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SCIENTIFIC AND EDUCATIONAL ANIMAL USE

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Introduction

Scientific animal use is one of the most controversial animal use issues. This controversy may stem from the fact that animals may be deliberately harmed during such use, and sometimes gravely so.

This chapter briefly reviews the history of scientific animal use, from ancient Greece to the present day. The multiplicity of animal welfare concerns created by such animal use are explored, including not only those associated with invasive procedures, but also with routine procedures, and laboratory environments. The justifications for such animal use are critically scrutinised – particularly, the key claim that such research is essential for the advancement of human healthcare. Systematic reviews of animal research within various fields are reviewed. These provide quantitative evidence of its limited utility in advancing human healthcare, and insights into the reasons for this. Replacement alternatives are reviewed, along with recommendations for the future of policy and practice relating to scientific animal research, in accordance with evidence and best practice.

Requirements for students to harm or kill animals during their education or training are also particularly controversial. Next, this chapter reviews the history and contemporary status of educational animal use. The animal welfare concerns associated with such use are explored, followed by a review of alternative teaching methods. The educational efficacy of the two methods has been studied within systematic reviews. These have clearly demonstrated that humane teaching methods usually produce learning outcomes as good or better than those achieved via harmful animal use. This evidence is then reviewed, and finally recommendations are provided for increasing the implementation of humane teaching methods within life and health sciences education.

Scientific animal use

Historical and contemporary scientific animal use

The first recorded scientific animal usage was steeped in controversy. Social taboos about dissecting human corpses greatly hampered the physicians of ancient Greece, during their anatomical and physiological studies (Von Staden and Von Staden, 1989), with the result that some
turned to the use of animals. Alcmaeon of Croton (6th–5th century BCE) and a few others even went as far as practising surgical and other invasive procedures on living animals (vivisection) (Court, 2005).

As scientific activity grew during the 17th century Renaissance, such experiments on living animals increased. Predating anaesthesia, some of these surgical investigations, demonstrations and experiments were infamously cruel. French philosopher René Descartes (1596–1650) prominently justified such practices, claiming that animals were merely mindless automata (Descartes 1989), whose cries were of no greater moral importance than the squeals of a poorly oiled machine. Such instrumental views of animal worth, and minimisation of their interests in living and avoiding suffering, continue to be used to attempt to justify invasive scientific and educational animal use to this very day.

Nevertheless, by the end of the 17th century, animal suffering within research and other social endeavours had become an increasingly prominent social concern. By the mid-1980s, animals were becoming broadly appreciated as beings with moral status and interests worthy of protection (Lairmore and Ilkiw, 2015), and campaigns against both scientific and educational animal use were increasing.

The most accurate evidence-based estimate of global laboratory animal use in recent times describes the year 2015. Global laboratory animal use for all purposes was estimated at 192 million (Taylor and Alvarez, 2019) – a 51% increase on the approximately 127 million animals used a decade previously, in 2005 (Knight, 2008, Taylor et al., 2008). Although very large, these totals nevertheless represent conservative estimates. Several animal categories are excluded, including advanced foetal developmental stages, and certain invertebrate species believed capable of suffering. Major drivers for the significant rise in overall numbers include greater production and use of genetically modified (GM) animals, and the implementation of large-scale chemical testing programmes in Europe and the US, following increasing concern about the possible toxicity of many chemicals produced in high volumes.

Animal welfare concerns

The magnitude and nature of animal welfare concern created by scientific animal use depends not only on the numbers of animals used, but also on the type of animals, and the procedures and environments they experience. More specifically, it depends on their sentience and other morally relevant characteristics, the level of invasiveness of scientific procedures, welfare impacts due to environmental, social or other circumstances, and the degree to which these are mitigated by strategies such as anaesthesia, *analgesia* (painkillers), and environmental enrichment.

Europe represents the largest region providing harmonised reporting between Member States, and at time of writing, the most recent EU reports described animal use from 2015 to 2017 (EC, 2020). In 2017, the main species used were mice (61%), fish (13%), rats (12%), and birds (6%), which together represented 92% of animals used. Similar proportions of these species are used internationally.

