Chapter 9

Animal Use in Education and the Alternatives

Any experienced teacher of physiology knows that the 'Tiling" of a beating heart in the opened chest of a dog does more to reinforce the lessons about cardiac physiology than any words he can speak. This is not an argument for unlimited use of animals, but it is a recognition that biology is ultimately about living organisms and that learning about living organisms require some experience with them.

Joel A. Michael
Rush-Presbyterian-St. Luke's Medical Center
March 4, 1985

Generations of surgeons and veterinary surgeons have been trained without practicing on live animals and the Government intends future generations to do so as well.

Microsurgery will be the only ***surgical skill which we at present contemplate permitting to be practised on living animals.***

Scientific Procedures on Living Animals, Command 9521
British Home Office
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Animal Use in Education and the Alternatives

Measured by the number of animals involved, the use of animals is far less significant in education than in research and testing. Yet few students emerge from the educational system without some contact with animals in the classroom—an interaction that may range from the observing and handling of small mammals in grade school to surgical training in medical school. In terms of fostering attitudes, education exerts a vital influence over the use of animals and the development and implementation of alternatives.

This chapter examines the patterns of animal use and the prospects for alternatives in primary, secondary, and college education and in the 127 accredited medical schools and the 27 accredited veterinary schools in the United States. Replacements, reductions, and refinements of animal use can today be found at all levels of education. Moreover, principles of humane treatment of animals are increasingly an integral part of curricula throughout the life sciences.

PATTERNS OF ANIMAL USE IN EDUCATION

Out of every 1,000 students entering the fifth grade, 285 will enter college and about 40 will obtain science degrees (2 I). Some of those 40 continue their education to become doctoral scientists and health professionals. As students journey from elementary school through high school and then perhaps onto college, universities, and other postgraduate programs, their educational exposure to animals takes many forms. The elements of the scientific method and scientific principles pervade every curriculum. In at least 21 States, some type of instruction in the value of animals and humane considerations is required. Acquaintance with animals instills a respect for and appreciation of life and conveys as well the fundamental principles of biology.

Three distinct educational goals dictate ways in which animals are used in the classroom:

- Development of positive attitudes toward animals. In the best instances, such development incorporates ethical and moral considerations into students' course of study.
- Introduction of the concept of "biological models," by which students learn to single out particular animal species as representative of biological phenomena. Such models vary in the degree to which they provide general information about a broader spectrum of life.
- Exercise of skills vital to intellectual, motor, or career development. Familiarity with living tissue, for example, enhances a student's surgical dexterity.

Alternatives to using animals in education therefore must satisfy these goals. In addition, the educational use of animals and alternatives can foster positive attitudes toward alternatives in research, testing, and education, which may in turn perpetuate the search for such options as these students themselves become scientists. The sum total of the educational use of animals and alternatives can be to reinforce as the guiding principle of the scientific method the judicious selection of the most appropriate system to generate the desired knowledge.

Primary and Secondary Education

Animals in the Classroom

Most students become initially acquainted with animals and their role in the biological sciences during primary and secondary education. In primary schools, animals are generally not subject to experimentation or invasive procedures of any sort. They are usually present in the classroom to teach students about care and to observe the social interactions of people and other animals.

Such interactions provide the vehicle for developing humane attitudes toward animals. In junior high and high school, students begin a more aggressive pursuit of science, which is reflected in the patterns of animal use. Dissections and investigational laboratory exercises are introduced into the curriculum. For most students, high school provides their last formal science education, in the form of biology class.

A recent study identified three stages in the development of students' attitudes about animals (6). The period from 2nd to 5th grade (ages 6 to 10) was characterized by an increase in emotional concern about and affection for animals. The years between 5th and 8th grades (10 to 13 years of age) were marked by increased factual understanding and knowledge of animals. From 8th to 1lth grade (ages 13 to 16), students exhibited broadening ethical concern about and ecological appreciation of animals.

Each phase of primary and secondary education appears to offer varying opportunities for education about animals. The 8th through 11th grades seem to be the most appropriate times for exercising meaningful influence on the development of attitudes toward animals (6).

Several national organizations and local school systems have issued specific policy statements on the use of animals; these suggest the practices both permitted and prohibited in the classroom at the secondary level (see table 9-1). All the policy documents generated by national groups share one distinct limitation: They have neither the power nor the mechanisms to enforce their provisions. They are merely guides and statements, not rules.

Science Fairs

Active involvement in the day-to-day aspects of science and the scientific method is not a usual component of primary and secondary science education, science fairs provide an opportunity for some students to enhance their understanding of science by pursuing independent investigations and competing with their peers in various local,

Table 9-1 .—Sample Policies Governing Animal Use in Primary and Secondary Schools

Group	Year last revised	Description of policy
Connecticut State Board of Education	1988	Policy urges that no vertebrate animal should be subjected to any procedure that interferes with its normal health or causes it pain or distress. No experiment should be carried out without the personal direction of an individual trained and experienced in approved techniques for such animals.
Alexandria (VA) City Public Schools	1989	No vertebrate animal used for secondary school teaching maybe subjected to any experiment or procedure that interferes with its normal health or causes it pain or distress. Dissections are not banned; however, they are to be done only with commercially prepared specimens.
Canadian Council on Animal Care	1975	Guiding principles apply to animal use in the classroom, not to science fairs. No experimental procedures are permitted on vertebrates that subject them to pain or discomfort or that interfere with the organism's health.
National Association of Biology Teachers	1980	Guidelines for the use of live vertebrates at the pre-university level apply to classrooms as well as school-related activities. No experimental procedures should be attempted that would subject the animals to pain or distinct discomfort. No experimental studies should be done outside the school. No live vertebrates are permitted in science fair exhibits. Exemptions to these guidelines maybe granted under limited conditions that include direct supervision by a qualified research scientist in the field, an appropriate facility designed for such projects, and the utmost regard for the humane care and treatment of the animals involved in the project.
National Science Teachers Association	1981	Code of practice applies to the use of vertebrates in schools or school-related activities. Experimental procedures conducted should include only those that do not involve pain or discomfort to the animal. Extracurricular protocols should be reviewed in advance of the start of the work by a qualified adult supervisor, and should preferably be conducted in a suitable area in the school. This code has been endorsed by the National Academy of Sciences and the American Veterinary Medical Association.

