REGULATING THE 3D PRINTING OF MEAT: ANIMAL ETHICS, ENVIRONMENTAL BENEFITS, AND HUMAN HEALTH ISSUES IN CANADIAN LAW

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Abstract

The fates of animals, human health, and the environment are entwined. The prevalence of COVID-19 and other zoonoses has only made such a reality more evident. Animal advocates and environmentalists have long called for reductions—if not the elimination—of industrial agriculture to stem the tide of animal abuse and environmental degradation. Similarly, health advocates have called for major changes to the typical Western diet, which is heavily reliant on animal protein, to improve overall health. The novel use of 3D printing to create animal proteins may be the catalyst to change these advocates seek. 3D printing of animal protein would remove the cruelty component animals suffer in the industrial agriculture context and perhaps make the consumption of animal protein healthier and more sustainable. But this new technology is fraught with concerns: costs may be exorbitant, food security is uncertain, and the regulation of these products must be addressed. This paper seeks to address some of these regulatory issues.

I INTRODUCTION

The fates of and relationships among non-human animals (animals), human health, and the environment are invariably entwined. The prevalence of zoonoses, including COVID-19 and other coronaviruses, which affect animals and humans alike, has only made such a reality in the Anthropocene era more evident. There is no question that there will be another zoonoses-induced pandemic; there are currently hundreds of coronaviruses and other zoonoses being tracked by the World Health Organization.[1] Instead, the question is merely *when* it will occur, and can anything be done to mitigate the consequences that will inevitably follow?[2] COVID-19 has laid bare for the general public the problems of industrial agriculture (and other animal consumption issues) and its impact on and contribution to zoonoses, with one claim putting the expected number of spillover events at four times and human mortality at twelve times the rate of COVID-19 by 2050.[3]

Problems associated with industrial agriculture existed long before the COVID-19 pandemic. Animal advocates, environmentalists, and epidemiologists have, for decades, been calling for drastic reductions—if not the elimination—of industrial agriculture (or "factory farms") to stem the tide of continued animal abuse, cruelty, harm, and suffering; environmental degradation; and increased threats to human health.[4] Similarly, human health advocates have called for major changes to (if all not altogether the elimination of) the typical Western diet—which is heavily reliant on animal protein, dairy, and animal by-products—as a way to improve

1. See World Health Organization, "Epidemic and Pandemic-Prone Diseases" (2024), online: <https://www.emro.who.int/entity/pandemic-epidemic-diseases/index.html> [perma.cc/SS8X-XWYK].

2. See e.g. Jennifer B Nuzzo & Lawreince O Gostin, "The First 2 Years of COVID-19: Lessons to Improve Preparedness for the Next Pandemic" (2022) 327:3 JAMA 217–218.

3. See Amanda Jean Meadows et al, "Historical Trends Demonstrate a Pattern of Increasingly Frequent and Severe Spillover Events of High-Consequence Zoonotic Viruses" (2023) 8:11 BMJ Global Health 1 at 3.

4. See e.g. Rob Wallace, *Big Farms Make Big Flu: Dispatches on Influenza, Agribusiness, and the Nature of Science* (New York: Monthly Review Press, 2016).

overall human health and to extend life expectancy.[5] Advancements in technology may finally be offering a solution to these complex problems, but they are not panaceas and they are not without problems of their own.[6]

Different from laboratory-cultivated meat, the use of novel 3D printing[7]—a complex process using computer technology and "ink" made from animal cells—to create animal proteins or "meat" may, however, catalyze the changes these advocates seek. Although initially generated from animal deoxyribonucleic acid (DNA), like laboratory-cultivated meat, 3D printing of animal protein might minimize the harm, cruelty, and abuse animals suffer in the industrial agriculture context; reduce the threat of zoonoses-induced pandemics; and perhaps make the consumption of animal protein healthier and more sustainable for humans and the planet. 3D printing might be described as a "promissory narrative," because it encapsulates and articulates the potential of novel technology and outlines the benefits it may offer to individuals, society, the environment, and the economy.[8] This new technology is, however, fraught with concerns: costs are exorbitant, food security is uncertain around the world, intellectual property concerns emerge, and the regulation of these products is unsettled and needs to be addressed.[9] Despite these concerns, this possibility offers a chance to save animals, humans, and the planet and is one that we explore in this article through the perspectives of animal ethics, environmental law, and human health law. In section II we explain our theoretical framework. In Section III we discuss the basics of 3D printing technology, and in section IV we address some of the practical problems that 3D printing may solve. Finally, in section V we identify and review the regulation of 3D printing technology.

II THE THEORETICAL FRAMEWORK

A. Animal Ethics and Moral Consideration

Animal ethics exist on a wide spectrum. Simply stated, the spectrum begins with animal welfare advocacy at one pole and ends with animal personhood and legal rights at the other. In the context of this article, we fall somewhere in the middle by adopting American philosopher Tom Regan's notion that animals have inherent value and exist as "subjects of a life."[10] Stated differently, animals are *sentient*: They can feel and have an interest in avoiding harm and in seeking pleasure—just like humans. Largely because of this sentience, it is morally

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5. See DI Givens, "Review: Dairy Foods, Red Meat and Processed Meat in the Diet: Implications for Health at Key Life Stages" (2018) 12:8 Animal 1709 at 1717; DI Givens, "Milk and Meat in Our Diet: Good or Bad for Health?" (2010) 4:12 Animal 1941 at 1952. See generally Eleni Linos & Walter Willett, "Meat, Dairy, and Breast Cancer: Do We Have an Answer?" (2009) 90:3 Am J of Clinical Nutrition 455.

6. See Sergiy Smetana et al, "Meat Alternatives: Life Cycle Assessment of Most Known Meat Substitutes" (2015) 20:9 Int'l J Life Cycle Assess 1254 [Smetana et al].

7. See generally Jian-Yuan Lee et al, "Fundamentals and Applications of 3D Printing for Novel Materials" (2017) 7 Applied Materials Today 120; See Zhenbin Liu et al, "3D Printing: Printing Precision and Application in Food Sector" (2017) 69 Trends Food Sci & Tech at 83.

8. Deborah Lupton & Bethaney Turner, "Food of the Future? Consumer Responses to the Idea of 3D-Printed Meat and Insect-Based Foods" (2018) 26:4 Food and Foodways 269 at 270 [Lupton & Turner].

9. See e.g. Jasper L Tran, "3D-Printed Food" (2016) 17:2 Minn JL Sci & Tech 855 [Tran]. See also Jasper L Tran, "The Law and 3D Printing" (2015) 31:4 John Marshall J Info Tech & Privacy L 505.

10. Tom Regan, *The Case for Animal Rights* (Berkeley: University of California Press, 1983).

inconsistent to argue that humans deserve moral consideration in the form of legal (and human) rights because of sentience and to argue that animals cannot enjoy the same or similar consideration simply because they are non-human. Such an inconsistency is a classic example of speciesism, which is insidious because it mirrors the racism, sexism, homophobia, ableism, and other forms of prejudice and discrimination extant in Canadian society.[11] Thus, again, while we do not take a position on the sometimes-viewed-as-extreme argument that animals are entitled to personhood and legal rights, we do acknowledge and recognize that animals are more than merely moveable property and deserve *greater* moral consideration than they have historically and modernly been accorded by Canadian society. Altogether, the kind of moral consideration we give to humans in our society is the kind of moral consideration we give to animals in this article. Our approach is therefore more closely akin to Indigenous notions of the comity of all living beings, including the totality of the environment, and the concept of "One Health" than it is to Western notions of animals as resources and the property of the human species. The "One Health" approach is a conceptual one that emphasizes the interdependence of humans, animals, and ecosystems.[12] "One Health" seeks to promote broad cross-disciplinary research, collaboration, and communication to expansively deal with complex health issues, such as infectious diseases, antimicrobial resistance, food safety, and environmental degradation.[13] In brief, we adopt the position that animals have inherent value, and in giving them moral consideration they deserve, as much as possible, to be free from harm, cruelty, suffering, and abuse in our interconnected world. As a result, as a form of greater moral consideration we explore whether the novel 3D printing of meat may lessen the harm, cruelty, suffering, and abuse animals currently endure in Canada and internationally (even if the goal is to eventually grant them legal personhood and rights).

B. The Precautionary Principle

We also root our discussion in the well-known precautionary principle in environmental and human health law as the technology being scrutinized here is novel in that it is still developing. In its most basic form, the precautionary principle holds that any substance or activity posing a threat or harm to the environment and its inhabitants is to be prevented from realizing that threat, even if scientific proof linking that particular substance or activity to that environmental threat(s) and harm is lacking.[14] The UN *World Charter for Nature*[15]—for which

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11. See Gary L Francione, "Animals—Property or Persons?" (2004) Rutgers University School of Law–Newark, Working Paper No 21 at 30, online: <https://law.bepress.com/rutgersnewarklwps/art21> [perma.cc/C4RP-VVY4].

12. World Health Organization, "One Health" (23 October 2023), online: <https://www.who.int/news-room/fact-sheets/detail/one-health> [http://perma.cc/95DX-JKEN].

