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THE MOVEABLE FEAST: LEGAL, ETHICAL, AND SOCIAL IMPLICATIONS OF CONVERGING TECHNOLOGIES ON OUR DINNER TABLES

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Abstract

From genetically modified crops to nanoparticles in our food, converging technologies are changing what we eat and how we eat it. "Converging technologies" refers to the union of Nanotechnology, Biotechnology, Information Technologies, and Cognitive Sciences (NBIC). Genetically modified organisms (GMOs) are already part of the legal landscape and nanofoods are not far behind. Nutraceuticals that claim to boost brain power are already available at your local health food store; the NBIC convergence promises to deliver such results as treatments for malnutrition and obesity, targeted nutrition, timed-release food, a cruelty-free and sustainable way to produce meat, and food packaging that reports spoilage before it is visible to the naked eye. In this article we review some of the latest trends and developments in the application of nanotechnology to our foods and food sources, define nanofoods, and argue that with proper regulation and oversight this technology may provide solutions to the problems of equity of scarce resources, sustainable food practices, and ethical treatment of animals without eliminating the need for smaller family farms.

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> I have long believed that good food, good eating is all about risk. Whether we're talking about unpasteurized Stilton, [or] raw oysters . . . food, for me, has always been an adventure.
>
> *Anthony Bourdain*[1]

> Don't forget that the flavors of wine and cheese depend upon the types of infecting microorganisms.
>
> *Martin H. Fischer*[2]

I. Introduction

Food is more than mere sustenance. It is the centerpiece of many cultural traditions and identity, a source of comfort, the subject of art, poems, and song. But it is also a limited resource, a source of conflict, and a sociopolitical hornet's nest.

In response to rapid population growth, humans have created new technologies to help meet the growing demand for food. Many of these advances have come at a hefty cost, such as the damage to the environment from factory farming, the suffering and pain to sentient beings from concentrated animal feeding operations (CAFOs), and the depletion of fish and mollusk stocks in the oceans due to overfishing.[3] Stewardship of the environment and resources has been placed in government hands, yet technologies have not always been used with due consideration to sustainability of our planet's resources and long-term consequences.[4]

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1 Anthony Bourdain, Kitchen Confidential 6 (2000).

2 Martin H. Fischer, Fischerisms: Being a Sheaf of Sundry and Divers Utterances Culled from the Lectures of Martin H. Fischer, Emeritus Professor of Physiology in the University of Cincinatti (1961).

3 Pew Oceans Comm'n, America's Living Oceans 61-64 (2003), *available* at http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Protecting_ocean_life/env_pew_oceans_final_report.pdf.

4 *Id*. at 10.

In 2003, two researchers at the National Science Foundation and their colleagues coined the phrase "NBIC," referring to the convergence of four science and technology provinces:

> (1) Nanoscience and nanotechnology;
> (2) Biotechnology and biomedicine, including genetic engineering;
> (3) Information technology, including advanced computing and communications; and
> (4) Cognitive science, including cognitive neuroscience.[5]

Nanotechnology is a fundamental enabling technology that allows the manipulation, creation, and/or manufacture of materials and products hereto unforeseen.[6] What makes it so unique is that the behavior and the properties of matter at the nano-scale (i.e., less than 100 nanometers) can change radically and display attributes (known as "quantum effects") not seen at the macro or micro level, such as conductivity, self-assembly, elasticity, increased strength, different color or greater reactivity.[7] These changes and behaviors are not always predictable.[8] As with any new technology, there always will be risks, challenges, and unintended consequences accompanying the benefits.[9]

In the opinion of the authors, technology, nano or otherwise, can and does often amplify the full spectrum of human nature—the good, the bad, and the indifferent. Because of advances in technology, life expectancies in civilized countries are longer than they ever have been; by the same token, technology has taken and shortened lives when used for destructive purposes. "Complexity theory proposes that actions have

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5 Converging Technologies for Improving Human Performance 1-2 (Mihail C. Roco & William Sims Bainbridge eds., 2003), *available* at http://www.wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf.

6 *See* Linda M. Glenn & Jeanann S. Boyce, *Regenerative Nanomedicine: Ethical, Legal, and Social Issues*, 811 Methods Molecular Biology 303 (2012).

7 *See* Linda M. Glenn & Jeanann S. Boyce, *Nanotechnology: Considering the Complex Ethical, Legal, and Societal Issues with the Parameters of Human Performance*, 2 Nanoethics 265, 266 (2008).

8 *Id.*

9 *Id.*; *see also* Tim Healy, The Unanticipated Consequences of Technology, Santa Clara Univ., http://www.scu.edu/ethics/publications/submitted/healy/consequences.html (last visited Dec. 5, 2011).

consequences" and that those actions can have "profound effects on the . . . system."[10] The authors contend that the creation of new technology is no different. In this paper, we are advocating a thoughtful, cautious approach with a systemic, inter-relational perspective.

II. Defining Nanotechnology and Nanomaterials–A Complex Task

A. Definitions

The National Nanotechnology Initiative (NNI) defines a nanometer as one billionth of a meter.[11] It also declares that "[n]anotechnology is the understanding and control of matter . . . at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications."[12] In the European Union, the "only legal definition for nanomaterials is" encapsulated "in the Cosmetics Regulation (EC 1223/2009), which defines nanomaterials (for labeling purposes) as 'insoluble or biopersistent and intentionally manufactured . . . with one or more external dimensions or an internal structure on the scale of 1-100-nanometres.'"[13] But size alone is insufficient to define for the purposes of regulation, as explained in the following section.