SOURCES: Connecticut State Board of Education, State *Board Policy on Animals in the School,* Feb. 7, 1968. Alexandria City Public Schools, Policy File 3107, Jan. 6, 1969. Canadian Council on Animal Care (Ottawa), *Guiding Principles Governing the Use of Animals* in the Classroom at *the Pre-University Levels,* May 1975. "National Association of Biology Teachers Guidelines for the Use of Live Animals at the Pre-University Level," *American Biology* Teacher 41:426, 1980. National Science Teachers Association, Code *of Practice on Animals in Schools*, Washington, DC, 1981.

State, and national competitions. The fairs stimulate an interest in science, and they reward active involvement. Many scientists have taken the first steps in their career paths by this route. The competitive nature of the fairs encourages budding scientists to stretch their skills to often sophisticated levels of investigation.

The National Science Teachers Association's ***Code of Practice on Animals in Schools*** *(see* table 9-1) applies to science fairs as well as animal use in the classroom and prohibits experimental procedures that would involve pain or discomfort to the animal (10). This code governs both projects conducted by students at schools that adhere to the policy, and science fairs that have adopted the standards. Several of the most prominent fairs have adopted other rules in addition.

The International Science and Engineering Fair (ISEF) is held annually with several hundred entrants in grades 9 through 12, drawn from many thousands of participants in local fairs. ISEF rules require that a Scientific Review Committee consider all research involving vertebrate animals prior to competition. Criteria include a completed research plan, evidence of a literature search, documentation of the type and amount of supervision, use of accepted techniques, demonstrated skill in such techniques, and compliance with any required certifications.

ISEF explicitly disallows procedures that would develop new surgical techniques or would refine existing ones, as well as research where the animal is not humanely killed (4). Surgical procedures may not be done at home. Sacrifices of animals and experiments involving anesthetics, drugs, thermal procedures, physical stress, pathogens, ionizing radiation, carcinogens, or surgical procedures must be done under the direct supervision of an experienced and qualified scientist or designated adult supervisor. Nutritional deficiency studies and studies of toxic effects may only proceed to the point where the symptoms appear. Steps must then be taken to correct the deficiency, or the animals are to be humanely killed. LD_{50} experiments (see chs. 7 and 8) are not permitted.

The Westinghouse Science Talent Search, an annual competition involving more than 15,000 participants, has since 1970 forbidden experimentation with live vertebrates with the exception of projects involving behavioral observations of animals in their natural habitat or of human subjects (17). In 1985, none of the 39 Westinghouse finalists carried out experiments on nonhuman vertebrate animals. One entrant studied gene expression in cultured mammalian cells. Living organisms used in the winning projects included leeches, butterflies, fruit flies, water fleas, and bacteria.

Finalist, 1985 Westinghouse Science Talent Search

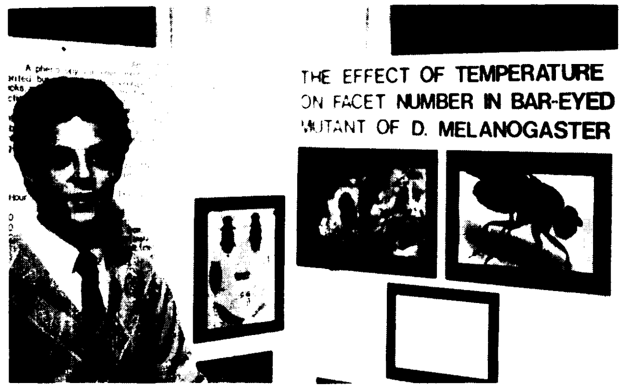


Photo *credit: Gary B. Ellis*

Louis C. Paul, age 18, Baldwin Senior High School, Baldwin, NY, with his research project, "Effect of Temperature on Facet Number in the Bar-Eyed Mutant of *Drosophila melanogaster.* "

In Canada, all animal experimentation for science fairs is subject to ***Regulations for Animal Experimentation in Science Fairs,*** the 1975 policy statement of the Youth Science Foundation of Ottawa, Ontario. Key provisions include:

- Vertebrate animals are not to be used except for observation of normal living patterns of: 1) wild animals in the free-living state or in zoos, aquaria, or gardens; or 2) pets, fish, or domestic animals.
- No living vertebrate animal shall be displayed in exhibits in science fairs.

Other rules include:

- Chick embryos may be used for observational studies only.
- If eggs are to be hatched, then humane considerations must be met in the disposal of the chicks.

- If humane requirements cannot be met, embryos must be destroyed by the 19th day of incubation.
- No eggs capable of hatching maybe exhibited at science fairs.
- All experiments shall be carried out under the supervision of a competent science teacher.

Enforcement mechanisms for these restrictions specify that students sign a declaration of compliance, and that this compliance be certified by the science teacher supervising the project.

Animal Use at the Postsecondary Level

Animals are used in undergraduate education for both the acquisition of knowledge and the acquisition of particular skills. Procedures involving animals can, of course, serve both purposes. Graduate science education (and, in some instances, advanced undergraduate education) involves an additional component—the student's first genuine research experience. The distinction between teaching and research virtually disappears in graduate school because the student simultaneously learns the methods and actually conducts research. The guidelines that dictate practices of animal use in graduate education are those that govern animal use in research (see ch. 15). Effects of earlier exposure to humane concerns may manifest themselves in graduate education through the student's choice of avenues of research and selection of model systems for investigation.

Because attitudes about animals will almost certainly affect the ways in which students may use (or not use) animals in education and, later, professionally, it is noteworthy that U.S. colleges and universities offer about two dozen full-length courses on ethics and animals, according to a 1983 survey (see table 9-2). These courses cover the bioethical issues surrounding humans' responsibilities regarding laboratory, agricultural, and wildlife animals. The Scientists Center for Animal Welfare maintains information on college courses on ethics and animals and advocates the inclusion of such courses as a standard component of the education of all students entering careers in the biological sciences (18). At virtually all veterinary schools, lecture material on ethical considerations of working with animals is included in required courses as part of the veterinary curriculum.

