• 专题：重访饮食革命 •

编者按：

食物史的学者认为，烹饪是人类历史上第一次科学革命。对此，科学史学界很少做出回应。直到夏平的近著《饮食与存在》（*Eating and Being: A History of Ideas About Our Food and Ourselves*）开创了一个先河。在著作中，夏平致力于证明革命从未孤立存在——比如化学的革命性思想就是率先进入到了饮食和治疗实践当中，并通过语汇慢慢占据了人们关于食物和身体的思考，其科学革命的部分才具备了条件。沿着这一思路，本专题辑录五篇论文，力图从不同的角度透视饮食革命与其他社会技术系统革命之间的交叉缠绕，或是彰显饮食革命所根植的人文环境如何使得“革命并不要求与过去彻底决裂”。五篇论文分别使用了历史学或是人类学的研究方法，旨在通过跨学科的对话为我们描画出饮食革命及其所嵌入的日常生活的复杂样貌。

（专题策划：王程韡）

食物链作为复杂系统：距离、尺度与涌现

Food Chains as Complex Systems: Distance, Scale, Emergence

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摘　要：在“漫长的十九世纪”（1775–1914），英国的食物供应系统经历了剧烈且永久的转型。首先，英国经历了所谓的“营养转型”，即饮食结构转向富含动物蛋白、小麦和糖的模式。其次，供应这些食物的链条在范围上变得全球化。本文探讨了这一饮食转型的部分后果，尤其关注肉类和牛奶的历史。随着蒸汽航运的发展，食物链得以大幅延长，随之带来了食物保存问题，并由此推动了制冷技术的革新。食物生产也开始在加工枢纽处实现集中和大规模化，其中最显著的是在澳大利亚、新西兰及美洲建造的大型屠宰场。这些更长、更复杂的食品系统通过新型病原体的出现引发了公共卫生问题：沙门氏菌、李斯特

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菌、大肠杆菌O157:H7型，以及导致变异型克雅氏病的朊病毒。距离、尺度与涌现这三种现象，使我们能够就能动性与拓扑结构得出若干结论。

关键词：食物系统　肉类　牛奶　距离　尺度　涌现

Abstract: During the “long” nineteenth century (1775-1914), the systems supplying Britain with food underwent dramatic and permanent transformation. First, Britain went through what is known as the “nutrition transition,” a shift to a diet rich in animal proteins, wheat, and sugar. Second, the chains supplying these foodstuffs became global in scope. This article explores some of the consequences of this dietary transition, with particular focus on the history of meat and milk. Food chains became considerably longer with the development of steam navigation, which created problems of preservation, leading to innovations in refrigeration technology. Food production became concentrated and scaled-up in processing hubs, most notably the large abattoirs constructed in Australasia and America. These longer and more complex food systems generated public health problems through the emergence of novel pathogens: salmonella, listeria, E. coli O157:H7, and prions causing variant Creutzfeldt-Jakob Disease. These three phenomena—distance, scale, and emergence—allow us to make some conclusions relating to agency and topology.

Key Words: Food systems; Meat; Milk; Distance; Scale; Emergence

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During the “long” nineteenth century (1775-1914), the systems supplying Britain with food underwent dramatic and permanent transformation. First, Britain went through what is known as the “nutrition transition,” a shift to a diet rich in animal proteins, wheat, and sugar. Second, the chains supplying these foodstuffs became global in scope. Beef came from Argentina, lamb from New Zealand, wheat from Canada, and bacon from Denmark. There were many consequences of this enormous transition, from concerns about food security to emergent lifestyle diseases (heart disease, diabetes etc.) [1] This article focuses on three such consequences: the increased *distance* over which foodstuff travelled to the consumer; the *scale* of novel food systems; and their *emergent* properties, particularly relating to pathogens. The article narrows focus by concentrating only on the history of animal protein: meat and milk.

Before beginning, a brief note about the term *system*. Over the past few decades, various theoretical approaches have been developed to analyze large-scale, materially heterogeneous systems: actor-network theory, assemblage theory, complexity theory, systems theory and so forth. [2, 3] These theories have certain points in common: they attempt to avoid abstractions like macro and micro; they eschew reductionism and essentialism and emphasize distributed agency; they endow small material artifacts with significance; they see large systems as possessing momentum rather than determinism; they regard such entities as being both fragile and unpredictable, with emergent properties; they have chokepoints or reverse salients; and they mix together the human and the nonhuman. [4, 5] Ervin Laszlo, for example, has emphasized that in systems, “there is nowhere to draw the line between the living and the nonliving.” [6] I’ll draw indiscriminately on this body of work throughout the paper.

The deliberate extension and technological enhancement of food chains is far from an exclusively modern phenomenon, as the Roman grain trade, the spice trade and the Columbian exchange demonstratey. [7] The nineteenth and early twentieth centuries, however, form a particularly important phase in world food history. This is when, helped by railways and telegraphs, food systems became longer, integrated and globalized. [8] Statistics show that this nineteenth-century process of globalization was particularly associated with Britain. [9] In 1860, 49% of food exports from Asia, Africa and South America went to Britain.[10, 11] In 1933, Britain took around 80% of beef entering world trade. [12] The modern British diet— rich in processed sugars, white wheat bread, and red meat— was impossible without these systems. They powered the industrial revolution but left Britain

potentially strategically vulnerable during times of international conflict or world economic collapse.