These animals are all higher vertebrates, with the neuroanatomical architecture and psychological capacities necessary to experience negative affective states such as pain, fear, and psychological distress. Some capacities for sentience and affective states may also exist in the small proportion of other animals, including some invertebrates, which are used.

A considerable array of stressors may cause significant stress and even fear, in laboratory animals. Relatively rarely, these may be associated with the capture of wild-sourced species such as primates, to supply breeding centres or research facilities. More commonly, stress may result from transportation, which may be prolonged for some animals, such as GM mouse strains avail-
able only from certain suppliers. Extremely commonly, laboratory housing and environments cause stress, as do laboratory procedures – both invasive, and more routine.

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[i]nvasive procedure [is] one interfering with bodily integrity, whether through puncture or incision, or insertion of an instrument or foreign material, as in surgical and some experimental procedures. Markedly invasive procedures include those resulting in death (whether or not the subjects are conscious), surgical procedures … , major physiological challenges, and the production of genetically modified animals.

(Knight, 2011)

There is a widespread view within the laboratory animal community that procedures, including those resulting in death, do not harm an animal, providing the animal is killed humanely, e.g., whilst under anaesthesia (Webster 1994). This provides a very important “legitimisation” of the killing of many millions of laboratory animals annually. However, this is not consistent with modern understandings of animal welfare, which note that for an animal to experience good welfare it requires more than the absence (as far as reasonably possible) of negative states (which can be achieved through death). Good welfare also requires that animals have the opportunity to experience positive states. As we’ve noted elsewhere (Zemanova et al., 2021),

Death permanently prevents such positive states, and indeed, the achievement of any other interests animals could seek to fulfill during the remainder of their lives (Kaldewaij, 2006, Yeates, 2010, Jensen, 2017). Accordingly, death is in fact one of the most profound harms that can be inflicted, barring exceptional cases such as genuine euthanasia of those faced with severe, ongoing suffering, with a poor prognosis for recovery.

This understanding of death is in accordance with both sound reasoning, and common sense. In contrast, lethal procedures (euphemistically termed “non-recovery”), are not considered “severe”, or even “moderate” or “mild”, in the severity classifications now required in the reporting of laboratory animal use within EU Member States, and some other nations. In 2017, EU animal uses were reported as severe (11%), moderate (32%), mild (51%), and non-recovery (6%) (EC, 2020). Figures for 2015–2016 were similar.

Moderate procedures are those “likely to experience short-term moderate pain, suffering or distress, or long-lasting mild pain, suffering or distress, as well as procedures that are likely to cause moderate impairment of the well-being or general condition of the animals” (Herrmann and Flecknell, 2018). Moderate, severe, and non-recovery procedures jointly accounted for almost half of all EU procedures in 2017.

This alone is concerning enough. However, it appears these figures markedly underestimate the harms experienced by laboratory animals. Herrmann and Flecknell (2018) published a systematic analysis of 684 surgical procedures within 506 animal research applications made to German competent authorities in 2010. They found that “researchers frequently underestimated the levels of pain, suffering, distress and lasting harm that were to be inflicted on the animals. Furthermore, the planned health monitoring strategies were generally flawed”. Germany is a leading EU Member State, with one of the largest and most developed animal research sectors. Its laboratory animal practice standards are likely to be at least as good as those of most other nations. Accordingly, it is likely that systematic underestimation of procedural severity, and inadequate animal health monitoring, also occur in many, if not most, other nations conducting invasive animal research.
The impacts of moderate or severe procedures can be mitigated via appropriate provision of anaesthesia or analgesia. These should normally be provided for any procedures likely to result in significant pain or discomfort, including for surgical procedures, which are normally among the most painful. However, Herrmann and Flecknell (2019) found that postoperative analgesia was not proposed for 30% of the 684 surgical procedures they analysed. In 10% of cases, animals were to be provided with analgesics if investigators considered this necessary; however, the use of recognised or validated pain assessment tools to detect pain were lacking. Where analgesia was proposed it was often suboptimal. Optimal techniques, such as **multimodal analgesia** (the concurrent use of multiple analgesics), were virtually never used, to alleviate postoperative pain. Once again, Germany is a leader within the animal research sector, and these disturbing results indicate that suboptimal analgesic provision is probably widespread within animal research internationally.

