NOTE

THE PIG-BRAIN-SIZED LOOPHOLE IN NEUROSCIENCE RESEARCH: HOW THE LAW FAILS TO PROTECT BRAINS LIKE OURS

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In 2019, Yale School of Medicine researchers brought thirty-two ostensibly dead pig brains to the brink of consciousness. The pigs, slaughtered four hours earlier, were part of an experiment that sought to determine whether brains could be resurrected. Although the pigs ultimately did not exhibit consciousness, the BrainEx study nonetheless felt ethically dubious to many observers. How could researchers legally bring pigs—animals with brains remarkably like our own—back from the dead?

The paltry regulatory scheme that authorized the BrainEx study, as well as other similarly high-risk neuroscience research on pigs, is the subject of this Note. In recent years, the number of studies conducted on pigs has proliferated, but the Animal Welfare Act—the sole piece of federal legislation regulating animal research in the United States—has failed to keep pace. Under the current regime, researchers were, for example, permitted to detonate C4 explosives within four yards of living, breathing pigs without providing follow-up pain relief. While many authors have documented the Animal Welfare Act's disappointing protections of lab animals, this Note identifies neuroscience research in pigs as an emerging animal welfare problem and articulates specific reforms to protect highly intelligent non-primates.

Part I provides a brief overview of current issues in neuroscience research and explains why nonhuman primates are decreasingly utilized in laboratories. Part II, in turn, describes why pigs are increasingly desirable subjects for

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neuroscience research and documents the various invasive experimental procedures used in pigs to study brain disease and develop neurotechnology. Part III examines the historical evolution and present version of the Animal Welfare Act. Although the Act has grown in regulatory force since its enactment in 1966, this Part argues that the Act carries with it a legacy of protecting conventionally high moral status animals (such as dogs and nonhuman primates), along with a general hesitance to intrude upon laboratory research. Finally, Part IV proposes comprehensive amendments to the Animal Welfare Act to afford pigs greater protection. Reform, in broad strokes, requires expanding the animals covered under the Act, improving the administrative apparatus undergirding enforcement, and implementing more rigorous standards for research protocols that create a presumption against invasive neuroscience research.

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INTRODUCTION

Four hours after their ostensible death during slaughter, thirty-two disembodied pig brains regained partial electrochemical functionality at the hands of Yale School of Medicine researchers in 2019.[1] The study was a test of BrainEx, an experimental chamber of pumps and filters designed to circulate blood substitute through brains to mitigate posthumous deterioration.[2] In a stunning rebuke of traditional conceptions of brain death, researchers found that brains could, at minimum, regain cellular activity hours after death.[3]

The study was never intended to resurrect dead pigs. The solution perfused into the animals' brains specifically contained several chemical agents to inhibit neural activity, and the length of perfusion was relatively short—only six hours—to obviate the development of more complex neural signals.[4] But, as a consequence of this experimental design, open questions remain as to whether the pigs *could have* experienced some posthumous sentience in the absence of a blocking medium or with a longer perfusion time.[5] Even after adjusting the experimental design as they did, researchers were still concerned about the possibility of consciousness arising during the experiment. Scientists continuously monitored for higher order brain activity and stood by ready to take countervailing measures—in the form of anesthetic agents or temperature manipulations—to extinguish sentience.[6]

Although the pig brains ultimately did not exhibit consciousness, it is nonetheless worth interrogating the regulatory framework that authorized the BrainEx study. Pigs are highly intelligent animals.[7] Their brains are more like ours than some nonhuman primates, and research suggests that pig cognition rivals that of human children.[8] How, then, were researchers permitted to bring a highly intelligent pig back from the dead to (perhaps) the brink of consciousness? The short answer is that the pigs in the Yale study were livestock, not laboratory animals.

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1. Zvonimir Vrselja et al., *Restoration of Brain Circulation and Cellular Functions Hours Post-Mortem*, 568 NATURE 336, 336 (2019).

2. Nita A. Farahany, Henry T. Greely & Charles M. Giattino, *Part-Revived Pig Brains Raise Slew of Ethical Quandaries*, 568 NATURE 299, 299 (2019).

3. Brian Resnick, *Scientists: We Kept Pig Brains Alive 10 Hours After Death. Bioethicists: "Holy Shit."*, VOX (Apr. 17, 2019, at 10:00 PDT), https://perma.cc/6Z4L-FZVP.

4. Vrselja et al., *supra* note 1, at 337.

5. Farahany, Greely, and Giattino, *supra* note 2, at 300.

6. *Id.*

7. Lori Marino & Christina M. Colvin, *Thinking Pigs: A Comparative Review of Cognition, Emotion, and Personality in* Sus domesticus, 28 INT'L J. COMPAR. PSYCH., at 1, 10 (2015).

8. *Id.* at 7-8; *see* Michael Mendl, Suzanne Held & Richard W. Byrne, *Pig Cognition*, 20 CURRENT BIOLOGY 796, 798 (2010) (revealing that "pigs can show sophisticated social behavior" and may possess episodic memory, a trait that was thought to be "uniquely human"); Brendan Hoffe & Matthew R. Holahan, *The Use of Pigs as a Translational Model for Studying Neurodegenerative Diseases*, FRONTIERS PHYSIOLOGY, July 10, 2019, at 4 (explaining that several nonhuman primates do not exhibit brain folding which "allows for the increased complexity of neuronal networks").

Under the Animal Welfare Act,[9] the sole piece of federal legislation regulating animal research in the United States, pigs may be excluded from protections afforded to research animals if (1) the pigs are livestock (raised for use as food, as in the BrainEx study) or (2) the research for which the pigs are used is considered to be agricultural, rather than biomedical, research. And even if certain pigs are deemed to be covered under the Animal Welfare Act (for example, if they were raised for biomedical research), pigs are afforded far fewer protections than nonhuman primates—the traditional stalwarts of neuroscience research—due to their perceived lower sentience and moral status. Pigs are routinely subjected to experimental procedures in U.S. laboratories that would be unthinkable for nonhuman primates.[10] The long answer thus is as follows: pig brains are desirable for the very reason that they are similar to human brains. However, unlike other animals with brains similar to our own, experiments involving pigs are poorly scrutinized under a fragmented regulatory framework. To borrow from legal bioethicist Hank Greely, "pig brains are in limbo."[11]

Prior scholars have documented the manifold ways in which the Animal Welfare Act fails to protect laboratory animals.[12] This Note, in four Parts, builds upon this body of work by identifying neuroscience research in pigs as a novel, rapidly growing animal welfare problem and articulating specific reforms.[13]

Part I provides a brief overview of the state of neuroscience research. Although we presently live in the "golden age" of neuroscience, with an insatiable demand for research subjects, there is a concurrent shortage of neuroscientists' most prized research subjects: nonhuman primates.[14] This Part explains why nonhuman primates are increasingly inaccessible, and often undesirable, research subjects for biological, economic, political, and ethical reasons.[15] Part II describes the comparative usefulness of pigs as subjects for neuroscience research, examining why we might (erroneously) perceive pigs as an ethical alternative to nonhuman primates. This Part also documents various invasive

9. 7 U.S.C. § 2132.

10. *See infra* Part II.C.

11. *How Late Is Too Late to Revive a Brain? Pig Brain Study Raises Questions*, CBC RADIO (May 3, 2019, at 15:57 EDT), https://perma.cc/65MJ-XB9B.

12. *See, e.g.*, Justin Marceau, *How the Animal Welfare Act Harms Animals*, 69 HASTINGS L.J. 925, 928 (2018) ("Previous scholarship has critiqued the AWA for failing to provide a comprehensive or readily enforceable set of protections for animals. This Article breaks new ground by identifying much larger, structural problems with the AWA that show it is not only ineffective, but worse, counterproductive. Because of the vast exemptions to the law, many forms of institutionalized animal suffering have been exacerbated—the welfare of most animals in this country is now worse than it was without the AWA.")

13. Gregory Simchick et al., *Pig Brains Have Homologous Resting-State Networks with Human Brains*, 9 BRAIN CONNECTIVITY 566, 567 (2019) ("Use of the pig brain as a model has been rapidly increasing in neuroscience research.").

14. Michio Kaku, *The Golden Age of Neuroscience Has Arrived*, WALL ST. J. (Aug. 20, 2014, at 19:23 ET), https://perma.cc/Y8BX-9D7Y.

15. David Grimm, *Supply of Monkeys for Research Is at a Crisis Point, U.S. Government Report Concludes*, SCI. (May 4, 2023, at 16:40 ET), https://perma.cc/G2H3-F83K.

experimental procedures used in pigs to study brain disease and develop neurotechnology.

Having established the rising popularity of pigs as subjects of neuroscience research, Part III examines the historical evolution and present version of the Animal Welfare Act. Although the Act has grown in regulatory force since its enactment in 1966, the Act still is characterized by a hesitation to intrude upon laboratory research and carries with it a legacy of protecting primarily high moral status animals such as dogs and nonhuman primates.[16] Part IV proposes comprehensive amendments to the Animal Welfare Act to afford pig brains more adequate protections. Reform, in broad strokes, requires expanding the animals covered under the Act, improving the administrative apparatus undergirding enforcement, and implementing more rigorous standards for research protocols that create a presumption against invasive neuroscience research. Undertaking these protocols, I argue, will help to close the pig-brain-sized loophole in neuroscience research.