I. Distance

Modern meat and milk systems operate over long distances. This was made possible by new forms of transportation and food treatment. Before the steam age, most of Britain's meat came from livestock moved internally by drove roads. Tenth-century ordinances suggest the existence of established cattle tracks running from Wales to England. [13] By the sixteenth and seventeenth centuries, cattle generally moved from Britain's north and west to its south and east to be slaughtered. [14] The number of cattle exported from Scotland multiplied fourfold between 1720 and 1814. [15] After 1800, however, the cumulative loss of common grazing grounds and the rise of steam transportation changed the topology of live animal transportation. [16] By 1865, increasing numbers of live animals were crossing the Atlantic in cattle ships, not least because this part of the world was less associated with epizootics like rinderpest, which devastated British herds in 1865. (16, 116) Live cattle were also imported from Argentina, particularly in the 1890s, following the introduction of stronger marine engines. [17, 18]

Railways also stimulated the milk industry. [19] By 1870, London was mainly supplied with railway milk. [20] By 1900, about 53 million gallons of milk was brought to the capital by rail, with supplies coming from up to 200 miles away. [20, 21] In 1903, Harold Swithinbank and George Newman reflected on how this transformation created challenges for the preservation of freshness, noting that "the great growth of cities" meant that milk underwent "a more or less lengthened railway journey," meaning that milk reached consumers when it was "twelve to twenty-four hours" old. [22] By the 1920s, motorized trucks were used for conveyance. Delivery to customers, meanwhile, was undertaken by bicycles, motorbikes, hand-barrows, horse-vans, and sometimes simply men with buckets. Delivery formed one of Thomas Hughes's "reverse salients"— a kind of chokepoint which hinders the functioning of the whole system— partly because of the complexities of local demography and geography. (5, 79-105) The electric milk float, first used on a small scale in the 1920s, was the ideal delivery technology and became widespread by the 1950s.

Transportation systems accelerated the flow of meat and milk, allowing foodstuffs to traverse increasingly long distances, but this raised a central problem of decay. Ancient techniques of salting and smoking meat often produced food with a strong or unpalatable taste. 110 British patents for preserving fresh meat were obtained between 1691 and 1855. [23] By 1860, preservation of fresh food was the major reverse salient in the food system, generating imaginative solutions like pneumatic curing and brine injection. [24, 25] "Jerked-beef banquets" were held an effort to retrain working-class palates to enjoy cured meat. [26]

Mechanical refrigeration was the ultimate solution. By 1880, numerous different systems were functional and reliable, and technological closure around the compression model, usually with ammonia as a refrigerant, was evident by 1920. Refrigerated railway cars made Chicago the centre of America's meat-packing industry. Beef was successfully transported from New York to London in 1875, and from Buenos Aires to Marseilles in 1877. Mechanically-refrigerated barges appeared in London in 1890. [27] One antipodean newspaper observed in 1882 that "virtually, the exportation of frozen meat makes the colony of New Zealand as much a province of England, as easy a source of supply for the London market, as Yorkshire or Devon." [28] By 1900, frozen meat was available in London year-round, but it was soon overtaken in popularity by chilled meat, kept just above freezing in a soft condition. Distance, declared Anthony and Blois in *The Meat Industry* (1931) was now "no object." [29] In 1911, the insulated space of Australasian and South American lines was 16,000,000 carcases (44,000,000 cubic feet).[30]

Temperature control bought time by arresting decay. Instead of multiplying in humid churns or warm meat, microbes could be kept in a state of "suspended animation" in railside depots. [31] Cold stores proliferated: by 1888, 300,000 carcases could be stored in London. (16, 179) Twenty years later, there were 27 metropolitan refrigerating stores available for

imported meat, with the capacity for nearly 3 million sheep carcases. The largest was that of the London and India Docks Co. at Victoria Dock. [32] Scientific research into the effects of cold flourished. The Low Temperature Research Station at Cambridge pioneered research into cold's effects on organic matter, and the use of novel refrigerants. Controlled atmospheric storage of apples and eggs thrived after 1918, as did ice-cream vans. (27, 204; 211) This new gelid ecology was first called the "cold chain" in 1908. (27, 105)

Receptacles mattered. Heated controversies erupted around pail and milk churn design. Standard churns carried seventeen gallons: they were hard to carry and difficult to clean. Dirt found its way into its funnel-shaped lids, and rainwater dribbled through ventilation holes. Numerous improved designs (for example with rain and dust-proofing) were developed, with insulated churns appearing by the 1930s. Writing in 1936, Harvey and Hill liked the ten gallon churn, which was "easy to clean and to carry, and can be quickly washed and sterilised in an efficient manner." [33] Some early twentieth-century observers thought the churn would be replaced by bulk tanks: "the milk churn, except for milk collection from farms, for direct sends, and for some primitive retailing in rural districts, is already rapidly becoming an anachronism and will soon be as archaic as the erstwhile petrol can." [34]

Traditionally, milk was ladled out by the deliverer into the consumer's individual can. This left milk vulnerable to contamination and adulteration. The solution was the milk bottle, first used by later-nineteenth century private companies as a guarantee of quality. Writing in the *Times* in 1925, Lloyd Griffiths stated that:

> the nearest way to guarantee the delivery of milk of the same quality "as it comes from the cow" is to sell it in hermetically sealed bottles filled up while it is fresh. These bottles should not be exposed to the sun and should be kept steady. [35]

A metal top or crown seal precluded the removal of stoppers by milkmen. [36] Yet when left outside houses it might attract animals or become covered with dirt, which fell into the bottle when opened. The milk bottle created emergent problems. Really thin-necked bottles were hard to clean: fatter necks (or better cleaning machines) were necessary. [37] Detailed studies of lip contamination of milk bottles were undertaken, and "the problem resolved itself into controlling the adhesive forces of the milk as it was poured over the glass surface. The smooth glass surface should be interrupted so as to break the film of milk adhering to it during pouring." [38] Bottles also presented challenges of standardization. The Sale of Food (Weights and Measures) Act, 1926, stated that there should be an Imperial stamp on all bottles in which milk was delivered. Customers, meanwhile, broke or lost bottles, or returned them in filthy condition. The next solution, the paper carton, proved initially very difficult to market. (19, 296-7) They were still only in limited use in the late 1960s: the milk bottle's momentum took decades to overcome.