13. *Ibid*. See also Elina Horefti, "The Importance of the One Health Concept in Combating Zoonoses" (2023) 12:8 Pathogens 1 at 1; Jakob Zinsstag et al, "Advancing One Human–Animal–Environment Health for Global Health Security: What Does the Evidence Say?" (2023) 401:10376 Lancet 591 at 592.

14. *114957 Canada Ltée (Spraytech, Société d'arrosage) v Hudson (Town)*, 2001 SCC 40 at paras 31–32. See also James Cameron & Juli Abouchar, "The Precautionary Principle: A Fundamental Principle of Law and Policy for the Protection of the Global Environment" (1991) 14:1 BC Int'l & Comp L Rev 1 at 2 [Cameron & Abouchar].

15. *World Charter for Nature*, 28 October 1982, UN A/RES/37/7 (entered into force 9 November 1982), online: <https://digitallibrary.un.org/record/39295> [*World Charter for Nature*].

Canada voted in favour[16]—enshrines this principle by declaring that "[a]ctivities which are likely to pose a significant risk to nature shall be preceded by an exhaustive examination; their proponents shall demonstrate that expected benefits outweigh potential damage to nature, and where potential adverse effects are not fully understood, the activities should not proceed."[17] The precautionary principle, as we understand it here, therefore acts a *guiding* principle that encourages decision makers to consider potential harmful effects of those substances and activities before engaging with or undertaking them.[18]

We do not, however, take a specific position on the precautionary principle itself (of which there are several contentious ones to take) other than the use of 3D printing technology is novel and that from a risk-management perspective proceeding *with caution* is better than proceeding without caution. Such an approach is not uncommon in the environmental and human health context.[19] For example, in a long-running trade dispute at the World Trade Organization, the European Union banned the importation of hormone-treated beef (shown to have cancer-related and other negative impacts on human health) produced in the United States and Canada on the basis of the precautionary principle.[20] If the use of hormones in animal husbandry is a source of concern, then artificially produced meat (and other food for human consumption) is likely to be one as well, both domestically and abroad, among legal authorities and consumers alike. Thus, recognizing and acknowledging that the precautionary principle has been the subject of controversy, we still nonetheless suggest it as an appropriate framework through which to consider some of the legal issues involved in the 3D printing of meat because of the largely unknown risks such technology may currently present to animal, environmental, and human health.[21]

III THE BASICS OF 3D PRINTING TECHNOLOGY

3D printing of meat and cultivated meat are similar but invoke different technologies. Both are manufactured or artificially produced meat based on cells derived from real animals. Both represent opportunities to decrease land, water, and energy use; reduce greenhouse gas emissions (GHG); lessen environmental pollution; potentially improve the health and safety of human diets; and promote animal welfare,[22] but to what extent remains unclear in the relative infancy of 3D printing technology. While we focus primarily on the 3D printing of meat, it is impossible to adequately discuss one without the other. We first briefly discuss cultivated

16. UNGA, 37th Sess, UN Doc A/37/PV.48 (1982) at 843 (voting record), online: <https://digitallibrary.un.org/record/755004?ln=en&v=pdf> [perma.cc/Q49Y-3XMA].

17. *World Charter for Nature*, *supra* note 15 at 18.

18. Cameron & Abouchar, *supra* note 14 at 2.

19. See e.g. Owen McIntyre & Thomas Mosedale, "The Precautionary Principle as a Norm of Customary International Law" (1997) 9:2 J Envtl L 221.

20. See Michael Balter, "Scientific Cross-Claims Fly in Continuing Beef War" (1999) 284:5419 Sci 1453 at 1453. See also Janet Rosenbaum, "A Case Study of the Application of the Precautionary Principle in US-EEC Trade of Beef from Hormone-Treated Cattle" (1999), online: <https://ideas.repec.org/p/osf/socarx/xrj96.html> [perma.cc/QT4P-NCGZ].

21. See Kenneth Foster, Paolo Vecchia & Michael Repacholi, "Science and the Precautionary Principle" (2000) 288:5468 Sci 979 [Foster et al].

22. Xudong Guo et al, "3D Bioprinting of Cultured Meat: A Promising Avenue of Meat Production" (2023) 17:7 Food & Bioprocess Tech 1659 at 1661 [Guo].

meat and then discuss the 3D printing of meat. It is also useful to note that the global 3D printing market, generally, "is expected to expand to $230–550 billion USD by the end of 2025,"[23] "the global protein analog market is expected to reach $7.5 billion USD around the year 2025,"[24] and that the global market for lab-grown meats is the fastest growing segment in the food industry and is expected to reach $140 billion by 2030.[25] Another scholar put it slightly differently: "[I]n a near future unconventional protein sources are likely to represent an increasing competitive alternative for inferior meat cuts and processed meats made from meat by-products."[26]

A. Cultivated Meat

Cultivated meat (also known as lab-cultured or cell-based meat), which cultivates animal cells in a laboratory setting, emerged prior to the 3D printing of meat as an alternative to industrialized meat.[27] Simply described, the typical method involves first isolating and cultivating animal cells, preparing the culture medium, constructing the cell-bearing scaffold, and then maturing the cells in a bioreactor.[28] Cultivated meat holds the potential to replace 35 per cent of global meat consumption by 2040, with major production focusing on beef, chicken, pork, and seafood.[29] The commercialization of cultivated meat has, however, experienced three major obstacles to success: (1) consumer expectations have not been satisfied as cultivated meat does not resemble the structure, texture, colour, flavour, or nutrition of conventional meat; (2) even with price variations as low as $66.40 per gram, it is too expensive for most consumers compared to conventional meat; and (3) the ecological sustainability of the technology is contentious and thus debatable.[30] Despite or perhaps because of these persisting challenges, the 3D printing of meat has emerged as a more viable alternative to conventional meat production.[31]

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23. Karna Ramachandraiah, "Potential Development of Sustainable 3D-Printed Meat Analogues: A Review" (2021) 13:2 Sustainability 1 at 2 [Ramachandraiah].

24. *Ibid*.

25. Deepi Harish, "Is 3D-Printed Meat the Next Big Thing? (And How It Really Tastes)" (4 February 2022), online: <https://www.foodnetwork.ca/article/3D-printed-meat-taste> [perma.cc/7G8L-ZB62].

26. Arianna Dick, Bhesh Bhandari & Sangeeta Prakash, "3D Printing of Meat" (2019) 153 Meat Sci 35 at 35 [Dick et al].

27. Guo, *supra* note 22.

28. *Ibid* at 1662.

29. *Ibid* at 1660. The production of "exotic meats," such as horse and mouse, has been explored.

30. Guo, *supra* note 22.

31. *Ibid*.

B. 3D Printing

Three-dimensional or "3D printing" is a type of fused deposition modelling (FDM), a major type of additive manufacturing.[32] 3D printing generally is achieved either by extrusion, inkjet printing, binder jetting, or bioprinting.[33] Fruit, pasta, chocolate, cookies, lollipops, and chewing gum can all be 3D printed.[34] In other applications, food that is not found in nature and personally nutritionalized foods can also be printed.[35] Lipton et al published the first study of the 3D printing of meat in 2010,[36] but very few additional studies on the 3D printing of fibrous materials such as meat and seafood have been published since then.[37] As it pertains to the 3D printing of food, there are different methods of 3D printing.[38] As Lipton put it several years later in 2017: "There is no one technology that is 3D printing . . . [the technology] is a family of additive manufacturing technologies that tend to involve solidifying powders, liquids or slurries, [and each] technique has its own technical challenges and applicability to food."[39]

Food can be 3D printed from a combination of powder and liquid or from cultured cells. Similar to cultivated meat, in that it begins with cells from real animals, 3D printed meat of the kind we are discussing here (i.e., 3D bioprinting) is printed from cultured cells (and this technique has also been used to produce tissue and organs when human cells are used).[40] Typically, the 3D printing of meat is achieved through an extrusion process where meat fibres or meat paste are extruded from a nozzle to create layered 3D structures.[41] The process basically involves generating freeform structures by introducing a prototype into computer-aided design software, which is then converted into a readable file by a slicing software application and is then recognized and processed by 3D printers to render the output as meat.[42] In one of the leading articles on this subject, the authors described the technology as involving

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32. Ramachandraiah, *supra* note 23 at 2. There are already restaurants that use 3D printing technology (though not animal protein) to make foods; the idea of 3D printing animal proteins from home has been discussed as a possibility. Nonetheless, our paper will limit the discussion to mass production of 3D printed meat for wholesale distribution.

33. Ramachandraiah, *supra* note 23 at 2.

34. See e.g. Tran, *supra* note 9 at 858–859. See also Jackie Wattles, "Researchers 3D Printed This Cheesecake" (21 March 2023), online: <https://www.cnn.com/2023/03/21/world/3D-printed-food-cheesecake-scn/index.html> [perma.cc/5ZTY-YZYQ].

35. See e.g. Tran, *supra* note 9 at 858.

36. See Jeffrey Lipton et al "Multi-Material Food Printing with Complex Internal Structure Suitable for Conventional Post-Processing," paper delivered at the Annual International Solid Freeform Fabrication Symposium, Austin, Texas, October 2010.