I. ANIMALS IN NEUROSCIENCE: THE SIMULTANEOUS RISE OF NEUROSCIENCE RESEARCH AND DECLINE IN NONHUMAN PRIMATE MODELS

A. The Golden Age of Neuroscience

Neuroscience is a relatively new field, emerging as a distinct discipline only in the late twentieth century.[17] Since the foundation of the Society for Neuroscience in 1969, the volume of work in the field has grown linearly,[18] a result that is largely attributable to the growing number of Americans that suffer from neurological disorders and the recent development of technologies that broaden the scope of scientific inquiry.

In a nearly twenty-year long study of disease burden in the United States, researchers found that a "large and increasing number" of Americans suffer from neurological disorders.[19] The three most common neurological disorders in the United States are stroke, Alzheimer's disease and other dementias, and migraine.[20] These disorders not only cause devastating physical symptoms[21] —of the 795,000 Americans expected to have strokes each year, 137,000 will die[22]—

16. *See infra* Part III.A.

17. Richard E. Brown, *Why Study the History of Neuroscience?*, FRONTIERS BEHAV. NEUROSCI., May 22, 2019, at 4.

18. Cara M. Altimus et al., *The Next 50 Years of Neuroscience*, 40 J. NEUROSCI. 101, 101 (2020).

19. *Burden of Neurological Disorders Across the US from 1990-2017: A Global Burden of Disease Study*, 78 JAMA NEUROLOGY 165, 166 (2021).

20. *Id.*

21. Toshihiko Shimizu et al., *Disability, Quality of Life, Productivity Impairment and Employer Costs of Migraine in the Workplace*, J. HEADACHE PAIN, Apr. 21, 2021, at 1, 8.

22. *How Many People are Affected by/at Risk for Stroke?*, NAT'L INST. CHILD HEALTH

but have a distinctly corrosive effect on a sufferer's psychology. Alzheimer's disease, for example, results in significant alterations in selfhood, including in high-order complex manifestations of self like autobiographical knowledge.[23] As stated by Hank Greely, "As a matter of science, the Cartesian dualism of mind versus body has been appropriately discarded. As a matter of identity, though, it is hard not to see the mind, and the brain, the organ that immediately creates it, as special . . . in a way [the] heart, liver, or kidneys are not."[24]

Coinciding with a growing need for research of neurological disorders is the proliferation of new research techniques for studying neuroscience.[25] Three key neuroimaging techniques to study the structure and function of the brain—magnetic resonance imaging (MRI), positron emission tomography (PET) scans, and functional magnetic resonance imaging (fMRI)—were developed in the last three decades.[26] Advancements in genetic techniques over the last twenty years have similarly advanced the field: scientists had historically relied on "lesions or pharmacological manipulations in animals to determine the role of a given brain region[, but] new genetic tools have increased [neuroscientists'] ability to precisely manipulate circuits."[27]

Despite growing interest in neurological disorders and meteoric technological progress, the full etiology of many brain disorders remains poorly understood. Studying neuroscience is infamously complicated: as stated by physicist Emerson Pugh, "If the human brain were so simple that we could understand it, we would be so simple that we couldn't."[28] At present, scientists have mapped many individual brain systems and are only now "better positioned to start deciphering how groups of neurons and distant regions work together to drive behavior."[29]

The vast majority of researchers argue that further advances are contingent upon research in nonhuman animals.[30] Animal models, for example, permit researchers to study the "early stages" of neurodegenerative disease that are undiscoverable in post-mortem analysis of humans.[31] And neuroscientists increasingly

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& DEV., https://perma.cc/JS2G-C74M (archived Aug. 12, 2025).

23. Aikaterini Mentzou et al., *Change in the Psychological Self in People Living with Dementia: A Scoping Review*, CLIN. PSYCHOL. REV., Mar. 5, 2023, at 1.

24. Henry T. Greely, *Predicting Alzheimer Disease*, 28 ELDER L.J. 313, 420 (2020).

25. *See* Jurong Ding, Wei Liao & Dajiang Zhu, *Editorial: Advanced Neuroimaging Methods in Brain Disorders*, FRONTIERS HUM. NEUROSCI., Aug. 30, 2023, at 1.

26. Anna Christina Nobre & Freek van Ede, *Under the Mind's Hood: What We Have Learned by Watching the Brain at Work*, 40 J. NEUROSCI. 89, 90 (2020).

27. Altimus et al., *supra* note 18, at 103.

28. *Why is the Human Brain So Difficult to Understand? We Asked 4 Neuroscientists.*, ALLEN INST. (Apr. 21, 2022), https://perma.cc/B2TA-LEKJ.

29. Altimus et al., *supra* note 18, at 103.

30. Allyson J. Bennett & Dario L. Ringach, *Animal Research in Neuroscience: A Duty to Engage*, 92 NEURON 653, 655 (2016). *See also* Judith R. Homberg et al., *The Continued Need for Animals to Advance Brain Research*, 109 NEURON 2374, 2376 (2021) (noting that animal research is "indispensable" because this research "generates fundamental knowledge about the function and structure of the healthy brain").

31. S.L. Eaton & T.M. Wishart, *Bridging the Gap: Large Animal Models in*

stress the importance of utilizing large animal models, as opposed to traditional rodent models, to study neurodegenerative diseases.[32] There is "more robust capitulation of the human disorder in models with a higher degree of genetic homology to humans." [33] As put by one researcher, "[t]he fact that rodents have only 48-66% genetic homology with humans, whereas swine and 'new world' monkeys have approximately 80% and 'old world' monkeys such as the baboon have up to 99%, does beg the question which model is best to fully mimic the condition."[34] Thus, the view generally held by researchers is that the advancement of neuroscience requires the continued use of animals, particularly animals with brains like ours.

B. Declining Appeal of Nonhuman Primates

Nonhuman primates have historically been considered the "ultimate" model for neuroscience study.[35] Yet, as the need for translational animal models is expanding, the supply of nonhuman primates is "in crisis."[36] A 2023 report sponsored by the U.S. National Institutes of Health found that two-thirds of U.S. researchers who sought to obtain nonhuman primates for research have reported challenges in doing so. Because of this shortage, some research has been delayed, compromised by less than desirable research subjects, or outright canceled.[37] Though the purpose of this Note is not to expound upon the pitfalls of nonhuman primate research, describing the involuntary and voluntary reasons underlying the declining use of nonhuman primate models should begin to explicate some of the comparative appeal of using pigs.

First, the present shortage is driven primarily by a decline in Chinese exportation of research animals and inadequate domestic breeding programs. Up until the COVID-19 pandemic, U.S. researchers received sixty percent of their imported monkeys from China.[38] But, soon after the pandemic's onset, China stopped exporting research monkeys in order to better support its own vaccine research.[39] In response, U.S. researchers began sourcing increasing numbers of nonhuman primates from Cambodia. While this sourcing was adequate for a time, Cambodian exporters were embroiled in scandal in November 2022 when it was discovered that hundreds of wild-caught nonhuman primates had been

Neurodegenerative Research, 28 MAMMALIAN GENOME 324, 333 (2017).

32. *Id.*

33. *Id.* at 327.

34. *Id.*

35. Fengyan Liang et al., *Non-Human Primate Models and Systems for Gait and Neurophysiological Analysis*, FRONTIERS NEUROSCI., Apr. 27, 2023, at 1.

36. Grimm, *supra* note 15.

37. *Id.*

38. *Id.*

39. *Id.*

falsely labeled as captive bred.[40] The U.S. Department of Justice has since charged two Cambodian wildlife officials, as well as several members of a primate supply company, with the illegal exportation of an endangered species.[41]

Domestic breeding programs have been unable to keep up with the resulting increase in demand. The problem was exacerbated when President Biden rejected the National Primate Centers' request for thirty million dollars in 2022 to expand domestic breeding initiatives.[42]

The tandem mounting demand and diminishing supply predictably resulted in price increases and timeline delays that made use of nonhuman primates untenable for many researchers. Take macaques—the nonhuman primates used most often for neuroscience—as an example.[43] As stated by one researcher, "[b]efore the pandemic, you could get them almost instantaneously for about $2000. Now, it's taking at least a year and a half, and I'm competing with others willing to pay more than $19,000 per animal."[44] The plain inaccessibility of nonhuman primates has thus driven a decline in their use as research subjects.

In addition to an involuntary shift away from nonhuman primate models, researchers are also electing not to use primates for a variety of practical and ethical reasons. A particularly potent disincentive is the potential transmissibility of disease between nonhuman subjects and researchers. For example, Herpes B viruses (HBV) are common in macaques. Although transmission to humans is rare—as of 2022 there were only fifty recorded infections of human HBV—human infection can result in a fatality rate of up to eighty percent.[45]

Beyond the biological dangers inherent in research on nonhuman primates, other researchers may oppose their use on purely ethical grounds. It is indisputable that nonhuman primates have complex behavioral and cognitive lives—it is for this very reason that their brains are so coveted for research.[46] Research settings eliminate virtually all of the social structures in which nonhuman primates thrive and subject them to mind-numbing monotony. In the United States,

40. *Id.*

41. David Grimm, *Indictment of Monkey Importers Could Disrupt U.S. Drug and Vaccine Research*, SCIENCE (Nov. 23, 2022, at 16:20 ET), https://perma.cc/9YZE-3NA6.