Another key receptacle was the metal can. In *Food Poisoning and Food Infections* (1920), William Savage observed that

> a striking feature of modern civilization is the extent to which food of various kinds is preserved and sold, not in the fresh condition, but stored in receptacles under conditions which preserve the food in eatable condition. The amount of food canned is now enormous. [39]

Canning, developed in the very early nineteenth century, was initially used for armies or polar explorations. "The cases have been carried into every latitude," effused Steet in 1865, "they have neither burst with the heat of the torrid zone, nor collapsed with the cold of the eternal snows; and whenever or wherever the contents have been required they have been available." [40] Several innovations, like double seams and thinner tinplate, helped cans become more widespread. In 1858, Ezra Warner of Warnerbury, Connecticut, applied for a patent for an opener with a large curved blade which cut around the can's edge. [41] Canning allowed vast quantities of perishable goods to enter the world market. [42] Heinz began canning baked beans in Harlesden at the start of the twentieth century. [43] The sociological consequences were described by Smith in The World's Food Resources (1919), who argued that "more than any other invention since the introduction of steam," canning "has made possible the building up of towns and communities beyond the all too narrow bounds of varied production." (42, 408)

Meanwhile, food processing techniques were producing a plethora of novel portable, durable foodstuffs. In London, George Dodd observed the proliferation of "sausages, saveloy, polonies…black puddings, German sausages, hung beef, spiced beef, cured tongues, [and] Bath chaps." [44] Such foods provided fast, intense bursts of protein and fat and were integral to the working-class urban food market. Another important processed food was margarine, invented by the French chemist Hippolyte Mège-Mouries in 1869. [45] Britain imported most of its margarine from the Netherlands. Britain's first margarine factory was founded by Otto Mønsted in 1889. [46, 47] Margarine became a classic industrial food, engineered in factories with "criss-crossing pipelines, and a flow of packaged product going into shipping boxes" and ultimately reliant on international flows of vegetable oils. [48]

Patents were taken out for condensed milk early in the nineteenth century, but the industry only developed later in the century. Condensed milk came in various forms (sweetened, skimmed, or just "evaporated"). Those deprived of cream were regarded as being unsuitable for feeding children, and legislation insisted on the appropriate labelling of cans. Most commercial brands of sweetened condensed milk contained between thirty and fifty per cent cane sugar. [49] Condensed milk was considerably more durable than fresh milk: it obviated the need for delivery, was available at odd hours of the day, and could be stored without refrigerators. The Dutch firm van den Burgh (which merged with Lever to form Unilever in 1929) produced condensed milk in Rotterdam in 1896, as a byproduct of margarine production. Much was sold to British and German industrial cities, to poor districts without milkmen. [50] By 1900, 65% of imported condensed milk and milk powder came to Britain from Dutch producers. (50, 134)

These technological developments produced food chains of historically-unprecedented distance. They contained reverse salients and developed unevenly: milkmen still used horses, carts, pails and dippers well into the twentieth century. These systems were, to use Charles Perrow's terms, "loosely coupled." [51] In a tightly-coupled system, if one thing goes wrong, the whole system suffers very quickly. Loose coupling, however, means that there is some slack: if something goes awry, there is time to intervene. Nuclear power plants are tightly coupled, but food systems, sprawling across continents, are loosely coupled. If something goes wrong with a refrigerator, a milk float, or a steamship, there is often time to fix it before the milk is spoiled.

The dramatic nature of the transformation was routinely observed by contemporaries, who spoke of distance "becom[ing] immaterial" or "the whole world" becoming "a neighbourhood." [52, 53] One 1883 writer observed that "New Zealand need have no fear as to obtaining a ready market for all her surplus dairy produce: the markets of the world are open to her. Steam and electricity annihilate time and distance." [54] Jason Moore notes that "railroadization" made possible the "audacious appropriation of soil and water, formed over millennia" and created "new conditions for Cheap Nature— and especially Cheap Food." [55] Food supply economics were definitively changed. It became cheaper to ship wheat from the American Great Lakes to Hull than to send it via railway from Hampshire to Birmingham, grumbled Viscount Lymington in 1938. [56] The cold chain made hoarding, speculation and sampling more physically feasible, while the capital investments necessary for such equipment favoured large companies. The British milk industry, for example, was largely controlled by a few wholesalers by 1900. [57] Speed and cold made possible a starker divide between the food-producing and food-consuming parts of the world. This was the "metabolic rift" of which Marx spoke. [58] The ecology of new food chains was itself predicated upon, and perpetuated, wider ecological transformations.

