Livestock and Poultry: Other Colonists Who Changed the Food System of the Chesapeake Bay

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Abstract

The introduction of domesticated animals into the Chesapeake Bay regions’ food system had profound consequences for the health of the ecosystem and its people. Draft animals provided the labor to clear and cultivate the majority of the Chesapeake Bay Watershed by 1900. Pigs brought by English colonists became important sources of food both for the settlers and native peoples. Initially, introduced chickens played a persistent but minor role in the food system. This changed with the development of the chicken for meat (broiler) industry on the Bay’s Delmarva Peninsula in the 1920s. The broiler industry pioneered the use of concentrated animal feeding operations (CAFOs) and vertical integration of all aspects of production, a model now dominating the entire livestock enterprise. This propelled a 50% rise in per capita consumption of animal-based foods and attendant rise in human diseases, particularly coronary artery disease. Industrialization of chicken also increased its share of the animal products market sevenfold. The broiler industry pioneered the use of antibiotics as growth promoters, resulting in development of antibiotic-resistant pathogens. Poultry workers face various health problems, including increased rates of respiratory disease and certain cancers. The poultry industry is the major source of Salmonella poisoning. Broiler chickens suffer crowded and polluted conditions in CAFOs. These CAFOs dominate the landscape of the Delmarva, producing air and water pollution. Nitrogen as a waste product from the industry reaches the Bay and is a major source of eutrophication.

Keywords

CAFOs · Broilers · Animal agriculture · Antibiotics · Chicken industry · Pollution

Domesticated Animals Restructure the Food System

The English men and women who colonized the Chesapeake Bay Region weren’t the only exotic animals to arrive at Jamestown in 1607–1608. Chickens and pigs came on the first English ships and, by 1611, the list of newly introduced domesticated animals included cattle and goats. The site of these creatures apparently startled the resident Algonquin tribespeople, as they kept no domesticated animals other than dogs (Roundtree 2014).

The domesticated animals brought by the English reflected the food system of the Old World. They raised chickens, pigs, cattle and goats for food (eggs, dairy and meat). The uneatable portions of the food animals provided
a second source of resources, goods made from animal parts. These included leather from dried skins and feathers used in bedding. Oxen, mules, and horses played essential roles in the food system by providing the labor to clear and cultivate the land, and to transport the harvest to market. English settlers used animals to muscle wooden plows through the soil. Whether pulling a wagon along a bumpy road or tugging a barge in a canal, animals also provided the labor to move the harvest to market. Like their Native American neighbors, the English used dogs to help in the hunting of game and birds.

The food system implemented by the English colonists treated domesticated animals as whole beings of nature. The ability to domesticate particular species hinged on their level of sociality. Horses, donkeys, cattle, pigs, sheep, goats, ducks, geese, and chickens are all highly social beings with strong structural relationships. Humans inserted themselves into the social orders of these animals, assuming the alpha, or dominant position. Domesticated animals also learned to associate humans with rewards of food. In a sense, the domesticated animals and their keepers struck a cultural evolutionary bargain. The humans provided shelter, protection, and access to food in exchange for the animal’s labor or the certainty of being slaughtered at some point in its lifecycle. Such was the way of life on a family farm for generations in the Chesapeake Bay region. The working animals were always given names and sometimes others raised as future meals were afforded the same respect. Some might say the farm animals were treated as part of the family, but more accurately, farmers and their domesticated animals belonged to a common interspecies social structure that was controlled by the farmer.

Ethicists might argue that the traditional use of animals for labor, food, and other products was inherently exploitive. But, certainly, those animals came much closer to living a life for which their ancestors had evolved rather than that experienced by creatures in the modern food system. Full industrialization of animal agriculture meant a reductionist approach steeped in the masculine view of the necessity of man’s dominance over nature to maximize profit. Modern animal agriculture disaggregates life histories to obtain the maximal growth at the least cost. Conception, gestation or incubation, lactation or nurturing, and growth to maturity are now just stops along an assembly line. For some species, controlled encounters replace evolved mate finding and courtship rituals. For cattle, chickens, pigs, and sheep, life now usually begins with artificial insemination. The animal industry obtains the semen by inducing ejaculation in males fooled by decoys or fingering of genitals. This facilitates complete human control of conception, and allows for the breeding of animals so oversized and disproportional as to preclude safe copulation (Ax et al. 2016). Mechanical incubators replace the warmth and egg turning attention of brooding chickens. The hog industry invented lactation crates in which the suckling piglets feed by inserting their heads through steel bars. After weaning or hatching, animals are “finished” in concentrated animal feeding operations (CAFOs) where the creatures live in densely populated factory buildings. They stand in their own manure and breath ammonia contaminated air as they imbibe machine delivered feed and water. The only time these animals see daylight or smell fresh air is in the back of trucks bringing them to slaughter. Chickens are no longer chickens, but “broilers” to produce breasts and thighs, or “layers” to deliver eggs (Davis 2009). Cattle are milk, cheese, yogurt, hamburger, steak, roast loin, and hot dogs. Pigs are barbecue, ham, bacon, and sausage. Industrialized agriculture makes its money by removing any sense of natural being from the creatures it uses to produce market commodities.

CAFOs and the complete industrialization of animal agriculture profoundly affects the ecology of the Chesapeake Bay and the health of its human residents. Often, the vast distances between where soy and corn crops are grown, and where that feed is turned into animal flesh, urine, and feces means the breaking of nutrient cycles. The nitrogen, phosphorus, potassium, and other nutrients released by the animals rarely makes it back to the soy and corn fields. Instead it pollutes the Bay and ground water, while growers of feeds use artificial chemicals to fertilize their fields. The CAFOs pollute the air with ammonia, methane, nitrous oxides and carbon dioxide. The CAFO system engenders the use of growth hormones and antibiotics. These additives contaminate both the Bay and its animal products. CAFOs are also breeding grounds for diseases that infect people, domesticated animals and wildlife.

Animal Labor Reshapes the Watershed The importance of animal labor to shaping the food system and its impact on the Chesapeake Bay can’t be understated. Agricultural experimenters, including Chesapeake Bay resident Thomas Jefferson, redesigned the plow (Jefferson 1953). First wooden, then iron, and finally steal plows were drawn across fields by oxen, mules, or horses. Various designs accommodated the needs of local conditions. Most plows used the moldboard design to dig deep furrows with adjacent linear mounds of over-turned sod. This method buried weeds and loosened the soil to accept plantings. Such plowing also promoted soil erosion, particularly on sloped fields (Craven 1926). Runoff from rainstorms carried vast quantities of soil into the tributaries of the Chesapeake Bay. When the soil dried out between rains, winds eroded the exposed earth carrying away clay and other fine particles. Much of that dust also found its way into the Bay.
The animal powered food system transformed the Chesapeake Bay and its watershed. Draft animals helped clear timber from forests, making the way for putting 40% of the land under cultivation by the mid eighteenth century. Application of fertilizers opened otherwise marginal land to cultivation, moving the watershed to 50% farmed by 1850, and 70% by 1890 (Fig. 1). Ultimately mechanization expanded the portion of the watershed under cultivation to a peak 80% in 1930. That meant that animal labor did most of the work to transform the watershed prior to the introduction of steam and internal combustion engines in the late nineteenth century (Brush 2008).

General William T. Sherman’s Field Order No. 15 of January 16, 1865 allocated 40 acres (16.2 ha) of confiscated land and a mule to each emancipated slave family in several southern states (Myers 2005). While this Civil War era order never came to fruition, Sherman’s inclusion of the mule in the promise makes the point of the necessity of a draft animal for a functioning farm.

Chesapeake Bay sediments record the transformation of the watershed by animal power. The plowed watershed released soil to the Bay six times faster than pre-colonial times. The onslaught of sediments filled previously navigable channels and suffocated oyster reefs. Submerged grass beds succumbed to both burial and the lack of sunlight transmitted by sediment laden waters (Brush 2008).

Steam and internal combustion power virtually eliminated the working animal from agriculture by the middle of the twentieth century. Steam- and diesel-powered trains brought farm products to markets well beyond those reachable by draft animals and carts. First steam, and then internal combustion powered tractors took over the duties of mules, oxen, and horses.

Animals to Eat The combination of mechanization and fossil fuel energy subsidies of agriculture meant an end to significant animal labor by the end of the twentieth century. While draft animals lost their prized position as unpaid farm hands, other species moved up in importance in agriculture, not as co-workers, but as sources of food. It’s not that the English settler’s and those that followed didn’t eat domestic animals, as they certainly did. However, in the long run, the work of a draft animal meant the difference between sustenance farming and bringing in enough harvest to make money. In their day, draft animals exceeded the importance of chickens, pigs, or cattle. The tractor, truck and fossil fuel...
freed the farmer to focus on raising animals for eating. The growing prosperity after World War II meant that consumers could afford to buy more meat and they did. Per capita consumption of animal products went from about 110 kg per year in 1910 to 137 kg per year in 2016, a 25% increase (Fig. 2). Growing per capita demand for animal products coupled with an expanding population provided a lucrative market for the producers and sellers of fresh and dairy.