42. Grimm, *supra* note 15.

43. *See* Daniel T. Gray & Carol A. Barnes, *Experiments in Macaque Monkeys Provide Critical Insights into Age-Associated Changes in Cognitive and Sensory Function*, 116 PROC. NAT'L ACAD. SCI. 26247, 26247 (2019); Hao Li et al., *A Cynomolgus Monkey with Naturally Occurring Parkinson's Disease*, NAT'L SCI. REV., Mar. 2021, at 1; *see also* Guoping Feng et al., *Opportunities and Limitations of Genetically Modified Nonhuman Primate Models for Neuroscience Research*, 117 PROC. NAT'L. ACAD. SCI. 24022, 24022 (2020).

44. Grimm, *supra* note 15.

45. Mugdha Vasireddi & Julia Hilliard, *Herpes B Virus, Macacine Herpesvirus 1, Breaks Simplex Virus Tradition via Major Histocompatibility Complex Class I Expression in Cells from Human and Macaque Hosts*, 86 J. VIROLOGY 12503, 12503 (2012).

46. Maria Padrell, Miquel Llorente & Federica Amici, *Invasive Research on Non-Human Primates—Time to Turn the Page*, ANIMALS, Oct. 19, 2021, at 3; Dorothy Cheney, Robert Seyfarth & Barbara Smuts, *Social Relationships and Social Cognition in Nonhuman Primates*, 234 SCI. 1361, 1361 (1986).

monkeys up to fifty-five pounds can be housed in cages as small as seventeen cubic feet, about the size of a large refrigerator. (The minimum cage volume for an animal of the same size in Europe is notably about 127 cubic feet—more than seven times larger.[47]) Though nonhuman primates must be "housed with visual and auditory contact with conspecifics," the animals are not required to be physically housed with other animals. Nonhuman primates therefore often live physically segregated from other animals in overcrowded rooms, culminating in significant stress.[48] Studies conducted on chimpanzees released to animal sanctuaries following invasive research reveal that the animals were nineteen times more likely to be diagnosed with depression and eighty-eight times more likely to exhibit post-traumatic stress disorder as compared to wild chimpanzees.[49]

In sum, the unavailability of nonhuman primates, coupled with ethical concerns about their use, has made nonhuman primate research increasingly undesirable.[50] The greater scrutiny placed on nonhuman primate research, however, has not eliminated scientists' need to use large animal models for neuroscience research.

II. ENTER PIGS: THE APPEAL OF THE PORCINE BRAIN

A. The Comparative "Palatability" of Pigs

Pigs are by and large given less moral standing than nonhuman primates.[51] This statement is both obvious—insofar as Americans consume roughly fifty pounds of pork per capita—and irrational.[52] Generally, humans' perception of other animals' moral status increases with intelligence.[53] In a study seeking to understand the division of animals into high- and low-moral status, researchers found that people routinely perceive food animals as both less sentient and intelligent than they really are. This trend is readily contrasted with the public's view of companion animals and other popular megafauna: research subjects perceive

47. *Id.*

48. Melinda A. Novak, *Self-Injurious Behavior in Rhesus Macaques: Issues and Challenges*, AM. J. PRIMATOLOGY, Dec. 23, 2020, at 12 (2021).

49. Padrell, Llorente & Amici, *supra* note 46, at 5.

50. David Grimm, *NIH Hosts Nonhuman Primate Workshop amidst Increased Scrutiny of Monkey Research*, SCI. (Feb. 20, 2020), https://perma.cc/G9TU-683X.

51. Victoria C. Krings, Kristof Dhont & Alina Salmen, *The Moral Divide Between High- and Low-Status Animals: The Role of Human Supremacy Beliefs*, 34 ANTHROZOÖS 787, 788 (2021); Olatz Goñi-Balentziaga et al., *A Survey on the Use of Mice, Pigs, Dogs and Monkeys as Animal Models in Biomedical Research in Spain*, LAB'Y ANIMAL RSCH., June 22, 2022, at 3 (2022).

52. Marianne Stein, *Slightly Bearish Report, Still a Contractionary Outlook*, PORK BUS. (July 5, 2023, at 10:00 PT), https://perma.cc/T7CM-W6MD.

53. Lucius Caviola et al., *Humans First: Why People Value Animals Less than Humans*, COGNITION, May 12, 2022, at 17.

dogs and dolphins as highly intelligent and sentient.[54] Researchers explain that this bimodal assessment of intelligence and sentience emerges from humans' "dementaliz[ation of] food animals" which in turn "makes it easier not to care morally for them . . . help[ing] to justify harming or eating them." In other words, because we eat them, pigs are significantly more morally palatable research subjects than other intelligent animals.

Beyond the greater social acceptability of pigs as research animals, they pose few of the practical constraints of nonhuman primates. First, pigs are readily and cheaply available in the United States. Because pigs reach sexual maturity quickly and produce large litters, swine researchers do not have to contend with the problems associated with sourcing animals from abroad or paltry domestic breeding programs.[55] Research pigs cost anywhere between $575 for a weaned wild-type animal to $2,250 for weaned genetically modified swine, costs that are dwarfed by those associated with nonhuman primate research.[56] Second, the zoonotic viruses associated with pigs pose significantly lesser threats to human health than HBV.[57] The viruses present in research pigs may cause pig mortality, inconveniencing research, but have relatively benign presentations in humans. Third, because humans and pigs have similar body sizes, pigs conveniently fit well into existing neuroimaging equipment.[58]

Pigs also have special advantages over nonhuman primates in tissue engineering and organ transplantation studies.[59] As a product of their anatomic and physiologic similarity to humans, pigs' tissues and organs are good candidates for xenotransplantation, the use of nonhuman cells for human transplantation.[60] Many Americans either directly benefit from, or are at least familiar with, xenotransplantation—a significant fraction of the tens of thousands of Americans receiving heart valve replacements each year will receive their replacement valves from pigs.[61]

In response to organ shortages, researchers have begun transplanting entire pig organs, as opposed to smaller tissue samples, into humans.[62] In August 2023,

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54. Krings, Dhont & Salmen, *supra* note 51, at 788.

55. Iris Ribitsch et al., *Large Animal Models in Regenerative Medicine and Tissue Engineering: To Do or Not to Do*, FRONTIERS BIOENG'G. & BIOTECH., Aug. 13, 2020, at 11.

56. *NSRRC Distribution Fees*, NAT'L SWINE RES. & RSCH. CTR., https://perma.cc/R7W3-DK4A (archived Aug. 12, 2025).

57. Kristi L. Helke et al., *Biology and Diseases of Swine*, *in* LAB'Y ANIMAL MED. 695, 709 (James G. Fox et al. eds., 3d ed. 2015).

58. Alesa H. Netzley & Galit Pelled, *The Pig as a Translational Animal Model for Biobehavioral and Neurotrauma Rsearch*, BIOMEDS., Aug. 1, 2023, at 2.

59. Ribitsch et al., *supra* note 55, at 11-12.

60. Tanya Lewis, *Milestone Pig-to-Human Heart Transplant May Pave the Way for Broader Trial*, SCI. AM. (Oct. 18, 2023), https://perma.cc/2S6B-P35Q.

61. Raheela Fareed Siddiqui, Johnathan Rajiv Abraham & Jagdish Butany, *Bioprosthetic Heart Valves: Modes of Failure*, 55 HISTOPATHOLOGY 135, 135-136 (2009).

62. Sheryl Gay Stolberg, *U.S. Organ Transplant System, Troubled by Long Wait Times, Faces an Overhaul*, N.Y. TIMES (Mar. 22, 2023), https://perma.cc/FL7R-FBAA.

two surgical teams transplanted pig kidneys, genetically modified to reduce the chance of immune rejection, into brain-dead human recipients.[63] And in September, researchers at the University of Maryland School of Medicine transplanted a pig heart into Lawrence Faucette, a 58-year-old with end-stage heart failure.[64] Though Faucette ultimately lived for only six weeks before his body rejected the transplant, researchers have called whole-organ xenotransplantations "watershed event[s]" that will "change how we treat organ failure."[65]

Acceptable pig consumption in the United States thus takes many forms in the twenty-first century: pigs are subject to our dietary, research, and xenotransplantation whims. Their lower-moral status, coupled with their practical accessibility advantages, renders pig use markedly more welcome than the use of nonhuman primates for similar ends.

B. Similarities to the Human Brain

Pig brains are surprisingly similar to our own brains in their anatomy and function. Human and pig brains are gyrencephalic, meaning that they possess folds in the outermost layer of the brain (the cortex).[66] The presence of a gyrencephalic cortex in a research model is critical for several reasons.

First, the presence of a gyrencephalic cortex indicates that pigs, like humans, experience the majority of their brain growth, composition, and myelination around birth.[67] Accordingly, researchers have been able to study brain development in pigs as a proxy for human brain development. This result is important because, as explained by a research article charting the brain growth of domestic pigs from two to twenty-four weeks of age, "few [human] studies have focused on the period from birth to 4 years of age when dramatic brain development occurs . . . [P]igs can be used in MRI studies to investigate how different insults at critical periods of rapid brain growth affect development and function."[68]

Second, folding of the brain promotes increased neuronal complexity that allows for coordinated, brain-wide activity that is "remarkably similar to [the

63. Thiago Carvalho, *Two US Surgical Teams Transplant Functional Pig Kidneys into Humans in Xenotransplantation Success*, 29 NATURE MED. 2671, 2671 (2023).

64. Lewis, *supra* note 60. Faucette received the heart through a "compassionate use" pathway that allows seriously ill or dying individuals to undergo an unapproved therapy as a last chance at life.