B. Size matters, but so does shape (and surface chemistry)

"If the definition" of nanomaterial "concentrated on size alone, it would encompass a vast swathe of perfectly innocuous" "nanomaterials in products from milk to chocolate."[14] However, "some researchers claim

10 Deborah Bowman & John Spicer, Primary Care Ethics 122-23 (2007).

11 Nat'l Nanotechnology Initiative, http://www.nano.gov (last visited Mar. 18, 2012). For comparative illustrations of the size of a nanometer, see *Nanotechnology 101*, http://www.nano.gov/ nanotech-101/what/nano-size.

12 *Id.* at http://www.nano.gov/nanotech-101/what.

13 Elaine Watson, *Nano Definition is a Legal Minefield, Warn Scientists*, FoodProductionDaily.com (Sept. 20, 2010), http://www.foodproductiondaily.com/Quality-Safety/Nano-definition-is-a-legal-minefield-warn-scientists. Regulation 1223/2009, art. 2(1)(k) of the European Parliament and of the Council of 30 November 2009 on Cosmetic Products, 2009 O.J. (L 342) 65 (EC).

14 *Id.*

that use of naturally occurring nanoparticles should be treated differently than their synthetically prepared or engineered analogs."[15] In fact, some naturally occurring nanoparticles can be dangerous. "Exposure to naturally occurring particles" or byproducts of human activity can pose a significant risk to health (e.g., pollution, smoke from forest fires, volcanic eruptions, coal dust, talc, second-hand smoke).[16]

Nanoparticles interact differently with their environment depending on the shape and surface chemistry. For example, silver nanoparticles are more effective if the shape is a truncated triangular nanoplate as opposed to a sphere.[17] Cobalt nanoparticles behave very differently if they are cube-shaped, rather than spherical.[18] Cobalt nanocubes possess different magnetic characteristics than nanospheres; nanocubes can fuse, forming nanowires that are no longer separable as individual nanoparticles.[19]

The current lack of standardized definitions and legally recognized means of determining the size, distribution, and interactive characteristics of such tiny components in foods poses serious problems. Enforcement of any such standards has been hampered by the "cost and complexity of the equipment typically used to examine materials at" the nanoscale (e.g., atomic force or scanning electron microscopes).[20] At a workshop that took place in the United Kingdom in 2010, scientists and legal experts attempted to tackle questions about consumer labeling requirements and definition of terms such as 'insoluble' or 'manufactured.'[21]

At a separate event, a roundtable debate facilitated by the United Kingdom's Food Standards Agency, a director of research and development at Unilever offered "several factors needed to be taken into account when

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15 Glenn & Boyce, *Regenerative Nanomedicine*, *supra* note 6, at 304.

16 *Id.*

17 Sukdeb Pal, Yu Kyung Tak & Joon Myong Song, *Does Antibacterial Activity of Silver Nanoparticles Depend on the Shape of the Nanoparticle? A Study of the Gram-Negative Bacterium Escherichia coli*, 73 Applied & Envtl. Microbiology 1712, 1717 (2007).

18 *See generally* Guangjun Cheng, Robert D. Shull & A.R. Hight Walker, *Dipolar Chains Formed by Chemically Synthesized Cobalt Nanocubes*, 321 J. Magnetism & Magnetic Materials 1351 (2009).

19 *Id.* at 1354.

20 Watson, *supra* note 13.

21 *See id.*

devising a workable definition of nanomaterial."[22] He opined "[It must take into account] particle size; deliberate engineering; digestibility for nanomaterials used in foods and solubility in conditions of use for materials used in home/personal care products; [and] the characteristic properties of the nanomaterial compared to its non-nano forms."[23]

Whatever definitions can be agreed upon will need to take into account the multiple shapes and surface chemistries, as well as the factors considered above.

C. A system of classification and categorization

This quandary is not exclusive to the food industry. It was only in late 2010 that the International Organization for Standardization (ISO) adopted the "Methodology for the Classification and Categorization of Nanomaterials. "[24] This methodology presented a systematic approach to classifying and categorizing nanomaterials according to their size, chemical nature, properties, and characteristics.[25] The methodology (referred to as ISO/TR 11360) "introduces a system called the 'nano-tree', which places nanotechnology concepts into a logical context by symbolizing relationships among them as a branching out tree. The most basic and common elements are defined as the main trunk of the tree, and nanomaterials are then differentiated in terms of structure, chemical nature and other properties."[26]

Within the food industry, the application of nanomaterials and nano-based technology "may include nanoparticulate delivery systems (e.g. micelles, liposomes, nanoemulsion, colloids, biopolymeric nanoparticles, and cubosomes), food safety and biosecurity (e.g. nanosensors), and nanotoxicity."[27]

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22 *Id.*

23 *Id.*

24 Int'l Org. for Standardization, Nanotechnologies—Methodology For the Classification and Categorization of Nanomaterials 2 (2010).

25 Press Release, Int'l Org. for Standardization, New ISO Methodology Demystifies Nanomaterials (Aug. 17, 2010), *available at* http://www.iso.org/iso/pressrelease.htm?refid=Ref1345.

26 *Id.*

27 Chi-Fai Chau, Shiuan-Huei Wu & Gow-Chin Yen, *The Development of Regulations for Food Nanotechnology*, 18 Trends in Food Sci. & Tech. 269, 269 (2007).

How the ISO's system of categorization and classification will impact the use of nanotechnology in food and food processing remains to be seen in the next few years as scientists, manufacturers, policy makers, and legal experts seek to apply this system to labeling, legislation, and/or regulation.

III. Nanofood

A. Definition

There have been few attempts at defining nanofood. Those attempts have been less than comprehensive, and the term has been used in different contexts in different journals.[28] Although this definition may change as the new ISO standards are incorporated into everyday use, our proposed working definition for nanofoods is:

> Food which has intentionally-produced materials in the order of 100-nanometres or less, and undergone one or more technological processes, at the nano-scale level, to manipulate the selection, extraction, storage, combination, transport, increase or decrease in one or more of its properties or characteristics, nutritional and organoleptic properties intrinsic to the substance or linked to specific physiological, social and economic properties of that substance.