It is well understood that invasive procedures may cause stress to animals. Less commonly appreciated is that routine laboratory procedures may also cause stress. However, numerous studies have demonstrated that routine procedures such as handling associated with cage-cleaning, blood sampling, and gavaging, can cause profound, statistically significant distortions in physiological parameters, including serum concentrations of hormones such as stress hormones, glucose, and various cardiovascular parameters (Balcombe et al., 2004). **Gavaging** is the insertion of a tube within the oesophagus to allow the forced administration of test compounds orally, and is one of the most common routes by which animals are dosed during toxicity tests (Knight et al., 2006).

Laboratory housing and environments, even when enriched, remain very significantly deprived compared to the natural environments of laboratory animal species, with the diverse stimuli and cognitive challenges intrinsic to these (Balcombe, 2006). The chronic stress caused by long-term confinement within standardised, relatively barren laboratory environments, combined with stress caused by both routine and more invasive laboratory procedures, is often sufficient to result in marked behavioural indicators of stress. Examples include stereotypies, aggression, self-injurious behaviour, lethargy, and other abnormalities such as “floating limb syndrome”. Lack of environmental stimulation when compared to natural environments also appears to result in cognitive deficits, such as decreased cerebrocortical thickness and weight, and impairments of memory and learning capacity (Balcombe et al., 2004, Balcombe, 2006, Baldwin and Bekoff, 2007).

Chronic stress causes not just psychological and behavioural effects, but also physiological effects, including immunosuppression. It can increase susceptibility to various pathologies. As well as creating significant animal welfare problems, acute and chronic stressors may distort a range of experimental outcomes, such as those dependent on accurate measurement of physiological, behavioural, or cognitive characteristics.

Accurate assessment of laboratory animal welfare nationally and internationally is frequently impeded by reporting deficits and inconsistencies, including important matters such as frequency of analgesic or anaesthetic use, their correlation with markedly invasive procedures, and the prevalence of environmental enrichment and socialisation opportunities. Additionally, we now understand that welfare impacts are cumulative over time (Honess and Wolfensohn, 2010). This warrants monitoring and reporting of welfare impacts over animals’ lifetimes, and of consideration of historical, as well as contemporary, welfare impacts. However, such monitoring and reporting are also rare.

**Human healthcare advancement**

The greatest justification for the frequent and potentially severe welfare impacts experienced by laboratory animals are the societal benefits it is hoped will flow from such research. We now
understand that most laboratory animal species are highly sentient, with intrinsic worth in their own right, independent of any potential benefit for humans. Accordingly, fulfilment of scientific curiosity alone – as occurs in fundamental research, when it is methodologically sound – cannot reasonably be considered adequate justification for the harms inflicted upon the many millions of animals used annually within scientific research.

“Translational and applied” research comprised 23% of all EU laboratory animal use in 2017 (EC, 2020). Most of this research is aimed at developing clinical interventions to combat human diseases. If this research were effective and efficient at achieving this goal, this would provide a much stronger justification for laboratory animal research. But is it?

Advocates of invasive animal research have regularly claimed such research is essential for preventing, curing, or alleviating human diseases (e.g., Festing, 2004), with their opponents making counter-claims (e.g., Greek and Greek, 2004). However, the most reliable, quantitative information about the utility of such research in advancing human healthcare, comes from systematic reviews. A **systematic review** is

> a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research and to collect and analyse data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyse and summarise the results of the included studies. (Moher et al., 2009)

Many systematic reviews of animal experiments within various research fields have now examined their utility for advancing human healthcare. Among 20 relevant published systematic reviews located by this author during a previous survey, animal models demonstrated significant potential to contribute towards clinical interventions that were efficacious in human patients, in only two cases, one of which was contentious due to a small sample size. This was despite some of these systematic reviews focusing on those animal experiments most likely to provide human benefit. These included experiments approved by ethics committees on the basis of specific claims that medical advances were likely to result from the animal research; very highly cited animal experiments published in leading scientific journals; and chimpanzee experiments, given that chimpanzees are the species most generally predictive of human outcomes, because they’re genetically most similar to humans (Knight, 2011).