37. Dick et al, *supra* note 26 at 36-37. See also Antonietta Baiano, "3D Printed Foods: A Comprehensive Review on Technologies, Nutritional Value, Safety, Consumer Attitude, Regulatory Framework, and Economic and Sustainability Issues" (2022) 38:5 Food Rev Int'l 986 [Baiano].

38. Fernanda C Godoi, Sangeeta Prakash & Bhesh R Bhandari, "3D Printing Technologies Applied for Food Design: Status and Prospects" (2016) 179 J Food Engineering 44 at 45.

39. Jeffrey Lipton, "Printable Food: The Technology and Its Application in Human Health" (2017) 44 SciDirect 198 at 199 [Lipton].

40. Kristen Rogers, "When We'll Be Able to 3D-Print Organs and Who Will Be Able to Afford Them" (10 March 2023), online: <www.cnn.com/2022/06/10/health/3D-printed-organs-bioprinting-life-itself-wellness-scn/index.html> [perma.cc/S667-BKC8].

41. Ramachandraiah, *supra* note 23 at 2-3.

42. Ramachandraiah, *ibid* at 2.

"a layer-by-layer deposition with predetermined thickness to create complex three-dimensional objects from different materials used as 'inks,' using strictly the necessary amount of material to consolidate the shape of the printed object."[43]

Unlike cultivated meat, however, 3D printing uses 3D model data along with gastronomic technology to fabricate various structures and complex geometries of food with specific shapes, colours, flavours, textures, and nutrition.[44] Because of its sophistication, the 3D printing of meat can produce customized meat for large-scale production.[45] Furthermore, according to some, unlike cultivated meat, 3D printed meat holds the potential to better satisfy consumer demand in terms of quality, yield, affordability, and ecological sustainability.[46]

IV THE PRACTICAL PROBLEMS THAT 3D PRINTING MAY SOLVE

Below we have identified some of most significant problems that the 3D printing of meat may lessen or even, in limited aspects, eliminate. We also note that while these problems and some of their related issues may stand alone, they also overlap and are, for the most part, invariably intertwined. Our discussion of these problems aims to show how even in the infancy of this novel technology, the quality of life for both animals and humans might be improved overall. Such an assertion is not without commonality among the academy, as "3D printed food technologies . . . have thus far been positioned as offering solutions to the 'wicked futures' of climate change, food insecurity, poor nutrition, and environmental degradation, as well as to the mistreatment of and killing of animals for food."[47]

A. Rising Animal Consumption

Animal Justice, one of Canada's preeminent animal advocacy organizations, sourcing data from Agriculture Canada and Agri-Foods Canada, reported that in 2022 "841 million land animals were killed for food in Canada, making it the highest year on record since [Animal Justice] began analyzing government slaughter statistics."[48] In total, 767,847,756 meat chickens, 23,773,792 egg-laying hens and breeding chickens, 21,542,608 pigs, 19,234,269 turkeys, 4,577,813 ducks and geese, 3,446,282 adult cows (dairy & meat), 497,101 sheep and lambs, and 187,959 calves were killed in Canadian food production activities in 2022.[49] Each of these numbers went up in 2023 with nearly 859 million land animals killed for food, "making it the deadliest year on record since Animal Justice began analyzing government

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43. Dick et al, *supra* note 26 at 36.

44. Guo, *supra* note 22 at 1664; Ramachandraiah, *supra* note 23 at 2.

45. Guo, *ibid* at 1664.

46. *Ibid*.

47. Lupton & Turner, *supra* note 8 at 271.

48. Animal Justice noted that as a result of disruptions caused by COVID-19, the number of slaughtered animals decreased during the pandemic: see Animal Justice, "Canada Slaughtered 841 Million Animals in 2022" (15 February 2023), online (blog): <animaljustice.ca/blog/2022-canada-slaughter-statistics> [perma.cc/D9K7-H6D8] [Animal Justice].

49. *Ibid*.

slaughter statistics [in 2015]."[50] In fact, with an exception for the restrictions precipitated by the COVID-19 pandemic in 2020, these numbers have steady increased each year since 2015.[51]

Problematically, such numbers do *not* paint an entirely accurate portrait of the total number of *all* animals killed for food each year in Canada. The figures above only account for land animals who were slaughtered and entered the food supply and do *not* account for animals who died on farms or during transport, including male chicks ground up alive as "waste" at hatcheries.[52] Even though billions of them are killed each year in Canada, making the true number of animals killed for food even more difficult to determine, fishes, lobsters, crabs, and clams are excluded from these statistics because the government "measure[s] their lives by weight, not as individuals."[53] Additionally, the federal government fails to provide data on how many horses are slaughtered in Canada for meat each year, leaving the last known number to be 54,000 horses in 2016.[54] The Observatory of Economic Complexity suggests that Canada was among the top ten horse-meat exporting countries in the world in 2021.[55]

Looking at the cattle/beef industry—which is the most problematic in terms of GHG emissions because of its intensive natural resource use[56]—the Government of Canada reported that as of July 1, 2023, Canadian farmers held an estimated 12.2 million cattle and calves on their farms.[57] In 2019, Canada was reported to be the world's eleventh largest producer of meat and dairy.[58] Obviously, meat and dairy production is big business and speaks with a powerful political voice in Canada.[59]

Such animals involved in meat and dairy "production" are, however, *property* in law, and from that perspective they are "correctly" measured in numbers and weight like other commodities, rather than from a position that grants them moral consideration as sentient beings who have inherent value and an interest in being alive—as individuals. Stated differently, these animals are merely "produced" so that they can be *killed* for human consumption, an altogether discomforting proposition. Unsurprisingly, Voiceless, an Australian organization advocating for social, political, legal, and institutional reform so that animals have legal rights

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50. Shannon Nickerson, "Canada Killed a Record 859 Million Land Animals for Food in 2023" (6 June 2024), online (blog): <https://animaljustice.ca/blog/859-million-animals-slaughtered-2023> [perma.cc/9K2R-KACJ].

51. *Ibid*.

52. Animal Justice, *supra* note 48.

53. *Ibid*.

54. *Ibid*.

55. Observatory of Economic Complexity, "Which Countries Export Horse Meat?" (2021), online: <https://oec.world/en/visualize/tree_map/hs92/export/show/all/10205/2021/> [perma.cc/LRN9-VY84].

56. Ramachandraiah, *supra* note 23 at 1.

57. Statistics Canada, "Livestock Estimates, July 1, 2023" (23 August 2023), news release, online: <https://www150.statcan.gc.ca/n1/daily-quotidien/230823/dq230823D-eng.htm?indid=3212-1&indgeo=0> [perma.cc/KV4T-R429].

58. Hannah Ritchie, Pablo Rosado & Max Roserl, "Meat and Dairy Production" (last modified December 2023), online: <https://ourworldindata.org/meat-production> [perma.cc/VCX9-ZK9R] (see beef production data); see also Sarah J Pogue et al "Beef Productions and Ecosystem Services in Canada's Prairie Provinces" (2018) 166 Agric Sys 152.

59. See Dimitrije Protic et al, "COVID-19's Economic Impact on the Canadian Meat Processing Industry" (14 July 2020), online (blog): <https://medium.com/economicsforbusiness/covid-19s-economic-impact-on-the-canadian-meat-processing-industry-6b51203a6cff> [/perma.cc/GXJ2-GNMH].

and may flourish on their own terms,[60] ranked Canada as thirty-ninth in the world among fifty countries in its "Animal Cruelty Index" for its feeble laws respecting the production, consumption, and sanctioning of animal cruelty.[61] Animal Justice has also said that "Canada continues to have some of the worst animal protection laws in the western world."[62]

Beyond the staggering numbers just provided, and perhaps more importantly, many of these animals suffer incredible abuse, harm, cruelty, and suffering before ultimately being killed for food. Much of this violence and death is kept well hidden from public view.[63] Animal advocates and animal activists have gone to great lengths—some even dying and others going to prison—to expose this violence.[64] For various reasons, including regulatory capture, Parliament and provincial legislatures seem to not only turn a blind eye to this violence, but to enact legislation with severe penalties (known as "ag-gag" laws) designed to prevent this violence from being exposed by advocates and activists.[65]

Under the guise of increased "animal welfare promotion," the federal government also invests in the meat and dairy industries by providing money to better track livestock inventories, rather than investing in measures designed to improve the conditions and circumstances under which animals are killed.[66] Leaving aside these thorny political concerns, the process of "producing meat" in laboratories through cell cultivation and 3D printing could potentially serve to reduce not only these staggering kill numbers but also the abuse, harm, cruelty, and suffering—the violence—these animals endure by making it largely *unnecessary*. But ending the violence against animals and perhaps obviating the promulgation of "ag-gag laws"[67] are not the only problem that 3D printing might alleviate—anthropogenic environmental degradation and destruction might be curbed too.

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60. Voiceless, "About Us" (last accessed 17 November 2024), online: <https://voiceless.org.au/about-us/> [perma.cc/K2GE-5LXH].

61. Voiceless, "The Voiceless Animal Cruelty Index" (2020), online: <vaci.voiceless.org.au/> [perma.cc/UDR5-M2L6].

62. Holly Lake, "Righting Canada's Wronged Animals" (10 September 2021), online: <https://nationalmagazine.ca/en-ca/articles/law/in-depth/2021/righting-canada-s-wronged-animals> [perma.cc/NPW3-TVBN].