Determining the number of animals used strictly for undergraduate and graduate education is difficult because laboratory education is often mixed with laboratory research. This is especially true for graduate education. The last survey of animal use that included questions regarding animals used for teaching purposes was done for fiscal year 1978 by the National Academy of Sciences / National Research Council's Institute of Laboratory Animal Resources (ILAR) under contract to the National Institutes of Health (23). Respondents that used animals for educational purposes included 69 medical schools, 10 veterinary schools, 42 additional health professional schools (e.g., dental, public health), 65 hospitals, and 149 colleges and univer-

Table 9-2.—Courses on Ethics and Animals Offered at U.S. Colleges and Universities, 1983.84

Institution	Course name (department and course number)
Appalachian State University	People, Plants, and Animals (Philosophy 3560)
California State University	Animal Rights (Philosophy 1941; General Studies 4279)
Central Michigan State University	Religion and Social Issues (Religion 335)
Colorado State University	Attributes of Living Systems (Biology 102; Honors)
	Moral and Conceptual Issues in Veterinary Medicine (Veterinary Medicine 712)
Eastern Michigan State University	Introduction to Philosophy (Philosophy 100)
Elmira College	Mankind? We and Other Animals (Humanities 0530)
Indiana University-Purdue University	Ethics and Animals (Philosophy 493)
Michigan State University	Ethics and Animals (Philosophy 494)
	Perspective in Veterinary Medicine (Veterinary Medicine 517)
Moorhead State University	Animal Rights (Philosophy 215)
North Carolina State University	Philosophical Issues in Environmental Ethics (Philosophy 332)
Purdue University	Ethics and Animals (Philosophy 280)
Stanford University	Animal Rights: Issues and Politics (Stanford Workshop on Political and Social Issues Program 161)
State University of New York at Stony Brook	Human/Pet Bonds (Psychology 391)
University of Connecticut	Problems in Environmental Law: Issues in Animal Rights and Protection (Law 852)
University of Maryland	Philosophy and Environmental Ethics (Philosophy 0255)
University of Minnesota	Perspectives: Animal-Human Relationships and Community Health (Public Health 5-303)
Virginia polytechnic Institute	Special Study, Ethics, and the Treatment of Animals (Philosophy 2980)
Wagner College	Bioethics (Biology 230)
Washington State University	Reverence for Life (Veterinary Anatomy, Physiology, and Pharmacology 499)

SOURCE Scientists Center for Animal Welfare (Bethesda, MD), "College Course on Ethics and Animals," *Newsletter* 5(2):3-6, 1963.

sities. Some of the health professional schools were included in other categories (e.g., universities with affiliated professional schools) and thus accounted for a smaller number of such schools identified separately than expected.

For this assessment, animal use in medical education and veterinary education was examined in detail for the school year 1983-84. Comparisons with the 1978 ILAR survey are inappropriate because of different survey methodology.

Medical Education

Animals are used in many capacities in medical education. In the basic sciences, they are often used to illustrate the structure and function of the systems under study and the complex physiologic interactions within a single organism. They function as intermediaries during a medical student's transition from trainee to practicing physician, letting students cultivate their skills on other living creatures before they actually apply those same techniques to human patients. Techniques such as venipuncture, insertion of catheters, and other procedure-oriented exercises are those cited by medical educators as needing practice before patients are worked with. The need to practice invasive surgical procedures prior to human surgery is probably the most compelling use of animals by medical students.

It is generally held that doctors must learn the techniques of their profession. And most commentators acknowledge the need for students in the health professions to subject animals to some practice surgery, albeit closely regulated (17). The issue of animal use in medical education thus seems more a question of degree and manner of use rather than one of whether or not animals should be used at all.

Yet, practicing techniques on animals is not universally condoned. In the United Kingdom, live animals cannot be used by students practicing ordinary surgery solely to improve manual dexterity and technique. (This does not necessarily mean that medical and veterinary students do not improve their techniques by using live animals, but such activities must have some other purpose.) Physicians are trained by a process similar to apprenticeship, learning by observation, demonstration, and example. They assist an accomplished surgeon and expand their active role only as their abilities increase.

In 1985, the British Government relaxed its stricture in order to allow animal use in microsurgical training (22):

> Generations of surgeons and veterinary surgeons have been trained without practicing on live animals and the Government intends future generations to do so as well. But the new development of microsurgery—which is surgery performed with miniature instruments under a microscope, for example, to repair blood vessels or nerves—presents special problems. The delicate techniques involved cannot be practised satisfactorily on dead subjects. Surgeons at present have to go abroad or practise on decerebrate animals which for this purpose is technically complicated and sometimes more wasteful of animals than using terminally anaesthetised ones. Microsurgery will be the only surgical skill which we at present contemplate permitting to be practised on living animals. The consent of the Secretary of State will be required in every case, and he will only give it to qualified surgeons working on approved microsurgical courses on rodents which are anaesthetised throughout the procedure and killed before the animal can recover consciousness,

In general, adequate training through staged exercises is regarded as a prerequisite for successful microsurgery (11).

To ascertain patterns of animal use in medical education during the school year 1983-84, the Association of American Medical Colleges (AAMC) surveyed 16 of the 127 accredited medical schools in the United States. The 16 schools surveyed were selected in an effort to achieve balance in three characteristics: ownership (10 public and 6 private); geographical region (4 each in the Northeast, Midwest, South, and West); and research expenditures (5 high, 5 medium, and 6 low) (2).

The AAMC distributed questionnaires to each department in the sample schools and followed up with telephone calls. Because differing curricula made analysis by department problematic, queries were oriented to each of the disciplines known to be present in undergraduate and graduate medical education. Anatomy, for example, is taught by the surgery department in some schools, but animal use in these exercises was still recorded in the discipline of anatomy (2).

Anatomy, biochemistry, microbiology, pathology, pharmacology, and physiology are part of the curriculum leading to the M.D. degree everywhere, and data for these disciplines were obtained from all 16 schools. The data for all other disciplines except family medicine and advanced trauma life support were obtained from at least 15 of the 16 schools surveyed. Family medicine is offered at only 10 of the 16 institutions (all responded). Advanced trauma life support, a course for house staff rather than medical students, is offered at only 7 of the 16 institutions (all responded) (2).

The use of animals was common in only a few disciplines (see table 9-3), although all 16 institutions used animaIs in some discipline. Animal use in medical education was most common in physiology (10 of 16 schools), surgery (10 of 16), and pharmacology (8 of 16). In other disciplines, no more than 7 of the 16 medical schools used animals for educational purposes. Advanced trauma life support involved animal use at all 7 schools where it was offered (2).

Table 9=3.—instructional Use of Animals in 16 Selected U.S. Medical Schools, by Discipline, 1983-84

Discipline	Number of schools with discipline	Use animals	Do not use animals	No response
Advanced trauma life support	7	7	0	0
Anatomy	16	2	14	0
Anesthesiology	16	2	14	0
Biochemistry	16	3	13	0
Dermatology	16	0	15	1
Family medicine	10	0	10	0
Internal medicine	16	1	14	1
Microbiology	16	4	12	0
Neurology	16	0	16	0
Neurosurgery	16	5	11	0
Obstetrics and gynecology	16	1	14	1
Ophthalmology	16	3	13	0
Otolaryngology	16	2	14	0
Pathology	16	0	16	0
Pediatrics	16	3	12	1
Pharmacology	16	8	8	0
Physiology	16	10	6	0
Psychiatry	16	1	15	0
Radiology	16	0	16	0
Surgery	16	10	6	0
Surgery, orthopedic	16	4	12	0
Urology	16	1	15	0

SOURCE: Association of American Medical Colleges, *Use of Animals in Undergraduate and Graduate Medical Education* (Washington, OC: 1985).