This definition deliberately encompasses nanomaterials that are being consumed as well as those in the packaging or preparation, because distinctions are not always possible or useful.[29] For example, different types of nanomaterials are incorporated into an organic polymer (such as chitosan) matrix to be sprayed onto fresh cut fruit, to extend

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28 *See, e.g.*, *id.*; Ai Lin Chun, *Will the Public Swallow Nanofood*? 4 Nature Nanotechnology 790, 790-91 (2009); Ksenia Takhistova, Note & Comment, *Food Nanotechnology—In Search of a Regulatory Framework,* 35 Rutgers Computer & Tech. L.J. 255 (2009).

29 *See generally* Timothy V. Duncan, *Applications of Nanotechnology in Food Packaging and Food Safety: Barrier Materials, Antimicrobials and Sensors*, 363 J. Colloid & Interface Sci. 1 (2011).

shelf life.[30] Nanoparticles of titanium dioxide are added to chocolate to avoid the separation of the cocoa butter from the cocoa solids.[31] Other "edible coatings and films are currently used on a wide variety of foods, including fruits, vegetables, meats, chocolate, candies, bakery products, and French fries."[32] These often serve as "moisture, lipid, and gas barriers" and may be used to "improve the textural properties of foods or serve as carriers of functional agents such as colors, flavors, antioxidants, nutrients, and antimicrobials."[33] Until there is a better understanding of the size, distribution, and interactive characteristics of the materials and technology used, such distinctions are, arguably, irrelevant.

B. What's for dinner?

1. Now (2011)

Nanoingredients already are appearing in food, but currently there are no laws requiring labeling.[34] But until more is known about nanomaterials and their interactive quality, both inside the body and out, and the public is more accepting, no major food company is touting its use of nanomaterials. Here are just a few of the items that contain intentionally produced materials as described in the previous section:

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30 Olga Martín-Belloso & Robert Soliva-Fortuny, Advances in Fresh-Cut Fruits and Vegetables Processing 382 (2010); *see also* Mª Alejandra Rojas-Graü et al., *The Use of Packaging Techniques to Maintain Freshness in Fresh-Cut Fruits and Vegetables: A Review*, 44 Int'l J. Food Sci. & Tech. 875, 885 (2009).

31 Antonietta M. Gatti et al., *Investigation of the Presence of Inorganic Micro- and Nanosized Contaminants in Bread and Biscuits by Environmental Scanning Electron Microscopy*, 49 Critical Reviews Food Sci. & Nutrition 275, 281 (2009).

32 Jochen Weiss et al., *Functional Materials in Food Nanotechnology*, 71 J. Food Sci. R107, R110 (2006).

33 *Id.*; *see also* Hongda Chen et al., *Nanotechnology in Nutraceuticals and Functional Foods*, 603 Food Technology 30, 30–6 (2006).

34 *See* Takhistova, *supra* note 28 (which describes what the FDA currently requires in terms of labeling).

Functional foods, nutraceuticals, and fortified foods[35]:

- Tip-Top Up Bread, made in Australia; bread with nano-capsules for fish oil, which contains health-enhancing Omega-3 fatty acids.[36]
- Nanoteas, which are selenium enriched and available "in black, green, dark green, yellow, white and dark — may be mixed in cold or hot water."[37] The manufacturer claims, "the tenfold release of phytonutrients and selenium is effective in boosting adsorption of free radicals, cholesterol and blood fat and the annihilation of viruses through rapid penetration."[38]
- Enhanced vitamin and antioxidant sports drinks, touting the increased "bioavailability" (via 'concentration') of the "healthful micronutrients" of "cranberry juice, blueberry juice, wine" or cocoa.[39]
- Milk, yogurt, dairy products, and wheat and rice-based foods fortified with iron nanoparticles.[40]

Food additives, enhancers, and nutritional supplements:

- "Multinational German chemical manufacturer BASF produces nano-scale synthetic lycopene (a carotenoid) as a food additive for lemonade, fruit juices, cheese and margarine. Carotenoids are antioxidants and are converted into vitamin A in the body. Nano-scale carotenoids, according to BASF, are more easily absorbed

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35 Functional food (also referred to as nutraceuticals) is any food claimed to have a health-promoting or disease-preventing property beyond the basic function of supplying nutrients (e.g., provision of probiotics or antioxidants, promotion of cardiovascular benefits, relief of menopausal symptoms). *See* Chen et al., *supra* note 33, at 31.

36 Kantha Shelke, *Tiny, Invisible Ingredients*, FoodProcessing.com, http://www.foodprocessing.com/articles/2006/227.html (last visited Dec. 23, 2011).

37 *Id.*

38 *Id.*

39 *Id.*

40 *See, e.g.*, *SunActive Iron*, HighVive.com, http://www.highvive.com/sunactiveiron.htm (last visited July 15, 2011); Nathan Gray, *Iron Nano-Structures Open Up Food Fortification Opportunities*, Foodnavigator.com (Nov. 9, 2010), http://www.foodnavigator.com/Science-Nutrition/Iron-nano-structures-open-up-food-fortification-opportunities.

by the body and increase product shelf life."[41]

- NanoCoffee Energy[42] tablets and NaNo X9 Hardcore Pro Series[43] (for sustained energy and power boost).