63. See generally Amy J Fitzgerald, "A Social History of the Slaughterhouse: From Inception to Contemporary Implications" (2010) 17:1 Hum Ecology Rev 58.

64. See Bobby Hristova & Christine Rankin, "Activist Killed after Being Struck by Vehicle during Burlington Pig Plant Protest" (19 June 2020), online: <https://www.cbc.ca/news/canada/hamilton/pedestrian-dead-pig-protest-burlington-1.5619144> [perma.cc/FFM9-N7ZL]. See also *CBC News*, "Animal Rights Activists Sentenced to Time in Jail for 2019 Protest at BC Hog Farm" (13 October 2022), online: <https://www.cbc.ca/news/canada/british-columbia/b-c-animal-rights-activists-get-jail-time-1.6614762> [perma.cc/43LS-DXGE].

65. See Bill C-275, *An Act to amend the Health of Animals Act (biosecurity on farms)*, 1st Sess, 44th Parl, 2022 (passed first reading 30 May 2022, passed second reading 21 June 2023, passed third reading 29 November 2023; consideration in committee in the Senate as of June 2024), online: <https://www.parl.ca/DocumentViewer/en/44-1/bill/C-275/first-reading> [perma.cc/U664-PLAK].

66. Agriculture and Agri-Food Canada, News Release, "Government of Canada invests in improving animal welfare" (08 August 2022) online: <https://www.canada.ca/en/agriculture-agri-food/news/2022/08/government-of-canada-invests-in-improving-animal-welfare.html#> [perma.cc/F6JF-B5C3].

67. See generally Katie Sykes & Sam Skinner, "Fake Laws: How Ag-Gag Undermines the Rule of Law in Canada" (2022) 28:2 Animal L 229.

B. Anthropogenic Environmental Degradation and Destruction

While the killing of land animals in Canada for human consumption (i.e., food) itself presents moral and legal issues, ending that violence against animals would also prove beneficial for environmental reasons. It is no secret that climate change is one of the greatest issues facing modernity and that anthropogenic GHG emissions are one of the most significant contributors to climate change (manifested by increases in temperature and the frequency of droughts, rainfall intensity, flooding, and other severe weather events).[68] By reducing GHGs, it is thought, the destruction of Earth, its climate, and its atmosphere can be forestalled. For example, in March 2022 the federal government released its *2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy* (the Plan).[69] The Plan acknowledged that the "evidence is clear: we are facing a joint climate and biodiversity crisis."[70] Through a variety of ways, the Plan seeks to reduce GHGs in Canada by better regulating emissions and investing in new technologies. The 3D printing of meat speaks to these goals.

Industrial agriculture is a significant contributor to GHGs because of the methane gas[71] the animals produce and because of other contaminants and pollutants (such as metals and pesticides) standard industrial agricultural practices and activities release into soils, rivers, lakes, and the atmosphere.[72] Raising animals strictly for human consumption is far more land and resource intensive and emits far more GHGs than growing plant-based foods for human consumption.[73] This in turn causes further environmental degradation through wildlife habitat destruction and deforestation.[74] The Canadian government has recognized that "currently the majority of emissions come from biological sources, such as *livestock production* (enteric fermentation), the application of synthetic nitrogen fertilizers, manure management, and on-farm fuel use."[75] Thus, based on simple mathematics or logic, if industrial agriculture and the amount of animals raised for slaughter (and then slaughtered) were to be reduced, then naturally the amount of GHGs from the agriculture sector would also be reduced and so too would anthropogenic environmental degradation and destruction. There is no way to avoid these very simple fact-based realities.

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68. Foster et al, *supra* note 21.

69. Prime Minister of Canada Justin Trudeau, Press Release, "Delivering clean air and a strong economy for Canadians" (29 March 2022) online: <www.pm.gc.ca/en/news/news-releases/2022/03/29/delivering-clean-air-and-strong-economy-canadians> [perma.cc/H8CS-CKFA].

70. Environment and Climate Change Canada, *2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy* (2022) at 142, online (pdf): <https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf> [perma.cc/93R7-KKKM] [Environment and Climate Change Canada].

71. *Ibid* at 30: "Methane is a potent greenhouse gas [and once] released into the atmosphere . . . has 86 times the warming power of carbon dioxide over a 20-year period."

72. See generally Navius Research, *Part I: Animal-Sourced Food Consumption and Canada's Emissions Targets: Report Prepared for World Animal Protection Canada* (World Animal Protection, 2022).

73. *Ibid*.

74. Wolfgang Brozek & Christof Falkenberg, "Industrial Animal Farming and Zoonotic Risk: COVID-19 as a Gateway to Sustainable Change? A Scoping Study" (2021) 13:16 Sustainability 1 at 2 [Brozek & Falkenberg]; see also United Nations Environment Programme and International Livestock Research Institute, *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission* (Kenya: United Nations Environment Programme, 2020) at 15–17, 29, 34, 55, 57, 68 [UNEP].

75. Environment and Climate Change Canada, *supra* note 70 at 59 [emphasis added].

The Plan goes on to recognize that "[d]emand for more environmentally-responsible and sustainable foods is increasing, as consumers around the globe are keen to know more about the food they purchase . . . thus [a]ctions taken on climate mitigation will help the Canadian brand stand out in a highly competitive global marketplace" and that "[n]ature-based solutions and alternative farming practices offer a large potential to reduce emissions in the agriculture sector, while providing additional co-benefits."[76] The Plan is largely silent on those co-benefits, however. While this omission is noticeable, an even more egregious omission is the Plan's failure to discuss—let alone contemplate—*reduced* livestock agriculture (and thus enteric fermentation) as a way to achieve the country's lowered GHG emissions goals, focusing instead on tree planting, grassland and wetland protection, improved forest management, using wood to store carbon, improving agricultural land use management, and reducing forest fires as carbon capture mitigation measures.[77] This is a stark omission given that, for example, industrial agriculture accounted for an estimated 10–12 per cent of total global anthropogenic GHG emissions[78] and in 2023 may account for as much as 40 per cent of all GHG emissions worldwide.[79]

Given, however, that the Plan seeks to reduce Canada's GHG emissions to net zero by 2050 (reducing emissions to the point that carbon emissions produced can be negated through carbon capture technologies),[80] a goal that it enshrined in the *Canadian Net-Zero Emissions Accountability Act*,[81] then reducing the amount of animals bred in industrial agricultural activities ought, naturally, to be pursued. An independent study prepared by the Canadian Climate Institute revealed, however, that while the Plan is credible and sets Canada on the path to mitigating climate disaster,[82] it is not calibrated to reach that goal.[83] Using three different animal consumption models and accounting for increased emissions from plant-based agriculture, another study conducted by World Animal Protection and Navius Research showed that Canada could close that gap if 35 per cent less meat and dairy was consumed by 2030 and 50 per cent less by 2050.[84] The 3D printing of meat naturally lends itself conceptually, if not

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76. Environment and Climate Change Canada, *ibid* at 60.

77. See generally Environment and Climate Change Canada, *ibid*.

78. Intergovernmental Panel on Climate Change, *Climate Change 2007*: *Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the IPCC* (Cambridge: Cambridge University Press, 2007) 497. See also Brenda B Lin et al, "Effects of Industrial Agriculture on Climate Change and the Mitigation Potential of Small-Scale Agro-Ecological Farms" (2011) CABI Rev 1 at 2.

79. Jake Young, "What Should Health Professions Students Know about Industrial Agriculture and Disease?" (2023) 25:4 Am J Ethics 264 at 265 [Young]; see generally Francesco N Tubiello et al, "Greenhouse Gas Emissions from Food Systems: Building the Evidence Base" (2021) 16:6 Envtl Research Letter 5007, online (pdf): <https://iopscience.iop.org/article/10.1088/1748-9326/ac018e> [perma.cc/P4KU-9QR2].

80. Environment and Climate Change Canada, *supra* note 70 at 6.

81. *Canadian Net-Zero Emissions Accountability Act*, SC 2021, c 22.

82. Dave Sawyer et al, "Independent Assessment: 2030 Emissions Reduction Plan" (April 2022) at 2, 4, online (pdf): <https://climateinstitute.ca/wp-content/uploads/2022/04/ERP-Volume-2-FINAL.pdf> [perma.cc/A3GP-FRFN].

83. *Ibid* at 11.