Table 9-4 shows the numbers of animals used by the 16 medical schools. The principal species used by those surveyed were rats, dogs, and mice. Most animals (84 percent) were sacrificed either before or at the end of the demonstration or laboratory, but over half the cats and all the sheep were allowed to recover. Anesthesiology, psychiatry, and biochemistry were the disciplines most likely to subject animals to multiple recovery procedures. According to this survey, only slightly more than 10 percent of the animals used in surgery are allowed to recover at all (2).

The majority of animals used in the 16 schools surveyed were used in the teaching of surgery (51 percent) and physiology (16 percent). No other single discipline accounts for even 10 percent of all animals used. Most of the dogs (64 percent) were used in the teaching of surgery and physiology. The total of 7,274 animals can be placed in context by noting the number of students taking part in the laboratory exercises and demonstrations—approximately 7,900 medical students and 6,700 residents, for a total of approximately 14,600 students at both levels. Calculating roughly from this, approximately one animal is sacrificed each year to support the training of two students (2).

The purposes for which animals are used vary, even within a discipline. Several general surgery and surgical specialty departments offer their residents a course in microsurgery. Residents learn microvascular suture techniques that they will later apply in human surgery designed to restore circulation. Nearly all small-animal use (i.e., rats, hamsters, and rabbits) is for such microsurgery training. Some general surgery departments offer their residents training in major surgery (e.g., splenectomy) using dogs, cats, or pigs, with the goal of recovery of animals. ophthalmology departments use rabbits to teach new residents the fundamentals of microsurgery of the eye (2).

Table 9-4.—Animals Used in Laboratory Exercises and Demonstrations in Medical Education in 16 Selected U.S. Medical Schools, 1983-84

	Kind of animal										
Discipline	Primate	Dog	Cat	Pig	Rabbit	Rat	Mouse	Guinea pig	Hamster	Other	Total
Advanced trauma life support	—	39	13	10	—	—	—	—	—	—	62
Anatomy	—	—	—	—	—	75	—	—	—	—	75
Anesthesiology	—	6	1	—	—	—	—	—	—	—	7
Biochemistry	—	7	—	—	—	—	40	—	—	—	47
Dermatology	—	—	—	—	—	—	—	—	—	—	0
Family medicine	—	—	—	—	—	—	—	—	—	—	0
Internal medicine	—	115	—	—	—	—	—	—	—	—	115
Microbiology	—	—	—	—	2	—	12	9	3	—	26
Neurology	—	—	—	—	—	—	—	—	—	—	0
Neurosurgery	—	12	—	—	6	100	—	—	—	—	118
Obstetrics and gynecology	—	52	—	—	—	—	—	—	—	—	52
Ophthalmology	4	—	20	—	122	—	—	—	—	—	146
Otolaryngology	—	5	1	—	—	5	9	—	—	—	20
Pathology	—	—	—	—	—	—	—	—	—	—	0
Pediatrics	—	—	14	—	4	—	—	—	—	—	18
Pharmacology	—	44	50	—	—	264	300	—		—	658
Physiology	—	490	—	—	2	294	—	—	G	327	1,193
Psychiatry	—	—	—	—	—	—	—	—	—	4	4
Radiology	—	—	—	—	—	—	—	—	—	—	0
Surgery	10	612	151	54	113	1,689	930	27	130	—	3,716
Surgery, orthopedic	—	—	—	—	113	279	20	—	—	1	413
Urology	—	20	—	—	—	—	—	—	20	—	40
Miscellaneous/basic sciences	—	365	16	—	16	72		—	—	72	541
Other	—	4	13	—	—	—	‘ 6	—	—	—	23
Total	14	1,771	279	64	378	2.778	1,317	36	233	404	7,274

alncludes frogs, sheep, and Pi9e0ns.

SOURCE: Association of American Medical Colleges, Use of *Animals in Undergraduate and Graduate Medical Education* (Washington, DC: 1985).

Dogs and pigs are used to teach techniques for incubation (establishing an emergency airway) and the installation of intravenous/intra-arterial catheters, In the AAMC survey, one anesthesia department used dogs to teach insertion of Swan-Ganz catheters into the right chamber of the heart, a common procedure in cardiac intensive care units. Two otolaryngology departments used dogs to teach the musculature and innervation of the trachea and oropharynx to ear, nose, and throat residents. One obstetrics and gynecology department used dogs as models to teach exposure and isolation of the Fallopian tubes from the nearby ureters, and three pediatrics departments use young cats as models for instruction in incubation of premature newborn babies. All of the techniques taught in these graduate medical programs must be learned to achieve competence in the desired specialty. In those programs that do not use animals, the techniques are mastered through experience with human patients during surgery (2).

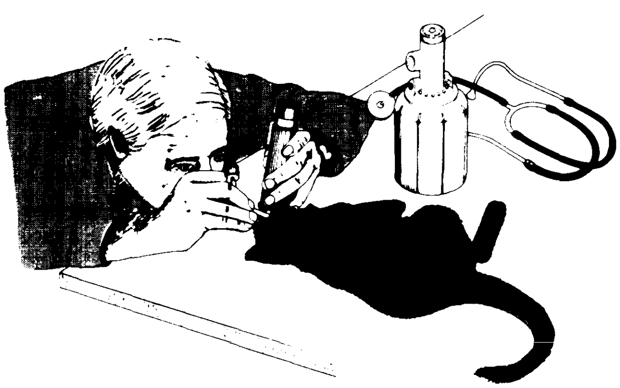
The AAMC survey found no relation between a medical school's level of research expenditures (high, medium, or low) and its use of animals in education. The medium expenditure schools used the most animals in education, perhaps because in the more research-intensive schools there is a greater opportunity for students to observe animal surgery in the course of participation in faculty research and less need to include such experience in the curriculum. Most of the schools surveyed expressed regret that they were not able to use animals to a greater extent in student instruction, often citing cost as a factor limiting instruction with live animals (2).