2. In the near future (2020 or sooner, hopefully)

Other practical applications in the works include the creation of sustained-release nutrition, which would be of tremendous use for sustenance in inaccessible areas (such as for the military or space travel).[44] Sustained-release nutrition combined with the use of nanosensors to trigger satiation could be used in the treatment of obesity and related diseases, such as diabetes and high cholesterol.[45] As promising as these developments sound, the technology has the potential to change one of the most difficult and controversial areas of the food industry: meat production.[46] The world's appetite for meat is growing, but current methods of mass meat production are unsustainable.[47]

As chronicled in an extensive report by the Food and Agriculture Organization of the United Nations (FAO) and as detailed in other recent publications, the commercial livestock sector and particularly concentrated animal feeding operations (CAFOs) are environmentally

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41 Shelke, *supra* note 36.

42 Nano Coffee Energy, http://www.nano-coffee.com/ (last visited Dec. 22, 2011).

43 *MuscleTech NaNO X9 Hardcore Pro Series*, BodyBuilding.com, http://www.bodybuilding.com/store/mt/nano-x9-hardcore-pro-series.html (last visited Jan. 24, 2012).

44 Inst. of Med., Nanotechnology in Food Products: Workshop Summary (Leslie Pray & Ann Yaktine eds., 2009), *available at* http://www.ncbi.nlm.nih.gov/books/NBK32730/pdf/TOC.pdf.

45 *Id.*

46 *See* Philip K. Thornton, *Livestock Production: Recent Trends, Future Prospects*, 365 Phil. Transactions Royal Soc'y 2853, 2864 (2010), *available at* http://rstb.royalsocietypublishing.org/content/365/1554/2853.full.pdf; *see also* H. Charles J. Godfray et al., *The Future of the Global Food System*, 365 Phil. Transactions Royal Soc'y 2771 (2010), *available at* http://rstb.royalsocietypublishing.org/content/365/1554/2769.full.pdf.

47 *See* Thornton et al., *supra* note 46, at 2864-65; *see also* The Royal Society, Reaping the Benefits: Science and the Sustainable Intensification of Global Agriculture (2009), *available at* http://royalsociety.org/Reaping thebenefits/.

damaging and present a risk to public health.[48, 49] This issue "emerges as one of the top two or three most significant contributors to the most serious environmental problems, at every scale from local to global."[50] The UN FAO Report explains that, "[t]his is not done simply to blame the rapidly growing and intensifying global livestock sector for severely damaging the environment but to encourage decisive measures at the technical and political levels for mitigating such damage."[51] One of the ways to mitigate the damage is to encourage policies that include environmental and health friendly technology development and promotion, "together with interventions in market development."[52]

The use of nanotechnology may present an alternative solution to this problem.[53] It is just one of the newer technologies in development

48 *See* Food & Agric. Org. of the United Nations, Livestock's Long Shadow (2006), *available at* ftp://ftp.fao.org/docrep/fao/010/a0701e/a0701e.pdf [hereinafter FAO Report]; *see also* Ramona Cristina Ilea, *Intensive Livestock Farming: Global Trends, Increased Environmental Concerns, and Ethical Solutions*, 22 J. Agric. & Envtl. Ethics 153, 154 (2009), *available at* http://www.springerlink.com/content/3x0564784525k717/fulltext.pdf.

49 *See generally* CAFO: The Tragedy of Industrial Animal Factories (Daniel Imhoff ed., 2010); Jonathan Safran Foer, Eating Animals (2010); David Kirby, Animal Factory: The Looming Threat of Industrial Pig, Dairy, and Poultry to Humans and the Environment (2010); Michael Pollan, The Omnivore's Dilemma: A Natural History of Four Meals (2006); The Fatal Harvest Reader: The Tragedy of Industrial Agriculture (Andrew Kimbrell ed., 2002).

50 FAO Report, *supra* note 48, at xx. *See also*, sources cited *supra* note 59.

51 *Id.* at iii.

52 *Id.* at 225.

53 *See generally* Rickey Yada, *Nanotechnology: A New Frontier in Foods, Food Packaging, and Nutrient Delivery*, *summarized in* Inst. of Med., Nanotechnology in Food Products: Workshop Summary, (Leslie Pray & Ann Yaktine eds., 2009), *available at* http://www.ncbi.nlm.nih.gov/books/NBK32730/pdf/TOC.pdf; Hongda Chen & Rickey Yada, *Nanotechnologies in Agriculture: New Tools for Sustainable Development*, 22 Trends Food Sci. & Tech. 585 (2011); Jennifer Kuzma & Peter VerHage, Project on Emerging Nanotechnologies, Woodrow Wilson Int'l Ctr. for Scholars, Nanotechnology in Agriculture and Food Production: Anticipated Applications (2006), *available at* http://www.nanotechproject.org/process/assets/files/2706/94_pen4_agfood.pdf; Dennis D. Miller, *Food Nanotechnology: New Leverage Against Iron Deficiency*, 5 Nature Nanotechnology 318 (2010); M. Ellin Doyle, *Nanotechnology: A Brief Literature Review*, Food

"that ha[s] the potential not only to increase farm productivity but also to reduce the environmental and resource costs often associated with agricultural production."[54]

One area of food production that is gaining attention is the development of cultured meat, also referred to as "in vitro meat" or "vat meat."[55] In vitro meat could potentially bypass many of the public health issues that are currently associated with livestock-based meat.[56] In fairly simple terms, cultured meat is created by adhering animal stem cells onto biodegradable edible scaffolds, and immersing them into a nutrient bath, causing the growth of muscle cells.[57] This technology borrows an engineering technique that is used to replicate and reproduce cells in regenerative nanomedicine,[58] and is presently capable of producing small yields of meat.[59] Pork produced in this manner has been described as "sort of like a scallop, firm but a little squishy and moist."[60] However, when this process becomes commercially feasible, there will be benefits to humans

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Research Inst. Briefings (Food Research Inst., Madison, Wis.), June 2006, *available at* http://www.fri.wisc.edu/docs/pdf/FRIBrief_Nanotech_Lit_Rev.pdf; Guillaume Gruère et al., *Agricultural, Food, and Water Nanotechnologies for the Poor* (Int'l Food Policy Research Inst., Discussion Paper No. 1064, 2011, *available at* http://www.ifpri.org/sites/default/files/publications/ifpridp01064.pdf; Cathy Garber, *Nanotechnology Food Coming to a Fridge Near You*, Nanowerk (Dec. 28, 2006), http://www.nanowerk.com/spotlight/spotid=1360.php; E. Nord, *Top 10 Reasons for Using Nanotech in Food*, Discovery.com, http://www.nanotech-now.com/news.cgi?story_id=32231 (last visited Feb 26, 2012).