II. Scale and Concentration

As well as distance, concentration was evident across the food system. Processing, distribution and marketing required the creation of hubs: food factories, roller mills, supermarkets. I will focus on the meat system. Traditionally, slaughter was undertaken in innumerable small spaces— *houses*— scattered across the urban and rural landscape. No point of the meat system was more vital than the slaughterhouse. Horrible descriptions of slaughterhouses filled the

nineteenth-century press, focusing on cruelty, filth, disease and demoralization. The Victorian author Mary Eliza Haweis reflected upon this particularly decrepit system:

> the sheds, old washhouses and disused stables converted to the grim purpose, have often been shown to be not only unsuitable for the work, but incapable of being made so by alterations; and being situated in the midst of dense populations seriously affect the health and comfort of neighbours, whilst, being private premises, they cannot be freely inspected, and are often not inspected at all. [59]

This was a real reverse salient: the speed and cold characteristic of the modern meat chain was palpably lacking.

This system was ill-equipped to rapidly and safely process an increasing quantity of meat. Another system was needed: this was the *abattoir* system, where slaughter was concentrated, scaled up, mechanized and regulated. Abattoirs had cooling-rooms: the cold chain began as soon as the animal died. The carcase slowly chilled to the requisite temperature before being transported to market. Overhead rails linked slaughtering chambers, cold stores and train terminals. Times and temperatures were carefully monitored. The process of slaughter was also to be removed from the public gaze. The anthropologist Noëlie Vialles argued that: "from this point on, slaughtering was required to be industrial, that is to say large scale and anonymous; it must be non-violent (ideally: painless); and it must be invisible (ideally: non-existent). It must be as if it were not." [60]

The system started in France around 1807, but it developed slowly in England and Wales, although more Scottish cities built abattoirs. [61, 62] In Germany, development was altogether more rapid: a combined cattle-market and slaughterhouse opened for the whole of Berlin in 1881, with 657 employees. [63] There were 900 public abattoirs in Germany by 1907. [64] Some had swimming-baths for employees, others gymnasia and even billiard rooms: these were veritable "industrial colonies." [65, 66] (64, 144) This process was particularly marked in those global regions producing meat for the European marketplace. By 1907, there were 27 abattoirs in Australia, largely for the export trade. (27, 82-3) Contemporaneously, New Zealand had 24 "large slaughtering and freezing works" through which all the colony's meat passed. (32, II, 436) In the United States, there were around 2000 packing plants by 1927: "they are modern, large-scale manufacturing plants where the animals are slaughtered as expeditiously as possible and their meat and other products made ready for market in the most careful manner." [67] The abattoir also allowed meat science to flourish, with research undertaken on bacterial changes, mold formation and the relationship between tenderness and hanging. [68, 69]

It is easy to assume that mechanization had really taken command here, but plenty of unhygienic, unmechanized slaughterhouses survived well into the twentieth century. There were still 20,000 small slaughterhouses in Britain in 1920, and 16,000 in France in the 1960s. [70] (27, 304) Wallasey abattoir (Liverpool) had no wash basin until 1928. [71] Techniques of slaughter remained unreformed. The traditional Christian technique of killing was to stun the beast with a poleaxe before slitting its throat; Jewish and Islamic techniques eschewed the former. A pithing-cane might be inserted through the hole to "stir the brain" and destroy movement. (32, III, 750) Both came under sustained attack from reformers: "the butcher wields his pole-axe with all the complacency of a youth having his innings at cricket." [72] They proposed new techniques, from improved forms of poleaxe like Whackett's Patent Needle Pole-Axe to chloroform, coal gas, electrocution and stunning-pistols. [72, 73] (32, III, 753) One example of the latter, Greener's killer, was, according to Leighton and Douglas, "extensively tried in Great Britain as well as abroad, and its use has been made compulsory by various councils as well as by the War Office and the Admiralty in their butchering and remount departments." (32, III, 753) But these techniques developed slowly. Slaughtering is an extremely conservative practice. Butchers were wedded to their poleaxes, which were banned by the European Union only in 2001. [74]

Another important dimension of abattoir practice was inspection. Small slaughterhouses distributed across large spaces were impossible to adequately oversee, particularly when refractory slaughtermen refused access to inspectors. The abattoir system

promised to concentrate inspection, and enable it to be undertaken over the entire process of slaughtering and dressing. The inspector should scour the carcase for signs of infectious disease or parasites. [75] The detection of tuberculosis was particularly significant, since the disease could spread to humans through meat (and milk), requiring familiarity with the lymphatic system. Ideally, the inspector should be present for the opening of the carcase, to examine the mesenteric glands, spleen, stomach, intestines and lungs, before scrutinizing the rest of the carcase and stamping it free of disease. (32, III, 790-2) Some abattoirs were constructed with pathological laboratories containing incubators, microscopes and photographic equipment. In Hamilton, Scotland, the abattoir had forms with a carcase diagram showing positions of glands: tubercular lesions were to be coloured in red pencil: "thus if any part of the carcase is condemned the exact area condemned is shown by the red colouring." (32, III, 809) Special notebooks could be "carried in the pocket of a coat." [76]

The rise of the global meat trade magnified the problem of inspection. All meat exported from New Zealand, for example, was guaranteed by staff of government inspectors to be fit for human consumption, with inspectors under the command of the chief government veterinarian, C. G. Reakes. (32, IV, 1277) In Argentina, government inspectors worked at each frigorifico. (30, 119) Following the publication of *The Jungle*, an American law was passed to ensure ante-and post-mortem inspection. [77] Freezing and refrigeration presented problems, for example "when the sanitary authority has to deal with boxes and barrels containing a conglomeration of parts of slaughtered animals which have been subjected to various more or less adequate processes of preservation." [78] Regulations followed, urging the packing of organs individually or in easily-accessible layers. (32, V, 1599) Imported meat often appeared with a ticket saying it had been passed by inspectors: it was usually inspected again, meaning that it was probably more scrupulously examined than home-killed meat.