National estimates of the numbers of animals used in medical education (see table 9-5) were calculated based on the assumptions that the 16 schools surveyed are typical of the 127 accredited schools in the United States. The mean number of animals of each species used in the sample schools was accepted as the best estimate of the mean for all schools, and an extrapolation was made to 127 schools (2).

Rats and dogs are the principal species used in medical education, accounting for about 70 percent of the estimated 36,700 animals used annually. These figures are very rough—the potential error inherent in the estimates ranges from 22 and 25 percent for rats and dogs to 100 percent for pigs and hamsters. The great uncertainty stems from variability among the 16 institutions in the sample. One school used 10 primates, for example, while another used 4, and 14 schools used none at all. Use of dogs and cats was more general; less uncertainty is associated with the national estimates of those species' use (2).

It is unlikely that any of the 127 medical schools in the United States train physicians without using any live animals. This is neither surprising nor alarming, particularly in light of the fact that the ultimate recipients of medical attention-humans—are not available for many of the types of educa-

Instruction in Incubation of Premature Newborn Babies, Using a Young Cat as a Model



Redrawn by: Office of Technology Assessment.

Table 9-5.—Estimated Animal Use in Medical Education in the United States, 1983.84

Kind of animal	Number used[a]
Rat	14,000
Dog	12,000
Mouse	3,000
Rabbit	1,700
Cat	800
Hamster	800
Pig	200
Primate	130
Guinea pig	70
Other[b]	4,000
Total	36,700

[a]Estimate is based on an extrapolation of a survey of 16 selected medical schools evenly distributed by geographic region (Northeast, Midwest, South, or West), ownership (public or private), and research expenditures (low, medium, or high).
[b]Includes frogs, sheep, and pigeons.

SOURCE: Association of American Medical Colleges, *Use of Animals in Undergraduate and Graduate Medical Education* (Washington, DC: 1965).

tional exercises that medical students routinely must perform. It should be noted, however, that it is possible for a student to complete medical school without using animals.

Veterinary Education

> Being admitted to the profession of veterinary medicine, I solemnly swear to use my scientific knowledge and skills for the benefit of society through the protection of animal health, the relief of animal suffering, the conservation of livestock resources, the promotion of public health, and the advancement of medical knowledge.
>
> I will practice my profession conscientiously, with dignity, and in keeping with the principles of veterinary medical ethics.
>
> I accept as a lifelong obligation the continual improvements of my professional knowledge and competence,
>
> ***The Veterinarian's Oath***
> American Veterinary Medical Association

Twenty-seven accredited veterinary schools in the United States educate and train veterinary scientists and veterinarians in the basic biomedical sciences and comparative animal health. An OTA survey of the 27 schools indicated that every veterinary school uses animals in its curriculum. As in medical education, the question of the use of animals in veterinary education is a matter of degree and practice.

Veterinary students—unlike medical students—train on models identical to their prospective patients. Animals are used in laboratory exercises and demonstrations, and students have the additional opportunity to interact with clinical cases owned by their schools as well as those brought in by clients. Privately owned pets, domestic livestock, and zoo animals all serve as resources for the clinical education of veterinary students,

Most animal use occurs in the third year of the curriculum, when surgical training takes place, using principally dogs and sheep. In earlier basic science courses, anatomy involves dissection of cadavers with live animals present in the lab for comparison, and physiology exercises involve the observation of live animals. The fourth year of veterinary studies is largely clinical apprenticeship.

With cooperation from the Association of American Veterinary Medical Colleges, OTA conducted a census of animal use in veterinary education in the 27 accredited veterinary schools in the United States for the school year 1983-84. The survey counted only those animals that began an exercise alive and either died or were subjected to euthanasia during the course of the laboratory session or demonstration. Cadavers or animals subjected to euthanasia prior to educational use were not counted, and clinical patients were not counted.

Of 16,655 animals used in 1983-84, half (8,020) were dogs. Mice, rats, and birds accounted for the bulk of the remaining animals (see table 9-6). No primates were killed during or after educational exercises in veterinary schools.

Laboratory-Animal Training

Technicians with specialized training in public health and animal care are needed at all levels by public health organizations, research institutions, pharmaceutical manufacturers, and universities. During the 1970s, several 2-year training programs were developed in response to an increasing need for personnel formally qualified to assist in pri-

Table 9.6.—Animals Used in Veterinary Education in the United States, 1983-84

Kind of animal	Number used[a]
Dog	8,020
Mouse	2,180
Rat	2,083
Bird	1,323
Reptile. .,	433
Sheep	423
Cat	414
Horse	378
Rabbit	195
Goat	194
Pig	140
Guinea pig	112
cow	111
Hamster	71
Other	578
Total	16,655

[a]This census of all 27 U.S. veterinary schools does not include privately owned or pet animals used for clinical demonstrations, animals purchased as cadavers, or those subjected to euthanasia prior to the laboratory exercise. It includes only those animals that began the course alive and then either died or were subjected to euthanasia during the course of the laboratory session.
[b]Includes fish, frogs, and exotic species.

SOURCE: Office of Technology Assessment, vate veterinary practices, biological laboratories, animal research, food inspection, and other areas requiring expertise in both science and animal care and use.

Graduates of these programs are generally referred to as animal technicians. The terminology may vary slightly among different schools or with individual State laws and regulations. Many employees of animal care and research and testing facilities have received training on the job, in secondary schools, or at less than the 2-year college level. These individuals are commonly referred to as animal attendants, animal caretakers, or animal health assistants. Two other types of animal-support personnel are laboratory-animal technicians (whose training has been oriented primarily toward laboratory animals) and animal technologists (who have had training in a 4-year baccalaureate degree program).

Most accredited animal technician programs cover 2 academic years of college-level study and lead to an Associate in Applied Science degree or its equivalent. The core curriculum usually includes animal husbandry, animal care and management, animal diseases and nursing, anesthetic monitoring and nursing, ethics and jurisprudence, veterinary anatomy and physiology, medical terminology, animal nutrition and feeding, necropsy techniques, radiography, veterinary urinalysis, veterinary parasitology, and animal microbiology and sanitation (l).

Many States require animal technicians to be registered or certified. The Laboratory Animal Technician Certification Board sponsored by the American Association of Laboratory Animal Science provides examinations and registry for technicians who are eligible and employed in laboratory-animal facilities.

In addition to increasing interest in laboratory-animal technician degree programs, a number of graduating veterinary students have begun to seek additional training and certification in laboratory-animal medicine. To date, about 700 full-time veterinarians are certified in this field nationwide (see ch. 15). As more' laboratory-animal technicians are trained and as the number of veterinarians specializing in laboratory-animal medicine increases, the resulting base of skills and knowledge will likely improve animal care in the laboratory.