84. Hanna Hett, "Eating Less Meat Could Help Canada Achieve Its Climate Goals" (23 August 2022), online: <https://www.nationalobserver.com/2022/08/23/news/eating-less-meat-could-help-canada-achieve-climate-goals> [perma.cc/9RV6-9KTD]; Foster et al, *supra* note 21.

entirely practically, to helping achieve these goals and more.[85] But that is not to say that the 3D printing of meat is without environmental concerns.[86]

Furthermore, the federal government referred to its own Agricultural Clean Technology Program (ACTP) in the Plan, which is a "$165.7 million fund that aims to create an enabling environment for the development and adoption of clean technologies that reduce emissions and enhance competitiveness [by prioritizing] energy and energy efficiency, precision agriculture and bioeconomy technologies."[87] The ACTP, in its "Research and Innovation" stream, contemplates supporting "pre-market innovation, including research, development, demonstration and commercialization activities, to develop transformative clean technologies and enable the expansion of current technologies, in 3 priority areas: green energy and energy efficiency; precision agriculture; and bioeconomy."[88] Activities eligible for funding under the ACTP include applied research and development of clean technologies, piloting and evaluating clean technologies, demonstration and knowledge and technology transfer activities, commercializing and scaling up clean technologies, and other activities that support the research and innovation stream as determined by the program.[89] The 3D printing of meat might be considered a clean technology or a form of precision agriculture that could satisfy any or all of these criteria. Thus, the 3D printing of meat, if economically efficient and sufficiently regulated to address some of the concerns we address in this article, might not only reduce the amount of livestock contributing to GHG emissions but also reduce the abuse, cruelty, harm, and suffering these animals endure. The 3D printing of meat is also well poised for further scientific research funding under the federal government's ACTP program. As Lipton warned, however, "3D food printing is a field dominated by secretive corporate research projects, sponsored research and startups [who] tend to publish their work less frequently and provide few technical details to maintain competitive advantage. This may enable capitalization of innovation, but slows its pace."[90] The nature of resistance that the meat and dairy lobby is likely to impart is also a concern in the development and deployment of 3D printing technology.

C. Health Concerns

There are a number of health concerns related to industrial agriculture, not all of which can be examined in detail here. While antimicrobial resistance, the effects of soil and water contamination and pollution on human health, and environmental health injustice (environmental racism) are all important considerations in the discussion we have undertaken

85. See Grace Hussain, "Reducing Meat Consumption by a Third Could Offset Almost All Global Airline Emission" (3 November 2023), online: <sentientmedia.org/reducing-meat-consumption-airline-emissions> [perma.cc/G9CB-PHD6].

86. Smetana et al, *supra* note 6.

87. Environment and Climate Change Canada, *supra* note 70 at 61.

88. Government of Canada, "Agricultural Clean Technology Program: Research and Innovation Stream: Step 1. What This Program Offers" (last modified 03 October 2022), online: <https://agriculture.canada.ca/en/programs/agricultural-clean-technology-research-innovation-stream> [perma.cc/PYU8-5YG5].

89. *Ibid.*

90. Lipton, *supra* note 39 at 199–200.

in this article, we touch on these only briefly and leave them for detailed discussion elsewhere.[91] Instead, we focus primarily on zoonoses-induced pandemics and human nutritional health as health concerns that 3D printing might alleviate.

1. Zoonoses-Induced Pandemics

The COVID-19 pandemic, which ranged from approximately late 2019 to 2021, was perhaps the most significant global event of the twenty-first century thus far.[92] Despite not being able to reach a firm consensus on COVID-19's origins, most epidemiologists and scientists agree that the COVID-19 pandemic was induced by a zoonotic disease(s).[93] Zoonotic diseases—or more simply zoonoses—are pathogens that are easily transmitted and retransmitted across various species, regardless of whether they are human or non-human. This interspecies transmission is what makes zoonoses so dangerous to animal and human health.[94] Each subsequent transmission may cause the pathogen to mutate, thus making vaccines extremely difficult to develop and deploy in the face of a raging worldwide pandemic.[95] The Centers for Disease Control and Prevention (CDC) in the United States, for example, estimates "that more than 6 out of every 10 known infectious diseases in people can be spread from animals, and 3 out of every 4 new or emerging infectious diseases in people come from animals."[96] Zoonoses are all around us.

Of course, COVID-19 is not the planet's first exposure to zoonoses in recent history (nor even in the last two centuries for that matter). The worldwide 2002–2004 SARS outbreak,[97] the

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91. See Young, *supra* note 79 at 265; see also Leo Horrigan, Robert S Lawrence & Polly Walker, "How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture" (2002) 110:5 Envtl Health Persp 445. See also Ellen K Silbergeld, Jay Graham & Lance B Price, "Industrial Food Animal Production, Antimicrobial Resistance, and Human Health" (2008) 29 Ann Rev of Pub Health 151 at 152.

92. Globally, as of October 2023, there were 6,960,783 deaths from COVID-19. See World Health Organization "WHO COVID-19 Dashboard," online: <data.who.int/dashboards/covid19/cases?n=c> **[perma.cc/W632-5RQZ].**

93. Annah Lake Zhu et al, "The Politicization of COVID-19 Origin Stories: Insights from a Cross-Sectional Survey in China" (2023) 13(2) Societies 1 at 15; Alessandra Borsetti et al, "The Unresolved Question on COVID-19 Virus Origin: The Three Cards Game?" (2021) 94:4 J Med Virol 1257 at 1258.

94. Gustavo Fermin, "Host Range, Host—Virus Interactions, and Virus Transmission" (2018) Viruses 101 at 127–28. See also Daniel T Haydon et al, "Identifying Reservoirs of Infection: A Conceptual and Practical Challenge" (2002) 8:12 Emerging Infectious Diseases 1468 at 1472; RW Ashford, "When Is a Reservoir Not a Reservoir?" (2003) Emerging Infectious Diseases 1495; M V Palmer, "*Mycobacterium bovis*: Characteristics of Wildlife Reservoir Hosts" (2013) 60:1 Transboundary and Emerging Diseases 1.

95. University of California at Berkeley, "The Deep Evolutionary History of the New Coronavirus" (April 2020), online: <evolution.berkeley.edu/evo-news/the-deep-evolutionary-history-of-the-new-coronavirus/> [perma.cc/7SND-KEPE].

96. Centers for Disease Control, "Zoonotic Diseases" (29 February 2024), online: <www.cdc.gov/one-health/about/about-zoonotic-diseases.html?CDC_AAref_Val> [perma.cc/RD7M-K7K6].

97. James D Cherry, "The Chronology of the 2002–2003 SARS Mini Pandemic" (2004) 5:4 PubMed Central 262.

worldwide 2009 swine flu epidemic,[98] and the worldwide 2015–2016 zika virus epidemic[99] are all good examples of previous zoonotic events. Innumerably more zoonoses-induced outbreaks, epidemics, and pandemics occurred and continue to occur at local, regional, and continental levels.[100] Furthermore, while so-called "wet markets" or live animal markets and the highly lucrative illegal trade in wildlife contributes to zoonotic transmissions,[101] a recent report from the United Nations prepared and reviewed by numerous experts warned that the "frequency of pathogenic microorganisms jumping from other animals to people is increasing due to unsustainable human activities. Pandemics such as the COVID-19 outbreak are a *predictable and predicted outcome of how people source and grow food, trade and consume animals, and alter environments*."[102]

It comes as no surprise then that industrial agriculture activities are harbingers of zoonoses, and given the prevalence of cattle and other livestock-breeding operations in Canada, the threats posed to human health are indeed real ones.[103] The overcrowding of animals; the use and overuse of antibiotics in animals; and the unimaginably cruel, abusive, and stressful conditions in which the animals are held all serve to exacerbate the risk of viral, pathogenic, and bacterial transmissions among the animals held captive and among the humans who work in these factory farms.[104] Some persons have even curtailed or even eliminated their consumption of meat and dairy in the interests of *other* humans.[105]

Reducing the number of animals slaughtered for human consumption would not only lessen the total GHG emissions discussed earlier, but it might also mitigate the potential for larger-scale zoonoses transmissions at these industrial agriculture livestock operations or

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98. See Krista J Howden et al, "An Investigation into Human Pandemic Influenza Virus (H1N1) 2009 on an Alberta Swine Farm" (2009) 50:11 PubMed Central 1153; Joanne Embree, "Pandemic 2009 (A)H1N1 Influenza (Swine Flu)—The Manitoba Experience" (2010) 88 Biochemry & Cell Bio 589; Donald Tremblay et al, "Emergence of a New Swine H3N2 and Pandemic (H1N1) 2009 Influenza A Virus Reassortant in Two Canadian Animal Populations, Mink and Swine" (2011) 49:12 PubMed Central 4386.

99. Joanne Tataryn et al, "Travel-Related Zika Virus Cases in Canada: October 2015–June 2017" (2018) 44:1 Can Communicable Disease Rep 18; Pia K Muchaal, "Zika Virus: Where to from Here?" (2018) 44:1 Can Communicable Disease Rep 27.

100. World Health Organization, "Zoonoses" (29 July 2020), online: <https://www.who.int/news-room/fact-sheets/detail/zoonoses> [perma.cc/29A7-8K7L].

101. Marcos A Bezerra-Santos et al, "Illegal Wildlife Trade: A Gateway to Zoonotic Infectious Diseases" (2021) 37:3 Trends in Parasitology 181 at 181; James M Hassell et al, "Urbanization and Disease Emergence: Dynamics at the Wildlife–Livestock–Human Interface" (2017) 32:1 Trends in Ecology & Evolution 55 at 55; Eric Wikramanayake et al, "Evaluating Wildlife Markets for Pandemic Disease Risk" (2021) 5:7 Lancet Planetary Health 400 at 400.