Seven additional systematic reviews demonstrated poor reliability of animal models in predicting human toxicological outcomes, including carcinogenicity and teratogenicity – the propensity to cause cancer and birth defects, respectively. These are the toxicities of greatest public health concern (Knight, 2011). Since then, many additional systematic reviews have yielded similar results (Knight, 2019). To date, no published systematic reviews in any healthcare fields appear to have yielded contrary results – that invasive animal research is an effective and efficient tool for the advancement of human healthcare.

**Limitations of animal models**

The poor rates of translation of animal outcomes into human patients and consumers are due both to the animal models themselves, and to the manner in which they are used. Animals differ from humans in multiple relevant ways. Differences in absorption, distribution, metabolism, and elimination pathways or rates, affect **toxico- or pharmaco-kinetics** (i.e., bodily distribution of test compounds). **Toxico- and pharmaco-dynamics** (mechanisms of action and biological effects) may
also differ. Jointly these may alter organ systems affected, and the nature and magnitude of those effects (Knight, 2011).

Human predictivity is further compromised by the experimental protocols used. Young animals, of single strains and sexes, lacking in biological variability and concurrent human risk factors, such as common comorbidities, become even less likely to predict outcomes of human patients, consumers, or workers (Knight, 2011).

Many toxicity tests also use maximum tolerated doses (above which dose increases become impossible, due to acute, toxicity-related effects), as well as chronic dosing. These factors do maximise sensitivity to toxins. However, these doses can also overwhelm physiological defences that are effective at environmentally realistic doses. As a result, many compounds that would not normally result in toxicity, are falsely indicated as toxic in animal tests, seriously undermining the reliability of any positive results. Human routes of exposure (e.g., inhaled) may also differ from those used in animals, requiring extrapolation between routes of exposure, introducing further uncertainty (Knight, 2011).

And as noted previously, laboratory animals experience stress both chronic and acute, resulting from laboratory environments and procedures. These stressors can alter physiological, hormonal, and immune status, and even behavioural repertoires and cognitive capacities, in ways that may be unpredictable (Balcombe et al., 2004, Balcombe, 2006, Baldwin and Bekoff, 2007).

**Methodological quality of animal studies**

Additionally, a sizeable body of systematic reviews have confirmed that significant methodological flaws are highly prevalent in most published animal experiments (e.g., Knight, 2019). To date, no systematic reviews have found that a majority of animal studies in any field, were of good methodological quality.

Bias of results occurs when factors systematically alter research outcomes. This may be conscious, but usually results from unconscious factors. Hooijmans et al. (2014) described ten types of bias with potential to influence animal research results. They grouped these into selection bias, performance bias, detection bias, attrition bias, reporting bias, and other sources of bias. Many of these flaws are highly prevalent within animal studies. Common examples include use of apparently arbitrary numbers of animals, rather than statistically justified and significant sample sizes. Failure to use randomisation during allocation to treatment and control groups, and blinding during outcomes assessment, are also common, as is lack of reporting of basic characteristics of animals used. Percie Du Sert et al. (2020) found that randomisation was reported in 30–40% of published animal studies, blinding in around 20%, sample size justification in < 10%, and all basic characteristics of animals used reported in < 10% of publications (Macleod et al., 2015, Avey et al., 2016, Leung et al., 2018).

Across a diversity of fields, studies that incorporate the fewest measures to minimise sources of bias, have also reported the greatest treatment effect sizes (e.g., Crossley et al., 2008, Vesterinen et al., 2010). Accordingly, we can conclude that such apparent increases in effect size, are not real, but are artefacts, resulting from flaws in experimental design, conduct, or reporting.

