony has helped the accused. In one case, “apparently one child was trying to take candy from an older child. He grabbed at it and fell over backwards. It didn’t kill him, but he was injured. Authorities assumed the father did something violent, in spite of the fact that other adults were there.” Reimann wrote to a local public defender explaining how to distinguish between injuries from shaking a baby and injuries from a head impact. Shaking is generally assumed when the retina has hemorrhaged, “but the medical community needs to look beyond that. If it was shaking, other organs would also be damaged,” he says. “Ultimately, it’s a physics or engineering issue,” adds Bohan. “Is it possible to kill a baby just by shaking, without any evidence other than hemorrhages and subdural hematomas? No.” Based partly on his letter, says Reimann, the father was let out of jail.

As for the cliff death in Australia, Cross determined that given the short run-up distance available, the victim could not have propelled herself as far from the cliff as she landed. The cliff is 30 meters high, and she was found almost 12 meters out. Cross did experiments with volunteers from a police academy, in which he measured how fast an average woman could run, jump, and dive. He also measured launch speeds by having men throw women into a swimming pool. “I tested a bunch of females, on flat surfaces, running uphill. . . . I spent a couple of years doing experiments—I did about 20 different experiments with 13 women,” says Cross. “I worked out that she had to have been thrown.”

Toni Feder

Accelerators shrink to meet growing demand for proton therapy

Smaller, cheaper accelerators promise to make proton radiation therapy available to more cancer patients.

STILL RIVER SYSTEMS

Table-sized superconducting cyclotrons are being developed by Still River Systems for single-room proton-radiation treatment.

The recent wave of newly constructed medical centers dedicated to proton radiation therapy comes as no surprise to James Slater, a radiation oncologist at Loma Linda University Medical Center. By 2010, four new US centers will start treating cancer patients. With two others that opened in 2006, that’s more than double the number that had existed in the US in the first 15 years after Slater led the Southern California medical center in building the first hospital-based proton center in 1990. “I expected [this growth] to happen much sooner,” he says.

In what may promise even more growth, some physics research labs and small companies are now developing room-sized proton accelerators to bring the treatment to existing medical centers. Those companies say their technology will supply a single treatment room for less than $30 million, a fraction of the $100 million to $200 million it now takes to build and equip larger proton centers. Treatments such as x-ray radiation and chemotherapy are still more available to cancer patients and less expensive than proton therapy. But x rays harm healthy tissue, and chemotherapy drugs weaken the immune system, among other things. Of late, many patients have been opting for proton therapy because of its minimal side effects when compared with the other treatments.

“Heavy lifting”

Protons penetrate human tissue to depths proportional to the incident energy, which for proton therapy ranges from 100 to 300 MeV. Because they have a relatively high mass, protons deliver

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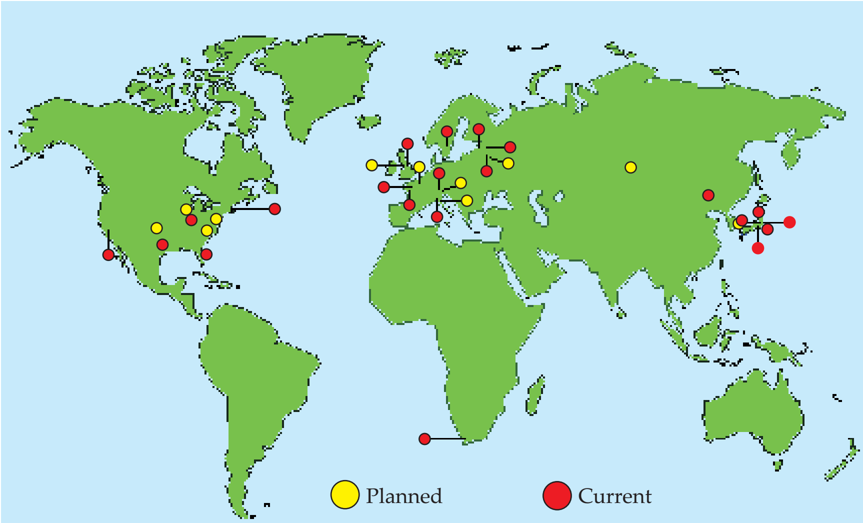

Fewer than 30 proton therapy centers exist worldwide (red), but a growing number are either planned or already under construction (yellow).

most of their radiation dose to the targeted tumor. Beam-delivery methods now emerging commercially can also simultaneously adjust the dose and shape the beam, thus minimizing damage to nearby healthy tissue. To date, 55 000 patients worldwide have been treated with protons, primarily for prostate, head, neck, brain, lung, bone, and eye cancers. (For reviews of radiation oncology methods, see the special focus in PHYSICS TODAY, September 2002, pages 34, 38, 45, and 52.)