The second half of the twentieth century saw not only an increase in the consumption of animal products, but also a shift in the proportions of which species people ate. In the early twentieth century, dairy comprised 35–40% of the animal mass in the US diet. Beef, pork, and eggs, each accounted for 15–20% of the animal mass consumed, followed by poultry and fish/shellfish, each at 5%, with veal and lamb each contributing 2–3%. Note that veal is juvenile beef.

The pattern changed considerably after World War II. Beef consumption doubled, peaking at 32% of total animal food intake in 1975, then declined back to 18% by 2016. Dairy consumption declined after the war to circa 25% between 1965 and 2016. Eggs also lost favor, comprising 11% of the animal product consumption in 2016. Pork remained fairly steady at around 15%. Fish/shellfish changed little, still accounting for only 5% of animal food consumed in 2016. Poultry consumption displayed the most dramatic shift after the war, going from only 5% in the early twentieth century to 25% of animal food consumed by 2016. Poultry is now the number one source of animal food in the US diet (Fig. 3). The five-fold increase in poultry consumption over the course of five decades has profound implications for the ecology of the Chesapeake Bay, since the chicken industry dominates the landscape of its Eastern Shore.

The two terrestrial animals used for food that most informs the Chesapeake Bay food system are pigs and chicken. These pioneer domesticated animals explain much about how the food system influenced the health of the Bay and its people. Although pigs were initially more important than poultry in feeding Bay area residents, it was adaptations of innovations in the breeding, growing, processing, and selling of chickens that revolutionized animal agriculture around the world. And that story began along the shores of the Chesapeake Bay. But let’s first look at Pigs.

**Pigs** The English colonists brought pigs (*Sus domesticus*) with them to Jamestown. Those European domesticated pigs descended from the wild boar of Western Asia (Giuffra et al. 2000). The colonists left a country where all land belonged to somebody; the Crown, private landlords, or the community in the form of a common. Wars and genocide pushed the Native Americans from their home territories. Eventually, the English royalty divvied up the stolen land in a system of ownership with grants awarded to favored individuals. But in the years before such formal transfer of land from the native residents to the new English lords, the colonists let their pigs run wild. This freed the colonists from having to feed the pigs, as was the practice in England. Instead, the free-ranging omnivorous hogs could feast on acorns and other offerings of the Virginia landscape. When desired, the colonists would kill a pig for its flesh and skin. The Algonquians were accomplished hunters and added this new invasive species to their diet. To quell disputes over ownership of the free ranging pigs, in the 1690s, the Virginia government instituted a system of earmarks (incisions in the floppy ears of the pigs) to indicate ownership (Roundtree 2014).

Pigs are highly social animals with the capacity for fast population growth. Both sexes reach sexual maturity between
5 and 8 months of age. The estrus cycle is rapid, with females becoming receptive to males every 19–23 days (Anderson 2009). Litter size is variable, but typically 10 piglets survive weaning (McGloughlin 1976). The piglets are about 1 kg (2.2 pounds) at birth, and 6.3 kg (12 pounds) when weaned three weeks later. Modern commercial feeding operations provide a ration of soy and corn. They are fed about 1.1 kg per day for 7 weeks, bringing the pigs to a mass of 25 kg (55 pounds). After that the ration is increased to 3.6 kg (8 pounds) per day for 16 weeks. The pigs reach market size in just 6 months after their birth. The typical mass of a marketed pig is 128 kg (282 pounds) and yields a 96 kg (211 pound) carcass that is dissected into at least twelve different food products. Selective breeding, altered feeds, industrialized barns, and antibiotics means that modern pigs are 1.6 times the size of those produced in 1959 (National Pork Board 2019).

Pigs figured prominently in the early colonial history of the Chesapeake Bay. Eleven km (7 miles) south of Jamestown, a peninsula called Hog Island juts out from the southern shore of the James River. In about 1609, the English introduced pigs to this isolated area in order to protect them from hunting by the native residents. The 60 colonists that survived the “starving time” (winter of 1609–1610) fled Jamestown in a ship on June 7, 1610, anchoring the night at Hog Island. Lord De La Warr arrived the next day on a resupply ship from England and persuaded the settlers to return to Jamestown and rebuild their crumbling colony. Hog Island remained an important producer of salted pork for many years and gave rise to the famed Smithfield Ham (Rouse 1994; Jamestown 2019). The Surry Nuclear Power Plant and a surrounding wildlife refuge replaced the pig colony in 1968.

Industrialization of the hog growing industry largely moved the pig production out of the Chesapeake Bay Watershed. Few pigs raised to make Smithfield hams are grown near Smithfield, Virginia, anymore. Smithfield Foods owns only 23 company farms in Virginia (Smithfield Foods 2019a). Instead, most pigs destined for slaughter and packaging in Smithfield arrive by truck from North Carolina and other states. The coastal plain of North Carolina houses

![Percentage by Mass of Each Type of Animal Product Consumed](image)

**Fig. 3** Changes in the proportions of various animal species comprising the US diet between 1909 and 2016. The percentages are calculated based on wet mass, with all dairy reported as milk equivalents (the amount of whole milk needed to make the dairy product). The relative proportion of types of animal products in the diet remained fairly constant until the end of World War II, when consumption of dairy declined people began to consume more poultry. Beef consumption also increased after WWII, reaching a peak circa 1975. Subsequently the fraction of the diet attributed to beef declined to pre-war levels by 2016. Data from the USDA (USDA 2019a).
thousands of pig CAFOs (Fig. 4, 225 owned by Smithfield Foods), primarily situated in rural areas with high African American populations. The disproportionate effect of pollution (air, water, noise) and pathogens produced by these CAFOs on the poor and people of color is an environmental justice issue (Nicole 2013). In one location, neighbors of Smithfield Foods CAFOs sued the company and were awarded in $473.5 million in damages in 2018. That decision went for appeal and the awards are likely to be reduced (Brown 2018).

The shift of pig CAFOs to North Carolina spared the Chesapeake Bay from the industry’s factory farm pollution. Yet, the large slaughterhouse and packaging facilities in Smithfield proved capable of supplying plenty of pollution to the Pagan River, a winding tributary to the James River. In 1999, the fourth US Circuit Court of Appeals upheld a lower court’s judgment of $12.6 million for polluting the Pagan River. At the time, it was the largest fine ever imposed under the Clean Water Act (USEPA 1999). Subsequently, Smithfield Foods purchased the right to direct its pre-treated effluent to the Hampton Roads Sanitation District, the municipal wastewater treatment system for the area.

Among states in the US, North Carolina’s nine million head of pigs ranks only second to Iowa’s 23 million head. The states of the Chesapeake Bay watershed combine to account for only 2.3% of the US pig population (Table 1). Yet, the slaughtering and packaging of pigs imported from other states remains an important part of the Chesapeake Bay food system. Smithfield Foods is headquartered in Smithfield Virginia, just 27 km (17 miles) from Hog Island, home to the first large pig colony on the Chesapeake. It is the world’s largest pork producer, doing $15 billion in sales in 2017 and employing 54,000 people. It has operations in 27 states across the US, Mexico, England, Poland and Romania. Founded by Joseph Luter in 1936, it was bought by WH Group of China for $7.1 billion in 2013. It was the largest stock acquisition of an American company by a Chinese firm in history. However, the company points out that WH Group isn’t owned by the government of China, nor does Smithfield Foods sell any pork from China in the US (Smithfield Foods 2019a).

The facilities located in the town of Smithfield slaughter and process 10,400 pigs per day when running at full capacity (Fig. 5). This complex employs 2410 people. In addition, Smithfield Foods has 87 workers producing pet food, 52 involved in distribution, 495 in headquarters’ offices, and 191 at Virginia farms (personal communication, Ari Durall, Communications Manager, Smithfield Foods).

But it’s not all animals for Smithfield Foods, as it employs 36 workers in its Gourmet Nut Products Division located in Toano, VA. The area around Smithfield supports many large peanut farms, making the legumes a natural, if minor secondary protein rich food for the pork-producing giant.

Fig. 4 Pigs in a Concentrated Animal Feeding Operation (CAFO). Relatively few such pig CAFOs exist in the Chesapeake Bay Watershed. Most pigs entering the Bay food system come from North Carolina and other states. Image from USEPA website. https://upload.wikimedia.org/wikipedia/commons/7/72/Hog_confinement_barn_interior.jpg
The Chesapeake Bay workforce of Smithfield Foods reflects the shifting demographics of food system employees for the entire area. African Americans from surrounding rural communities traditionally provided much of the labor at the facilities, as they did for seafood and chicken processing plants around the Bay. By the end of the twentieth century, many of those positions went to Hispanic workers coming from Mexico and more recently Central America. However, one aspect of the food system employment picture at Smithfield Foods remains fairly static, as whites dominate management positions (92% in 2017), while people of color make up 68% of the blue collar staff that does the slaughtering, packing, shipping, and farm work. On a company-wide basis, the break down for non-management positions is: 30% Hispanics, 29% black or African American, 7% Asian, and 1% Native Americans. Males account for 90%.