102. UNEP, *supra* note 74 at 7 [emphasis added]. See also Ann Linder et al, *Animal Markets and Zoonotic Disease in the United States* (Cambridge: Brooks McCormick JR Animal Law and Policy Program, 2023), online (pdf): <https://animal.law.harvard.edu/wp-content/uploads/Animal-Markets-and-Zoonotic-Disease-in-the-United-States.pdf> [perma.cc/6BV6-R7ET].

103. See generally François Meurens et al, "Animal Board Invited Review: Risks of Zoonotic Disease Emergence at the Interface of Wildlife and Livestock Systems" (2021) 15:6 Animal 100241; see Nicholas H Ogden & Philippe Gachon, "Climate Change and Infectious Diseases: What Can We Expect?" (2019) 45:4 Can Communicable Disease Rep 76 at 78.

104. Brozek & Falkenberg, *supra* note 74, at 2, 13.

105. Steven Ammerman & Monica L Smith, "Vegetarianism in the Pandemic Era: Using Digital Media to Assess the Cultural Politics of Meat Avoidance during COVID-19" (2023) 4 Digital Geo and Soc at 1.

factory farms. Furthermore, while such a reduction is a reward in itself, any such reduction in consumption could be counterbalanced by the 3D printing of meat, which is likely to be safer than current industrial agriculture practices. The 3D printing of meat therefore holds potential to stave off environmental threats. It may also offer certain nutritional benefits to human health.

2. Human Nutritional Health

Not only would reduced consumption of meat and dairy assist in the reduction of GHGs and lessen the potential for zoonoses outbreaks, epidemics, and pandemics, it would also improve human health overall. The overconsumption of red meat (in particular) and dairy have been shown to have negative effects on human health.[106] Nutritional science increasingly encourages Canadians to reduce—if not eliminate—meat and dairy consumption by adopting a plant-based diet and seeking out alternative sources of protein and calcium (such as soy, spinach, oat-milk products, and even insect protein).[107] Furthermore, notwithstanding personal preferences, some people may not be able to consume regular foods because of age, disability, or allergies, and 3D printing of other foods, not just meat, enables automated customized food products to be produced for them.[108] A 3D printed food option may provide suitable alternatives to the status quo and have a transformative effect on human health.[109] It might also assist those in developing countries who may struggle to achieve an adequately nutritional diet.

V THE REGULATION OF 3D PRINTING TECHNOLOGY

Several major regulatory issues will need to be addressed prior to the large-scale production and sale of 3D printed meats in the Canadian market. 3D printed meat and cultivated meats are at a crossroads. While 3D printed meat is still in its nascent state and therefore product regulation is underdeveloped, lab-cultivated meat is further along the regulatory pathway. Both the United States and Singapore have regulatory provisions in place that allow for the

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106. Susanne Stoll-Kleemann & Tim O'Riordan, "The Sustainability Challenges of Our Meat and Dairy Diets" (2015) 57:3 Env't 34 at 43; see also Xiao Gu et al, "Red Meat Intake and Risk of Type 2 Diabetes in a Prospective Cohort Study of United States Females and Males" (2023) 118:6 Am J of Clinical Nutrition 1153.

107. See generally Hrvoje Fabek et al, "An Examination of Contributions of Animal- and Plant-Based Dietary Patterns on the Nutrient Quality of Diets of Adult Canadians" (2021) 46:8 App Physiology, Nutrition, and Metabolism 877 at 878.

108. Baiano, *supra* note 37 at 198; Lupton & Turner, *supra* note 8 at 270.

109. Baiano, *ibid* at 994.

sale of lab-cultivated meats.[110] Other countries have taken a different approach. Recently, Italy has passed a law banning the sale and import of lab-cultivated meats, and France has now introduced a similar bill.[111] In January 2024, Italy, France, and Austria brought the matter before the EU Council of Ministers and EU agriculture ministers.[112] Controversy around these products is not surprising; similar battles have been waged in the past when science and food products have collided. For example, when genetically modified foods were introduced, public backlash against the products were significant.[113]

Using the precautionary principle, it is important that regulatory responses are carefully thought out. While there are a multitude of regulatory issues that need to be addressed prior to 3D printed meat being approved for sale, this section focuses on the post-manufacturing aspects of regulation;[114] specifically, issues surrounding the safety assessment, labelling, and marketing of 3D printed meat. Our arguments will serve to highlight emerging areas in need of regulatory consideration and will examine how laws and regulations have been developed and implemented in other areas of emerging food technologies, including areas related to genetically modified foods and cultivated meat products and the potential application and relevance to 3D printing technology.

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110. It should be noted that while the US Department of Agriculture has approved the sale of lab-grown meats, some individual states have tried to ban the sale of the products within their jurisdiction. See for instance Florida, which attempted to pass a law banning "cultivated meats." The definition of cultivated meats included was broad enough to include a prohibition on 3D-printed meats. See US, Senate Bill 586, *An act relating to cultivated meat*, Florida, 2024. The bill died in the Agriculture Committee (8 March 2024) (a companion bill on an unrelated subject matter passed), online: <https://www.myfloridahouse.gov/Sections/Bills/billsdetail.aspx?BillId=79230&> [perma.cc/MQV6-5NG6]; "Arizona Bills Aim to Ban Cell-Based Meat; Restrict Labeling of Meat Alternatives as 'Meat,'" *Food Safety Magazine* (16 January 2024), online: <https://www.food-safety.com/articles/9171-arizona-bills-aim-to-ban-cell-based-meat-restrict-labeling-of-meat-alternatives-as-meat> [perma.cc/3NTP-W9EQ].

111. Italy has stated that the law prohibiting cell-cultivated meats protects the nation's food heritage and was thus a necessary step. See Paul Kirby, "Italy Bans Lab-Grown Meat in Nod to Farmers" (17 November 2023), online: <www.bbc.com/news/world-europe-67448116> [perma.cc/5UX9-2DRQ]. See also European Food Agency, "Cultivated Meat, Law Proposal to Ban It in France" (12 November 2023), online: <www.efanews.eu/en/item/36576-cultivated-meat-law-proposal-to-ban-it-in-france.html> [perma.cc/XD9H-ZWKY].

112. See Gerardo Fortuna, "Coalition Puts Fake Meat on Ministers' Menu, and Sinks in Teeth" (19 January 2024), online: <www.euronews.com/my-europe/2024/01/19/coalition-puts-fake-meat-on-ministers-menu-and-sinks-in-teeth> [perma.cc/H493-CG2X].

113. Annie Gasparro, "The GMO Fight Ripples Food Chain: Facing Pressure, More Firms Are Jettisoning GMOs from Their Foods" (7 August 2014), online: https://www.wsj.com/articles/the-gmo-fight-ripples-down-the-food-chain-1407465378. See also Stefaan Blancke, "Why People Oppose GMOs Even though Science Says They Are Safe" (18 August 2015), online: <https://www.scientificamerican.com/article/why-people-oppose-gmos-even-though-science-says-they-are-safe/> [perma.cc/9N3Q-AGZH?type=image].

114. There are already restaurants that use 3D printing technology (though not animal protein) to make foods; the idea of 3D printing animal proteins from home has been discussed as a possibility. Nonetheless, our paper will limit the discussion to mass production of 3D printed meat for wholesale distribution. See Eustacia Huen, "3D Food Printing: Is It Ready for Luxury Dining?" (31 July 2015), online: <https://www.forbes.com/sites/eustaciahuen/2015/07/31/3D-food-printing-is-it-ready-for-luxury-dining/?sh=4a73D4051236> [perma.cc/MV3N-PAE2]; Gareth Rubin, "How Do You Like Your Beef…old-Style Cow or 3D-Printed?" (10 November 2019), online: <https://www.theguardian.com/technology/2019/nov/10/3D-printed-meat-european-restaurant-menus-environment> [perma.cc/SWG2-QQ56] [Rubin].

A. Production and Safety

The regulation of food products in Canada is complex and involves federal, provincial, and municipal governments. Several different departments and agencies are responsible for overseeing and enforcing legislation related to food safety.[115] As of writing, Canada has not adopted new regulations for lab-cultivated or cultured-cell meats, which might be similarly applied to the process involving the 3D printing of meat. The question therefore is whether 3D printed animal proteins will fit into the current regulatory framework (that does not include special regulations for lab-cultivated meats) or whether new regulations will need to be developed for this innovative technology.

The *Food and Drugs Act*[116] and its associated regulations is the primary piece of legislation responsible for regulating food safety in Canada. Food is broadly defined as "any article manufactured, sold or represented for use as food or drink for human beings, chewing gum, and any ingredient that may be mixed with food for any purpose whatever."[117] Given the broad definition of food, animal proteins that are designed for human consumption, even if using a new technology to produce them, would fall into this category. Because 3D printed animal proteins would be defined as food, how these products would be approved and made available to the public would need to be addressed. Recent innovations in food and food technology, including "vegetarian meats" and genetically modified foods (GM foods), may provide some guidance on how 3D printed meat may be regulated. Should Canada choose not to adopt specific regulations for 3D printed meat, the current regulatory system to approve foods for consumption is still broad enough to capture 3D printed animal proteins; however, as shown below, without amendments there are significant areas of uncertainty that exist in the current regulatory system. It would be prudent to address these prior to the introduction of 3D printed meat to the Canadian market.

