Introduction

Education accounts for less than ten percent of the current level of laboratory animal use in the United States, but this figure belies the importance of applying the alternatives approach to education. Scientists of tomorrow will be more likely to adopt the approach if they are exposed to it as students. Recently educated, young scientists are likely to play an important role in the development and implementation of alternatives.

Even students who have no desire to become scientists may nonetheless benefit from exposure to the alternatives approach. These students will come away with a better appreciation of animals and a more positive view of scientists' activities.

According to biology teacher G. Russell, the power of science without the control of compassion and admiration for life is too immense to be applied merely for the satisfaction of scientific curiosity. If biology were taught in a manner that developed a sense of wonder and of reverence for life, and if students felt inwardly enriched from their study of life, these students would formulate as a life-long goal the steadfast determination to protect and preserve all life and would bring healing to a world desperately in need of it.

These philosophical changes might even motivate some students to consider careers in science.

Recognizing the importance of reaching young students, the American Fund for Alternatives to Animals in Research supports annual training sessions in \textit{in vitro} toxicology for students planning a biomedical career.

This summary of alternatives in education applies primarily to the college and graduate levels, where the challenge for the alternatives approach is the greatest. Discussions of alternatives that focus on the pre-college level can be found in several compilations of humane biology projects. The challenge for alternatives at the post-secondary level is not in devising projects that convey the general principles of biology, but in devising ones that convey specific information or confer specific skills. Examples include learning surgery without practicing on animals, learning comparative anatomy without killing large numbers of animals, or learning the effects of common drugs without giving those drugs to animals.
Alternatives

There is a wide variety of alternatives to educational uses of animals.

(1) Surgical Apprenticeships

In the United States, medical students practice surgical techniques on animals. This custom accounts for half of all animals used in medical education. An alternative is the British system: medical students in Britain gain their initial experience in surgery by observing demonstrations on cadavers. Then comes a clinical apprenticeship: students observe experienced surgeons operating on sick humans, gradually begin to take part along with the surgeons, and finally carry out operations under their supervision.

The use of animals solely to gain surgical dexterity is prohibited in Britain by the Cruelty to Animals Act of 1876. According to the Royal College of Surgeons of England, the prohibition "has not proved an obstacle to the effective training of young surgeons in the United Kingdom." This view is supported by a recent study of British and American surgeons, which indicated that practice surgery on animals made no difference to long-term competency.

A similar prohibition applies to the use of animals in training veterinary students in Britain. These students train with experienced veterinary surgeons and use animals that need the operations for therapy. According to the British Veterinary Association, "The idea of making healthy animals sick for purposes of training is totally repugnant to the [veterinary] profession in this country."

Unfortunately, this is not the case in U.S. veterinary schools, where healthy animals—primarily dogs and sheep—are subjected to practice surgery. Such procedures account for a significant percentage of the animals used in veterinary education.

(2) Placentas for Microsurgery

Apprenticeships work well for practicing most types of surgery but are ill-suited for the new field of microsurgery. Used primarily to reconnect severed fingers or hands or to reconstruct badly damaged tissue, microsurgery involves, among other things, reconnecting tiny blood vessels. It is not the sort of operation a trainee can readily learn at the shoulder of an accomplished microsurgeon.

For this reason, Britain is considering lifting its ban of practice surgery on animals for microsurgery. However, a promising alternative using human placenta, funded by the Lord Dowding Fund for Humane Research, is being developed by Dr. Paul Townsend, a plastic surgeon at the Frechay Hospital in England. The surface of the placenta has blood vessels of various sizes that can provide opportunities to practice microsurgery. A pump simulates blood flow through the vessels. Unfortunately, the pumped blood cannot clot, and clotting is a primary consideration in clinical microsurgery. Dr. Townsend thinks that this limitation can be overcome and that placental tissue can be a replacement for animals in microsurgery training.

The British newspaper The Guardian has suggested that the British government should encourage development of the placenta alternative rather than relax controls on animal use in practice surgery.

(3) Computer-Assisted Mannequins

Carefully designed mannequins can simulate the appearance and selected responses of humans or animals and, therefore, can play an important role in education. Widely cited examples include Sim, the mannequin discussed earlier, and "Resuscit-Dog," a canine mannequin that teaches cardiopulmonary resuscitation to students at the New York State College of Veterinary Medicine. Resuscit-Dog, whose development was supported by the Geraldine R. Dodge Foundation, is one component of a computerized cardiopulmonary emergency simulator that confronts students with various "emergencies." It also evaluates the students' diagnoses and treatments and causes "patients" to respond realistically. The latest version costs $1,200 and has replaced 100 dogs per year in veterinary classes at the New York school.