As far back as 1954, proton therapy was conducted in particle and nuclear physics research labs such as Lawrence Berkeley National Laboratory and the Harvard Cyclotron Laboratory. Although several physics labs around the world still offer the treatment, it transitioned to medical centers on the back of a combined $19 million from a congressional earmark and the US Department of Energy in 1988. That money was used to help build Loma Linda's center and acquire a 250-MeV synchrotron from Fermilab.

Since then, the US government has scaled back support for proton centers that are not affiliated with federal research facilities. But the number of proton centers in the US is growing because private investors and local governments have been willing to take the financial risk to build them. In contrast, a slower growth is seen in Europe, where proton centers receive fewer private donations and less support from national governments for the expensive treatment.

The second hospital-based US proton center, established in 2001 at Massachusetts General Hospital, uses a commercial cyclotron from Belgium's Ion Beam Applications (IBA) SA. The center's construction was partially funded by the National Cancer Institute. Medical physicist Jay Flanz, the center's technical director, says that private developers needed to see that commercial accelerators could be made reliable and that their manufacturers would take responsibility for their upkeep.

Most existing centers use cyclotrons, which weigh more than synchrotrons and deliver protons at a fixed energy that can be reduced by inserting a beam-degrading object. Synchrotrons can electronically control the beam's energy, but they are more complex and more expensive to build. Although accelerator size and cost pose constraints on building new centers, "doctors really don't care about the type of accelerator," says Brookhaven National Laboratory particle physicist Stephen Peggs. He recently invented a method to rapidly cycle protons in a synchrotron and focus the extracted beam down to a 1-mm "sharp scalpel"—one-tenth the width of existing synchrotron beams.

"Loma Linda and Mass General did the heavy lifting for all the centers that followed," says Cynthia Keppel, technical director of the Hampton University Proton Therapy Institute in Virginia. Equipped with a 230-MeV cyclotron, the $200 million, four-treatment-room institute is one of the new centers opening this year; it is not owned or operated by an existing hospital. Keppel, who is also a staff physicist at nearby Thomas Jefferson National Accelerator Facility, says that a big motivation for Hampton University, a historically black institution, is the success of proton therapy in treating prostate cancer, which disproportionately affects black men. "We feel we are bringing proton therapy into a real community setting—with not one dominant hospital system," says Keppel.

Bare bones

Efforts to bring smaller and less expensive proton accelerators to market are on the rise. A compact synchrotron design by a Russian research lab was recently licensed by Texas-based ProTom International Inc. Scientists at the Lebedev Physics Institute in Moscow set out to design a "bare bones, simple [synchrotron] to be used only for proton therapy," says Flanz, who consults for the company. Unlike traditional synchrotrons, the new model is stripped of such components as sextupole magnets and has a simpler beam injector. At 6 m in diameter, the compact synchrotron can vary the beam energy up to 330 MeV, can deliver protons to multiple treatment rooms, and is small enough to fit into one room. A prototype of the synchrotron arrived at MIT's Bates Linear Accelerator Center last month for validation tests and private demonstrations for potential buyers.

Other commercial developers are pursuing even smaller proton accelerators for medical facilities that are unwilling or unable to invest in a standalone center. One such effort has resulted in a cyclotron small enough to be mounted on the beam-delivery system that rotates around the patient. Emerging from MIT's Plasma Science and Fusion Center is a 1.8-m-diameter, 250-MeV cyclotron, which uses a superconducting high-field magnet to accelerate and bend the proton beam. The cyclotron is being developed by Massachusetts-based Still River Systems. Company founder and chief technology officer Kenneth Gall says that 15 medical centers have already signed contracts to buy the compact cyclotron, the first of which will be ready in a few months. "Due to financial constraints, people will be looking for compact systems which can be deployed one room at a time," adds Gall.