In response to such problems, in 2010 Kilkenny and colleagues proposed the Animal Research: Reporting of In Vivo Experiments (ARRIVE) guidelines. These comprised a checklist of 20 items, designed to minimise such flaws by ensuring animal research publications include basic information on animal numbers and characteristics, housing and husbandry conditions, and experimental, statistical, and analytical methods employed. Steps to reduce bias were prominent, such as randomisation, blinding, statistical justifications of sample sizes, reporting of exclusion criteria, and of investigator conflicts of interest. Several similar guidelines have been published, but
the ARRIVE guidelines are most prominent. Despite their very widespread publication and endorsement by research journals, major funding agencies, and biomedical research organisations, multiple studies have demonstrated that compliance with the ARRIVE guidelines remains poor (Macleod et al., 2015, Avey et al., 2016, Leung et al., 2018, Percie du Sert et al., 2020). In response, the guidelines have been simplified into “essential” and “recommended” checklists in ARRIVE 2.0 (Percie du Sert et al., 2020). It remains to be seen whether this will improve compliance.

**3Rs alternatives**

Given that animal models are so unreliably predictive of humans, what alternatives might be used instead? Famously proposed by Russell and Burch in 1959 (e.g., USDA, 2015), the 3Rs are the:

1. **Replacement** of animal use with non-animal alternatives, wherever possible;
2. **Reduction** of animal numbers to the minimum possible;
3. **Refinement** of animal use, to avoid or minimise animal pain, distress, or other adverse effects suffered at any time during the animals’ lives, and to enhance well-being (Buchanan-Smith et al., 2005).

Compliance with these 3Rs is universally considered fundamental to good laboratory animal practice. As stated by Russell and Burch, “Refinement is never enough, and we should always seek further reduction and if possible replacement … replacement is always a satisfactory answer”.

I’ve previously reviewed 3Rs alternatives in detail (Knight, 2011). Replacement alternatives include mechanisms to enhance sharing and assessment of existing data, physicochemical evaluation of test compounds, and computerised modelling of their effects. Advanced tissue cultures include *immortalised cell lines* (which continue to differentiate indefinitely), *stem cells* (which can differentiate into other cell types), and *organotypic cultures* (three-dimensional cell cultures that retain features of the original organ). Tests using bacterial, yeast, protozoal, mammalian, or human cell cultures exist for numerous toxic and other endpoints. Human *hepatocyte* (liver cell) cultures and metabolic activation systems may allow identification of metabolic pathways (which break down test compounds), and of resultant compounds produced. “Human on a chip” systems connect cell cultures from different organs via microfluidic systems that mimic the circulatory system, allowing assessment of organ–organ interaction. Microarray technology can allow genetic expression profiling of toxins, greatly speeding up their detection, well prior to more invasive endpoints. Surrogate human tissues, e.g., harvested during surgery or childbirth, advanced imaging modalities, and human epidemiological, sociological, and psychological studies, may all increase understanding of illness *aetiology* (causation) and *pathogenesis* (development). Finally, human clinical trials may be enhanced in various ways to increase safety for volunteers, and predictivity for diverse patient populations. As I’ve noted previously (Knight, 2011), “Non-animal investigative methods cannot, of course, provide answers to all questions about humans, particularly given present technological limitations. However, the same is certainly true of animal models, which have a more limited capacity for further development”. Additionally, when human tissues or volunteers are used, these methods may generate faster, cheaper results, that yield superior insights into human biochemical processes, and that are ultimately more reliably predictive for human patients, consumers, and workers.
Recommendations for scientific animal use

As we’ve described elsewhere (De Boo and Knight, 2008), a multifaceted strategy is warranted to increase the implementation of 3Rs principles, improve the welfare of laboratory animals, and improve the methodological quality of animal research.