### Table 1

| Jurisdiction | Rank Among States | Population of Pigs | % of Total US |
|--------------|-------------------|--------------------|---------------|
| Iowa         | 1                 | 23,330,000         | 31.29         |
| North Carolina | 2            | 9,000,000          | 12.07         |
| Pennsylvania | 12                | 1,310,000          | 1.76          |
| Virginia     | 18                | 345,000            | 0.46          |
| New York     | 31                | 46,000             | 0.06          |
| Maryland     | 33                | 17,000             | 0.02          |
| Delaware     | 40                | 6500               | 0.01          |
| West Virginia| 44                | 4000               | 0.01          |
| US           | –                 | 74,550,200         | 1             |

Note that Chesapeake Bay region account for only 2.3% of the US pig population. Data from the USDA (2019b)

### Fig. 5

View of the large Smithfield Foods meat processing complex in Smithfield, VA taken September 30, 2017. The plant is adjacent to the Pagan River, a tributary to the lower James River. Image from: Nyttend, https://commons.wikimedia.org/wiki/File:Smithfield_Foods Processing_plant_from_Ivy_Hill_Cemetery.jpg
of the management and 64% of the overall positions in the company. The corporation acknowledges the disparities of race and gender and claims to have programs in place to address the situation (Smithfield Foods 2019b).

In the 1990s, Joe Luter (the son of Joseph) embraced a business model of vertical integration pioneered by the poultry industry. Vertical integration meant Smithfield Foods controlled every aspect of the industry from conception to feed production, growing, slaughtering, packaging, and marketing. However, they claim no ownership of the manure produced in their CAFOs nor the risk taken by their contract pig farmers.

Despite the relatively few hogs still raised in the Chesapeake region, its food system remains strongly connected to pork production through the oily clupeid fish called menhaden (*Brevoortia tyrannus*). Discussed in detail in chapter “Menhaden, the Inedible Fish that Most Everyone Eats”, the menhaden fishery is the largest on the Bay. The fish are reduced to oil and meal, both of which end up in commercial hog and chicken feed (Carson 1945; Auchterlonie 2017).

**Chickens and Chicken People** The chickens that arrived with Capt. John Smith and company at Jamestown traveled more than the distance from England to Virginia to get there. These exotic birds journeyed halfway around the world and through 5 millennia on their way to the Chesapeake Bay. The origins of domesticated chickens trace to the red jungle foul (*Gallus gallus*) of Southeast Asia (Fig. 6). Archeology and genetics indicate the first of multiple domestications about 3400 years BCE (Storey et al. 2012). Evolution restricted red jungle fowl to Southeast Asia until humans transported their domesticated decedents around the world (Lawler 2016). Along the way, chicken keepers applied artificial selection to produce a wide variety of breeds for various purposes including production of eggs, production of meat, sporting (fighting and attendant betting), and show.

Most Chesapeake Bay area farmers and many townsfolk kept a small flock of chickens for a regular supply of eggs, and a limited supply of meat. The arrival of the first African slaves at Jamestown in 1619 shaped the trajectory of agriculture and the food system for the next four centuries. Chattel slaves formed the backbone of the plantation system that produced the cash crops of tobacco and cotton, in addition to much of the grain and produce that fed the region. As slaves weren’t paid for laboring for their masters, they needed some other way to obtain cash or barter items to participate in the economy. Many slaveholders allowed their human property to raise and sell chickens. These stolen Africans brought with them their own traditions of raising chickens, and in America earned the reputation as masters of the art (Lawler 2016).

Despite the status of being one of the first domesticated animals to arrive from England, chickens played a limited, yet persistent role in the early colonial food system in regard to flesh. Wild birds, pigs, sheep, goats, and cattle, as well as, shad, sturgeon, and shellfish dominated the animal foods of that time (Lawler 2016). Alarmed that some slaves bought their freedom with proceeds from the selling of larger animals, the Virginia Assembly put a stop to this in

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Fig. 6 Red jungle fowl (*Gallus gallus*), the ancestor of the domesticated chicken. The male is pictured on the left and the female on the right. Both images taken in India. Male image by C K Subramanya [https://commons.wikimedia.org/wiki/File:Red_jungle_fowl.png](https://commons.wikimedia.org/wiki/File:Red_jungle_fowl.png) and female by Lip Kee [https://commons.wikimedia.org/wiki/File:Gallus_gallus_female_Kaziranga_3.jpg](https://commons.wikimedia.org/wiki/File:Gallus_gallus_female_Kaziranga_3.jpg)
1692 by outlawing such further transactions involving horses, cattle, and pigs. However, the prohibition didn’t include chickens. “Chicken bones account for a full third of all bones found among the African American quarters of Maryland and Virginia plantations, and plantation records show frequent cash payments to slaves for poultry (Lawler 2016).”

Perhaps to stimulate poultry sales to the wealthy white class of slaveholders and merchants, slaves and freedmen introduced their customers to the African version of fried chicken. Chicken meat dredged in flour and fried in lard became the signature dish of the southern cuisine. While the Scotts and Italians evolved similar traditions of cooking chicken, it would have been the West African version that slaves brought to their master’s and client’s tables (Graber and Twilley 2016).

While meat from chickens was a part of the Chesapeake Bay food system since the birds made landfall in Jamestown, most people raised them primarily for their eggs. Killing and eating the chicken was reserved for special occasions. Up until World War II, people consumed three times more mass of eggs than they did poultry. The War changed that. Poultry escaped the rationing placed on other animal flesh, creating greater demand for chicken to replace beef and pork (Sundin 2018). The wartime taste for chicken led to a continuous growth in the industry. By 1975, chicken flesh tied eggs in consumption at about 12.5% of animal food for each. Chicken meat consumption doubled that 40 years later in 2016, checking in at 25% of animal consumption. Chicken eggs continue to hover around 12% of total animal flesh consumed (Fig. 3).

The advance of the chicken-flesh market created two different types of breeds, chickens for producing eggs (“layers”) and chickens for producing meat (“broilers”). Neither of these new specialized classes of breeds much resembled the various breeds of all-purpose chickens that populated the barnyards of the Chesapeake Bay region until the mid-twentieth century.

**Chicken Mostly for Eggs** The pre-industrial breeds of hens that roamed the barnyards of the Chesapeake Bay region reached sexual maturity at about 6 months and would lay about 3–4 eggs per week over their decade long lifespan. The annual egg production of about 150 eggs by traditional captive breeds was tenfold that of their red jungle fowl ancestor (Table 2). After their tenures as egg producers expired, the spent hens would end up in a pot of soup. Farmers also used some of the young males for meat before they matured and could engage in territorial fights with the other roosters kept for breeding. The system of traditional small chicken flocks presented a sustainable source of animal food for family farms. While the farmers might supplement the chicken’s diet with grain and kitchen waste, the free roaming birds ate insects, seeds, and whatever else the barnyard offered. This channeled otherwise unavailable nutrition and energy to the human food system. The traditional barn yard chickens lived a life different from their ancestors, yet it retained all of the basic features experienced by the red jungle fowl. Roosters protected and mated with their hens. The hens incubated and rotated their eggs. The newly hatched chicks found protection and instruction from their brooding mothers. The chickens formed social structures, built nests, scratched the earth and pecked the ground in long-evolved foraging behaviors. They lived an altered, but full life.

**Industrialized Egg Production** In 1800, about 94% of the US and the Chesapeake Bay Region population resided in rural areas. This declined to 40% by 1900, and 19% by 2010 (USCensus 2019). Modern agriculture is so thoroughly mechanized, industrialized, and subsidized by fossil fuel that by 2016, only 1.5% of the US population worked in this sector (USBLS 2019). In 1910, 87.7% of farms reported having chickens. That dropped to 5.6% by 1992 (USDA 2019c). This means that scarcely 1% of chicken eggs now come from barnyards or backyards. Instead, huge factory farms now produce almost all eggs for eating. About 89% of US chicken egg production keeps the hens in cages for their entire lives. The newly laid eggs roll through holes in the cages and onto conveyor belts that carry them to machinery for washing, size-sorting, and boxing (UEP 2019, Fig. 7).