65. Timothy Bella, *Second Pig Heart Transplant Patient Dies in Maryland Weeks after Surgery*, WASH. POST (Nov. 1, 2023), https://perma.cc/QL7P-UHA4; Roni Caryn Rabin, *In a First, Man Receives a Heart From a Genetically Altered Pig*, N.Y. TIMES (Jan. 10, 2022), https://perma.cc/77TK-QKJZ.

66. Hoffe and Holahan, *supra* note 8, at 3.

67. *Id.*

68. Matthew S. Conrad, Ryan N. Dilger & Rodney W. Johnson, *Brain Growth of the Domestic Pig (*Sus scrofa*) from 2 to 24 Weeks of Age: A Longitudinal MRI Study*, 34 DEVELOPMENTAL NEUROSCI. 291, 292 (2012).

functionality seen in] humans."[69] Functional similarities, in turn, give rise to similar behaviors as well as manifestations of injury. With regards to behavior, pigs have exhibited—in a reprisal of a familiar adjective—a "remarkable . . . behavioral and cognitive flexibility."[70] And, unlike some other research animals, pigs have demonstrated high inter-individual variability during behavioral tests, akin to the significant inter-individual diversity that is observed within humans.[71] These traits make pigs strong candidates for neurotrauma research.[72]

Finally, porcine brain folding, coupled with pigs' twelve-to-fifteen-year life spans, allows researchers to conduct longitudinal studies on neurodegenerative diseases.[73] The long-term pathogenesis, and subsequent deterioration, caused by Alzheimer's disease and other neurodegenerative diseases remains poorly understood in part due to the inadequacy of rodent models.[74] Rodents' short lifespans are convenient for observing some aspects of disease progression, but their lissencephalic (smooth) brains do not recapitulate neuropathological symptoms nor do their short lifespans allow researchers to study the yearslong development of neurodegenerative diseases.[75] Pig models of neurodegenerative disorders function to "bridge the gap of preclinical investigations between rodents and humans."[76]

Pig brains are not just similar to human brains in the absolute sense—rather, even as compared to some nonhuman primates, pig brains more closely resemble the structure of the human brain. Marmosets, increasingly prized in neuroscience research for their human-like prosocial behavior, have lissencephalic brains.[77] The usefulness of the small nonhuman primates in the study of neuropathological response to disease and injury is thus limited as compared to pig models, which sustain many of the same pathologies observed in humans.[78] The phylogenetic distance between humans and pigs obfuscates the tangible similarities between our brains and minds.[79]

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69. Netzley and Pelled, *supra* note 58, at 8.

70. Candace C. Croney & Sarah T. Boysen, *Acquisition of a Joystick-Operated Video Task by Pigs (*Sus Scrofa*)*, FRONTIERS PSYCH., Feb. 11, 2021, at 6.

71. Hoffe and Holahan, *supra* note 8, at 5.

72. Netzley and Pelled, *supra* note 58, at 12.

73. Hoffe and Holahan, *supra* note 8, at 3.

74. Ida E. Holm, Aage Kristian Olsen Alstrup & Yonglun Luo, *Genetically Modified Pig Models for Neurodegenerative Disorders*, 238 J. PATHOLOGY 267, 276 (2016).

75. *Id.*

76. *Id.*

77. Cory T. Miller et al., *Marmosets: A Neuroscientific Model of Human Social Behavior*, 90 NEURON 219, 220 (2016).

78. Nicole L. Ackermans et al., *Unconventional Animal Models for Traumatic Brain Injury and Chronic Traumatic Encephalopathy*, 99 J. NEUROSCI. RES. 2463, 2469 (2021).

79. Ruth R. Faden et al., *Toward a Theory of Moral Status Inclusive of Nonhuman Animals: Pig Brains in a Vat, Cows versus Chickens, and Human–Nonhuman Chimeras*, *in* RETHINKING MORAL STATUS 169 (2021).

C. Current Uses of Pig Brains

The purpose of this Subpart is twofold. It is first meant to illustrate that the use of pigs in neuroscience is not inconsequential—both in terms of the number of pigs sacrificed and the results attained from the research. This Subpart is also intended to provide an accurate, albeit deeply disconcerting, depiction of the research procedures used to study sentient animals with brains like ours.

In recent years, pigs have been used to study two of the three most common neurological disorders in humans—strokes and Alzheimer's disease—as well as the most common brain affliction, traumatic brain injury (TBI).[80] Researchers have also used pigs, perhaps more notoriously, in the development of neurotechnologies.[81]

Pigs have primarily been used to study TBI, a broad diagnosis that encompasses any disruption to brain function caused by an external force strong enough to displace the brain within the skull.[82] In studying TBI, researchers have sought to understand the pathology of the acute resulting injury and the chronic effects of the illness that increase long-term disability and mortality rates.[83] The two most prominent methodologies used to induce TBI are controlled cortical impact (CCI) and rotational acceleration models.[84] CCI involves a craniotomy—the surgical removal of a portion of the skull to expose the brain—followed by the application of an impactor device to deliver a "controlled impact to the exposed brain tissue."[85] CCI has been useful in mimicking open-head injuries, such as gunshot wounds, but this model does not capture the pathology of closed-head injuries, the most common type of TBI experienced by humans.[86] Rotational acceleration models provide an alternative.[87] Under this nonsurgical protocol, pigs are positioned in a device that allows for the measured application of rotational forces. Rotation leads to the "deformation and shearing of brain tissue," mimicking the rotational forces experienced by humans during closed-brain TBIs.[88] A final method available is blast injury: an animal is exposed to a shockwave to

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80. Marc Melià-Sorolla et al., *Relevance of Porcine Stroke Models to Bridge the Gap from Pre-Clinical Findings to Clinical Implementation*, INT'L J. MOLECULAR SCI., Sep. 8, 2020, at 1; Hoffe and Holahan, *supra* note 8, at 2.

81. Rachael Levy, *Exclusive: Musk's Neuralink Faces Federal Probe, Employee Backlash over Animal Tests*, REUTERS (Dec. 6, 2022, at 06:57 PST), https://perma.cc/6SC2-UAHC.

82. D. Kacy Cullen et al., *A Porcine Model of Traumatic Brain Injury via Head Rotational Acceleration*, *in* INJURY MODELS OF THE CENTRAL NERVOUS SYSTEM: METHODS AND PROTOCOLS 158 (2016).

83. Helen M. Bramlett & W. Dalton Dietrich, *Long-Term Consequences of Traumatic Brain Injury: Current Status of Potential Mechanisms of Injury and Neurological Outcomes*, 32 J. NEUROTRAUMA 1834, 1834 (2015).

84. Netzley and Pelled, *supra* note 58, at 9.

85. *Id.*

86. *Id.*

87. *Id.* at 10.

88. *Id.*

simulate an injury resulting from an explosive force.[89]

TBI-inducing procedures are performed under anesthesia, but the vast majority of pigs who undergo experimental procedures do not receive post-procedure pain management.[90] In a review article examining pain management in pigs following experimental surgery, researchers found that only thirty-seven percent of papers reported providing postoperative analgesic, and few researchers provided pain management drugs for a sufficient time period.[91] One blast injury study, for example, reported the following in their methods section: "anaesthetized swine was positioned from the centre of the blast, the distance between swine head and the C4 charge [a potent explosive] was 125 inches, just outside the fireball . . . The swine wore a protective foam-lined lead vest that protected the torso from physical injury."[92] The animals were "maintained on propofol [a pain management drug] for 2 hours after the blast." No further mention is made of analgesic provision, and the animals were kept alive for at least an additional seventy hours after the blast.

While it may be unfair to rebuke this particular study, it serves as an example of research that, without greater insight into its experimental protocols, failed to treat pigs humanely.[93] It also exemplifies a trend in animal research: the arguably excessive repetition of studies tracking pain and traumatic injury.[94] The key conclusion of this study was that quantitative electroencephalogram (qEEG), a test to measure electrical activity in the brain, is sensitive to changes in the brain immediately after injury. However, as the authors of the article themselves explain, this study was the third large animal study of its kind: "[changes in EEG were] reported in two other blast brain injury [studies] using a large animal model."[95] One of the prior studies used goats rather than pigs. In the goat blast study, Chinese military researchers reported that nearly ninety percent of the goats were burned and exhibited brain bleeding as well as other signs of severe brain injury.[96] Taking the results of that study in tandem with the present pig study, researchers argued that the concordant results served to reveal that "non-

89. *Id.*

90. A. G. Bradbury, M. Eddleston & R. E. Clutton, *Pain Management in Pigs Undergoing Experimental Surgery; a Literature Review (2012–4)*, 116 BRIT. J. ANAESTHESIOLOGY 37, 40 (2016).

91. *Id.*

92. Chaoyang Chen et al., *Quantitative Electroencephalography in a Swine Model of Blast-Induced Brain Injury*, 31 BRAIN INJ. 120, 121 (2017).

93. It may not actually be all that unfair to highlight this study—Wayne State University, responsible for authorizing the experiment, has a history of mistreating research animals, including pigs. *See* James McCandless, *PETA Accuses Ford of Going Back on Animal Testing Ban, Funding Study Using Euthanized Pigs*, NEWSWEEK (Oct. 8, 2021, at 06:52 EDT), https://perma.cc/A2DE-65YG.