Compliance must become mandatory, with 3Rs principles, the ARRIVE guidelines, and other best practice standards, during the design, conduct, and reporting of animal experiments. Such standards should cover animal sourcing, housing, handling, environmental enrichment, socialisation opportunities, appropriate use of anaesthetics and analgesics, and of refinement modalities such as non-invasive or humane endpoints (the latter being the humane killing of animals early within terminal protocols). Compliance with a range of measures designed to minimise bias and ensure methodological quality, must also become mandatory. Compliance should be necessary for securing ethical approval and research funding; for licensing of researchers, facilities, and experimental protocols; and for publication of subsequent results.

To enable animal researchers and technicians to meet the necessary standards, regular training in 3Rs methodologies, and in the design, conduct, and reporting of animal research, should be universally compulsory. The widespread lack of attention to replacement methods (in favour of refinement methods) must be rectified.

Greater efforts must also be made to publish negative results. Studies that fail to show a treatment effect are generally less likely to be published, as they’re considered less noteworthy. The subsequent exclusion of negative results from systematic reviews that aim to consider all published evidence concerning test treatments leads to overestimations of treatment efficacy, and partly explains the widespread failures in human patients of treatments apparently effective in animals.

To date, compliance with such best practice standards by the animal research community has been demonstrably poor (Leung et al., 2018, Percie du Sert et al., 2020). To achieve the substantial improvements for both laboratory animal welfare, and human predictivity, that are so urgently needed, widespread change is needed. This would require a willingness and commitment to very significant change, from researchers and their professional associations, regulators, licensing bodies, ethical review committees, funding bodies, and scientific journals.

Educational animal use

Historical and contemporary educational animal use

Animals have also been, and still are, widely used within life and health sciences education. Students dissect dead animals within biology and anatomy courses, and conduct invasive procedures on living animals in subjects such as physiology, biochemistry, pharmacology, and parasitology. Animals are frequently killed prior to, or at the end of, such procedures.

In many veterinary schools, animals have been used to teach surgical and clinical procedures, including invasive procedures such as resuscitation. Surgical procedures have progressed historically from multiple survival procedures on individual animals, to terminal procedures, with animals killed at the completion of the surgery, usually via anaesthetic overdose. Such terminal surgical procedures have been common within many countries, with a notable exception being the UK, where students instead gain surgical experience through closely supervised externships and internships. Alternatives to terminal surgeries, such as cadavers and inanimate models, have become increasingly common in countries such as the US and Canada (Bauer 1993). Nevertheless, Bauer reported that 27% of veterinary schools were still utilising terminal surger-
ies, with 69% using terminal exercises in “small” animals (typically, dogs and cats), and 20% using them in “large” animals (typically, large agricultural species).

In 2001 this author completed the veterinary surgical program at Western Australia’s Murdoch University. At that time, terminal animal use within surgery and other subjects was routine within most Australian veterinary schools. However, student-led campaigns by this author and others resulted in the introduction of alternatives in all Australian veterinary schools. In 2000 terminal animal use was completely abolished at the University of Sydney, and by 2005, the first students had graduated from all four established Australian veterinary schools without participating in terminal surgical training. By 2012 terminal animal use was uncommon, and was expected to cease entirely within a few years. Similar developments have occurred at numerous other veterinary schools internationally, usually also driven by student-led campaigns.

Educational animal use has been estimated at 1–10% of total numbers of animals used globally for scientific purposes (Akbarsha et al., 2013). Applied to the estimated 192 million animals used in 2015 (Taylor and Alvarex, 2019), this equates to some 2–19 million animals used annually, worldwide. Among those EU Member States which reported data, from 2014 to 2018, total EU educational animal use was 124,000–172,000 (Zemanova et al., 2021). However, these estimates are very conservative, because animals killed for cadaver use (as is very common within anatomy or biology courses) are usually excluded from reported figures.

**Animal welfare concerns**

Not all educational animal use is harmful to animals, of course. Non-harmful uses of animals may include handling and physical examination of domesticated species, and observational studies of wild, free-living, or sanctuary animals, where animals are not stressed by excessive use or human presence.