**Chicken for Meat** Although African American slaves and freedmen proved central in developing the early chicken business of the Chesapeake Bay Region, it was a white women in Delaware who inadvertently pioneered the industrialization of producing chicken exclusively for meat. In 1923 Cecilia Steele, the wife of a Coast Guardsman ordered 50 chicks from a hatchery with the intention of raising a flock of laying hens. By accident the hatchery delivered 500 chicks. She succeeded in bringing 387 to a 0.9 kg (2 pound) market

| Breed type          | Longevity (months) | Number of Eggs Produced per Hen per Year | Mass at Maturity or Market Size (kg) |
|---------------------|--------------------|------------------------------------------|--------------------------------------|
| Red Jungle Fowl     | 180–240            | 10–15                                    | 0.9                                  |
| Broiler             | 1.5–3.0            | 0                                        | 2.3                                  |
| Layer               | 12–24              | 260–300                                  | 2.9                                  |

Females are used for both the meat producing broilers and the egg producing layers. Both broilers and layers reach sizes two to three times the ancestral stock and experience much shorter lives (UEP 2019).
weight, selling them for 67 cents a pound, or fivefold the price fetched for spent chickens from the egg industry (Spinrad 2015, McKenna 2017a, b). The Steele’s used the profits to buy another thousand chicks to raise for meat production. It wasn’t locals who bought Ms. Steele’s chickens, as most were shipped to New York City to be sold in markets servicing the growing Jewish population interested in observing traditional religious dietary requirements. The Delmarva hens were slaughtered in view of the purchasers using kosher techniques. Ms. Steele created what is now called the broiler industry, the raising of chickens in concentrated feeding facilities, and shipping them off to slaughter to service remote markets. In 1925 the Delmarva Peninsula produced 50,000 chickens. The adoption of Ms. Steele’s broiler model meant seven million chickens brought to market from the region in 1935. The modern era of raising chicken for meat was underway (Lawler 2016).

Ms. Steele’s original 24 m² (256 ft²) chicken shed is a broiler industry shrine, preserved at the Delaware Agricultural Museum (Del. Ag. Museum 2019).

World War II, Delmarva Chickens and Antibiotics While the broiler business grew during the 1920s and 1930s, it was WWII that accelerated the expansion of the industry on the Delmarva Peninsula. As noted above, wartime rationing of beef and pork brought attention to chicken as an alternative source of animal protein. Much of that attention came from the Department of War, which contracted for essentially all of the Delmarva broiler production for feeding the troops. The civilian market denied Delmarva hens, turned instead to Georgia, Arkansas, and elsewhere for its chicken. However, WWII drained many of the broiler farms and slaughterhouses of their laborers. Some 33,000 Delmarva workers left to be soldiers and sailors. To alleviate the labor shortage, the government put German prisoners of war to work in the broiler industry. One contingent of 550 prisoners of war worked the Armour Company chicken processing plant in Harrington, DE (Brown 2017).

The end of WWII left the broiler industry with overcapacity. Lifting of wartime rationing meant consumers returning to eating beef and pork. The oversupply of broilers depressed the price of chicken, driving producers to search for ways to cut the cost of production. They did so using four different approaches; (1) adding growth promoters to feed, (2) developing a new class of breed exclusively for meat production, (3) restructuring the industry along the lines of vertical integration, (4) making it easier for consumers to buy chicken by bringing most of it to market as cut-up pieces or highly processed and battered un-chicken-like shapes.

Antibiotics as Growth Promoters In 1928, Dr. Alexander Fleming discovered that a chemical produced by the mold Penicillium notatum would kill pathogenic bacteria. During...
WWII, the US government invested in the production of this new antibiotic drug dubbed penicillin. Its use during the war saved thousands of lives by curing infected battlefield injuries. After the war, penicillin went on to save thousands of civilians from death by infection. This promoted the search for other such antibiotics produced by microorganisms.

The Lederle Corporation used the Actinobacteria Streptomyces aureofaciens to make a new antibiotic, Aureomycin (a tetracycline). Dr. Thomas Jukes was a nutrition scientist interested in chickens, and employed by Lederle. Acting on a tip from a scientist at Merck Laboratories (a rival business) in 1948, he performed an experiment to see if adding an antibiotic to chicken feed would improve the growth of the birds. Jukes didn’t use the expensive refined drug, but instead fed his chickens with the brew-mash of bacteria from which the Aureomycin was extracted. The point was to find an inexpensive supplement, not to dose the chickens with costly drugs. It worked. Hens eating the antibiotic containing bacterial mash gained two and one-half times the mass of those on the control diet. Most remarkably, only 60 g of mash produced an extra 167 g of chicken mass! Jukes had discovered a growth promoter that reshaped the broiler industry and animal agriculture in general (Stokstad and Jukes 1950; McKenna 2017a, b). Low doses of antibiotics and the high growth rates they provided helped return the post-WWII broiler industry to profitability.

Throughout his life, Jukes (he died in 1999) remained a steadfast proponent of his innovation of using antibiotics as growth promoters. He also championed all other aspects of chemical industrial agriculture. He attacked Rachel Carson for publishing Silent Spring. He saw DDT as a miracle pesticide rather than as a persistent environmental toxin that nearly drove to extinction raptors and many other species of birds (Stoll 2012, see chapter “Pesticides Bring the War on Nature to the Chesapeake Bay”).

Why do antibiotics promote growth in chickens (and other farmed animals)? Chickens and other livestock packed densely into CAFOs present ideal conditions for the spread of bacterial infections. Close proximity means easy transmission of contagious disease and a stressful environment that reduces immune response. The low-dose of antibiotics in the feed might help thwart infection and thus allow the animal to direct more of its nutrition into growth. However, another mechanism seems at play. The antibiotics alter the animal’s microbiome, promoting the growth of species of bacteria and fungi in the intestine that enhance the uptake of nutrients, particularly energy-rich fats (Lin et al. 2013; Lin 2014).

After their introduction to the broiler business in the 1940s, antibiotic growth promoters became a central feature of industrial animal agriculture in the US and Europe. In 2015, about 70% by mass of all medically relevant antibiotics produced in the US went to promote the growth of chicken and other livestock (Pew 2016). In addition, between 1955 and 1965, the industry used antibiotics as a meat preservative. Spraying the drugs on the dead animal parts meant they could be shipped and stored refrigerated (not frozen) for a month before reaching the consumer (McKenna 2017a, b).

The extensive use of antibiotics in the industrial animal food system created a health care system crisis. The use of low doses of antibiotics to promote growth and preserve meat in industrial animal agriculture rendered those life-saving drugs nearly useless for much of the human population of the US. The pathogenic bacteria present in the guts of chickens and other livestock are normally held in check by the animal’s immune systems. However, exposure to the antibiotics exerted artificial selection on those small populations of pathogens, initially killing most of them. The surviving pathogens were the few individuals with genetics that conferred resistance to the antibiotic. Over time the few became the many. Making matters worse, antibiotic resistance is transferred between different species of bacteria via R-plasmids that contain the information in segments of DNA (Levy and Marshall 2004; Tazzyman and Bonhoeffer 2014). Consequently, humans sickened with antibiotic resistant bacteria cultured in the guts of industrial animals have one less tool to fight infections (Fig. 8, CDC 2017a).

Each year in the US, 400,000 people contract antibiotic resistant food borne diseases (CDC 2018). The list of multiple-antibiotic resistant pathogenic bacteria is growing with Salmonella spp. and Campylobacter spp causing substantial increases in morbidity and mortality (Economou and Gousia 2015). Food sourced Salmonella infects one million Americans annually, causing 23,000 hospitalizations and 450 deaths (CDC 2019a). Campylobacter, which traces almost exclusively to poultry, infects 1.2 million people annually but is less deadly than Salmonella (CDC 2017b). Other antibiotic resistant pathogens from animal agriculture include, Listeria, enterococci, and some strains of E. coli (Levy and Marshall 2004).

In 1945, Alexander Fleming warned of the potential for development of antibiotic resistant bacteria with the overuse of his penicillin. The livestock industry proved him right about an array of antibiotics (Rosenblatt-Farrell 2009). By 1977, it was clear that the use of antibiotics to promote growth in farm animals was causing antibiotic-resistance in important human pathogens. Thus, Donald Kennedy, the then newly appointed head of the Food and Drug Administration, moved to ban their use. However, opposition from powerful members of Congress with links to the animal agriculture industry derailed Kennedy’s efforts (McKenna 2017a, b). As of 2020, the use of antibiotic growth promoters remains virtually unregulated in the US. This contrasts with the European Union, which began banning antibiotic growth
Fig. 8 US Center for Disease Control poster explaining how antibiotic use in animal agriculture leads to the development and spread of antibiotic-resistant pathogenic bacteria that sicken humans. The poster neglects to mention that most antibiotics used on farms is for promoting growth. Image from https://www.cdc.gov/foodsafety/challenges/from-farm-to-table.html (CDC 2017a)
promoters for livestock in the 1990s, and prohibited them for use in chickens in 2003 (Castanon 2007).

While the official line of the CDC is to discourage the use of antibiotics for growth promotion, the agency does support their use to: “Treat disease in animals that are sick, control disease for a group of animals when some of the animals are sick, and prevent disease in animals that are at risk for becoming sick” (emphasis added) (CDC 2018).” Administering antibiotics to prevent disease is a way around the growing public dislike of using the drugs for growth promotion. Note that such preemptive use of antibiotics is discouraged in human medicine and reserved for certain conditions and surgeries where postoperative infection is likely (Enzler et al. 2011).