54 Chen & Yada, *supra* note 53, at 585.

55 Lauren Davis, *Vat-Grown Meat Alive in the Lab, But Not Ready to Eat*, io9 (Nov. 30, 2009, 11:55 AM), http://io9.com/5415385/vat+grown-meat-alive-in-the-lab-but-not-ready-to-eat.

56 Thornton, *supra* note 46, at 2863-2864.

57 *See* David Szondy, *The First Lab-Grown Hamburger Will Cost $345,000*, Gizmag (Nov. 27, 2011), http://www.gizmag.com/lab-grown-meat/20625/; *see also Advancing Meat Substitutes*, New Harvest, http://www.new-harvest.org/faq.htm (last visited Dec. 23, 2011); *Primer on Technology*, The In Vitro Meat Consortium, http://invitromeat.org/content/view/30/51/ (last visited Dec. 23, 2011).

58 *See generally,* Glenn & Boyce, *supra* note 6.

59 *See* Szondy, *supra* note 57.

60 Maria Cheng, *Scientists Turn Stem Cells Into Pork*, MSNBC.com (Jan. 15, 2010, 1:57:19 PM), http://www.msnbc.msn.com/id/34881174/ns/technology_and_science-innovation#.TzFjMM12mPU.

in terms of sustainability and environmental impact, and to animals in terms of reduction of suffering.[61]

Anecdotally, when the authors have mentioned the idea of cultured meat to friends and family, the reaction in many instances has initially been one of disgust and revulsion.[62] That is somewhat ironic for a society that is perfectly fine with spraying cheese out of a can or eating a turkey hotdog or chicken nugget. These foods bear little resemblance to their antecedents, having been manipulated by consistency or taste into a form more convenient, or in the case of turkey hotdogs, into a "healthier" version of another highly processed product. We will probably see the first use of this "vat meat" in something like a sausage, although a burger may be on the horizon soon.[63]

According to Paul Shapiro of the Humane Society of the United States, "in vitro meat has the potential to prevent an enormous amount of animal suffering."[64] By reducing the number of CAFOs where animals are kept in tight, unsanitary quarters, it is obvious that it has the potential to reduce animal suffering as well.[65]

In 2008, People for the Ethical Treatment of Animals (PETA) announced a $1 million prize to the first organization that could develop a commercially viable in vitro meat product.[66] In a statement regarding the prize, PETA co-founder and president Ingrid Newkirk said, "We don't mind taking uncomfortable positions if it means that fewer animals suffer."[67] Newkirk's rationale is consistent with PETA's goals. Acknowledging that most people are not going to give up eating meat, PETA prefers that the meat come at a more humane price. While far-

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61 Thornton, *supra* note 46, at 2863.

62 Or, as said Lucretius: "What is food to one, is to others bitter poison." Lucretius, De Rerum Natura, Book VI, Line 637.

63 *See* Nick Collins, *First Artificial Burger to Cost £250,000*, The Telegraph (Sept. 1, 2011, 6:40 AM), http://www.telegraph.co.uk/science/science-news/8733576/First-artificial-burger-to-cost-250000.html.

64 James McWilliams, *Eating (Synthetic) Animals*, The Atlantic (June 30, 2010, 9:19 AM), http://www.theatlantic.com/life/archive/2010/06/eating-synthetic-animals/58930.

65 Thornton, *supra* note 46.

66 Collins, *supra* note 63.

67 John Schwartz, *PETA's Latest Tactic: $1 Million for Fake Meat*, N.Y. Times (Apr. 21, 2008), http://www.nytimes.com/2008/04/21/us/21meat.html?pagewanted=print.

reaching, PETA's stance has drawn fire from more radical animal rights groups for not going far enough.[68]

The Humane Society of the United States and PETA are in conflict with other environmental organizations, which see cultured meat as a step in the wrong direction.[69] In an article in *The Atlantic*, Professor James McWilliams counters the arguments, raised by Kate McMahon of Friends of the Earth and Josh Viertel of Slow Food USA, that cultured meat is a threat to small farms as it increases the gap between the food source and the consumer.[70] McWilliams argues:

> Both McMahon and Viertel seem to forget that an integral aspect of animal cruelty is not just how an animal is treated while it's alive but also the inconvenient truth that—*no matter how they are raised*—the animals we eat ultimately succumb to a violent death, one that they are smart enough to anticipate, sentient enough to suffer through, and, were they given an option, wise enough to avoid. On some (philosophical?) level, the humanity of the treatment is compromised the moment the death blow lands—this is certainly "one of the problems with cruelty to animals."[71]

Another significant benefit to producing cultured meat is the greatly reduced risk of deadly foodborne pathogens, such as E. coli and Salmonella, both of which are introduced into the food supply as the result of conditions at CAFOs and pose serious health risks.[72] Given the limited resources of the Food and Drug Administration (FDA), it is impossible to perform adequate testing to prevent outbreaks of these microorganisms.[73] The resources, out of necessity, go toward tracking down the sources of

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68 McWilliams, *supra* note 64.