However, many of the animals used in demonstration experiments do suffer significant welfare impacts, including during initial sourcing and transportation, the involuntary disruption of their social networks, confinement within relatively unenriched environments, as well as during the experiments themselves (Knight, 2011). Clinical skills training may be stressful for animals, particularly when invasive procedures are being demonstrated or practiced. Many animals used within education are also killed, whether for sourcing of cadavers or body parts for anatomy, physiology or biochemistry laboratories, or at the end of terminal physiology demonstration experiments, or practice surgeries. As discussed previously, viewpoints are common that humane killing of animals does not constitute a harm to them, and this viewpoint serves to legitimise large-scale animal killing for educational purposes. However, a more reasoned and critical consideration of the impacts of killing clearly reveals it to be one of the most profound harms that can be inflicted on healthy animals.

**Alternatives to educational animal use**

Many humane alternatives have been developed for harmful educational animal use, and successfully implemented within life and health sciences curricula internationally. I’ve described these in detail elsewhere (Knight, 2012). They include computer simulations and videos of professionally performed dissections (prosections) and experiments, non-invasive self-experimentation, *ethically-sourced cadavers* (from animals who have died naturally, or in accidents, and been donated for teaching purposes), anatomical specimens preserved using several different methods, models, mannequins and surgical simulators, and supervised clinical experiences.
Alternative surgical training

Humane training of surgical practical skills should comprise three main stages. First, students should practice basic skills such as instrument handling and suturing, and should refine their motor skills, using knot-tying boards, plastic organs, and other models. Second, they should participate in simulated surgery, using ethically sourced cadavers. Third, students should observe, assist with, and then finally perform, beneficial surgery on real patients. The latter should be conducted under close one-to-one supervision, similarly to the training of human surgeons (Knight, 2011).

Spaying and castrating cats and dogs are some of the most common procedures veterinary students will later need to perform in clinical practice, and shelter animal neutering programs are a very popular way for veterinary students to gain surgical experience. In the Shelter Medicine Program at Mississippi State University, for example, fourth year students averaged 65 sterilisation surgeries in two weeks (Shivley et al., 2018), demonstrating the high volume of surgical experience these programmes can provide, when compared to other forms of surgical training. Additionally, neutered shelter animals are more likely to be adopted, decreasing pet overpopulation due to uncontrolled breeding, and delivering important animal welfare benefits.

Educational efficacy of alternatives

Despite the successful implementation of such teaching alternatives within numerous courses worldwide, harmful animal use persists within many others. Why does such harmful animal use persist? The answers may be revealed through systematic analysis of the summary reports of scientific and educational animal use that EU nations are required to publish annually. Our analysis of reported summaries from 18 EU and EEA Member States during 2017–2019 (Zemanova et al., 2021) revealed that the two main reasons why some educators felt animal use remained necessary, were 1) the necessity of using a living animal for “proper” learning; and 2) the perceived lack of an adequate alternative.

However, in 2021 Zemanova and I published a systematic review of published studies which compared learning outcomes achieved by humane teaching methods with those achieved through harmful animal use. Such studies are often conducted by educators, when trialling a new teaching method, and subsequently published. Fifty such studies were published from 1968–2020, primarily from the US, UK, and Canada. Humane teaching methods produced learning outcomes that were superior (30%), equivalent (60%), or inferior (10%) to those produced by traditional harmful animal use (Figure 13.1). This is the most comprehensive systematic review published to date within this field, with studies covering all educational levels and disciplines in which animals are used, and its results are clear. Accordingly, it may be concluded that the preference of some educators for harmful animal use is not evidence-based; indeed, it is contrary to the best available evidence in this field.

The demonstrably superior educational efficacy of humane alternatives in 30% of relevant published educational studies may be due to certain advantages offered by alternatives. Unlike animals, many simulators accurately replicate key elements of humans, allowing human medical students to practise clinical skills procedures. Simulated procedures in any species may generally be repeated or otherwise customised to individual learner needs. Repeated practice results in superior skill retention (Andreatta et al., 2015). Live animal laboratories are also very time- and resource-intensive, with the majority requiring an entire morning or afternoon to set up, prepare and stabilise animals, conduct procedures, recover or euthanase animals, and clean and pack.
away. Humane alternatives frequently offer significant savings in both time and costs (Leonard 1992), freeing student and staff time, space and financial resources, for other learning or academic activities. Accordingly, as we noted (Zemanova and Knight, 2021), “wide-spread implementation of humane teaching methods would not only preserve learning outcomes, but may in fact be beneficial for animals, students, educators, and institutions”.