In Canada, any "novel" food is subject to Health Canada approval. A "novel" food can include both new foods, meaning a food that has not traditionally been consumed as a safe food product, "a food that has been manufactured, prepared, preserved or packaged by a process that: (i) has not been previously applied to that food, and (ii) causes the food to undergo a major change," or a "food that is derived from a plant, animal or microorganism that has been genetically modified."[118] 3D printed foods, like lab-cultivated meats, would likely fall into this definition because of their novel manufacturing process.[119]

In Canada, novel foods are subject to a safety evaluation prior to the food being made available for sale or consumption. Manufacturers are required to submit an application package to Health Canada's Food Directorate that provides evidence on the safety and

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115. This paper will not delve into the minutia of food regulation in Canada. For more information on the various government agencies and legislation, please see Canadian Institute of Food Safety, "Who's Responsible for Food Safety in Canada?" (4 November 2021), online (blog): <https://blog.foodsafety.ca/whos-responsible-food-safety-canada> [perma.cc/KFR2-AJTD].

116. RSC 1985, c F-27.

117. *Ibid*, s 2.

118. *Food and Drugs Regulations*, CRC c 870 at B.28.001 (2024) [*Food and Drugs Regulations*].

119. In February 2024, Health Canada used the novel food regulations to approve the "first animal-free milk protein"; see Laura Brehaut, "First Animal-Free Milk Protein Approved for Sale in Canada" (10 February 2024), online: <nationalpost.com/news/canada/first-animal-free-milk-protein-approved-for-sale-in-canada> [perma.cc/8D6F-FYBB].

suitability of the food product.[120] Health Canada has produced guidelines on how to assess novel foods derived from plants and microorganisms; as of January 2024, Health Canada is still developing specific guidelines for the safety assessment of novel foods derived from animals.[121] 3D printed animal protein, as well as lab-cultivated meats, will fall under these yet to be released guidelines. Although the exact safety assessment requirements are unknown, based on those currently in place for novel foods derived from plants and microorganisms, safety assessments for novel foods derived from animal protein will likely consider similar concerns, notably toxicology, nutrition, microbial safety, dietary exposures, and allergens, amongst others.[122] Environmental impact assessment is not currently part of the considerations on whether to approve novel foods; however, guidelines on this are under development and this should be an important consideration when examining 3D printed meats and lab-cultivated meats.[123] Only once a product has been determined to be safe for human consumption can the product be made available to the public. It should be noted that this process is not without criticism. As Angela Lee points out, "[t]he decision is generally based on the information provided by the petitioner, with little to no independent testing, and little to no opportunities for participation by other stakeholders or the general public."[124]

Given the potential rapid global expansion of 3D printed meat technology, and in light of the precautionary principle, safety of the food product should be at the forefront of concerns. While Health Canada's approval process would require an examination of key safety concerns, ensuring a robust and rigid review process will be critical to public confidence in these products. As mentioned, regulations are currently being developed, and how these key safety concerns are assessed will be important.

B. Legal Name of the Output

Perhaps the most contentious area emerging that is associated with cultivated meats, and which would equally apply to 3D printed meats, involves the labelling and marketing of these new meat products. Naming, labelling, and marketing has always been a contentious issue when novel foods try to break into long-standing traditional markets, such as the meat or

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120. Accordingly, "[t]he safety criteria for the assessment of novel foods outlined in the current document were derived from internationally established scientific principles and guidelines developed through the work of the Organization for Economic Cooperation and Development (OECD), Food and Agriculture Organisation (FAO), World Health Organisation (WHO) and the Codex Alimentarius Commission." Health Canada Food Directorate, "Guidelines for the Safety Assessment of Novel Foods" (updated July 2022), online: <https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/guidance-documents/guidelines-safety-assessment-novel-foods-2006.html> [perma.cc/ZE7E-KMTK] [Health Canada].

121. *Ibid*, s 4.3.

122. *Ibid*, s 2.2.

123. *Ibid* at s 3.1. Some studies have indicated that cultivated meat may require more energy use than traditional meat manufacturing (these same concerns have not been expressed for 3D printed meat). See e.g. Jordan Wiklund, "Study: Lab-Grown Meat Potentially Worse for Environment than Retail Beef" (26 May 2023), online (blog): <https://foodinstitute.com/focus/study-lab-grown-meat-potentially-worse-for-environment-than-retail-beef/> [perma.cc/3GP7-JTAY] (the study cited in the article has yet to be peer reviewed).

124. Angela Lee, "The Stakes in Steak: Examining Barriers to and Opportunities for Alternatives to Animal Products in Canada" (2018) 41:1 Dalhousie LJ 219 at 236.

dairy industries. In recent history there have been objections (largely from the industry) to the naming of milk alternatives (including oat, soya, and almond) as "milk"[125] and vegetarian-based meats as "meats."[126] There has been such intense lobbying surrounding the naming and marketing of these products, that some countries have chosen to address these concerns through legislative response.[127] Internationally, this type of protest has already started against lab-cultivated meats, and legislative responses have been introduced, predominantly in the United States.[128] Constitutional litigation on the basis of freedom of expression has also been

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125. In Canada, milk alternatives have traditionally been named and labelled as beverages instead of milk. This "legal" name and labelling on the package is a result of the *Food and Drugs Regulations* definition of what constitutes milk. According to the regulations, milk refers specifically to cow milk. See *Food and Drug Regulations*, *supra* note 118, s B.08.003. In countries that do not have a specific definition of "milk" linking it with specific animals, the fight over what to call these "milk" products has turned legal. See e.g. Leanne Garfield, "Dairy Companies Are Fighting with Soy Milk Producers over What Can Be Called Milk" (6 March 2017), online: <https://www.businessinsider.com/dairy-pride-act-soy-almond-milk-congress-2017-3> [perma.cc/9DSG-UVJ4]. Other countries do not have the same definition of milk and litigation on the issue of the definition of milk has occurred. See *Verband Sozialer Wettbewerb eV v TofuTown.com GmbH,* C-422/16, [2017] ECR I-1 at I-24.

126. Jonah Engel Bronwich & Sanam Yar, "The Fake Meat War" *The New York Times* (25 July 2019), online: <https://www.nytimes.com/2019/07/25/style/plant-based-meat-law.html> [perma.cc/K2BS-3DZ3].

127. Even Canada has started consultation on this issue. See Canadian Food Inspection Agency, "News release: Government of Canada Launches Consultation on Guidelines for Simulated Meat and Poultry Products" (30 November 2020), online: <https://www.canada.ca/en/food-inspection-agency/news/2020/11/government-of-canada-launches-consultation-on-guidelines-for-simulated-meat-and-poultry-products.html> [perma.cc/R73Q-P9CR]; see also Joshua Pitkoff, "State Bans on Labeling for Alternative Meat Products: Free Speech and Consumer Protection" (2021) 29 NYU Envtl LJ 297; Leo Sands, "'Steak' and 'Ham' Labels on Plant-Based Food? France Says Non" (5 September 2023), online: <https://www.washingtonpost.com/world/2023/09/05/vegan-meat-ban-france/> [perma.cc/K4T3-XDZT]; Daniel Fitzgerald, "Senate 'Fake Meat' Inquiry Recommends Overhaul of Plant-Based Protein Labelling Laws" (24 February 2022), online: <https://www.abc.net.au/news/rural/2022-02-24/definition-of-meat-inquiry-food-labelling/100855864#> [perma.cc/3P7D-YH4Z].

128. See US Bill S 3281, *Real Marketing Edible Artificials Truthfully Act of 2023*, 118th Congress, 2023, online: <perma.cc/M6S8-DBVC> and US Bill S 3693, *Fair and Accurate Ingredient Representation on Labels Act of 2024,* online: < perma.cc/9WKL-QFBW> and US Bill HR 71370, *Fair and Accurate Ingredient Representation on Labels Act of 2024*, 118th Congress, 2024, online: <perma.cc/ZE4R-WCD3>, as well as a number of US states that have implemented various measures; for example: US AB *555*, *An Act to create 97.50 of the statutes: Relating to: labeling a food product as containing lab-grown animal cells, providing an exemption from emergency rule procedures, and providing a penalty,* 2023–2024, Reg Sess, Wis, 2023, online: <perma.cc/4K93-7X2D>; US HB 2121, *Cell-cultured animal product, prohibition,* 2024, 56th Leg, Reg Sess, Ariz, 2024, online: <perma.cc/G872-L8RY>; US HB 908, *Food service establishments; certain food products to be disclosed as containing cell cultured meat and plant based meat alternatives require*, 2023–2024, Reg Sess, Ga online: <perma.cc/XB9D-8R5D>; US SB 586, *An Act Related to Cultivated* Meat, 2024, Reg Sess, Fla, 2024, online: <perma.cc/9GU8-QBNB>; US SB 582, *Prohibition on Cell Cultured Animal Products Act*, 2024, 86th Leg, Reg Sess, W Va, 2024 online: <perma.cc/JB8V-WCK3>; US HB 5349, *West Virginia Truth in Food Labeling Act*, 86th Leg, Reg Sess, W Va, 2024, online: <perma.cc/5XJF-SLL5>; US HB 2860 & SB 2870, *An Act to amend Tennessee Code Annotated, Title 39; Title 40; Title 44; Title 47 and Title 53, relative to cell-cultured food products*, 2023–2024, 113th Gen Assem, Tenn, 2024, online: <https://perma.cc/Y4FQ-CMV5>; US SB 1649, *Misbranding; misrepresenting; food products,* 56th Leg, Reg Sess, Ariz, 2024, online: <perma.cc/M4ZY-7QPX>; US SB 23, *Food Products, manufacture and distribution of meat from cultured animal cells prohibited*, 2024, Reg Sess, Ala, 2024, online: < https://perma.cc/ZJD9-VLKJ>.