The abattoir also made possible unprecedented economies of scale for the collection and processing inedible parts of animals. Cattle are perambulating assemblages of organic materials, making them a versatile animal resource for humans. [79] The carcase became an industrial feedstock. Triperies, glue works, bonemeal plants and fertilizer factories clustered around abattoirs, a process amplified by economy drives during the first world war. Traditional uses for bones remained (combs, toothbrushes), but they were also ground into fertilizer. Gelatin, culled from skin, bones, tendons, and connective tissue, was used to make photographic plates, medicinal capsules, bacteriological cultures, sweets. (68, 273; 275) Fat was still for making candles and soap, but it found new uses, as margarine, lubricating oil, and in dog biscuits. (32, II, 610-3) Intestines and weasands (throats) were used for sausage-skins, violin strings and snuff packages. (32, II, 498) (70, 93) Dried hair insulated refrigeration systems. Blood, collected and sometimes separated, found multiple applications, including sugar refining, dying and clarifying. The pharmaceutical industry relied upon abattoirs for its supply of various glands: pancreatic, pituitary, thyroid, testicular, suprarenal. Harvested, chilled, and packed, they reached pharmaceutical plants ready for extraction. It took 25,200 suprarenal glands to produce one pound of purified epinephrine. (68, 440) German abattoirs pioneered the collection of lymph used for vaccines. Large quantities were exported to Britain and America. [80]

This is what Alex Blanchette called the "extreme evisceration" of a "radically disassembled animal." [81] The systems which industrially process livestock cannot be reduced to meat consumption alone. "Every bodily substance save for the microscopic," he argues, "has been measured and acquired some worth." (81, 209) It is actually extremely difficult, he argues, to live without using materials containing deceased porcine bodies. (81, 213-4) Livestock processing systems also generate vast quantities of excrement. In 2012, US factory farms produced 369 million tons of untreated waste, which is thirteen times more than that of the human population. (81, 224)

The abattoir, finally, allowed offal and ground bonemeal to enter the diets of domesticated animals. By the 1920s, the ground offal industry was using a large proportion of American packinghouse trimmings, which was steamed and transformed into a dry meal

palatable to chickens. Bones became “soft and chalky” after processing in the digestor, and were turned into bonemeal. (32, II, 626) Meat residues could be steamed for six to eight hours, producing a form of meal that could be kept indefinitely in dry conditions. (68, 306-7) Blood meal was a high-protein feed as well. (68, 309) The recycling of animal products as feedstuffs raised the issue of disease transmission: “the question is often raised as to the danger of disease being transmitted to farm animals and poultry through the feeding of animal by-products from diseased animals.” (68, 309) Steaming was held to destroy bacteria, but emergent pathogens could still escape and potentially cross the species barrier. (68, 310) This brings us to the final part of the paper, on emergence.

III. Emergence

Emergence is a concept used by systems and complexity theorists: it refers to properties of systems not possessed by individual parts, or for the capacity of a system to spontaneously generate something new. In technology studies, a somewhat similar concept of *unintended consequences* is used to refer to the tendency of technological systems to behave unpredictably. Emergence and unpredictability were evident across the food system: we see this in, for example, genetic homogenization of world cattle stocks, massive fossil fuel reliance, soil erosion, and deforestation. Again, I’ll just address one type of emergence: the tendency of food systems to produce novel pathogens.

Food has always generated fear and anxiety. In the premodern period, perhaps the greatest fear was that of dearth. After 1800, on the British mainland at least, food fears came to be intimately related to the complexity, opacity and size of food systems. Milk adulteration, for example, only became a serious public health concern when the gap between farm and consumer lengthened, multiplying opportunities for duplicity. William Savage expressed this concern in 1919, noting how:

> milk is fatally easy to adulterate, and, equally to the expert as to the man on the street, the addition of even a fifth or a quarter of water, or the abstraction of a considerable proportion of its cream, makes to the eye no detectable difference. [82]

Although water was by far the most common adulterant, urban myths about the addition of substances like sheep’s brains abounded. [83] The circulation of such stories— repeated many times in primary sources— is testimony to consumer unease at disconnection from sources of food supply and connection to a gestating mass media network that amplified rumours and exaggerations.

Milk was an almost perfect disease-bearing medium, capable of transmitting viruses, parasites, bacteria and chemical toxins. It provided “a complete bacterial diet” for germs at every stage in the milk’s journey from udder to customer: dank cowsheds, careless milkers, unattended railway platforms, open counter pans in shops and uncovered cans in houses lacking storage space or refrigeration. (22, 19) The American philanthropist Nathan Straus put it thus:

> this rich animal fluid, sterile and presumably wholesome at the start, but drawn by unclean hands into half-cleaned pails, and meanwhile sprinkled from above by the dust of the stable, by hairs, dandruff, dirt, and particles of excrement from the skin and udder of the cow shaken from the milker or brushed with his hat, becomes infested with organisms. [84]