94. PETER SINGER, ANIMAL LIBERATION 92-105 (2015).

95. Chen et al., *supra* note 92, at 124.

96. Bing Cang Li et al., *Blast-Induced Traumatic Brain Injury of Goats in Confined Space*, 36 NEUROLOGICAL RES. 974, 974 (2014).

invasively obtained qEEG . . . may, thus, be of clinical value."[97] In the next paragraph, researchers wrote that the conclusions of the pig study were further corroborated by the existence of studies tracking EEG in human civilians who suffered mild TBI. Reproducibility in science is important, but this study likely went too far in needlessly sacrificing highly intelligent animals.

Nonetheless, it is incontrovertible that at least some neuroscience research conducted in pigs yields significant results with potentially life-altering outcomes for sufferers of neurodegenerative diseases.[98] For example, a growing body of stroke research in pigs has led to new treatment pathways for humans.[99] In a study on the benefits of administering neural stem cells to pigs' brains after stroke, researchers concluded that the work "strongly supports that [neural stem cells] may be the critically needed therapeutic for human stroke patients."[100] Moreover, a study investigating the benefits of facial nerve stimulation first used anesthetized pig subjects to assess the efficacy of the treatment before, in the same publication, applying the stimulus to human subjects. The non-invasive stimulation in pigs translated into "safe, tolerable, and effective" stimulation of healthy volunteers.[101]

Again, the methods used to develop these treatments are not benign. The first technique used to induce stroke is electrocoagulation, a procedure which fuses blood vessels together by destroying tissue with electricity. And gaining access to the blood vessels of interest first requires invasive surgical intervention, a procedure that, as late as 2000, involved eye enucleation—the removal of the animal's eyes.[102] Fortunately, in 2023, researchers developed minimally invasive techniques to access blood vessels that, while retaining targeting accuracy, mitigate the need for disfiguring procedures.[103]

In addition to physical manipulations to recapitulate disease conditions, other neuroscience research manipulates pigs' genes. To model Alzheimer's disease, researchers began engineering transgenic pig models in 2009.[104] While scientists abroad have been able to create pigs that accumulate amyloid beta and tau, the proteins associated with Alzheimer's disease in humans, the research remains in a relatively nascent stage as pigs do not also exhibit the behavioral phenotypes observed in humans.[105] To support the generation of better models,

97. Chen et al., *supra* note 92, at 124.

98. Hoffe and Holahan, *supra* note 8, at 5-6.

99. Marc Melià-Sorolla et al., *supra* note 80, at 2.

100. Emily W. Baker et al., *Induced Pluripotent Stem Cell-Derived Neural Stem Cell Therapy Enhances Recovery in an Ischemic Stroke Pig Model*, SCI. REPS., Aug. 30, 2017, at 1.

101. Olivia Sanchez et al., *Facial Nerve Stimulation in Normal Pigs and Healthy Human Volunteers: Transitional Development of a Medical Device for the Emergency Treatment of Ischemic Stroke*, J. TRANSLATIONAL MED., Feb. 15, 2018, at 12.

102. Melià-Sorolla et al., *supra* note 80, at 7.

103. Alexandra Le Bras, *Modeling Stroke in Pigs*, 52 LAB ANIMAL 114, 114 (2023).

104. Hoffe and Holahan, *supra* note 8, at 4.

105. Olav M. Andersen et al., *A Genetically Modified Minipig Model for Alzheimer's*

the National Institute of Aging, a branch of the National Institutes of Health, continues to transfuse the field with significant funding: in 2022, researchers across three universities were awarded $446,000 to develop a pig model of Alzheimer's disease that allows for adequate drug testing.[106]

Pigs have also been used in the testing of neurotechnology. Neuralink, Elon Musk's medical device company, was recently under federal investigation for its potential mistreatment of animals.[107] More than twenty current and former employees have spoken out against the cruelty involved in tests of the company's brain implant device, attributing the poor animal welfare to pressure from Musk to accelerate timelines. Pushed to meet deadlines, researchers allegedly performed tests using unfinished technologies, resulting in botched experiments and excessive animal suffering.[108] In 2021, staff incorrectly fitted twenty-five out of sixty pigs with brain devices. The mistake, which could have "been avoided with more preparation," resulted in the animals' deaths and the need to perform additional research.[109] On another occasion, researchers implanted the Neuralink device on the wrong vertebra of two pigs. The company veterinarian supported the immediate euthanasia of one of the animals because of her "low chance of full recovery" and her "poor psychological well-being."[110] In all, at least four experiments, involving eighty-six pigs and two monkeys, were impaired by human errors.[111]

Pig brains have been used, and will continue to be used, extensively in understanding neurological injury and disease. Accompanying this rise in use is the opportunity for misuse, in sloppy experimental procedures to meet the pressures of publication or timelines, as well as the opportunity for abuse, in the administration of seemingly barbaric or unnecessary procedures.[112] As stated condescendingly—but accurately—by one Neuralink researcher: "It's hard on the little piggies."[113]

Disease with SORL1 Haploinsufficiency, CELL REPS. MED., Sep. 20, 2022, at 6, 14.

106. Max Esterhuizen, *Virginia Tech Researcher Earns Two-Year National Institutes of Health Grant to Develop a Pig Model of Alzheimer's Disease*, VA. TECH. NEWS (Sep. 16, 2022), https://perma.cc/3RB7-VGNE.

107. *Elon Musk Company Neuralink Given Free Pass for Animal Welfare Act Violations, USDA Reveals in Letter to Congress, Physicians Committee for Responsible Medicine*, PHYSICIANS COMM. FOR RESPONSIBLE MED. (July 19, 2023), https://perma.cc/LK66-YF6R.

108. Levy, *supra* note 81.

109. *Id.*

110. *Id.*

111. Marisa Taylor, *Regulator Says Found No Animal Welfare Breaches at Musk Firm beyond 2019 Incident*, REUTERS (July 19, 2023, at 13:09 PDT), https://perma.cc/82VK-V9SA.

112. Marina Bolotnikova, *What's Worse than a Cruel Animal Experiment? A Cruel and Fake Animal Experiment.*, VOX (July 14, 2023, at 13:00 UTC), https://perma.cc/5VSB-HG3W (last visited Mar 10, 2024).

113. Levy, *supra* note 81.

III. EXISTING "REGULATION": THE DISAPPOINTMENTS OF THE ANIMAL WELFARE ACT

A. A Truncated History of the Animal Welfare Act

The modern deficiencies of the Animal Welfare Act (AWA) are better understood in light of its somewhat idiosyncratic history. Enacted in 1966, the AWA arose in response to years of lobbying by animal welfare organizations to protect against a very particular problem: the abduction of pets for sale and use in research facilities. A Dalmatian stolen in the summer of 1965 was in many ways the catalyst for the most impactful animal welfare legislation in the United States.[114] Prior to her abduction, Pepper worked alongside her owner at nursing homes and wards for handicapped children. A dogcatcher captured Pepper in Pennsylvania and sold her, alongside several other dogs, to a hospital looking for animals to use in vivisection and other experimental procedures. Pepper's owners eventually acquired her cremated body from a New York hospital that had used the Dalmatian in an experimental cardiac pacemaker implantation surgery.[115] *Sports Illustrated* reported on Pepper's story, and, soon after, a New York Congressman introduced the first version of the legislation: the "Laboratory Animal Welfare Act" (LAWA).[116]

LAWA's goals were narrowly tailored to preventing mistreatment of companion animals in research. The goals were stated as follows: "(1) to insure that animals intended for use in research facilities or for exhibition purposes or for use as pets are provided humane care and treatment; (2) to assure the humane treatment of animals during transportation in commerce; and (3) to protect the owners of animals from the theft of their animals by preventing the sale or use of animals which have been stolen."[117] To fulfill these narrow objectives, the original version of the Act codified an unintuitive definition of the term animal that implicitly excluded farm animals. Animal was defined to include only ""live dogs, cats, monkeys (nonhuman primate mammals), guinea pigs, hamsters, and rabbits."[118] To protect this limited group of animals, the Act mandated animal dealers and laboratories to conform to minimum standards of care. Research facilities that used cats and dogs were also required to register with the government and to create an identification system for the animals in an attempt to curb pet snatching.[119] In its first iteration, the LAWA was therefore narrowly tailored to

114. Daniel Engber, *Where's Pepper?*, SLATE (June 1, 2009, at 10:53 PT), https://perma.cc/83QP-D445.

115. *Id.*

116. *Animal Welfare Act Timeline*, NAT'L AGRIC. LIBR., https://perma.cc/NR55-XMW5 (archived Aug. 12, 2025).

117. Pub. L. No. 89-544, 80 Stat. 350 (1966) (codified as amended at 7 U.S.C. §§ 2131-2156).

118. *Id.*

119. *Id.*

appeasing lobbying groups and curbing a specific form of animal abuse.[120]

In a 1970 amendment of the Act, Congress modified the definition of animal, required greater regulation in research, and increased the Secretary of Agriculture's enforcement powers. Rather than affording protections only to the animals in the previously delineated categories, the Act broadened its definition of protected animals—now including "other warm-blooded animal[s]"—while more explicitly stating the animals it sought to exclude. The Act excluded farm animals "such as but not limited to livestock or poultry used or intended for use for improving animal nutrition, breeding management, or production efficiency, or for improving the quality of food or fiber" from its protections.[121]

The 1970 amendment also clarified—in spite of the more encompassing and forceful language used—that the Act was not intended to actually interfere with research.[122] "Nothing in this Act shall be construed as authorizing the Secretary to promulgate rules, regulations, or orders with regard to design, outlines, guidelines, or performance of actual research or experimentation by a research facility."[123] In effect, researchers' choice to use animals, often in needlessly cruel ways, was subject to no real scrutiny.