THE ALTERNATIVES

Finding alternatives to the use of animals in education is a complex challenge. Alternatives must satisfy the demands of science education, teaching both the scientific method and the fundamental skills and techniques necessary to carry out scientific investigation. Yet science education does more—as it trains aspiring students, it establishes a framework of values and molds attitudes that will long influence their work. Therefore, exposure to alternatives, particularly the concepts underlying animal use and alternative methods, strongly influences the paths investigators choose to follow in the future. Viewed from this perspective, the acceptance (or rejection) of a specific alternative method in education assumes an importance that is, in fact, secondary to the impact it may have on the development of a student's overall attitude toward animal use in research, testing, or education.

Implementing alternative technologies and methods in education does not necessarily mean banishing animals from the classroom or laboratory. As in research (see ch. 6) and testing (see ch. 8), certain techniques are available that allow for the continued, but modified, use of animals, the use of living systems, the use of nonliving systems, and the use of computers. In education, computer simulation stands as a particularly promising alternative.

Continued, But Modified, Use of Animals in Education

Demonstrations

In contrast to animal experimentation in research and testing, animal use in the educational laboratory is unlikely to result in novel findings.

In education, a traditional laboratory exercise with a well-known outcome is usually repeated by a new student or group of students. The process of self-discovery and training is generally of greater importance than the specific data being collected. Under these circumstances, live demonstrations can often provide experiences that combine the best of direct student participation in animal laboratories with a reduction in animal use. Such exercises, when carried out by practiced professional instructors, avoid clumsy errors that students may make at the expense of laboratory animals. They also provide a convenient intermediate in the constant tension between active student participation in the laboratory and the limitations imposed by large class sizes.

In a variation on the laboratory demonstration, students may work together in groups on a single animal, again using fewer animals than if each student worked alone on a single animal. Exercises based on animal cells, tissues, or organs may be coordinated such that the minimum number of animals required can be sacrificed. Or animals may be subjected to multiple procedures, although if these involve sequential survival surgeries the advantage of reducing the number of animals used stands in conflict with the undesirability of repeated insults imposed on a surviving animal.

Noninvasive Procedures

observation can give rise to an appreciation of the diversity of the animal kingdom in general and important principles of physiology and behavior in particular. A sense of responsibility and an understanding of the life processes of animals are also conveyed when animals are maintained for observation in the laboratory. Areas for study in which animals can be used in a noninvasive manner include:

- simple Mendelian genetics (e.g., the inheritance of coat color in successive generations of small rodents);
- reproductive behavior (e.g., behavioral receptivity of a female during estrus);
- normal physiological processes of maturity, aging, and death (e.g., the relationship between aging and body weight);
- disease processes (e.g., the incidence of spontaneous tumor growth in a population);
- biological rhythms (e.g., nocturnal and diurnal feeding and drinking patterns); and
- social interactions (e.g., territoriality and dominance relationships among males).

Reduction in Pain

Reduction in pain and distress may be accomplished with the use of anesthetics, analgesics, and tranquilizers. In education, this is of primary importance in surgical training, when animals are anesthetized, operated on, and then subjected to euthanasia. Principles of pain and pain relief—common to research, testing, and education—are discussed in chapters 5, 6, and 8.

Substitution of Species

The substitution of nonmammalian for mammalian species, of cold-blooded vertebrates for warm-blooded ones, or of nonpet species for companion animals is occasionally possible in education. Swine have replaced dogs in one surgical teaching and research laboratory (20). The pigs were especially successful replacements in a basic operative surgery course offered as an elective to medical students. The principal advantages cited were closely shared anatomic and physiologic characteristics with humans, better health than dogs, and economic factors.

Use of Other Living Systems in Education

Invertebrates

The use of invertebrates as an alternative is already widespread in primary and secondary schools. Most laboratory manuals include common exercises that teach biological principles and introduce students to the scientific method of inquiry using organisms such as hydra, planaria (flatworms), annelids (earthworms), mollusks, and a variety of arthropods (e.g., insects and crustaceans). The use of invertebrates at the college and graduate levels may also increase as more is known about them. These deceptively simple systems are valuable resources for the laboratory investigation of sophisticated biological principles.

In Vitro Methods

Like the use of invertebrates, in vitro manipulation and maintenance of animal components such as cells, tissues, or organs (see chs. 6 and 8) can illustrate many biological principles. The incorporation of in vitro techniques into students' education and training also bears potential for shaping their later attitudes about the utility of in vitro methods. The stimulus provided by in vitro laboratory exercises can therefore ultimately alter the general course of research and testing.

One noteworthy endeavor in training researchers in in-vitro methods is the program of the Center for Advanced Training in Cell and Molecular Biology at Catholic University of America in Washington, DC. With funding from the American Fund for Alternatives to Animal Research, the American Anti-Vivisection Society, and the Albert Schweitzer Fellowship, the Center offers courses to students interested in the biomedical sciences and to professional researchers. In 1985, its third year of existence, the Center offered:

- Basic Cell and Tissue Culture,
- In Vitro Toxicology: Principles and Methods,
- Tissue Culture Technology in Neuroscience Research, and
- An Introduction to Tissue Culture and In Vitro Toxicology.

The first three courses were attended by technicians and Ph.D. and M.D. researchers. The last course was specifically designed for high school seniors and college freshmen (9). Activities of this nature are useful in that they enable professionals and, particularly, beginning students to become acquainted with and proficient in in-vitro methodologies and to comprehend the possibilities as well as the limitations of alternative methods.

The debate about whether or not the training of medical and veterinary students requires animals has spawned development of an alternative technique in microsurgery training. The most prominent use of microsurgery is for reconnecting arteries and veins, for example in restoring circulation to severed fingers. To reproduce vascular circulation for microsurgical training, a British plastic surgeon connected human placentas to a pump and an artificial blood supply, thereby simulating a heartbeat and typical blood pressures. Because the placenta contains blood vessels of widely ranging diameters, a single placenta can provide material for a substantial amount of practice (14).

At present, the human placenta cannot fully substitute for living animals. One of the problems is that the placenta contains an anti-blood-clotting agent or mechanism that is not understood and cannot be controlled. Clotting therefore does not occur in placental vessels. since learning how to avoid clotting during repair is a critical aspect of training, and since students training on placental tissue cannot detect their errors that cause clotting, the existing system is not fully adequate in microsurgical training (14).