Tuberculosis attracted the most anxiety, since it was acknowledged to be a major cause of the obstinately high infant and child mortality rate, and it infected children through the medium of milk. It was estimated that around 2,000 infants died from milkborne TB in late 1920s and early 1930s. [85] The Glasgow Medical Officer of Health, James Burn Russell summed up the fundamental problem:

> if we remember the habits of the tubercle-bacillus, we cannot imagine a more favourable nurture-ground than the typical byre—a dark or badly lighted space, with insufficient ventilating apertures, which are unhesitatingly closed when necessary to maintain a temperature of 60 deg. to 70 deg. F. by the heat of the animals; the air consequently loaded with carbonic acid, with organic impurities and moisture, full of the dust of dried dung, never penetrated by a direct ray of sunlight, in winter never vacated either in country or town for weeks, and in cities never vacated at

all. [86]

This was, argued some, a result of the extreme complexity of the modern food system. Hugh Macewen, in *The Public Milk Supply* (1910) argued that those in the dairy industry had "for many years been engaged in trying to produce cows with the largest possible udders, and retains only those of the heaviest milking strain," producing animals with limited disease resistance. (36, 30)

Around 1870, public health officials began noticing another phenomenon: milk-borne epidemics. These were small, localized, and explosive epidemics of typhoid, diphtheria and scarlet fever whose epidemiological pattern corresponded to the milk rounds of particular dairies. These epidemics usually afflicted anything up to a few hundred people. Unravelling the pathways of transmission was difficult, but usually implicated a single farm or dairy and involved the contamination of milk by infected water or a human carrier. For example, in a case in Rochdale in 1880, 8 people died of typhoid after consuming infected milk. The infection was traced to a particular farm, where water was polluted with waste from a woman with typhoid, while a surveyor noted the possibility of soakings from a cesspool "percolating into the well." [87] We should note that this came from a very "leaky" system which opened out onto, and intersected with, other systems. Milk also caused outbreaks of sore throat and infantile diarrhoea, a major summer killer associated with poor domestic sanitary practices.

Although food poisoning has a long history, it only appeared as a term in English in the 1880s. [88] Contemporaries noted the rising tendency of seemingly good food to induce sickness. [89] (76, 193) Anne Hardy associates the emergence of this modern kind of food poisoning with urbanization and processed meat products like sandwiches and pies. (88, 297) Modern food poisoning was a consequence of extended food chains and their ecologies: prepared foods were more frequently cooked, cooled and reheated, which gave bacteria ample scope to infect food. (88, 309) New food ecologies produced novel public health risks. Dense concentrations of livestock in industrial hubs and abattoirs afforded greater opportunity for infection to spread between animals. Increasingly complex ecosystems increased the chances of host-switching and novel pandemics. [90]

Meat products and canned meats were particularly dangerous, especially brawn and pork pies, whose jelly was an "admirable nutrient media for bacteria" particularly when slowly cooled. (39, 168) The food hygienist Betty Hobbs linked rise of food poisoning to cinema, motor transport, and cheap restaurants with pre-cooked meals, with "cream-filled cakes and made-up meat dishes," and also observed how development of communal feeding in World War II hastened the process. [91] Another expert, Graham Wilson, observed in 1962 that:

> one of the most striking changes in public health during the past two decades has been the enormous increase in the incidence of food poisoning and, at the same time, in our knowledge of the multiple factors responsible for it. [92]

Botulism, which multiplies in anaerobic conditions, also spread through canned foods. This deadly neurotoxin was thankfully rare, but there were cases. In 1922, all 8 people consuming a jar of wild-duck paste died at Loch Maree.[93, 94] (76, 195) This is the first case of botulism in Britain. [95] The *British Medical Journal* warned that botulism might appear in canned fruit too. [94, 96]

Trichinosis produced a genuine food panic in Britain. This disease, caused by the parasite *Trichinella spiralis*, was first identified in 1822. In 1860, Zenker found the parasite in the muscle of a girl who had recently died, and then located the same parasite in ham and sausage prepared shortly before the fatality occurred. [97, 98] He called the disease *trichiniasis* but later adopted *trichinosis*. (97, 13) This parasite, which spreads through pork (as well as lion, horse and walrus, among other animals), was liberated when the flesh was eaten, leading it to grow and breed, producing more parasites which burrowed into muscle, generating cysts and, according to contemporary reports, agonizing pain and excruciating death. [99] Trichinosis was very rare in Britain, being associated with American and German meat, particularly undercooked sausages, but this did not prevent panic surrounding every case. (32, I, 253) One German outbreak, at Hedersleben in 1866 killed 101 people. Consuming a cold foreign sausage was a reckless

practice. [99] "It must not for a moment be supposed that the object of the present article is to convey alarm," wrote William Cochran in the *Food Journal*. "On the contrary it is simply to place the public on their guard." [99] In 1879, there was an outbreak at Thaxted, Essex. Fifty-two people developed the symptoms (diarrhoea, vomiting, thickly coated tongue, and pain, sometimes in the finger-ends) after consuming undercooked sausage. Some developed double vision and eye-swelling. "Some of the pork used in making the sausages was salted, and probably foreign," warned the *British Medical Journal*, "and it was only in certain portions that trichinæ were found." [100]

The solution was a ramifying para-system of regulation, involving food inspectors, public analysts, veterinarians and bacteriologists and new technologies designed to minimize risk. Milk adulteration, for example, was combated by chemical analysis and the establishment of legally-recognized standards for milk's composition. Preservatives were regulated by early twentieth-century legislation which effectively listed e-numbers. [101] Food poisoning was controlled through inspection of slaughterhouses and raised sanitary standards for food preparation, although it has continued to grow in incidence since 1945: at least 3,000 Americans die of food poisoning each year. In extreme cases, food chains might be shut down altogether. In the wake of the trichinosis panic, American pork imports were banned across Europe in the 1880s, and only reinstated when President Harrison authorized microscopic inspection of pork intended for export in 1890. [102]