After being renamed the Animal Welfare Act in a 1976 amendment, the 1985 AWA marked the opening of the "laboratory door" to substantive regulation.[124] That is, in contrast to the 1970 amendment which made clear that research scientists still had the ultimate decision-making authority in designing experimental procedures, the 1985 amendment permitted the Secretary of Agriculture to create standards for experimental procedures "to ensure that animal pain and distress are minimized," which "include[ed the provision of] adequate veterinary care with the appropriate use of anesthetic, analgesic, tranquilizing drugs, or euthanasia." Researchers were also required to "consider alternatives to any procedure likely to procure any pain to or distress in an experimental animal."[125] The effect of the aforementioned provisions, however, was mitigated by an exception for all AWA standards when inhumane treatment was "specified by research protocol." Practically, researchers were required to merely *consider* alternatives to invasive procedures and, generally, to employ "professionally acceptable standards" in all experiments.[126]

Beyond articulating pain mitigation requirements in greater detail, the 1985 amendment also mandated some minimal quality of life standards for research animals. In one somewhat unusual amalgamation, the Act prescribes the

120. Andrew D. Cardon, Matthew R. Bailey & B. Taylor Bennett, *The Animal Welfare Act: From Enactment to Enforcement*, 51 J. AM. ASS'N LAB'Y ANIMAL SCI. 301, 302 (2012).

121. Pub. L. No. 91-597, 84 Stat. 1560 (1970) (codified as amended at 7 U.S.C. §§ 2131-2156).

122. *Id.*

123. *Id.*

124. *See* Henry Cohen, *The Animal Welfare Act*, 2 J. ANIMAL L. 12, 16 (2006).

125. *Id.*

126. *Id.*

"exercise of dogs . . . and for a physical environment adequate to promote the psychological well-being of primates." Coalescing the standards for nonhuman primates and dogs, particularly in the absence of any other animal-specific delineated standards, is perhaps indicative of the intentions of the 1985 AWA: hierarchical scaling of care for animals with arbitrarily higher moral status.

To implement the AWA, the 1985 Amendment required the creation of Institutional Animal Care and Use Committees (IACUCs), animal equivalents of institutional review boards, in each research facility.[127] IACUCs were tasked with at least semi-annual inspections of animal study facilities and review of all "practices involving pain to animals, and . . . the conditions of animals." The committees were also created to evaluate the protocols to be used by their home institution. Though IACUCs were given the responsibility to report noncompliance, the AWA also provided insulation for proprietary information: neither the research facility, nor the IACUCs, are required to "disclose publicly . . . trade secrets or commercial or financial information which is privileged or confidential."[128]

In sum, the AWA has evolved significantly, but not wholeheartedly, over the course of the twentieth century. That is, while the AWA had come to protect more than just dogs and cats by the start of the twenty-first century and had imposed some meaningful regulation on research scientists, many research procedures and animal subjects continue to remain outside of its control.

B. The Modern Animal Welfare Act: The Three-Pig System and Problems with Implementation

Given the AWA's legacy of exempting agricultural animals from full coverage and lukewarm intrusion into invasive experimental design, it is unsurprising that the modern statute fails to adequately protect pigs. This Subpart describes the three-pig system of coverage under the AWA and describes problems with the implementation of the statute at large.

The language of the modern AWA, as relevant to research, is as follows: "The term 'animal' [includes any] warm-blooded animal, which is being used, or is intended for use for research, teaching, testing, experimentation [but] excludes (1) birds, rats of the genus Rattus, and mice of the genus Mus, bred for use in research, (2) horses not used for research purposes, and (3) other farm animals, such as, but not limited to livestock or poultry used or intended for use as food or fiber, or livestock or poultry used or intended to be used for improving animal nutrition, breeding, management, or production efficiency."[129]

The AWA thus effectively divides pigs into three categories: (1) pigs raised

127. Pub. L. No. 99-198, 99 Stat. 1645-1650 (1985) (codified as amended at 7 U.S.C. §§ 2131-2156).

128. *Id.*

129. 7 U.S.C. § 2132.

for meat (livestock), (2) pigs used for agricultural research, and (3) pigs used for non-agricultural research. Pigs in the former two categories are exempted from coverage under the AWA, while pigs in the final group receive coverage under the statute. This three-pig system may seem straight-forward enough, but the reality is more complicated. The latter two categories—agricultural-research pigs and non-agricultural research pigs—often bleed into one another, making it difficult to define regulatory coverage. Studying endocrinology in pigs, for example, can arguably be classified as agricultural, if done to improve pig breeding, or as non-agricultural, if used to better understand human hormonal signaling.[130] Pigs' coverage under the AWA hence may be contingent on a somewhat arbitrary classification of research as agricultural or non-agricultural.[131] Additionally, as evidenced by the BrainEx study, pigs raised for meat (falling into the first category) may still be used for research. There, the partially revived brains were acquired from pigs slaughtered for food.

Coverage under the AWA for some pigs is certainly better than nothing, but coverage should not be taken to be a panacea for ethically dubious pig research. Pigs used in non-agricultural research still fail to receive adequate protection, even though the AWA applies to them. IACUCs are, among other duties, responsible for evaluating research projects to ensure that they comply with the Department of Agriculture's (USDA's) standards. But IACUCs are unable to properly review experimental protocols if board members do not have access to tailored regulatory standards. Such is the case for pigs. As articulated by the members of the Pig Welfare Working Group, a stakeholder group composed of members across six countries, because pigs are a "common food animal species, pigs generally have not received the same attention to their welfare [from IACUCs] . . . The environment and interactions that will promote positive experiences for pigs and personnel in a biomedical facility have not been well-studied."[132] Indeed, the Guide for the Care and Use of Laboratory Animals (hereinafter the Guide)—the guidebook of standards used by IACUCs—only provides "general comments" on the use of pigs.[133] The historical flippancy towards pig welfare is readily contrasted with the extensive (and appropriate) regulation of nonhuman primates in neuroscience research.[134] The Guide provides specific

130. *See* Joseph D. Thulin & Wendy J. Underwood, *IACUC Considerations for the Use of Livestock in Translational Research*, 56 INST. LAB'Y ANIMAL RSCH. J. 139, 140 (2015) ("[A]gricultural research explores subjects with parallels in human medicine, for example, nutrition and endocrinology. Therefore, IACUCs, particularly at land grant academic institutions, should be open to the possibility that some T1 research involving livestock might . . . not be subject to the provisions of the [AWA].")

131. *Id.*

132. Lois M. Wilkinson et al., *Using Stakeholder Focus Groups to Refine the Care of Pigs Used in Research*, 62 J. AM. ASS'N LAB'Y ANIMAL SCI. 123, 124 (2023).

133. *Id.*

134. See Renée Hartig et al., *A Framework and Resource for Global Collaboration in Non-Human Primate Neuroscience*, CURRENT RSCH. NEUROBIOLOGY, Feb. 17, 2023, at 2 ("[Nonhuman primate] neuroscience research is strictly regulated around the world and work

instruction on how to conduct neuroscience research in nonhuman primates in a manner that produces the least harm, including the careful administration of analgesics.[135] As described in Part II, pig pain assessment and management remains suboptimal across all fields of research but particularly in neuroscience.[136]

Furthermore, IACUCs often misapply the AWA framework to research involving pigs. The AWA adopts the replacement, reduction, and refinement (3Rs) approach to animal research.[137] Replacement, the R pertinent to the present discussion, recommends that researchers use a "lower species of animal" if non-animal models are not available.[138] Problematically, in neuroscience research, pigs have been considered to be a "lower species," which is perceived to mitigate ethical problems.[139] One study on adolescent brain development declared that "[p]igs are less complex than non-human primates thus satisfying the 'replacement' principle of animal research."[140] For the reasons described in the first Part of this Note, this assertion is incorrect or at the very least misleading: pigs are at least as cognitively complex, or sometimes more complex, than some nonhuman primates. Meaningful AWA regulation for pigs in biomedical research is thus stifled by both a flawed application of the replacement principle and a lack of comprehensive pig-specific Guide standards.

Insufficient regulation is also attributable to more general problems with the administration of the AWA: namely, the bias of IACUCs, the lack of private causes of action for enforcement, and the implied preemption of state animal cruelty suits. As to the first, IACUCs are far from unbiased regulatory bodies. A report published in the Journal of Medical Ethics observed that "IACUCs at [American] research institutions are dominated by animal researchers and institutional employees whose livelihoods are linked to animal research."[141] A recent survey of the top twenty-one National Institutes of Health (NIH)-funded research institutions found that eighty-two percent of committee members and ninety-three percent of chairpersons leading IACUCs participate in animal research.[142] Other studies have found that in-house approval rating of research proposals was

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with [nonhuman primates] requires appropriate species-specific knowledge and individual animal oriented expert care and specialized training.")

135. NAT'L RSCH. COUNCIL, GUIDE FOR THE CARE AND USE OF LABORATORY ANIMALS (8th ed. 2011).

136. *See* Sarah H. Ison et al., *A Review of Pain Assessment in Pigs*, FRONTIERS VETERINARY SCI., Nov. 28, 2016, at 1; Bradbury, Eddleston, and Clutton, *supra* note 90, at 37.