Although the animal food industry continues to escape meaningful government regulation of antibiotic abuse, recently consumers have forced the issue through the marketplace. Both Perdue and Tyson, the two major broiler companies on the Delmarva Peninsula, now advertise the absence of antibiotic growth promoters in the diets of their chickens (McKenna 2017a, b).

Finding a New Breed of Chicken for Meat The new broiler industry called for a new breed of chicken. The lineage of the modern broiler chicken traces to the winners of a contest held in the Chesapeake Bay’s University of Delaware’s Agricultural Experiment Station, in 1948. After WWII, USDA partnered with the pioneering A&P (The Great Atlantic and Pacific Tea Company) grocery chain to create the “chicken of tomorrow.” To understand this, we need to take a voyage back in time and explore how the A&P changed the food system in the US.

Founded in 1859 as a tea and coffee shop, the A&P evolved to a chain of nearly 200 stores in 1900 that sold dry groceries (grains, beans, flour, etc.). By 1930, the A&P became the first supermarket, adding dairy, meat and fresh produce to their offerings. By then, it was the world’s largest retail company, with 16,000 stores in the US and Canada. The A&P was revolutionary. Prior to its invention of the supermarket, shopping for groceries meant visiting several stores to get the fixings for a meal. Milk and cheese came from a dairy shop; meat from a butcher; flour, oils, canned goods and cereals from the dry grocer; fruit and vegetables from the green grocer; breads and cakes from the bakery. The A&P Supermarket put this all under one roof. A&P also created self-serve shopping, eliminating the person behind the counter that gathered the list of desired goods for the shopper. Although A&P succumbed to more innovative competitors and ceased operations in 2015, it forever changed how consumers interfaced with the food system (Funding Universe 2019).

Part of the A&P legacy was the ability of supermarkets to deliver uniform low-cost food. The Chicken of Tomorrow Contest invited farmers across the nation to offer-up a breed that would best fill the new demand for a tasty chicken with a large amount of meat on its bones. The winner of the contest wasn’t one of the hundreds of distinct breeds that farmers developed to fit best to their local situations. Instead, it was a hybrid between two of those breeds. “The winner was Charles Vantress from California, who had crafted a red-feathered hybrid out of the New Hampshire, the most popular meat bird among East Coast growers, and a California strain of Cornish (McKenna 2018).” That the winner was a hybrid and not a true breeding line meant that fertile eggs supplied by Charles Vantress’s company were destined to dominate the fledgling broiler industry. Only the company possessing the two different breeds had the capacity to keep the appropriate mating going to produce the desired hybrid. Chicken growers wouldn’t get the same results if they let the hybrids copulate. This is exactly what seed companies began doing years earlier, selling high-yielding hybrid varieties that required the farmers to buy new seed each year. Seed saved from the hybrid corn or wheat wouldn’t be like the parent generation.

The emerging broiler industry promoted the 1948 Chicken of Tomorrow competition with a parade and celebration in Georgetown, Delaware. The Delmarva chicken industry turned this into an annual event featuring the world’s largest frying pan capable of cooking 800 chicken quarters at a time, beauty queens, games, art, and food. The industry ended the festival in 2014, redirecting funds to lobbying (Old Line Plate 2015).

The hybridization industry continued to “improve” the broiler chicken, going for faster growth, larger size, and greater efficiency of converting feed to chicken mass. The modern (2005 strain) broiler reaches a mass of 4202 g in 56 days. That’s fourfold the 905 g size of a common strain from 1957 given the same feeding regime and time to grow (Fig. 9). The 2005 strain also converts feed to mass of chicken 50% more efficiently (Zuidhof et al. 2014). In general, larger homeotherms (warm blooded birds and mammals) feature lower surface area to volume ratios, meaning less loss of heat to the environment and therefore less food energy diverted from growth to keeping the animal warm.

The rapid growth, giant size and more efficient food conversion of the modern broiler hen is a boon to the industry but comes at a cost to the chickens. They suffer from cardiovascular disease, pulmonary hypertension, deformities, bone defects, and lameness (Julian 1998). This creates significant pathology for a bird over its extremely abbreviated 7–9 week life span. The industry
sends the birds to market prior to their reaching sexual maturity for two reasons. First, pre-sexual chickens don’t present the antagonistic behaviors that would make coexistence impossible in crowded CAFO’s. Second, none of the energy and nutrition of the feed is diverted away from growth to sexual reproduction. Ironically, the selective breeding means that most of the juvenile hens sent to slaughter suffer from ailments otherwise restricted to old-age.

Fig. 9 The increasing size of commercial broiler chickens with genetic selection over time. These are images of actual chickens produced with the same simultaneous feeding regime for strains used in the broiler industry in 1957, 1977 and 2005. From Zuidhof et al. (2014)
And what of the males? Skilled workers determine the gender of chicks, and dispose of the males in machinery that turns them into animal feed.

**Vertical Integration of the Broiler Industry** In the post WWII era, the broiler industry pioneered a new model for animal agriculture, called vertical integration. This means that a single company owns or controls all aspects of production and marketing (McKenna 2017a, b). The pork industry discussed above saw the success of the poultry business and adopted the same approach in the 1970s.

The broiler companies contract farmers to raise the hens. Farmers find the capitol to build and maintain the chicken houses, provide the labor, pay for utilities, and are responsible for disposal of dead birds and the huge quantity of manure produced in the operation. The broiler corporations (called integrators) provide the farmers with newly hatched chicks, feed, pharmaceuticals, veterinary services, technical guidance, and transport of the market-weight hens to slaughter/processing plants. The corporation pays the farmers based on the amount of broilers they produce and how that performance ranks in comparison to other contractors in the area. It is called the tournament system, with highest rewards going to the best producers. “Fees are determined in the following way. The integrator measures the average cost of the inputs that the integrator provided to growers for chickens delivered to the processing plant in a week—the total value of feed, chicks, and veterinary services provided to growers divided by the total weight of chickens delivered that week. The company develops this calculation for each grower. Each grower is then paid a base fee, and those growers whose costs are lower than the average for all growers receive a premium over the base fee; those whose costs exceed the average for all growers receive a deduction from the base. The amount of the premium or deduction reflects the size of the cost difference (USDA 2014).”

High mortality or poor growth means little compensation for the farmer. Despite the risk of failed flocks, the median family income for contract broiler producers in 2011 was $68,455 compared to $57,050 for all farm households, and $50,504 for all US households. Yet, this obscures the fact that 20% of contract poultry growers earn less than the federal poverty limit (USDA 2014).

Access to capital for building and maintaining the CAFOs helps determine the demography of contract broiler growers. They are overwhelmingly white males (85%) with an average age of 55 years. Only 16% completed college. In contrast, much of the workforce in the slaughter houses consists of African Americans, Latinx (circa 50%) and women. About 25% of the slaughter house workers are undocumented immigrants (NCFH 2014).

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**Fig. 10** Fate of chickens brought to market in the US since the 1960s. Prior to 1965 over 80% of the broiler chickens were sold as whole carcasses. In 2015, that fell to 11%, with most sold as cut-up parts (40%) and processed foods (49%) such as batter fired nuggets (NCC 2019)

**Making Chicken Easier to Eat** Residents of the Chesapeake Bay Region, like the rest of US, buy chicken in a very different way than their ancestors did two generations ago. In 1962, consumers bought 83% of their broilers as whole birds. By 2015, that dropped to 11% of the market, with cut-up parts (40%) and highly processed foods (49%)—meaning the vast majority of the chicken consumed (Fig. 10). This shift in the way people eat chicken accounts for much of its growing popularity illustrated in Fig. 3. Buying a whole chicken means the consumer either roasts the bird whole, or must butcher it prior to cooking (frying, baking, using in other dishes). That labor is saved by buying chicken parts. Easier still is purchasing preformed processed masses of chicken flesh already battered, fried and frozen, as invented in 1963 by Dr. Robert Baker of Cornell University. Baker didn’t patent his “chicken sticks” (McKenna 2017a, b). The McDonalds Corporation brought its version of the chicken stick to market as “Chicken McNuggets” in 1983. The popularity of the battered bits of processed tissue quickly made that company the second largest seller of chicken meat, behind KFC (formerly Kentucky Fried Chicken) which specialized in more identifiable chicken parts (Rude 2016). Chicken McNuggets and similar products sold frozen at the grocery, or in fast food restaurants, provides the consumer with chicken flesh absent of any of the trappings of real animals. There is no identifiable skin, bones, tendons, blood vessel, or other tissue to remind one they are eating the...
remains of a bird. This is quite unlike the experience of ancestors who would decapitate a spent laying chicken in the backyard to produce the Sunday dinner. Thus, the fried and battered piece of processed chicken is very easy to eat, both physically and mentally.

Broiler CAFOs Dominate the Food System Landscape of the Delmarva Peninsula Several thousand imposing steel chicken houses dot the landscape of the Delmarva Peninsula. They stand as the legacy of Cecilia Steele’s invention of the broiler industry in the 1920s, and the subsequent new-found hunger for the consumption of chicken meat. On a clear day, a peak out of the window of an airliner reveals a never ending string of broiler CAFOs stretching nearly the full length of the Delmarva Peninsula (Figs. 11 and 12).