initiated on this issue.[129] While 3D printed meat has not been singled out, most of the current legislative responses are broad enough to encompass all forms of cell-derived meats, including 3D printed meats. It is highly unlikely that Canada will be exempt from this controversy.[130]

Nonetheless, the first issue that will need to be addressed is what will 3D printed meat be named? Colloquially, many people may refer to the product derived from the 3D printing of animal proteins as "meat," but the question remains as to whether that is in fact an appropriate term for such a product. While the product is derived from animal cells, including commonly consumed fat and muscle cells which are then made into bioink, the manufacturing process does not require the use of an animal carcass or the slaughter of an animal.[131] Currently, the *Food and Drugs Act* and its regulations define meat in relation to the slaughter process,[132] while the *Safe Foods for Canadians Act*[133] and its regulations define meat products as "the carcass of a food animal."[134] 3D printed animal meat would not comport with either of these definitions. Thus, while the public may choose to identify and call the 3D printed product as "meat," classifying the product as such under the law will require amendments to current laws and regulations.

If the federal government fails to expand the definition of meat to include those derived from technologies not requiring the slaughter of animals or animal carcasses, manufacturers will be required to identify their meat using a different term.[135] This issue will be further complicated when attempting to identify the type of meat, grade, and cut that is being sold. For instance, scientists have successfully 3D printed a cut of wagyu beef that "looks just like the real thing."[136] Can this type of 3D printed meat legitimately be called "wagyu beef"? Again, in Canada, most of the regulatory provisions surrounding the naming of the meat, grade, and cut are premised on the meat being derived from an animal that was alive before slaughter and not on cell-derived technology.[137] These are issues that ultimately will require government

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129. Animal Legal Defense Fund, "Challenging Texas' Unconstitutional Label Censorship Law: Turtle Island Foods v. Abbott" (5 August 2024), online: <https://aldf.org/case/challenging-texas-unconstitutional-label-censorship-law/> [perma.cc/U2ZF-CYGY].

130. For instance, vegan cheese being labelled as "cheese" has created litigation in Canada. See *Rawesome Raw Vegan Inc c Procureur générale du Québec,* 2024 QCCS 9.

131. Jane McNaughton, "Printing Meat from Stem Cells Could Be the Future of Food, but Consumers Will Need Convincing" (17 May 2021) online: <https://www.abc.net.au/news/rural/2021-05-18/3D-printed-meat-grown-in-lab-from-stem-cells/100131276> [perma.cc/XJ4G-AZAK].

132. *Food and Drug Regulations, supra* note 118, s B.14.002, which states "Meat shall be the edible part of the skeletal muscle of an animal that was healthy at the time of slaughter."

133. SC 2012, c 24.

134. *Safe Food for Canadians Regulations,* SOR/2018-108, Part 1, made under the *Safe Foods for Canadians Act, ibid.*

135. This will be similar to what has transpired with "milk" alternative beverages.

136. Corryn Wetzel, "Scientists Create First 3-D Printed Wagyu Beef" (2 September 2021), online: <https://www.smithsonianmag.com/smart-news/scientists-create-first-3-d-printed-wagyu-beef-180978565/> [perma.cc/L89W-SUH3].

137. See e.g. the Canadian Beef Grading Agency (a corporation that has been accredited by the Canadian Food Inspection Agency) whose trained graders assess the whole animal carcass to determine its grade. Beef Cattle Research Council, "Carcass Grading" (last accessed 12 December 2024), online: <https://www.beefresearch.ca/topics/carcass-grading/> [perma.cc/3U4Y-PZ6G].

intervention to fully resolve, and clarification on this nomenclature and how it can be applied to a wide variety of meats produced using 3D technology will need to happen.

C. Other Labelling Concerns

In addition to naming the 3D printed product, other discussions on how to label the product will also likely produce disputes. If the definition of "meat" is updated in Canadian law to include products derived from animal proteins, how the product will be labelled for consumer information will be an area of concern. Specifically, concern will focus on whether the product needs a label identifying that the meat has been produced using 3D printed technology instead of the current slaughter process. Food labelling is also regulated in Canada. Pursuant to the *Food and Drugs Act* and the *Safe Food for Canadians Act*, food labels must not be deceptive, misleading, or untrue,[138] and they must comply with providing specific nutritional information about the food product,[139] among other requirements. These would apply to 3D printed meat, but would the manufacturing or production process need to be included? How the government handled the labelling of GM foods may provide some insight as to how this issue might be addressed.

GM foods must comply with the food labelling outlined in the *Food and Drugs Act* and the *Safe Food for Canadians Act* and their associated regulations; there are no additional legal regulations that mandate that the product must be labelled to indicate that the food was produced using genetic modification technology. The rationale for the lack of labelling requirements is that "[t]hey are labelled like any other food because our safety assessments have found them to be as safe and nutritious as non-GM foods."[140] Despite the lack of mandatory provisions, the Canadian government has supported the development of a voluntary labelling system to allow foods to identify as genetically modified or to identify as non-genetically modified.[141] The decision to include this information is left to individual manufacturers of the food product. A similar approach could work for 3D printed meat. In fact, manufacturers of 3D printed meat may want to advertise the production process given the potential market benefits of producing cruelty-free, environmentally friendly meat products.[142] But whether this is an appropriate approach to 3D printing technologies should

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138. *Food and Drugs Regulations*, *supra* note 118, s 5.

139. *Ibid* at part 11.

140. Government of Canada, "Novel Foods: Labelling Genetically Modified Foods" (18 May 2022), online: <https://www.canada.ca/en/health-canada/services/food-nutrition/genetically-modified-foods-other-novel-foods/labelling.html> [perma.cc/ZY4K-326W].

141. Canada, Standards Council of Canada & Canadian General Standards Board, *Voluntary Labelling and Advertising of Foods That Are and Are Not Products of Genetic Engineering*, reaffirmed May 2021, CAN/CGSB-32.315-2004 (2021) online (pdf): <https://publications.gc.ca/collections/collection_2021/ongc-cgsb/P29-32-315-2021-eng.pdf> [perma.cc/7XCT-774W].

142. As stated, this type of produced animal protein may have significant environmental benefits and offers a non-cruel alternative to traditional meat processing; there currently is a segment of the population who do not consume meat because of the concerns associated with traditional meat production. This population may be willing to consume this alternatively produced meat. See European Food Information Council, "Lab Grown Meat: How It Is Made and What Are the Pros and Cons" (17 March 2023) online: <https://www.eufic.org/en/food-production/article/lab-grown-meat-how-it-is-made-and-what-are-the-pros-and-cons> [perma.cc/5LQ7-C39E].

be carefully considered, and it is an issue that should be resolved prior to public sale of these products.

VI CONCLUSION

What will consumer response to 3D printed meat be? The answer to this question will likely ultimately determine whether the animal benefits, environmental benefits, and public health benefits discussed herein will be realized. One study showed that novel methods of food production that use digital technology are not well understood by consumers, meaning, essentially, that significant public education and advertisement will need to happen before these products become part of mainstream diet.[143] Even if consumers are willing to try these products, affordability may ultimately remain an issue.[144] Another key area of concern for consumers is where these products will be available. Will this process be a new form of mass industrialization replacing or building new printing factories beside traditional abattoirs? Will these processes become so efficient that restaurants or individuals will start purchasing their own 3D printers, bioinks, and recipe software? One of the biggest hurdles for consumers is how these products will taste. Will they really be able to replicate the texture and taste of traditional meat? How will these rapidly changing markets be regulated, if at all? These are several of the many questions that the 3D printing of meat raises and that need further investigation and research.

That said, despite the complicated regulatory demands this novel technology potentially presents, the 3D printing of meat could, once several of these regulatory concerns are adequately dealt with, be used to reduce some of the animal law concerns we have identified in this article, to reduce environmental degradation and destruction, and maybe to improve both animal and human health. Our article was limited in scope and focused on identifying key issues that the technology could alleviate in its application and some of the key regulatory issues that are bound to arise. As noted, more questions exist than we have raised here, and all of these will need to be answered at some point. However, while 3D printing of meat is not a panacea for the issues we have identified, it is certainly a new and developing technology that, when viewed through a system of animal ethics that gives greater moral consideration to animals and abides by the precautionary principle, offers considerable promise to make our world safer now and for future generations.

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143. Ramachandraiah, *supra* note 23 at 15.

144. Rubin, *supra* note 114. Currently the cost of production is approximately twice the current market price of beef available for purchase, but eventually current manufacturers of 3D printed meat expect the cost to be cheaper than traditional meat.