137. 7 U.S.C. § 2143.

138. Ricki J. Colman et al., *Marmosets: Welfare, Ethical Use, and IACUC/Regulatory Considerations*, 61 INST. LAB'Y ANIMAL RSCH. J. 167, 169 (2021).

139. Hoffe and Holahan, *supra* note 8, at 4 ("With the ethical issues surrounding testing on nonhuman primates, there was a shift toward using the device on large animals such as pigs.").

140. Meghann C. Ryan et al., *Miniature Pig Model of Human Adolescent Brain White Matter Development*, 296 J. NEUROSCI. METHODS 99, 99 (2018).

141. Lawrence Arthur Hansen, *Institution Animal Care and Use Committees Need Greater Ethical Diversity*, 39 J. MED. ETHICS 188, 188 (2013).

142. *Id* at 189.

ninety-eight percent, but, when the same research proposals were blinded and sent to other institutions, the approval rating dropped to sixty-one percent.[143] Non-in-house IACUCs criticized the research design in the unapproved proposals, finding researchers' justifications for the type and number of animals intended for use in their studies "not very convincing or not convincing at all."[144]

As described by Pamela Frasch, founder of the Center for Animal Law Studies at Lewis and Clark Law School, a further problem with the structure of the AWA lies in the absence of a private cause of action.[145] These causes of action, also known as citizen suit provisions, allow private citizen plaintiffs to bring lawsuits for violations of a statute. Without a private cause of action, it is difficult to achieve standing in animal welfare suits: human plaintiffs can rarely prove that they suffered direct and concrete harm as a consequence of a statute designed to protect animals. Other animal welfare legislation, including the Endangered Species Act, includes a private right of action, but the creation of this right for the AWA was specifically rejected in *International Primate Protection League v. Institute for Behavioral Research*.[146] There, plaintiffs alleged that, in violation of the AWA, the defendant failed to provide adequate food, water, sanitation and veterinary care to nonhuman primates in their research laboratory.[147] The Fourth Circuit concluded that the case failed to meet standing, reasoning that recognizing a private cause of action under the AWA would interfere with medical advancement.[148] Judge Wilkinson interpreted the AWA's goal of animal welfare supervision as being "subordinat[e] . . . to the continued independence of research scientists."[149] He thus concluded that enforcement authority for the AWA does not extend beyond the USDA administrative apparatus.[150]

The final problem with coverage under the AWA, again articulated by Frasch, is not a problem with the statute itself but rather with how the statute may be interpreted to preclude other forms of laboratory regulation.[151] In *Taub v. State*, Maryland's highest state court overturned a conviction for animal cruelty under state law, citing the AWA. The Court reasoned that, because the AWA provides a comprehensive plan for protecting animals used in research facilities, the Maryland legislature had contemplated the existence of the AWA in the enactment of their animal cruelty statute.[152] As such, the court determined that

143. *Id.*

144. *Id.*

145. Pamela D. Frasch, *Gaps in US Animal Welfare Law for Laboratory Animals: Perspectives from an Animal Law Attorney*, 57 INST. LAB'Y ANIMAL RSCH. J. 285, 287 (2016).

146. Katharine M. Swanson, *Carte Blanche for Cruelty: The Non-Enforcement of the Animal Welfare Act*, 35 U. MICH. J. L. REFORM 937, 944 (2002).

147. *Id.*

148. Frasch, *supra* note 145, at 287.

149. *Id.*

150. *Id.*

151. Frasch, *supra* note 145, at 287.

152. *Id.* at 288.

Maryland's animal cruelty statute implicitly exempted enforcement against research facilities.[153] In other words, some courts have chosen to limit the application of state animal cruelty statutes to research animals on the grounds that the AWA comprehensively regulates the field.

As illustrated by this Part, the regulatory framework surrounding pigs in neuroscience is simultaneously complex and insubstantial. Two groups of pigs—pigs raised for meat and those used in "agricultural" research, often defined broadly—are exempt from coverage. The remaining group, pigs used in biomedical research, often fail to receive adequate protections because of a combination of pig-specific shortcomings with the AWA and broader issues pertaining to enforcement.

IV. CLOSING THE LOOPHOLE: COMPREHENSIVE ANIMAL WELFARE ACT REFORM

Prior to describing methods to amend the Animal Welfare Act, I should preface this Part by restating that this Note maintains a discrete goal: remedying the particularly egregious exclusion of pigs from protection in translational neuroscience research. This narrow goal should not be taken to indicate my support for the AWA but-for the under-protection of pigs. I support the inclusion of all sentient organisms under the protection of a fortified AWA and see addressing the issue of pig welfare in neuroscience as one *realistic* step towards broader change.

Animal rights organizations have been working for years to include mice, rats, and birds—a staggering ninety-five percent of research animals—under the AWA to no avail.[154] For practical, but nonetheless morally illegitimate reasons, it is unlikely that any of the 111.5 million mice and rats used in laboratory research will be subject to protections anytime soon.[155] As stated by a former USDA official, the animals are simply too numerous to be subject to any real regulation without substantial additional investment of resources: "The math just did not allow it."[156]

Regulation of other research animals under the AWA, in contrast, seems more plausible. The Animal and Plant Health and Inspection Service (APHIS), which administers the AWA, has suggested that "evolving" perceptions of animal welfare and wildlife are placing "increasing pressure on related government activities." In APHIS's report analyzing trends affecting the organization over the next twenty to thirty years, the review predicts that "APHIS will be challenged by the increasingly blurred line between livestock and pets [because the]

153. *Id.*

154. Daniel Engber, *Some Animals Are More Equal Than Others*, SLATE (Apr. 11, 2016, at 11:51 PDT), https://perma.cc/4CKX-GZRG.

155. Larry Carbone, *Estimating Mouse and Rat Use in American Laboratories by Extrapolation from Animal Welfare Act-Regulated Species*, SCI. REPS., Jan. 12, 2021, at 1, 2.

156. Engber, *supra* note 154.

public is more interested in wildlife and livestock welfare."[157]

The solutions I discuss in this Part are therefore designed to address the more specific, and relatively more achievable, goal of closing the pig-brain-sized loophole in our neuroscience research. Pig brains, of course, cannot be saved in a vacuum, so many of the solutions I put forward will have broader implications despite their narrow targeting. I propose three broad reforms to the AWA: (A) restructuring the coverage of the statute to better include pigs, (B) strengthening the administrative apparatus to increase enforcement, and (C) reforming IACUC approval procedures to more appropriately limit the use of invasive neuroscience research.

A. Expanding Coverage Under the AWA

While pigs could be inserted into the definition of "animal" in the AWA in a piecemeal way, I recommend, in the spirit of broader animal protection and greater logical consistency, adopting one of three constructions: (1) straightforward protection of agricultural animals (including former livestock) in all research settings, (2) a formalist protection of animals with gyrencephalic brains, or (3) a functionalist option that protects animals with cognitive capacities akin to those of nonhuman primates. A prerequisite for the implementation of any of these constructions is eliminating the three-pig system—livestock, agricultural research pigs, and non-agricultural research pigs—and creating a simplified two-pig system: pigs used in any form of research (agricultural and non-agricultural, living and dead) and pigs used exclusively for consumption. Practically, this would entail replacing the current language that excludes "other farm animals" from protection with language that excludes only "farm animals not used for any research, testing, or experimentation purposes."[158]

The first approach to amending the AWA does not require making any changes beyond changing the exemption described above. As "animal" is already defined to include "warm-blooded animal[s], as the Secretary may determine is being used, or is intended for use, for research testing experimentation," all warm-blooded animals agricultural used for research would be subject to protection under the AWA.[159] This approach beneficially affords protection to *all* agricultural animals. And this broader protection is important because other agricultural animals, beyond pigs, are also gaining traction as models for neuroscience research. Older cows, for example, exhibit the pathology of Alzheimer's disease.[160]

157. ANIMAL & PLANT HEALTH INSPECTION SERV., PLANNING FOR THE FUTURE: AN ANALYSIS OF TRENDS AFFECTING APHIS AND U.S. AGRICULTURE OVER THE NEXT 20–30 YEARS, at 10 (2023).

158. I am assuming that the wholesale elimination of the farm animal exemption is impossible.

159. 7 U.S.C. § 2132.

160. Ines Moreno-Gonzalez et al., *Aged Cattle Brain Displays Alzheimer's Disease-Like*

The second approach, formalist in nature, seeks to protect all animals with gyrencephalic brains. Instead of current language that provides for regulation of listed species "or such other warm-blooded animal," the language should be amended to provide for regulation of listed species "or such other warm-blooded and/or gyrencephalic animals." As compared to the first approach, specifying the protection of gyrencephalic animals carries several benefits. From an expressive perspective, it highlights a key phenotypic commonality between studied animals. And, in terms of practical benefits, coverage of gyrencephalic animals could function to protect animals previously excluded from coverage under the AWA. Gyrencephalic cold-blooded animals, like highly intelligent octopi, for example, could receive protection based on their gyrification index.[161] Additionally, studies that involve rodents that are engineered to be gyrencephalic would be subject to regulation. While these rodents represent a small portion of studies, the sensitive nature of the experimentation makes associated protocols ripe for regulation.[162]

The final, functionalist approach would cover animals with cognitive capacities similar to nonhuman primate mammals. Animal would therefore be defined as "any live or dead dog, cat monkey (nonhuman primate mammal) or an animal with a similar cognitive capacity to a monkey." On its face, this construction would not appear to be significantly different that the first approach, but, in actuality, this phraseology could be beneficial during IACUC review of experiments involving pigs. Protocols using nonhuman primates are subject to greater scrutiny than protocols involving "lesser species."[163] By linking monkeys and pigs—animals with an equivalent cognitive capacity—in the same clause of the AWA, IACUCs may be required to practice similar caution in approving pig studies as they would in their consideration of procedures involving monkeys. For example, the AWA specification that primates are to be provided a "physical environment adequate to promote [their] psychological well-being" may also be applicable to pigs or other animals with a similar cognitive capacity to

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Pathology and Promotes Brain Amyloidosis in a Transgenic Animal Model, FRONTIERS AGING NEUROSCI., Jan. 31, 2022, at 1, 6-7 ("The results of this study show that some old cows spontaneously develop amyloid deposits in their brain. Interestingly, these deposits were similar to those present in human cases of [Alzheimer's disease].")