A linac technology to accelerate protons to 100 MeV in 1 m is being developed at Lawrence Livermore National Laboratory. Originally developed for x-ray radiography to image explosives, the so-called dielectric wall accelerator generates a pulsed electric field that lasts a few nanoseconds. That proton-accelerating field propagates along an insulating wall at a controlled rate, says LLNL physicist George Caporaso. Compact Particle Acceleration Corp has licensed the technology and is now funding its development for proton therapy. Because the DWA is a pulsed linac, "it is easy to control not only the beam's intensity but also its spot size and beam width," says CPAC president Thomas Mackie. Commercial DWA systems are still in early development.

Compact accelerators may "transform the proton-therapy landscape in this country" if they work and get US Food and Drug Administration approval, says Leonard Arzt, executive director of the National Association for Proton Therapy. Loma Linda's Slater adds that what matters to him is that proton therapy becomes available to as many patients as need it. "The concept is solid," he says. "It's science, good science."

Jermey N. A. Matthews

Brookhaven light source to brighten x-ray beams

Leading European synchrotron also approves a seven-year upgrade.

The US Department of Energy (DOE) has given the okay to begin construction of a $912 million light source that will breathe new life into Brookhaven National Laboratory (BNL) and establish the Long Island facility as a powerhouse for nanotechnology. The second National Synchrotron Light Source, scheduled for completion in 2015, will produce 3-GeV beams that are 10 000 times brighter than the 27-year-old BNL machine it will replace. Using that bright, tightly focused light, researchers hope to achieve the nanometer-scale spatial resolution they need to reveal the structures of highly complex proteins and other biological molecules, develop new and more efficient catalysts, and invent the next generation of computer chips.

The nod to NSLS-II came two months after the announcement of a seven-year, €178 million ($230 million) upgrade program for the European Synchrotron Radiation Facility in Grenoble, France. That project is aimed at maintaining the ESRF's status among the brightest sources of experimental x rays in the world.

Currently the most expensive of the construction projects under way at the 10 national laboratories that are operated by DOE's Office of Science, NSLS-II had been considered a long-term priority among the major new scientific facilities under consideration by the agency as recently as 2003 (see Physics Today, January 2004, page 23). But it jumped to the head of the line in 2007 following a redesign that received high marks from outside reviewers.

The project still must overcome a shortfall in funding resulting from congressional inaction on appropriations for the current fiscal year. BNL has received just $21.5 million of the $103 million that DOE requested for NSLS-II. If no further funding is provided in FY 2009—a real possibility—construction could be delayed by more than six months, and project costs will increase, warns Steven Dierker, BNL associate director and project manager.

Synchrotron light sources attract about 50 000 researchers a year from a broad array of disciplines and fields, including materials science, structural biology, geology, and paleontology. More than 20 sources worldwide have opened for business since 1994, when the ESRF came on line. This year China is set to finish construction of its Shanghai Synchrotron Radiation Facility, the nation's largest science project, and a new machine is scheduled to open in Germany. Spain will open its first in 2010. In the US, DOE maintains four light sources, with universities offering a number of smaller ones.

Among a select few

The NSLS-II will have the most brilliant beam anywhere, says Dierker. In addition to the ESRF, today's brightness leaders in hard x rays include the Advanced Photon Source (APS) at Argonne National Laboratory and the SPring-8 at Japan's Harima Science Garden City. Among the synchrotrons that, like NSLS-II, produce photons in the soft x-ray to UV range, the Advanced Light Source at Lawrence Berkeley National Laboratory, the Stanford Synchrotron Radiation Lightsource at SLAC, France's SOLEIL, and the UK's Diamond are the brightness leaders, Dierker adds.

The brighter the light source, the more tightly its users can focus the photons that are directed to the dozens of experimental stations at beamlines that tap synchrotron radiation from the storage ring. NSLS-II's exceptional brightness and coherence will permit beams to be focused to 1 nm, enabling spectroscopy to be performed on a single atom, says Dierker. Such beams also will give crystallographers a tool for determining the structures of many