69 *Id*.

70 *Id*.

71 *Id*. (emphasis in original).

72 FAO report, *supra* note 48 at 16, 17.

73 *See generally* Inst. of Med. & Nat'l Research Council, Enhancing Food Safety: The Role of the Food and Drug Administration (Robert B. Wallace & Maria Oria eds., 2010), *available at* http://www.nap.edu/catalog.php?record_id=12892#toc.

outbreaks.[74] It is vastly easier to monitor a food production operation than a farm.[75] By moving the operation from the feedlot to the factory, there is the opportunity for better FDA oversight.

In addition, producing cultured meat is far more sustainable than traditionally farmed meat. According to a lifecycle assessment performed by Tuomisto and Teizeira de Mattos, cultured meat uses 35 to 60 percent less energy, emits 80 to 95 percent less greenhouse gas, and uses 98 percent less land than traditional agriculture.[76] In a tightening global energy economy, these savings may make it possible for meat/protein scarce communities to have access to an inexpensive, environmentally friendly and sustainable commodity.

C. Feeding the world's hungry

Nanotechnology has the potential to provide enormous benefits to poor communities worldwide. At the basic level, the issue of food insecurity can be mitigated by the benefit of increasing crop yields on small subsistence farms where the farmers generally consume most of what they grow.[77] There is, of course, the question of how to get such technology to this audience. Poor countries face roadblocks and challenges with any effort at introducing nanotechnology into their agricultural programs. Governments, research institutions and private investors are reluctant to financially support "expensive, potentially risky or uncertain research."[78] Of the ten most promising nanotechnology applications likely to benefit the poor in developing countries, agricultural production ranked second, and food processing and storage ranked sixth.[79] Each of the previously discussed technologies can play a role in meeting this goal. These include the use of nanoherbicides and nanofertilizers for crops as well as nanofeed additives such as bioactive polystyrene nanoparticles to reduce food-borne

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74 *Id.*

75 *Id.*

76 Hanna L. Tuomisto & M. Joost Teixeira de Mattos, *Environmental Impacts of Cultured Meat Production*, 45 Envtl. Sci. & Tech. 6117, 6117 (2011).

77 See generally, The Royal Society, *supra* note 47.

78 Gruère et al., *supra* note 53, at 9-10.

79 Fabio Salamanca-Buentello et al., *Nanotechnology and the Developing World*, 2 PLoSMedicine 383, 385 (2005).

pathogens in poultry.[80] In addition, nanoporous zeolites can be used to facilitate "slow release and efficient dosage of water and fertilizer."[81] The benefits in terms of food security far outweigh the obstacles, and efforts need to be directed at developing partnerships between those nations most actively involved in advancing nanotech approaches in agriculture.

IV. Food Safety, Storage, Transport

Nanotechnology has many possible applications to food preservation and transportation. Three areas that are relatively non-controversial are "sensing volatiles, detecting microorganisms, and improving packaging and product information."[82] An example of a device that could be used is a nanotechnology-based electronic nose, which could sense contamination or early detection of pests (which, in turn, "would help agricultural production").[83] Such a device could also be used in the monitoring and control of processes such as baking, pasteurizing, or vacuum sealing, or in quality assurance (for example, freshness or early warning about spoilage in a refrigerated environment).[84]

One of the applications that the food industry is employing is the use of microcomposite clay coatings to decrease gas permeability and opacity in bottles.[85] The polymer composites incorporating clay nanoparticles are among the first nanocomposites to emerge on the market as improved materials for food packaging.[86]

> Nanoclays are nanoparticles of layered mineral silicates with a specialized structure, characterized by platelet morphology. The platelets have submicron dimensions, excepting their thickness, which is only about one nanometer. These platelets force gases to follow a

80 Gruère et al., *supra* note 53, at 4.

81 *Id.*

82 Inst. of Med., *supra* note 44, at 37.

83 *Id.* at 37-38.

84 *Id.*

85 *Food Packaging Based on Nanoclay Composites: Multilayer PET*, ObservatoryNANO, http://www.observatorynano.eu/project/document/2092 (last visited Dec. 23, 2011).

86 *Id.*

> tortuous path through the polymer greatly slowing their transmission. Nano-layer structure of clays thus increases the path of diffusion that penetrating molecules of gases or other substances must take and significantly improves the polymer's barrier properties.[87]

Nanoclays are being incorporated into plastic beer bottles to aid in packaging stability, as well as reduce oxygen permeation to nearly the extent of glass bottles.[88] European Union-funded project ObservatoryNano gives a detailed illustration of the future of the beverage bottle: a picture of a fruit punch bottle with nanotechnology applications that are currently in use or in development.[89] The applications illustrated include nutraceuticals (e.g., Aquanova, DuraFizz, Nutralease); gas barrier coatings (e.g., NanoPack, nSec); antimicrobial coatings (e.g., Nanux, Bio-Gate); radio frequency identification (RFID) tags; UV-blocking plastic (e.g., NanoProducts, Evonik); and food quality sensors (e.g., Hanson Technologies, pSiNutria, Nanoident).[90]

Use of silver nanoparticles in all manner of appliances for their antimicrobial properties has recently become re-popularized.[91] In the late 19th century, the botanist von Nägeli discovered that minute concentrations of silver contained microbicidal properties,[92] but with the discovery of penicillin and other antibiotics, this common medicinal remedy fell into disuse.[93] With the advent of "super-bugs" and strains of bacteria showing a growing resistance to antibiotics, silver has come back into fashion.[94] There are a number of companies incorporating nano-silver

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87 *Id.*

88 *Id.*

89 *Nanotechnologies Applications in a Juice Bottle*, ObservatoryNANO, http://www.observatorynano.eu/project/document/2077/ (last visited May 5, 2011).