Regulation of milk came in two overlapping stages: an "inclusive" or sanitary phase targeting dairy and cowshed conditions, and an "exclusive" or more bacteriological phase which addressed more precise vectors of infection. Dairies and cowsheds were registered from 1885, while inspection became more common. Central inspection came in 1925. [103] Exclusive methods included notification of infectious disease's presence on a farm, isolation of patients, and disinfection of diseased spaces. (22, 374) Urban areas developed systems of regulation. In Manchester, all milk entering the city was sampled and bacteriologically analyzed. If disease was found, it was traced to the farm where implicated cattle were sometimes slaughtered in the presence of the council's veterinary surgeon. [104] Exclusive techniques could be furthered by the use of the tuberculin antigen, which produced a reaction in cattle indicative of tuberculosis's presence. This could then be used to isolate and then potentially cull positive cattle.

Technology was also mobilized to improve the milk supply, from better refrigeration to the use of stainless steel in cowsheds. Bovine space attracted almost as much attention as public housing. The most important technology, though, was pasteurization. In 1888, Louis Parkes noted that

> no other animal food is consumed by civilised nations in an uncooked state; and by the light of our recently acquired knowledge it would appear that there is as much, or more, danger connected with the practice of drinking unboiled milk as of eating raw flesh. [105]

Pasteurization of milk involves heating it to around 160 degrees Fahrenheit, which destroyed pathogens. However, it also destroyed vitamin C and other micronutrients. Hence pasteurization was often attacked as a technical fix rewarding unscrupulous dairying and generating childhood scurvy. [106] (85, 177) Such objections began disappearing in the 1930s, reinforced by incentives to dairies to produce pasteurized milk, but it was only in the post-1945 period that pasteurization became normative. [107]

For some, of course, pasteurization remained fundamentally unnatural, emblematic of our artificial food chain. Drinking unpasteurized milk, like eating organic or locally-produced food, is part of a familiar phenomenon: the formation of "counter-chains" of food provision which are shorter, more transparent, and less "artificial" than standard food chain. New forms of subjectivity emerge from plugging oneself into different food chains. Such counter-chains are not a recent trend. They emerged alongside the modern food chains and were just as capitalistic as those they critiqued. One early example was the Aylesbury Dairy Company, founded in 1867 to provide premium milk for London's West End. It supplied 5000 families by 1878. [108] All farms supplying milk to the company signed a contract, agreeing to immediately chill milk and wash equipment with boiling water, and not to employ anyone suffering from an infectious disease. "Here a more extended and thorough control over the

milk passing through the business is executed than exists anywhere in the world," effused *The Analyst* in 1887. [109] The chemist Henry Richmond became "a global leader in laboratory research." [110] The company banned preservatives and bottled its milk from an early date. It also provided special nursery milk for infants. This lactic utopia only made sense in a world where food quality had become something mysterious and disconcerting.

At no point do food systems cease to stop being surprising. Listeriosis, for example, was first recognized as an illness in the early twentieth century. It was originally named *Bacterium monocytogenes*, and renamed *Listeria hepatolytica* by Pirie in 1927, then given its present name by him in 1940. [111] The foodborne transmission of listeria was first identified in the 1980s in North America, and became associated with milk, soft cheese, and coleslaw. There was an outbreak caused by imported pâté in Britain in the 1980s. [112] The highest-risk foods, experts warned, were "cold ready-to-eat foods not heated before consumption (things like sliced ham, egg and tuna salad, soft cheese) and the risk increased with the duration of refrigerated storage. [113]

Escherichia Coli O157:H7 was first recorded in 1982, and it is very likely to be a totally novel disease entity produced within large-scale meat complexes. [114, 115] The defining clinical features of E. coli O157:H7 are bloody diarrhoea and, in serious cases, hemolytic-uremic syndrome (HUS) and death. [116] A 1988 article in the *Journal of Infectious Diseases* reported that there was evidence of "dramatic increase in the frequency of O157:H7 strains in the E. coli population of North America and Great Britain over the last five years." [117] The causes can be found in major transformations in food systems. Humans have created a new ecosystem within which E. coli O157:H7 has been "pumped from humans to livestock through farm fields and slaughterhouses, through rivers and sewers rife with toxin-bearing viruses." [118] One persuasive argument is that the addition of antibiotics to animal feeds in the 1950s changed the environment of cattle's gut microbiome and provided the circumstances within which the bacteria's acquisition of a deadly Shiga toxin would be beneficial. (90, 83) Mutations giving the bacterium the ability to expel antibiotics suddenly had an evolutionary edge. (118, 100) Abattoir facilities, particularly pre-slaughter lairage, provide a perfect milieu for contamination. Cattle hides easily become splattered with E. coli O157:H7. There was a major outbreak in Wishaw, Scotland, in 1996. (115, 1-24) The disease spread from a butcher's shop, and was caused by poor hygiene (using the same knives, machines and scales used for raw and cooked meat and so on). (115, 3; 21) This outbreak involved 500 cases and 21 deaths. [119]