Modern broiler CAFOs on the Delmarva Peninsula average about 2000 m² in floor space and house 20,000 to 30,000 hens (Fig. 13). This means a density of about 12 birds per m². The flock arrives as new hatchlings and is taken to slaughter in about 45 days. They spend the entire time in the chicken house, standing in a mix of their own manure and sawdust, eating feed from troughs and drinking water from nipples attached to pipes (Fig. 14).

Chicken Dominates the Terrestrial Animal Food Scene of the Bay The advent of the broiler industry changed the nation’s eating habits and the local food system. As addressed above, the production of pigs for regional consumption has been mostly farmed out to North Carolina and other states, but the processing of pork is still a big industry in the lower Bay. Dairy and beef cattle production remains present throughout the watershed, but those industries concentrate in the states of New York and Pennsylvania (Table 3). Neither of those jurisdictions physically touches the Bay, yet effluents from their dairy and cattle producers drain to the Chesapeake via the Susquehanna River. However, its poultry that’s left its mark on the Bay ecosystem more than any other of the terrestrial animals exploited for food.

Working Conditions and Health Hazards for Broiler Industry Workers During 2015 and 2016 Poultry workers rank 12th among professions in severe injury reports, with Tyson Foods (one of the two dominant broiler companies on the Delmarva Peninsula) ranking fourth for all employers. In 2016, Tyson received $700,000 in OSHA (Occupational Safety and Health Administration) fines. Injuries included cuts, amputations, bone fractures, contusions, and chemical burns (Berkowitz and Hedayati 2017). Fast production line speeds, 12–14 hour shifts, dangerous equipment and blood slickened floors make for hazardous working conditions in slaughter and packaging houses. Repetitive injuries also afflict these workers (SPLC 2013).

Injuries are also a regular feature of one specialized class of employment, chicken catchers. These mostly Latinx and African American workers must physically collect each of the 25,000 or so chickens in a CAFO house and place the armloads (seven at a time) of unwilling hens in cages on trailers for transfer to the slaughter house. Chicken catchers suffer from back, hand, and respiratory injuries (SPLC 2013).

In addition to physical injuries, broiler industry workers suffer health problems from exposure to polluted air and pathogens. The high density of chickens in CAFOs and no system for removing dung means the buildup of high levels of ammonia, hydrogen sulfide, volatile organic compounds, and particulate matter in the air. Yet CAFOs are agricultural facilities and therefore exempt from regulation by the USEPA and most state laws other than direct discharge into waterways (USEPA 2017).

Chicken eliminates excess nitrogenous waste as urea. Bacteria in soil or on the floor of a chicken house convert it to ammonia. The gas irritates the mucus membranes of the hens, increasing susceptibility to respiratory infections, conjunctivitis of the eyes, and lesions of the cornea (Aziz 2010). It also causes chemical burns on the feet and legs of the chickens. Ammonia exposure causes acute and chronic respiratory pathologies in chicken catchers and poultry house workers. Poultry workers exhibit significantly more chronic occurrences of burning eyes, sneezing, stuffy noses, running noses, cough, bronchitis, phlegm and chest tightness than other laborers. Reducing the protein and increasing the fiber content of the feed helps reduce ammonia production (Naseem and King 2018). But that would mean slower growth rates and reduced profits.

Slaughterhouse poultry workers suffer significantly higher rates of various cancers including: “... buccal and nasal cavities and pharynx (base of the tongue, palate and other unspecified mouth, tonsil and oropharynx, nasal cavity/middle ear/accessory sinus), esophagus, recto-sigmoid/rectum/anus, liver and intrabiliary system, myelofibrosis, lymphoid leukemia and multiple myeloma...” (Johnson et al. 2010a). Poultry workers also display an 8.6-fold increase in the chances of death from penial cancer. Poultry slaughterhouse workers show an 8.9 fold increase in chances of contracting pancreatic cancer and 9.1 fold increase for liver cancers (Felini et al. 2011). A possible cause of the high cancer rates is oncogenic retroviruses that induce various tumor types in chickens (Johnson et al. 2010b). Poultry plants became centers of outbreak for the Covid-19 virus epidemic of 2020. The close proximity of workers on the production line makes for rapid spread of disease, similar to the situation for chickens in CAFOs. Purdue and Tyson plants reported hundreds of cases of infected workers, including fatalities in each of their facilities across the entire Delmarva Peninsula on the Chesapeake Bay’s Eastern Shore (Ash 2020; Sternberg 2020; Vogelsong and Bravender 2020).
Fig. 11 The distribution of broiler house Concentrated Animal Feeding Operations (CAFOs) on the Delmarva Peninsula. Image is from Google Earth based upon satellite images taken in 2016. Each pin represents one CAFO. Each CAFO contains 1–14 broiler houses, with an average of 3.3 houses per each of the 1116 pined location. This yields a count of 3687 broiler houses on the Delmarva, with a calculated density of 0.26 units per km². Image Landsat/Copernicus, Data SIO, NOAA, US Navy, NGA, GEBCO. The estimated number of houses presented here may be low, as another source reports 5091 units for the Delmarva (Gustin 2018).
Health Hazards for Neighbors of Broiler CAFOs  CAFO operators use large ventilation fans to control concentrations of ammonia in the houses. However, this pollutes the air surrounding the facilities, exposing neighbors of the facility to high levels of irritating ammonia (Naseem and King 2018). CAFOs with four or more chicken houses regularly surpass the 100 lbs. (45.4 kg) per day limit for ammonia that USEPA places on stationary facilities (Pescatore et al. 2005). The occurrence of exacerbated asthma attacks is associated with proximity to dairy and pig CAFOs (Rasmussen et al. 2017). Is this also true for broiler CAFOs? In 2017, residents of the Maryland portion of the Delmarva Peninsula pushed for legislation (Community Healthy Air Act) to assess air pollution and its health effects emanating from chicken CAFOs, and to determine compliance with state and federal laws. The measure failed in the state legislator, illustrating the political grip of the broiler industry in the region (Gustin 2018). However, in 2019, the Delmarva Poultry Industry funded a small scale pilot study to compare upwind and downwind air quality at two CAFOs. Critics worry about the validity of any results from a study funded by the broiler industry (Miller 2019).

Health Hazards for Consumers of Poultry and Eggs  Consumers of poultry products face two types of hazards, pathogens and dietary components that cause non-contagious diseases.

Poultry and Pathogens  As discussed above, poultry subjected to antibiotics for growth promotion present consumers with drug-resistant diseases. This is a serious problem, as poultry is the most common source of food-borne disease outbreaks in the US. One study found that between 1998 and 2012...“poultry was associated with
279 (25%) of cases, accounting for the highest number of outbreaks, illnesses, and hospitalizations, and the second highest number of deaths. Of the 149 poultry associated outbreaks caused by a confirmed pathogen, *Salmonella enterica* (43%) and *Clostridium perfringens* (26%) were the most common pathogens (CHAI et al. 2016). Restaurants (37%), private homes (25%) and catering facilities (13%) were all associated with outbreaks. Food-handling errors accounted for 64% of the outbreaks. Yet, practicing safe handling of poultry appears beyond the resources and abilities of most consumers. Only 17.5% store raw poultry properly, and only 11% thaw frozen birds safely (Kosa et al. 2015). The shift from selling whole chickens to chicken parts as discussed above, increases exposure to dietary pathogens. A comprehensive study done in 2012 found *Salmonella* and *Campylobacter* contamination on chicken parts at the rate of 26.3% and 21.4% respectively. This compares to 5.9% for *Salmonella* and 10.6% for *Campylobacter* for whole young chickens (USDA 2019d). The USDA sets a maximum acceptable percent positive standard for pathogens in poultry products (Table 4). The findings from the 2012 study well exceed those standards. Depending on the product, contamination rates for *Salmonella* of 9.8–25.0% is permissible. This means that unsafe handling or undercooking of the products is likely to result in significant rates of exposure for consumers (between one in ten and one in four), even if the poultry companies complied with the standards. *Raw poultry as sold in the US is a perfectly legal biohazard for consumers. According to a 1974 court ruling, Salmonella is a natural part of poultry, destroyed by proper cooking, and therefore not subject to regulation (Legal 2019). A second ruling in 2001 prevents the USDA from closing down processing plants for producing Salmonella contaminated products (FindLaw 2019). Thus poultry plants producing Salmonella contaminated products don’t face fines and can’t be shut down by regulators. In contrast to the US, Sweden doesn’t allow the sale of Salmonella contaminated poultry, eliminating the pathogen from broilers by 1972, and layers 20 years later. That nation instituted hygienic practices throughout the production process, including heating the feed to eliminate pathogens (Wierup et al. 1995). As with the meat, chicken eggs also transmit *Salmonella* to consumers and account for 53% of infections. Pasteurization or complete cooking is recommended to reduce infection, but just handling the eggs may transmit the pathogen to consumers (Whiley and Ross 2015). In addition to *Salmonella* and *Campylobacter*, poultry is a source of pathogenic strains of Escherichia coli. Extraintestinal Pathogenic *E. coli* (ExPEC) survive outside of the gut, as the name indicates. ExPEC causes 70–90% of urinary tract infections (UTIs) in humans (Singer 2015). Poultry appears to be the main source pool for UTI causing ExPEC (Manges 2016).
Poultry, Eggs and Non-communicable Disease Dietary cholesterol and saturated fats cause cardiovascular disease (CVD), the number one cause of death in the US and the world (Ference and Mahajan 2013). “Among 29,615 adults pooled from 6 prospective cohort studies in the United States with a median follow-up of 17.5 years, each additional 300 mg of dietary cholesterol consumed per day was significantly associated with higher risk of incident CVD (adjusted hazard ratio [HR], 1.17; adjusted absolute risk difference [ARD], 3.24%) and all-cause mortality (adjusted HR, 1.18; adjusted ARD, 4.43%) and each additional half an egg consumed per day was significantly associated with higher risk of incident CVD (adjusted HR, 1.06; adjusted ARD, 1.11%) and all-cause mortality (adjusted HR, 1.08; adjusted ARD, 1.93%) (Zhong et al. 2019).”