90 *Id.*

91 Samuel N. Luoma, Woodrow Wilson Int'l Ctr. for Scholars, Silver Nanotechnologies and the Environment: Old Problems or New Challenges? 12 (2008).

92 Carol Wickenkamp, *Old Fashioned Remedies Effective Against Superbugs: Part I*, PureInsight.org, http://www.pureinsight.org/node/3563 (last visited Apr. 3, 2012)..

93 Luoma, *supra* note 91, at 14.

94 *See id.* at 26.

particles into their products.[95] Samsung, for example, has introduced a Silver Nano Health System, which includes a refrigerator, air conditioner and "silver wash."[96]

Silver is also incorporated in such items as cutting boards and food storage containers.[97] A web search of "silver nano food storage" returned several thousand hits.[98] However, concerns about the safety of the use of nanosilver particles remain. Studies suggesting that nanosilver particles interfere with DNA replication and interact directly with the genome,[99] evidence of the harm nanosilver particles cause to aquatic environments and creatures,[100] and the filing of a lawsuit by a consumer group seeking the removal of more than 200 nanosilver products from the market[101] all serve as a reminder that nanosilver particles are not yet considered entirely safe.

Despite consumer wariness about nanofoods and despite the concerns mentioned about the safety of nanosilver, the initial indications are that consumers are more comfortable with the application of nanotechnology to food storage[102] and the use of silver nanoparticles "to disinfect and deodorize surfaces in kitchens, bathrooms and even baby clothes."[103]

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95 *Id.* at 11-12.

96 *Samsung Silver Nano Technology*, Samsung Elec. Co., http://www.samsung.com/my/consumer/learningresources/silvernano/silvernano/index.html (last visited Dec. 23, 2011).

97 Luoma, *supra* note 91.

98 http://www.google.com/ (type "silver nano food storage" into the search bar; then click "Google Search").

99 Michael Berger, *Nanosilver Used in Food Storage Materials Found to Interfere with DNA Replication*, Nanowerk (Feb. 19, 2009), http://www.nanowerk.com/spotlight/spotid=9340.php.

100 Sandy Chase, *Nanotechnology Risks: The Unclear Fate of Nanosilver*, Nanowerk (June 25, 2008), http://www.nanowerk.com/news/newsid=6190.php.

101 Press Release, Int'l Ctr. for Tech. Assessment, Groups Demand EPA Stop Sale of 200+ Potentially Dangerous Nano-Silver Products (May 1, 2008), *available at* http://www.icta.org/files/2011/12/CTA_nano-silver_press_release_5_1_08.pdf.

102 Food Standards Agency, FSA Citizens Forums: Nanotechnology and Food 2 (2011), *available at* http://www.food.gov.uk/multimedia/pdfs/publication/fsacfnanotechnologyfood.pdf.

103 Luoma, *supra* note 91.

IV. Current Laws and Policy Recommendations

A. Case law

Case law on issues of safety or regulation in nanotechnology is nil or non-existent. However, we may, by analogy, extrapolate the approach the United States courts would take to such issues by considering the case of *Monsanto Co. v. Geertson Seed Farms*.[104] The case arose from the struggle over the regulatory status of Roundup Ready alfalfa (RRA), a crop genetically engineered by petitioner Monsanto to tolerate glyphosate, the active ingredient in the herbicide Roundup.[105] "The United States has never passed legislation focused on regulating biotech crops; instead the United States Department of Agriculture (USDA) regulates biotech crops under its rules governing 'plant pests.'"[106] Under the Plant Protection Act (PPA), the Secretary of Agriculture or his designee, which in this case was the Animal and Plant Health Inspection Service (APHIS), was given authority to promulgate regulations governing the introduction of genetically modified organisms (GMO) that are or are believed to be plant pests.[107] Monsanto's RRA was initially classified as such a GMO.[108] In 2004, Monsanto filed a petition with APHIS, seeking a determination under the PPA that RRA was not subject to the regulations.[109] Under the National Environmental Policy Act (NEPA), such a petition triggers several procedural requirements before an exemption to the regulations is granted.[110] Those procedural requirements include an environmental assessment (EA) and, depending on the assessment, an environmental

104 Monsanto Co. v. Geertson Seed Farms, 130 S. Ct. 2743 (2010)

105 Allison M. Straka, Casenote, *Geertson Seed Farms v. Johanns: Why Alfalfa is Not the Only Little Rascal for Bio-agriculture Law*, 21 Vill. Envtl. L.J. 383, 385 (2010).

106 Paul Voosen, *USDA's Alfalfa Decision Postpones Reckoning on Biotech Crops*, N.Y. Times (Jan. 28, 2011), http://www.nytimes.com/gwire/2011/01/28/28greenwire-usdas-alfalfa-decision-postpones-reckoning-on-69218.html.

107 Monsanto Co. v. Geertson Seed Farms, 130 S. Ct. 2743, 2749 (2010).

108 *Id.* at 2750.