The term "prion" comes from the expression "*pro*teinaceous *in*fectious particle," and was first used by the American scientist Stanley Prusiner in 1982, to refer to novel disease agents thought to cause several mysterious brain diseases including bovine spongiform encephalopathy (BSE) in cattle and variant Creutzfeldt-Jakob Disease (CJD) in humans. In 1984, British farmers began reporting cases of cows losing coordination and weight, drooling and eventually dying. (74, 107) BSE rapidly became an epizootic: 446 cases in 1987 became 36,682 in 1992. (74, 137) Despite reassurances to the contrary, scientists showed that the disease could be transmitted to mice and marmosets. In April 1996, the *Lancet*, a British medical journal, reported ten cases of a new variant form of CJD, now called vCJD, which affected younger people, began with psychiatric disturbance, and created florid plaques in the brain. [120]

BSE, it appears, was an unpredictable consequence of decades of feeding cattle with meat-and-bonemeal (MBM) recovered from the offal and carcasses of animals deemed unfit for human consumption. [121] (115, 147) BSE was caused by MBM becoming infected with prions. One possibility is that the disease spread from a sheep infected with scrapie, an ovine prion disease. [122] This practice can be dated back to late nineteenth-century meat complexes in South America, where cattle were described as being initially "reluctant" to eat it. [123] What is certain is that infected MBM spread the disease, and that cows with BSE were recycled through feed, spreading the disease until the practice was stopped in 1988. (120, 199) It is unlikely that the exact way in which the disease emerged will ever be known. [124]

Conclusions

In conclusion, I will make a few general points

about food systems and concepts. First, what does studying food systems tell us about agency? Ideas of "nonhuman agency" and "distributed agency" have, of course, become commonplace over the last couple of decades. Nonhuman agency was certainly a concept familiar to bacteriologists and public health officials, who spoke of bacteria having "habits" or being "agent[s]." [125, 126] (86, 558) They grappled with the complexities of milk, a delicate, unstable and internally heterogeneous substance that is still not fully understood. (110, 18-9) Their epidemiological maps are little diagrams of networked agency. So bacteriologists were perhaps actor-network theorists *avant la lettre*.

Agency has, however, become something of a blunt concept. Like power, it seems to be everywhere— indeed, it is in more places than power, since humans, animals, microbes and inorganic objects possess it. We need a more nuanced vocabulary. One useful concept is that of *entanglement*, developed by the archaeologist Ian Hodder, who argues that "the defining aspect of entanglement with things is that humans get caught in a double bind, depending on things that in turn depend on humans." [127] We might say that humans build food systems (composed of things like cows, milk, grain, and sausage), and depend upon them for survival. But these entities in turn depend entirely upon humans for their existence. Without humans, there would be no Holstein dairy cattle and no bottled milk. The idea of entanglement tells us that agency is not the sole preserve of an agent, but is a product of *relationality*:

> the idea of material agency loses its shock value if we stop treating agency as a zero-sum quantity associated with individual, volitional mastery. It makes perfect sense within a relational view of agency: people act within relationships with things as much as with other individuals and groups. [128]

Another useful concept is disposition, "an unfolding relationship between potentials."[129]

"Infrastructure space possesses disposition just as the ball at the top of an incline," says Keller Easterling, "disposition is immanent, not in the moving parts, but in the relationship between the components." (129, 72) We might say that we have built and become entangled in food systems which are disposed towards the production of heavily-processed animal products. We also create the potential conditions under which bacteria become disposed to emerge, multiply, and evolve. Agents like prions and tuberculosis bacteria have a very delimited and powerful form of agency: they multiply and they kill. Moreover, they only do this in very particular places: lukewarm jelly, dirty abattoirs, the corners of dirty milk churns, or unwiped meat slicers. [130] Bacteriologists and public health officials, by contrast, had a kind of meta-agency, in that they could potentially control the conditions under which this agency was shaped. Such meta-agency, of course, has obvious limits, as the never-ending emergence of new strains and even types of disease demonstrates.

Finally, perhaps some forms of nonhuman *agency* hardly deserve the epithet agency at all. When pewter tankards or copper pots released poisonous metals into liquids, this is perhaps best conceptualized as *reaction*, not agency. Reactions are relational events which are passive, unconscious and predictable. The behavior of, say, copper, when brought into contact with milk, meat or fruit juice was reactive, even if emergent. Reactivity, limited agency and meta-agency are three crudely defined types of action along what is obviously a far more complicated spectrum. This is not an attempt to smuggle humanism in through the back door: it is merely to say that the world contains entities with different degrees of agency and capacities for action.

Second, how are we to characterize the physical form of these systems? They are, generally, to return to Perrow, loosely coupled: there was a reasonable amount of slack between component parts, so that food disasters emerge slowly and insidiously, unlike, say explosions at chemical plants. They overlay rather than fully replace older methods of food provision. Food systems are big, but they are not necessarily global— liquid milk does not reach us through global networks, and even meat circulates through circumscribed, if long, networks. Each foodstuff has its own, materially-specific, system. Food systems include lots of unruly elements— animals, microbes and technology. Small things matter— milk bottle tops, animal feed. So they have had many reverse salients, from preservation methods to slaughtering techniques.

They are also rather porous, opening onto other systems and ecologies (watermains, animal and insect ecologies). Their size, shape and complexity makes them impossible to fully police. A working definition of a complex modern food system would include their openness, loose coupling, sprawling extent, nodality and multiple reverse salients. To conclude, the complex food systems supplying modern Britain with its food were slack, slow, porous, opaque and vulnerable.

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