![Interior of a broiler chicken house illustrating the density of the hens, the system of pipes and troughs for watering and feeding the birds, and massive ventilation fans. A mix of saw dust or similar organic material and feces covers the floor. That manure remains in place during the 42 day-long residency of the flock. The manure removal and disposal takes place after the flock is sent to slaughter. Image from the USDA. It was taken Aug. 23, 2013 by Bob Nichols.](http://www.publicdomainfiles.com/show_file.php?id=13986676816105)

**Table 3** The annual production of key animal products from the jurisdictions with drainages that reach the Chesapeake Bay

| Jurisdiction | Annual Egg Production (millions) | Annual Broiler Production (millions) | Annual Dairy Production (million kg) | Number of Cattle |
|---------------|----------------------------------|-------------------------------------|-------------------------------------|-----------------|
| Delaware      | 0                                | 259.8                               | 45                                  | 16,000          |
| Maryland      | 833.7                            | 306.7                               | 446                                 | 182,000         |
| New York      | 1694.10                          | 0.59                                | 6396                                | 1,450,000       |
| Pennsylvania  | 8212.80                          | 185.2                               | 4901                                | 1,620,000       |
| West Virginia | 273.1                            | 86.1                                | 64                                  | 380,000         |
| Virginia      | 691.4                            | 277.4                               | 803                                 | 1,530,000       |
| Total Bay States | 11,705.1                        | 1115.79                             | 12,655                              | 5,178,000       |
| Total US      | 105,688.70                       | 8831.20                             | 94,648                              | 93,700,000      |

The percentage of the US production accounted for by the products are 12.6% for broilers, 11.1% for chicken eggs, 13.4% for dairy, and 5.5% for cattle. Note that 89% of the dairy production takes place in New York and Pennsylvania, states with no land contacting the Bay. Data from USDA 2018 and USDAERS 2020.
Most consumers consider chicken to be the healthiest form of meat, thinking it contains less cholesterol and saturated fat than beef or pork (Malone and Lusk 2017). Yet, a metaanalysis of 124 randomized control studies with various diets found no significant difference in blood cholesterol and lipids for beef, chicken or fish consumption (Maki et al. 2012). This is consistent with the modern broiler bred to contain up to 10 times the fat per kg of chickens from 1896 (Wang et al. 2009). Modern broilers differ little in their cholesterol and saturated fat content from beef, pork, and seafood. And chicken eggs contain nearly six times the cholesterol found in beef tenderloin steak (Table 5).

About 12% of adults older than 20 years of age in the US have total cholesterol levels higher than 240 mg/dl, while any total concentrations above 150 mg/dl (and low density lipid cholesterol above 70 mg/dl) means increased risk of heart attack (O’Keefe et al. 2004; CDC 2019b). In addition to heart disease, dietary cholesterol and oxidized cholesterol are associated with a host of other maladies. These include; dementia, erectile dysfunction, inflammatory bowel disease, and macular degeneration (Schwartz and Kloner 2009; Poli et al. 2013; Testa et al. 2016).

After decades of decline, egg consumption in the US is on the rise (Fig. 3), which may attribute to intensive marketing that influences the perception of the healthfulness of the product and misleading egg-industry funded studies (AEB 2019; Fernandez 2012). The Freedom of Information Act allowed Dr. Michael Greger (2018) to obtain communication between the USDA and one company that sells chicken eggs. The USDA officer denied the companies’ attempt to use any of the following terms for eggs in promotional literature: “nutritional powerhouse that aids in weight loss,” “healthy snacking,” “healthy,” “nutritious,” “relatively low in calories,” “healthful,” and “high in nutritional content.” As the officer pointed out, the high level of cholesterol and saturated fats in eggs disqualifies them from labeling as healthy. However, the official suggested the statement, “can reduce hunger” as an alternative to words that refer to health. This interaction highlights the internal contradiction created by the mixed mandate of the USDA. It is supposed to both promote US agricultural products and to recommend healthy diets.

Table 4 The USDA maximum allowable rates (%) of contamination for Salmonella and Campylobacter on chicken parts

| Product         | Salmonella | Campylobacter |
|-----------------|------------|---------------|
| Broiler carcass | 9.8        | 15.7          |
| Broiler parts   | 15.4       | 7.7           |
| Comminuted chicken | 25.0   | 1.9           |

Comminuted chicken refers to the process of crushing the tissue to form a shaped product, which is usually sold breaded in the form of a nugget. The USDA considers facilities with contamination rates above these percentages to be in violation of the standard (USDA 2016, 2019e).

Consumers wishing to eliminate or reduce dietary cholesterol won’t fulfill that desire by continuing to consume any sort of animal product. They should instead look to beans and nuts as protein-rich replacements for meat, since plants don’t produce cholesterol (Table 5).

The High Cost of Cheap Chicken Meat for the Chesapeake Bay Ecosystem The system of producing the modern giant boiler chicken comes with oversized environmental consequences. Industrialized broiler production completely compartmentalizes the chicken’s life cycle in time and space. Corn, soy, and amendments such as fish meal and leftovers from food processing plants form the feed. These products may hail from the Chesapeake Bay watershed, but feeds typically includ items trucked in from remote farms. About 48% of the feed turns into chicken tissue, as the modern broiler exhibits a remarkable Food Conversion Efficiency (FCE) of 1.9 (Zuidhof et al. 2014). So if half of the chicken feed becomes chicken parts, where goes the rest? Modern delivery systems mean only a small portion of the feed never finds its way into a hen’s beak. The excreted metabolites from the ingested food yields manure rich in nitrogen and phosphorus. Noxious ammonia released from the manure pollutes the air of the chicken house and the surrounding communities. Carbon dioxide and nitrous oxides from the birds and their litter contribute to the stock of greenhouse gasses. Soluble fractions of the manure may run into the Bay immediately, or leach into groundwater where they are detained before eventually seeping into the waters of the estuary. Ideally, the industry would return all of the manure to fields that produced the chicken feed in the first place, as what used to happen in the days of small family farms. The nitrogen and phosphorus in the manure are critical plant nutrients. Manure from poultry should be prized for its particularly high concentrations of these elements (Table 6). Yet handling and transport costs keeps the bulk of the manure close to the CAFOs where it is more likely to contaminate the Bay. The current economics of broiler production means it pays to ship chicken feed from farms, but not to send the resulting chicken manure back to those fields. Instead, corn and soy farmers prefer the low price of artificial fertilizes to sustain crop production (see chapter “The Journey from Peruvian Guano to Artificial Fertilizer Ends with Too Much Nitrogen in the Chesapeake Bay”).

The years of plentiful and cheap chicken litter resulted in manure-saturated fields throughout the Delmarva Peninsula. Adding excess manure is prohibited by state laws designed to reduce nutrient runoff and migration into ground water. To promote export of manure out of the Delmarva, the state of Maryland provides a $ one million per year ($18 per ton) subsidy to the giant Perdue Farms poultry company to process chicken manure into fertilizer at its AgriRecycle facility.
in Delaware. The plant processes 50,000 tons of Delmarva chicken manure annually. Its product goes not to the farmer’s fields that produce the feed crops, but to retailers of fertilizer for golf courses and home gardens (Dance2017). This short-circuits nutrient recycling, contributing to the environmental unsustainability of the broiler industry.