Figure 13.1 Number of studies comparing learning outcomes of humane teaching method and harmful animal use: (A) from 1968 to 2020, (B) grouped by discipline, and (C) by humane method used. Note: years with zero publications are not included in (A). Adapted from: Zemanova and Knight, 2021.
Recommendations for educational animal use

Clearly, remaining harmful animal use within life and health sciences courses worldwide should be replaced with humane teaching alternatives, as soon as possible. We recently recommended several steps to facilitate the appropriate implementation of humane teaching methods (Zemanova and Knight, 2021):

1. the training of life and health sciences educators should be designed to increase their awareness about the efficacy of humane teaching methods,
2. exchange of information and best practice strategies among universities should be encouraged,
3. there needs to be more financial support from governmental and international institutions to universities for implementing alternatives, as well as for non-profit organizations that are distributing information about humane teaching methods (e.g. InterNiche, Animalearn), and
4. more stringent enforcement of legislation requiring alternatives to animal use, is necessary.

Additionally, those universities offering courses in which harmful animal use continues to persist, should implement policies committing to providing alternatives for students (or staff) who conscientiously object to participating in harmful animal use. I’ve previously provided detailed guidance on this matter, including examples of such conscientious objection policies, and the jurisprudential (legal) bases for their implementation (Knight, 2014).

Detailed information about curricular animal use and related conscientious objection policies should also be publicised to all students, well in advance of such animal use, via university handbooks, curricular and course guides. Such information should also be circulated to teaching faculty, along with guidelines about the assessment of conscientious objection claims, and the necessary provision of alternative teaching or assessment activities.

Conclusions

Scientific and educational animal use is particularly controversial. With 192 million animals conservatively estimated as being used globally for scientific and educational animal purposes in 2015, the numbers are large, even if significantly smaller than some other fields in which animals are impacted by humans. Animal research is also one of the very few fields in which animal suffering may be knowingly or deliberately inflicted, as well as severe. Requiring students to engage in harmful or lethal use of animals is also fraught with controversy. Social unease in both domains has been reflected by abundant campaigns and lawsuits, and decreasing public support over time for such uses of animals (Funk and Rainie, 2015).

A paradigm change is clearly warranted concerning scientific and educational animal use. Instead of uncritically assuming human benefits, we must subject such use to much more rigorous and critical evaluation, consistent with common legislative requirements for researchers and ethics committees to conduct harm–benefit analyses, before proposing or approving such work (e.g., EU, 2010). Systematic reviews have clearly indicated that most animal research does not yield hoped-for human healthcare benefits, and have also identified multiple reasons for this. Systematic reviews have also clearly demonstrated that learning outcomes achieved by humane teaching methods, are normally as good or better than those achieved through harmful animal use. Modern understanding of the animals used for scientific and educational purposes has
clearly demonstrated the existence within such species of a range of morally relevant character-
istics. It is clear these animals have lives and interests that matter profoundly to them. And it is
incumbent on us to respect these, if we aspire to act as moral agents.

Accordingly, when conducting the harm–benefit analyses required both by good ethics, and
commonly, by legislation, it is not normally reasonable to conclude that benefits accruing for
human patients, consumers, industry workers, or students, or even for those motivated by simple
scientific curiosity or profit, exceed the harms incurred by the animals used.

Accordingly, a range of measures are clearly warranted, to increase compliance with 3Rs
methods, across the domains of scientific and educational animal use. Where animal use persists,
measures are also warranted to improve the methodological quality of animal research. Where
scientific and educational animal use fails to meet the harm–benefit standards expected by soci-
ety, and frequently required by legislation, such animal use should cease. Resources consumed
could then be redirected into more justifiable, and potentially more promising, research and
teaching modalities.

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