109 *Id.*

110 *Id.*

impact statement (EIS).[111] Although APHIS prepared an EA, they did not prepare an EIS before granting Monsanto's petition to deregulate RRA.[112]

In 2006, Geertson Seed Farms and a number of environmental groups filed suit against the Secretary of Agriculture and other federal officials, seeking injunctive relief.[113] In order to grant a permanent injunction, four factors must be satisfied:

> (1) The plaintiff has to have suffered an irreparable harm.
> (2) The remedies available by law "are inadequate to compensate for that injury."
> (3) The court needs to "consider the balance of hardships between the plaintiff and defendant."
> (4) The public interest would not be harmed by this permanent injunction.[114]

In the lower courts, where injunctive relief was granted and upheld, it was noted, "irreparable harm already existed in the case, as irreversible contamination of conventional and organic alfalfa had already occurred from planting and the cross-pollination of Roundup Ready alfalfa."[115]

The United States Supreme Court reversed the injunctive relief issued by the lower courts and held that the lower courts had ruled incorrectly when they enjoined the planting of RRA because of claims RRA might be environmentally unsafe.[116] The Court explained that the injunctive relief was not an appropriate judicial remedy because the respondents could not "show that they will suffer irreparable injury if APHIS is allowed to proceed with any partial deregulation . . . . partial deregulation need not cause respondents any injury at all. . . [I]f the scope of the partial deregulation is sufficiently limited, the risk of gene flow to their crops could be virtually nonexistent."[117] The Court went on further to explain that if and when the APHIS pursues a partial deregulation that

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111 *Id.*

112 *Id.*

113 *Id.* at 2750-51.

114 *Id.* at 2756.

115 Straka*, supra* note 105, at 384.

116 Monsanto*, supra* note 107, at 2757-58.

117 *Id.* at 2759-2760.

arguably runs afoul of NEPA, respondents could file a new action seeking appropriate relief.[118]

Considering the Supreme Court was not persuaded in this case that irreparable harm would occur with the deregulation of GMOs, it seems unlikely that there will be any action on cases such as the one mentioned in the previous section, where consumer groups sought to have nanosilver products removed from the shelves.[119] Such an action would be particularly difficult as 1) nanomaterials are not currently being regulated by one agency, but by a multitude of agencies (see Section B, below) and 2) until the newly adopted ISO standards are recognized, adopted, and incorporated into United States laws, adequate definitions do not exist.[120]

B. Acts, rules, regulations

As discussed previously in section I.A, the novel characteristics of nanomaterials strongly suggest that existing laws need to be modified or replaced. The Toxic Substances Control Act (TSCA)[121], and Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)[122], both administered by the Environmental Protection Agency (EPA); the Federal Food, Drug, and Cosmetic Act (FDCA)[123], administered by the FDA and EPA; the Occupational Safety and Health Act[124], administered by the Occupational Safety and Health Administration (OSHA); and the Consumer Product Safety Act (CPSA)[125], administered by the Consumer Product Safety Commission (CPSC), are just a handful of the acts that have mechanisms for regulating nanotechnology risks. Yet, in the opinion of the authors, none of these considered or were designed with the peculiar characteristics of nanotechnology in mind.

As discussed earlier in section II.B, the acceptance and adoption of the ISO's Methodology of Classification and Categorization of Nanomaterials will go a long way in prompting legislators and policy makers, in the United

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118 *Id.* at 2760.
119 *See* Int'l Ctr. for Tech. Assessment, *supra* note 101.
120 Glenn & Boyce, *supra* note 6.
121 15 U.S.C. § 2601 et seq., (1976).
122 7 U.S.C. § 136 et seq., (1996).
123 21 U.S.C. § 301 et seq., (1938).
124 29 U.S.C. § 651 et seq., (1970).
125 15 U.S.C. § 2051 et seq., (1972).

States as well as other countries, to revise the rules, regulations, and laws intended to monitor and regulate nanotechnology risks.[126]

C. Some other approaches

Two international reports have recently come out that have several recommendations that could and should be adopted in the United States:

> A general moratorium on engineered nanomaterials in food and food packaging is not currently necessary.[127]
>
> Existing food regulations should be adapted to reflect changing definitions.[128]
>
> Ongoing, transparent, credible dialogue between manufacturers, consumers and parties of interest; "dialogue platforms on benefits and risks as well as a social communication process on the handling of nanomaterials in the food sector should . . . form an integral component of the future development process."[129] Further, consumers "are more likely to look more favourably on its use when they perceive a real benefit to them."[130]

As discussed in the previous section, after incorporation of the ISO standards into law, a revisitation to the re-creation of a comprehensive regulatory framework would be warranted.

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126 Glenn & Boyce, *supra* note 6.

127 Martin Möller et al., Ctr. for Tech. Assessment, Nanotechnology in the Food Sector 144 (2009), *available at* http://www.ta-swiss.ch/en/nano food/.

128 *Id.* at 145.

129 *Id.* at 151.

130 Press Release, Food Standards Agency, Views on Nanotechnology: Research Published (Apr. 21, 2011), *available at* http://www.food.gov.uk/news/ newsarchive/2011/apr/nanoviews.

V. Conclusion

In conclusion, the application of nanotechnology to agriculture, food, food processing, and food storage holds many promises. It may satisfy the needs and demands of a growing global population, and it may reduce or prevent the needless suffering of sentient creatures by helping to eliminate CAFOs. These applications would not replace the need for small family farms. The technologies could be used to extend and amplify production from the small family farms, resulting in a move away from centralization and back to localization.

Of course, the technology is not without its perils; regulation and oversight is needed. Adoption and incorporation of the ISO standards as quickly as possible is essential, so that a regulatory framework can be created. Much more study is needed about the impact of nanomaterials and nanotechnologies within the body and on the environment.

To quote *New York Times* columnist Mark Bittman, let us "[r]einvest in research geared toward leading a global movement in sustainable agriculture, combining technology and tradition to create a new and meaningful Green Revolution."[131] With proper monitoring and regulation by the international community, nanotechnology, within the context of converging technologies, can find an appropriate place at the dinner table and play a major role in the emerging Green Revolution.

131 Mark Bittman, *A Food Manifesto for the Future*, N.Y. Times Opinionator (Feb. 1, 2011, 10:28 PM), http://opinionator.blogs.nytimes.com/2011/02/01/a-food-manifesto-for-the-future/.