Use of Nonliving Systems in Education

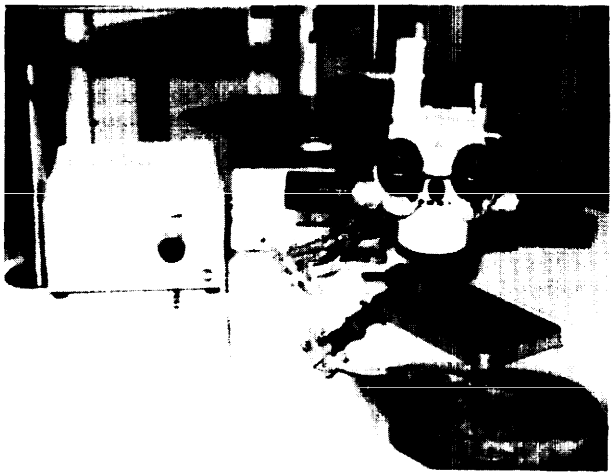
Audiovisual presentations bring the abstract prose of lecture and text one step closer to the biological reality of living organisms. Films and videotapes can demonstrate principles and protocols performed with live animals, while sparing additional animals. They may also present experiments and situations that cannot be performed live in the average classroom setting. As replacements for animals, however, they lack the living dimension; most cannot behave interactively. Recently developed computerized videodisks offer an opportunity for student interaction with an audiovisual program.

When audiovisual aids are used in concert with animals, they may enhance the value of live animals used in the laboratory. Students may learn a technique from a taped demonstration, for example, and then build on that experience as they perform the actual laboratory exercise in vivo.

Medical education substitutes audiovisual techniques for animals in several cases. This has less to do with educational philosophy than with factors external to the particular laboratory exercise, Those factors include the costs of animals and the facilities required to perform quality experiments, large medical school classes, lack of faculty time, and competition within a tightly packed curriculum.

Animal cadavers (e.g., frogs, sharks, cats, and fetal pigs) are currently used at all levels of educa-

Use of the Human Placenta for Training in Microvascular Surgery



Human placenta perfused under dissecting microscope.

Phcto credits: Paul/l LG Townsend, Consultant Plastic Surgeon, Frenchay Hospita/, Brlstol

Sutures and valves implanted in vessels of human placenta.

tion as models for dissection. Commercially prepared specimens are often used in junior high and high school education; medical and veterinary schools are more likely to prepare their own specimens. In some situations, cadavers may provide adequate replacements where living animals were once used.

Computer Simulation in Education

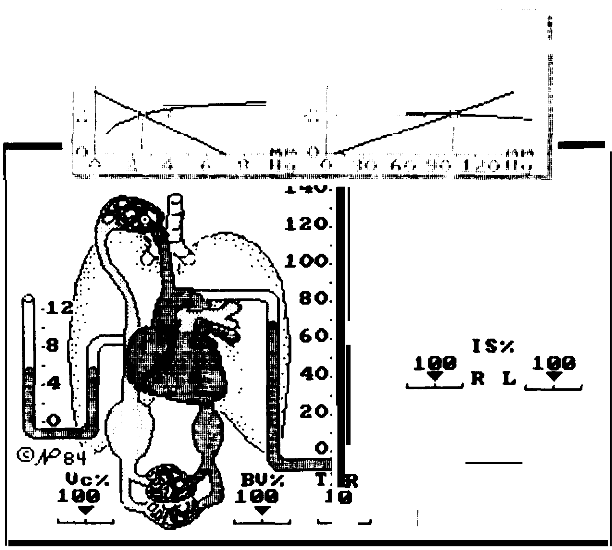
Computer simulation offers a variety of alternatives for studying animal and human biology at all levels of education, and the field is evolving quickly as experience grows and computer technology advances. Although at this time popular expectations for computer simulation still outdistance actual performance, the options that simulations present to educators can be expected to increase. Educational computer simulations fall into two categories: computer models of biological events and interactive simulations of biological experiments.

Computer simulations of biological events-primarily mathematical models of physiological and cellular phenomena—present in quantitative form phenomena that might be difficult or impossible to study in animals or humans. By altering parameters within the programs and noting results, students learn principles of biology from an ersatz animal system, the computer program. For example, a dog's circulatory functions are converted to a series of mathematical equations, which are programmed into a computer. As students change individual values or groups of values, the program resolves the various equations and reports values that mimic the effects of altering those parameters of the circulatory system in a living dog. Figure 9-1 depicts a portion of such a simulation.

An array of computer models of physiological processes are used in undergraduate and graduate laboratory exercises. The range of physiological simulations includes simulations of blood chemistry, cardiovascular physiology, the digestive system, the musculoskeletal system, respiratory physiology, and renal physiology. Computer simulations currently used in physiology laboratory exercises include:

- HUMAN: a comprehensive physiological model (3),

of



Overview of a computer simulation of the complete cardiovascular system, showing student-controlled variables such as heart rate (HR%), total active blood volume (BV%), and total peripheral resistance (TPR%).

SOURCE: N.S. Peterson and K.B. Campbell, "Teaching Cardiovascular Integrations With Computer Laboratories," Physlo/oglst 26(3):159-169, 1965.

- pH regulation and carbon dioxide (24),
- pulsatile hemodynamics in the aorta (5),
- determinants of cardiac output (16),
- effects of medically important drugs on the circulatory system (25),
- simulation of the digestion of a meal (25),
- responses of organisms to exposure to high and low temperatures (25),
- influence of hormones on muscle cells (25), and
- renal excretory response to volume and osmolarity changes (12).

Computer simulation of a particularly sophisticated laboratory exercise—for example, one that is too difficult for beginning veterinary students to perform-can enable students to carry out laboratory exercises they otherwise would not have had (13).

Table 9-7 summarizes the advantages, disadvantages, and barriers to substituting computer models of biological systems for animals in education. Some characteristics apply to one type of computer application more than another. Viewed as a whole, the descriptors of computer simulations listed in table 9-7 illustrate the potential as well as the limi-

Table 9-7.—Advantages, Disadvantages, and Barriers to Using Computer Simulations in Education

Advantages:

Quality of teaching material:

- *Simplification.* Some biological events that are too complicated or not accessible to human study by vivisection or dissection are better approached through computer simulation.
- ***Quantitative ski//s.*** Physical mechanisms and mathematical variables that underlie biological events are emphasized.
- *Emphasis.* Student attention is shifted from techniques to concepts, supporting lecture and textbook material.
- *Reliability.* Strong consistency from experiment to experiment.
- *Response time.* Simulations yield immediate results.