161. *See* Wen-Sung Chung, Nyoman D. Kurniawan & N. Justin Marshall, *Comparative Brain Structure and Visual Processing in Octopus from Different Habitats*, 32 CURRENT BIOLOGY 97, 104-105 (2022) ("[D]iurnal reef octopuses possess gyrencephalic [optic lobes] and [vertical lobes] with relatively high [gyrification index] . . . apparent adaptations that go with complex visual tasks and partially social interaction in a complex, well-lit environment.")

162. Achira Roy et al., *PI3K-Yap Activity Drives Cortical Gyrification and Hydrocephalus in Mice*, ELIFE, May 16, 2019, at 1, 2. To better understand hydrocephalus, a neurological disorder involving the abnormal buildup of cerebrospinal fluid in the brain, researchers induced gyrification in mice.

163. *See* Suzette D. Tardif et al., *IACUC Review of Nonhuman Primate Research*, 54 INST. LAB'Y ANIMAL RSCH. J. 234, 234 (2013) ("Nonhuman primates (NHPs) have a unique position in biomedical research related to their close phylogenetic proximity to humans.")

monkeys.[164]

B. Strengthening the AWA Administrative Apparatus

Coverage under the AWA, although symbolically important, is ultimately irrelevant if enforcement mechanisms are inadequate. Improving the AWA administrative apparatus is contingent upon: (1) the substantive amendment of IACUC membership, (2) the creation of a private cause of action, and (3) ending implied preemption.

IACUCs that are composed of over eighty percent animal researchers fail to provide sufficient deference to animal welfare. Per the AWA, an IACUC must have at least three members: at least one member is required to be a veterinarian, and at least one other member must "provide representation for general community interests in the proper care and treatment of animals" and may not be affiliated with the research facility.[165] The AWA does not specify board composition beyond the third member.[166] Consequently, small boards may appropriately balance animal welfare interests but larger boards, composed of increasing numbers of animal researchers, routinely fail to do so.[167] The AWA should be amended to require that a greater proportion of board members represent animal interests. Practically then, I would suggest that at least every third additional member of an IACUC, beyond the original three, be an animal welfare representative. This solution roughly maintains the ratio of interests originally prescribed by the AWA.

Additionally, the provision of a private cause of action would support greater accountability under the AWA. Although it is difficult to determine the exact number of lawsuits that have been initiated under the Endangered Species Act's citizen suit clause, the litigation costs paid on behalf of the government provide a sense of the enforcement power of a private cause of action. A 2012 report from the U.S. Government Accountability Office found that the federal government paid over twenty-one million dollars in litigation costs under the Endangered Species Act.[168] Shifting enforcement power to concerned citizens, rather than placing this power exclusively in the hands of the USDA, will likely bolster the administration of the AWA.

Similarly, the AWA should be amended to include a saving clause that unambiguously permits the enforcement of state animal cruelty laws. Although Congress stated that the AWA "shall not prohibit any State . . . from

164. 7 U.S.C. § 2132.

165. *Id.*

166. The AWA specifies that additional board members cannot be from the same department but does not add any interest-based requirements.

167. Hansen, *supra* note 141, at 189.

168. *Endangered Species Act Litigation*, BALLOTPEDIA, https://perma.cc/9WD9-WDH7 (archived Aug. 12, 2025).

promulgating standards in addition to those standards promulgated by the Secretary,"[169] a "myth of AWA preemption" is perpetuated by judges (including Judge Wilkinson in *Taub*).[170] For the sake of thoroughness, despite the absence of actual preemption, an amended AWA should make clear that the statute allows states to develop and enforce more stringent regulations on laboratory research. Doing so would, in tandem with the other enforcement provisions, function to improve lab animal welfare.

C. Creating More Rigorous Approval Standards for Neuroscience Research

The previously discussed reforms, while critical in improving the applicability of the AWA to pigs and its enforceability more broadly, do not specifically address the issue of neuroscience research. This final reform seeks to address this problem by delineating an IACUC review protocol that requires research involving neuroscience to be reviewed with greater caution. The specific procedures that IACUCs use to review protocols are opaque and vary from institution to institution.[171] To standardize approval procedures across institutions, and to promote the more careful consideration of invasive brain research, I recommend that neuroscience proposals be subject to a strict scrutiny test that I detail below.

In constitutional law, scrutiny tests are applied by courts to assess the constitutionality of actions taken by the legislature. Under strict scrutiny, a test applied in some equal protection challenges and First Amendment cases, the court presumes that a government action is unconstitutional.[172] The government may only prevail if it provides a compelling justification for its end and demonstrates that the use of the constitutionally suspect means was narrowly tailored to achieving that end. Analogously, IACUCs, in assessing neuroscience research protocols, should presume that neurologically invasive experiments are disallowed under the AWA. However, a researcher can ultimately receive institutional support for the research if they offer a (1) compelling justification for their experiment and (2) show that the proposed methodology is narrowly tailored to achieve that end.

The presumption against the approval of neuroscience research may seem to make research authorization unduly cumbersome, but this procedural safeguard is necessary to preserve the dignity of animals used in neuroscience research. This strict scrutiny test would theoretically function to prevent studies that are derivative in their ends or employ needlessly harmful techniques. Consider the blast injury paper examined earlier in this Note. In that study, researchers

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169. *Id.* at 186.

170. Ani B. Satz & Delcianna Winders, *Animal Welfare Act: Interaction with Other Laws*, 25 ANIMAL L. REV. 185, 185 (2019).

171. *The IACUC*, NAT'L INST. HEALTH, https://perma.cc/J2U9-DZWY (last updated Oct. 30, 2024).

172. *Strict Scrutiny*, LEGAL INFO. INST., https://perma.cc/VY4F-3U2Q (archived Aug. 12, 2025).

measured electrical activity in the brain following close-range traumatic brain injury involving the detonation of C4.[173] If the strict scrutiny test were to be applied to that research, I think it would be unlikely that it would have a compelling enough end. The experiment seemingly lacked novelty: the study replicated (or nearly replicated) the results of studies observed in both goats and humans.[174] Furthermore, in the stroke studies contemplated earlier, the application of the strict scrutiny test would preclude the use of outdated induction procedures like eye enucleation.[175] Instead, to satisfy the tight ends-means fit of strict scrutiny, a researcher would be required to utilize the modern, catheter-driven approach that minimizes harm to animals.[176]

Provided that the IACUC is composed of members that take animal welfare seriously, the application of a strict scrutiny test for neuroscience research should encourage researchers to design more compassionate research procedures for all brains, including oft-forgotten pig brains.

CONCLUSION

In this golden age of neuroscience, pigs have arisen—by way of necessity or choice—as a prized research model. Gyrencephalic pig brains effectively recapitulate much of the development and pathology of human brains, allowing researchers to study strokes, Alzheimer's disease and traumatic brain injury. Inducing these ailments often requires the use of invasive experimental procedures in brains that are highly similar to our own.

The current neuroscience research regulatory scheme defies the basic intuition that some correlation exists between the protections afforded to brains and their complexity. The Animal Welfare Act, a statute with a legacy of arbitrarily favoring companion animals over similarly intelligent animals and a sometimes-pernicious hesitance to intrude into laboratory research, divides pigs into three categories. Pigs used for food and pigs utilized in ostensibly agricultural research do not receive coverage under the Animal Welfare Act. And, even for pigs that do receive coverage, the actual protections tend to be paltry: pigs have historically been given little consideration as lab animals, culminating in an absence of pig-specific welfare standards and a general misunderstanding of porcine intelligence and sentience.

This Note proposes solutions to amend both the pig-particular, as well as some of the broader, problems with the Animal Welfare Act. Remedying current deficits requires covering all research pigs under the statute, improving the enforceability of the Act, and architecting new neuroscience-specific IACUC standards that afford complex brains the deference they deserve. These reforms,

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173. *See* Chen et al., *supra* note 92, at 121.
174. *Id.*
175. *See* Melià-Sorolla et al., *supra* note 80, at 7.
176. *See* Le Bras, *supra* note 103, at 114.

however, should not be taken to correct all the ills of animal research. Poorly regulated neuroscience research in pigs is part of a larger problem of unfettered animal research done without due care for animal welfare. Closing the pig-brain-sized loophole in neuroscience research should be one of the first, but most definitely not the last, steps in creating a more ethical regulatory framework that values all animals, including creatures with brains very unlike our own.