What’s in the industrial chicken manure may also deter farmers from using it as fertilizer. The enteric pathogens discussed above (Salmonella, Campylobacter, and E. coli) and residues of antibiotics render manure less useful for growing crops, as farmers seek to avoid contamination of their harvest. The broiler industry also poisoned the manure with arsenic. The crowding of hens into CAFOs created the ideal situation for diseases to rapidly spread through the flocks. Crowding meant suppression of the immune system and easy transmission of pathogens. Outbreaks of the intestinal parasite coccidiosis (Eimeria sp.) plagued the emerging broiler industry. In the 1940s, they began adding the arsenic-containing-compound Roxarsone (3-nitro-4-hydroxyphenylarsonic acid) to chicken feed to control the disease and promote faster growth (Reid 1990). However, public response to arsenic contamination of poultry meat, soils, and surface waters eventually ended the practice with bans enacted in the European Union in 1999, Maryland in 2012 and the entire US in 2013 (Garbarino et al.2003; Fisher et al. 2015). Arsenic is a carcinogen and a general toxin, interfering with over 400 enzymatic pathways in the human body (Ratnaike 2003). Although no longer permitted for use in poultry, the legacy of arsenic contamination continues to pollute soils, ground water and the Chesapeake Bay food chain.

in Delaware. The plant processes 50,000 tons of Delmarva chicken manure annually. Its product goes not to the farmer’s fields that produce the feed crops, but to retailers of fertilizer for golf courses and home gardens (Dance2017). This short-circuits nutrient recycling, contributing to the environmental unsustainability of the broiler industry.

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While antibiotics, arsenic and other pollutants from chicken manure threaten the Chesapeake Bay and our food system, it’s the excess nitrogen that causes the most visible effects. Chapter “The Journey from Peruvian Guano to Artificial Fertilizer Ends with Too Much Nitrogen in the Chesapeake Bay” and “Eutrophication: Obesity of the Bay and Its People” discusses how nitrogen from the chicken industry is helping to drive eutrophication of the Bay. The Clean Water Act of 1972 (discussed in chapter “What Nature, Politics and Policy Demand of the Chesapeake Bay and Its Food System”) authorizes the USEPA to regulate pollution from point sources (end of pipe) entering waterways.

### Table 5
The nutrition content per 100 g (wet mass) of various food substances found in the Chesapeake Bay food system

| Item               | Energy (kcal) | Protein (g) | Total Saturated Fat (g) | Cholesterol (mg) | Total fat (g) | Protein (g/Kcal) |
|--------------------|---------------|-------------|-------------------------|------------------|---------------|------------------|
| Atlantic croaker   | 104           | 17.8        | 1.09                    | 61               | 3.17          | 0.17             |
| Striped bass       | 97            | 17.7        | 0.51                    | 80               | 2.33          | 0.18             |
| Flounder           | 86            | 16.2        | 0.54                    | 56               | 2.37          | 0.19             |
| American shad      | 197           | 16.9        | 3.12                    | 75               | 13.8          | 0.09             |
| Oyster             | 107           | 12.5        | 1.79                    | 62               | 4.46          | 0.12             |
| Blue crab meat     | 119           | 23.81       | 0.20                    | 107              | 1.19          | 0.20             |
| Chicken breast with skin | 172   | 20.9        | 2.66                    | 64               | 9.25          | 0.12             |
| Chicken breast no skin | 107  | 23.2        | 0                      | 58               | 0.89          | 0.22             |
| Chicken egg        | 155           | 12.6        | 3.27                    | 373              | 10.60         | 0.08             |
| Ground beef 70% lean | 332    | 14.4        | 11.75                   | 78               | 30.00         | 0.04             |
| Beef tenderloin steak | 129  | 22.35       | 1.76                    | 65               | 5.29          | 0.17             |
| Cured Smithfield honey ham | 125 | 17.9        | 0                      | 54               | 3.60          | 0.14             |
| Bacon Smithfield hickory smoked | 471 | 29.4        | 14.71                   | 118              | 41.80         | 0.06             |
| Whole milk         | 62            | 3.33        | 1.88                    | 10               | 3.33          | 0.00             |
| Soy bean, organic  | 92            | 8.46        | 0.77                    | 0                | 4.62          | 0.09             |
| Navy beans         | 85            | 9.38        | 0                      | 0                | 0.77          | 0.11             |
| Peanuts boiled     | 278           | 13.89       | 4.17                    | 0                | 22.22         | 0.05             |
| Raw walnuts        | 700           | 16.67       | 1.5                     | 0                | 66.67         | 0.02             |

Data is from the USDA (2019f). The scientific names of the foods are: Atlantic croaker, Micropogonias undulatus, Blue fish, Pomatomus saltatrix, Striped bass, Morone saxatilis, Flounder, Pleuronectes americanus, American shad, Alosa sapidissima, Oyster, Crassostrea virginica, Blue crab, Callinectes sapidus, Chicken, Gallus gallus domesticus, Cattle (beef), Bos Taurus, Pig (ham and bacon), Sus scrofa domesticus, Soybean, Glycine max, Navy beans, Phaseolus vulgaris, Peanuts boiled, Arachis hypogaea, Walnuts, Juglans sp.

### Table 6
The production of manure, nitrogen and phosphorus per 1000 kg of animal mass per day of different livestock types

| Live stock          | Manure | Nitrogen | Phosphorus |
|---------------------|--------|----------|------------|
| Beef                | 26.81  | 0.10     | 0.05       |
| Dairy               | 36.29  | 0.20     | 0.03       |
| Pigs                | 28.62  | 0.19     | 0.07       |
| Chickens (layers)   | 27.44  | 0.38     | 0.14       |
| Chickens (broilers) | 36.29  | 0.50     | 0.15       |
| Turkeys             | 19.78  | 0.34     | 0.13       |

Note that poultry manure is significantly richer in nutrients than that from cattle or pigs. Data from NRCS 1995.
Table 7  Key pollutants from livestock operations and animal manure

| Pollutant        | Description of pollutant                                                                 | Pathways to the environment                                                                 | Potential impacts                                                                 |
|------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Nitrogen         | Organic forms (e.g., urea) and inorganic forms (e.g., ammonium and nitrate) in manure may be assimilated by plants and algae | • Overland discharge • Leachate into ground water • Atmospheric deposition as ammonia       | • Eutrophication and harmful algal blooms (HABs) • Ammonia toxicity to aquatic life • Nitrate linked to methemoglobinemia |
| Phosphorus       | As manure ages, phosphorus mineralizes to inorganic phosphate compounds that may be assimilated by plants | • Overland discharge • Leachate into ground water (water soluble forms)                      | • Eutrophication and HABs                                                        |
| Potassium        | Most potassium in manure is in an inorganic form available for plant assimilation; it can also be stored in soil for future plant uptake | • Overland discharge • Leachate into ground water                                           | • Increased salinity in surface water and ground water                            |
| Organic Compounds| Carbon-based compounds decomposed by micro-organisms. Creates biochemical oxygen demand because decomposition consumes dissolved oxygen in the water | • Overland discharge                                                                      | • Eutrophication and HABs • Dissolved oxygen depletion, and potentially anoxia • Decreased aquatic biodiversity |
| Solids           | Includes manure, feed, bedding, hair, feathers, and dead livestock                       | • Overland discharge • Atmospheric deposition                                               | • Turbidity • Siltation                                                            |
| Salts            | Includes cations (sodium, potassium, calcium, magnesium) and anions (chloride, sulfate, bicarbonate, carbonate, nitrate) | • Overland discharge • Leachate into ground water                                           | • Reduction in aquatic life • Increased soil salinity • Increased drinking water treatment costs |
| Trace Elements   | Includes feed additives (arsenic, copper, selenium, zinc, cadmium), trace metals (molybdenum, nickel, lead, iron, manganese, aluminum), and pesticide ingredients (boron) | • Overland discharge • Leachate into ground water                                           | • Aquatic toxicity at elevated concentrations                                       |
| Volatile Compounds Including Greenhouse Gasses | Includes carbon dioxide, methane, nitrous oxide, hydrogen sulfide, and ammonia gases generated during manure decomposition. | • Inhalation • Atmospheric deposition of ammonia                                            | • Eutrophication • Human health effects • Climate change                           |
| Pathogens        | Includes a range of disease-causing organisms, including bacteria, viruses, protozoa, fungi, prions and helminths | • Overland discharge • Potential growth in receiving waters                                 | • Animal, human health effects                                                    |
| Antimicrobials   | Includes antibiotics and vaccines used for therapeutic and growth promotion purposes    | • Overland discharge • Leachate into ground water • Atmospheric deposition                  | • Facilitates the growth of antimicrobial-resistance • Unknown human health and aquatic life effects |
| Hormones         | Includes natural and synthetic hormones used to promote animal growth and control reproductive cycles | • Overland discharge • Leachate into ground water                                           | • Endocrine disruption in fish • Unknown human health effects                      |
| Other Pollutants | Includes pesticides, soaps, and disinfectants                                           | • Overland discharge • Leachate into ground water                                           | • Unknown human health and ecological effects • Potential endocrine disruption in aquatic organisms |

From USEPA 2013

However, it exempts the non-point source pollution released from agricultural operations (Janasie 2018). Table 7 presents the various pollutants emanating from livestock manure, their pathways of movement through the environment and their potential impacts on ecosystem health. These remain largely unregulated.