Cost and efficiency:

- *Long-range cost reduction.* Following initial purchase of computer hardware, computer laboratory costs are often lower than relatively high animal laboratory costs.
- Speed *and coordination.* Increased teaching efficiency through expeditious testing, drills, and tutorials.
- *Laboratory availability.* Increased access for students to laboratories.

Disadvantages:

- ***Bio/ogica/ complexity.*** Computers cannot be programmed to simulate many integrative interactions between internal organs.
- *Missed experiences.* In the view of some teachers, students should have experience with living tissue.
- *Bioogical variability.* Computers do not accurately portray the large degree of uncertainty that arises from biological variability, whereas comparisons of animals do present this concept.
- *Publication of results.* Developers of computer simulations sometimes find publication of their work in the usual scientific journals difficult since some simulations require ponderous documentation; in cases where publications are intrinsic to tenure and other faculty decisions, computer modelers may be discriminated against,
- *Student attitudes.* In some cases, dubious student outlook on computer replacement of animals undermines teaching of concepts. In other cases, simulations may unintentionally train students (e.g., medical students) to ignore the behavior and appearance of patients and to place unwarranted importance on data from instruments.

Barriers:

- *Incompatibility.* Hardware components and software systems often are not interchangeable; this is especially true of graphic simulations.
- *Computer /imitations.* Some complex digital computer programs are not fully realistic because they must approximate biological processes that are continuous and simultaneous by using a series of discrete steps. The only way to make such a computer approximation more realistic is to reduce the time the computer takes between steps. This may require more sophisticated hardware.
- *Tradition.* Widespread lack of training in mathematics modeling leads many talented people to write textbooks rather than computer models.
- *Proprietary considerations.* Many of those who are developing programs or catalogs of programs for commercial purposes will only disseminate useful information about computer simulations if they are paid, restricting applications.

SOURCE: Office of Technology Assessment

tations of this alternative in a variety of teaching situations. Several of the disadvantages listed in table 9-7 underscore the small likelihood that computers can completely replace animals in the classroom. Those who are developing computer simulations are among the most vocal in maintaining that this technique is not the optimal method in every teaching situation; in some cases, they say, animals serve the lesson better (8,13,15,26).

In addition to providing models of biological experiments, computer programs serve in the classroom and laboratory as reusable training devices to teach specific skills, just as airline pilots train in flight simulators. These simulations are based on graphic presentation of the experiments and involve interaction between the program and trainee. An interactive videodisk program, for example, enables students to simulate dissections using photographic images stored on the disks, rather than animals. Production of such a videodisk can cost from $60,000 to $200,000 for a 30-minute program and involves thousands of still photographs, computer overlay, and touch screen interaction. The sales price of such a videodisk can range from $1,000 to $5,000.

The most sophisticated types of videodisk programs have not achieved widespread use, largely because of economic factors. Apart from steep initial production costs, the hardware supporting videodisk use is expensive.

Computer-linked mannequins and robots currently provide the most sophisticated simulations. Resusci-Dog, developed at the New York State College of Veterinary Medicine at Cornell University in Ithaca, NY, is a canine cardiopulmonary resuscitation training mannequin, the equivalent of the human dummies used in training paramedical technicians. Constructed of plastic, Resusci-Dog can simulate a femoral artery pulse, and pressure can be applied to its rib cage for cardiac massage or cardiopulmonary resuscitation. The first microprocessor-laden canine simulator cost $7,000; the second $700. Resusci-Dog has replaced about 100 dogs per year in veterinary classes at the New York school (19).

Despite the widespread enthusiasm for the potential of computer models and interactive simulations in the life sciences, three general problems

Scenes From Interactive Videodisk Laboratory Exercise —Canine Hemorrhagic Shock

Photo credits: Charles E. Branch and Gregg Greanoff, Auburn University

These photographs were taken from the monitor screen of a video program on blood flow and hemorrhagic shock in use at the Auburn University School of Veterinary Medicine. The interactive video simulated experiment depicts actual experiments conducted by experts. Several treatments are videotaped and students then simulate performing the experiment, testing different treatments and dealing with the results as if they were actually performing the study. Top: Anesthetized dog in experimental setup. Bottom: Response of dog's pupil to light.

confront computer-based education in the mid-1980s (7,8):

- The rapid advance of computer technology has resulted in many–frequently incompatible—machines in competition for the same market. This has limited the transportability of existing computer-based education materials. Users of different systems cannot eas-

Canine Cardiopulmonary Resuscitation Simuiator (Resusci-Dog) in Use

Photo credit: Charles R. Short, New York State College of Veterinary Meidiine, Cornell University

ily share or exchange materials. As a result, there is a serious problem of duplication of effort, with individuals and institutions developing similar teaching programs. Although ideas are clearly portable, actual computer programs may not be, and the avenues for effective dissemination of programs remain limited.

- The resources available to support research and development in computer-based education are too limited. Few institutions have committed funds for such activity, and much current work is supported by departmental or individual resources. Many new computer-based education materials are developed by individuals on their own time out of personal interest. There is virtually no external funding available to support advances in this field.
- In the long run, the most serious problem 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 soft ware. 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 creditable enterprise.

SUMMARY AND CONCLUSIONS

In elementary school, student exposure to animals in the classroom generally takes the form of exercises in humane awareness. Later, involvement in science becomes more active and the role of the animal as a tool of science is explored. As students advance to and through college, animal use often becomes more invasive during instruction in laboratory techniques. At the highest levels, especially in professional and research training, students are expected to attain levels of skill that may be difficult to reach without the use of animals.

Taken together, the approximately 53,000 anireals used in accredited medical and veterinary schools for education and training make up less than one-half of 1 percent of the estimated 17 million to 22 million animals used annually in the United States for research, testing, and education. (No data are available on the number of animals used in primary, secondary, and college education.) Yet the development of students' attitudes toward animals during the classroom years overshadows in importance the actual quantity of animal subjects used in education. Each phase of primary and secondary education appears to offer an opportunity for shaping students' attitudes toward animals. Grades 8 through 11 seem to be the most appropriate times for influencing the development of attitudes toward animals.

Alternatives applicable to different levels of schooling vary with the educational goals of each level. whereas classroom demonstrations or noninvasive observation could be appropriate in primary and secondary education to teach the scientific method and aspects of biology, a nonliving system is inadequate to teach surgical technique and manual dexterity to medical and veterinary students. Computer models of biological phenomena and interactive simulations of biological experiments are especially promising alternatives to animal use, even in sophisticated laboratory physiology exercises. Interactive videodisk programs—although expensive and not currently widely available-offer particularly realistic training simulations.

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