(4) Computer Simulations

Some learning exercises can be conducted entirely on computers, without live animals or even mannequins. Computer programs can simulate dissections, metabolic functions, drug responses, and so on. The realism of these simulations can be increased by use of sophisticated interactive videodiscs, which display television-quality images on computer monitors.

Dr. J. Walker of the University of Texas uses computers to simulate physiological responses for medical students. Two inexpensive computers substitute for experiments that demonstrate a dog's cardiovascular regulation, digestive system, and drug responses. A recent article entitled The Electronic Guinea Pig describes two specific examples:

During the cardiovascular experiment... one computer screen displays a chart that tracks blood pressure, heart rate, cardiac output, and similar information, updated every three seconds; the other screen provides a continuous reading of the most vital data. If a student wished to see the effects of the drug epinephrine—a standard medical school experiment—he presses a key marked E. Immediately the screen registers a jump in blood pressure and heart rate.

Another standard experiment involves slitting open a dog's throat and pinching off the arteries. A student can simulate this on Walker's machine by pressing the O key: immediately the blood pressure drops, and some lucky dog lives.

A wide variety of such computer simulations is now available.

(5) Other Procedures or Systems

Other alternatives to traditional educational uses of animals include replacing dogs with videotapes to demonstrate the effects of poisons to veterinary students,
having two or more anatomy students dissect the same specimen or use prosections as demonstrations, and suggesting that adequately trained supervisors oversee students working on live animals. Finally, the potential for the use of neonots in medical education should not be overlooked.

Discussion

Educators can have a profound effect on the replacement, reduction, and refinement of educational uses of animals. In order to develop and implement alternatives, educators need the proper motivation, the support of their colleagues, and financial and academic incentives. Scientists recognize the importance of academic incentives in developing educational alternatives, as this observation on development of computer--based simulators indicates:

In the long run, the most serious problem to developing these simulators may well be the lack of professional academic rewards for faculty members working in this area. Promotion, tenure, and salary increments are awarded predominantly for productivity in the research laboratory, not for efforts to develop innovative teaching techniques and materials. With essentially no external grant support for computer--based education activities and with few refereed high--quality journals in which to publish, two of the measures by which rewards are apportioned are not available to developers of novel educational software. This is a particular problem for junior faculty members, who often must devote their major efforts to climbing the academic ladder. Computer--based education seemingly fails to meet the perception of an academically valid and credible enterprise."

Although lack of funding may impede the development of alternatives in some cases, it may actually dictate the adoption of non--animal methods in others. For example, the expense of procuring and housing dogs in medical schools may force these schools to implement computer programs instead.

Money, therefore, is not all that's needed to foster widespread application of the alternatives approach in education. Concerned instructors, educational administrators, funding agencies, students, and parents must be involved as well.

But no amount of effort will succeed unless the existing alternatives have merits in their own right. Does each alternative get the job done as well as or better than its animal--related counterpart? If not, is each alternative still adequate? Educators should clearly spell out the goals of their animal projects and determine whether or not alternatives meet those goals.

General Discussion

PROGRESS IN IMPLEMENTING the alternatives approach has been encouraging, especially in light of the modest investment of money and effort. In toxicity testing, the first generation of alternative screening tests is being developed, validated, and implemented. In biomedical research, investigators are applying alternative techniques to answer questions in diverse fields. In education, technological innovation is yielding new alternatives, such as robot--like mannequins and computer simulators.

Much of this progress has occurred within the last ten years, as the animal--rights movement has infused the search for alternatives with an ethical imperative. Prior to this, alternatives were pursued primarily for economic, public health, and scientific reasons but rarely as a reflection of a sense of moral duty or compassion. Even today, when specific alternatives are introduced to the scientific community in research reports, concern for animals is not necessarily cited as a reason for their development or possible implementation. Nevertheless, the introduction of new alternatives, for whatever reason, is still good news.

The most exciting alternatives in the areas of research and testing are based on the development of techniques such as tissue culture and computer modeling. Such breakthroughs in technique have been extremely important in the history of science, as Rowan has emphasized. Technical innovations are used to answer old questions and address new ones. A historical example is the application of tissue culture to the prevention of polio. The development of a polio vaccine required that large amounts of polio virus be readily available. This was impractical using mice and monkeys, which were used extensively in polio research. Enders and coworkers discovered that the virus could be cultivated in vitro. This paved the way for Salk, Sabin, and others to develop effective vaccines. A testament to the importance of the tissue--culture work in combating polio is that Enders and coworkers, not Salk or Sabin, were awarded the Nobel Prize for their polio research.

Some new techniques are not alternatives in themselves but can, nonetheless, decrease reliance on laboratory animals by creating new possibilities for studying humans without recourse to questionable animal models. An example is positron emission tomography, discussed earlier in relation to human studies of Parkinson's disease.

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