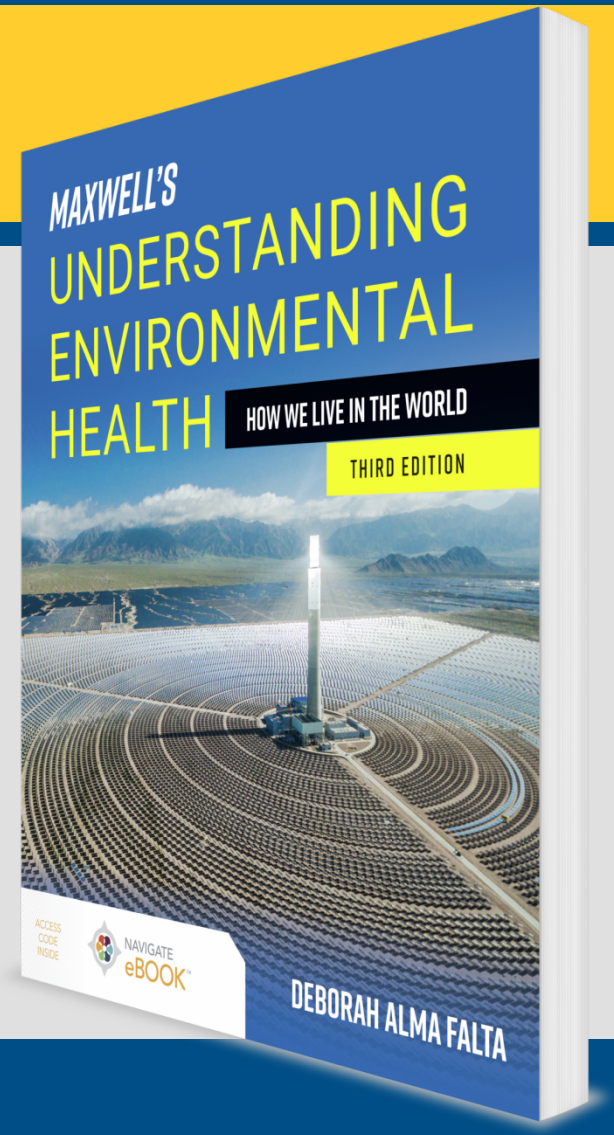
CHAPTER 5

Producing Food



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Nature of the Pest Problem

- Pest comes from *pestis* (Latin for plague)
- Three main problems humans have with pests:
  - Vectors of disease
  - Sources of discomfort
  - Resources competition

Early Pest “Controls”

- Initially, physical efforts employed
- During Middle Ages, the Chinese and Middle Eastern countries employed knowledge of plant poisons.
- The horrible blights in the 1800s (Irish Potato famine of 1848) prompted research into chemical controls.

Early Chemical Agents

- Bordeaux mixture (copper sulfate and lime)
- Paris Green (copper with arsenic)
- Lead with arsenic
- ***All of these inorganic metals are highly toxic!***

DDT created around 1940

- Dichlorodiphenyltrichloroethane (DDT)
- Very toxic to pests, but seemingly harmless to humans
- Dr. Paul Mueller awarded 1948 Nobel Prize
- This organochlorine ushers in the era of chemical pesticides!

Pesticide

- Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating pests
- Pests can be weeds, insects, rodents, and a host of other unwanted organisms.

Types of Chemical Pesticides

- Generally, recognize type by its prefix (herba-, rodenta-, etcetc.)

Herbicide

- A chemical pesticide designed to control or destroy plants, weeds, or grasses
- Selective and nonselective types
- Examples:
  - Atrazine
  - Paraquat
  - Agent Orange (2,4-D and 2,4,5-T)

Insecticide

- A pesticide compound specifically used to kill or prevent the growth of insects

Fungicide

- A pesticide that is used to control, deter, or destroy fungi

Rodenticide

- A chemical or agent used to destroy rats or other rodent pests, or to prevent them from damaging food, crops, etc.

Nematocide

- A chemical agent that is destructive to nematodes
- Nematode: worm

Examples of Organochlorine Pesticides

- DDT
- Lindane
- Chlordane
- Mirex
- Hexachlorobenzene
- Methoxychlor

Facts about DDT

- Primarily used as an insecticide
- Credited with savings millions from death due to malaria
- Focus of Rachel Carson's Silent Spring
- Concerns about possible reproductive adverse effects in wildlife and humans led to ban on DDT applications in 1972

Organochlorines Pesticides Work as Nerve Toxins

- Persistent in the environment
  - *Initially thought to be a good feature*
- Lipophilic
- Bioaccumulated in fatty tissue
- Biomagnified up the food chain

Other Pesticides that "Poison" the Central Nervous System (CNS)

- Organophosphates, carbamates, and neonicotinoids
- Term: anticholinesterases (inhibit neurotransmitter that aids in cell-to-cell transfer of nerve impulses; *think "knockdown"*
- Receptors activated by acetylcholine
- While low to moderate activation of these receptors causes nervous stimulation, high levels overstimulate and block the receptors, causing paralysis and death.

Organophosphates (OPs)

- Related to “nerve gases”
- Frequently the cause of fatal poisonings, especially among agricultural workers
- Benefits of using OPs:
  - Control a wide range of insects
    - Wliminates need for multiple applications of different pesticides
  - Tend not to persist in the environment.

Common Types of OPs

- Malathion and methyl parathion
- Diazinon
- Dursban
- Appear in a wide variety of products: baits, sprays, foggers, flea collars, granules, etc.

Carbamates

- Closely related to OPs
- Approved for controlling garden pests and an ingredient in tick and flea products for furry pets
- Dissipate quickly as a result of rapid breakdown into other substances

Examples of Carbamates

- Carbyl (Sevin)
- Aldicarb
- Fenoxycarb
- Propoxur
- Metam sodium

Methyl Isocyanate (MIC)

- Methyl isocyanate (MIC) is an intermediate chemical used for the manufacture of carbamate pesticides.
- When acute exposure occurs, MIC is extremely toxic to life forms (e.g., human beings, aquatic organisms, and plants).

MIC Release in Bhopal, India

- Accidental release of MIC during a 1984 industrial accident in Bhopal, India, that killed more than 3,800 people
- Outrage over Bhopal disaster impetus for U.S. Emergency Planning and Community Right-to-Know Act

Pyrethrins

- Derived from natural sources: certain varieties of chrysanthemum flowers
- Also impair the nervous system
- Have great ability to paralyze and kill flying insects
- Interfere with transmission of neural impulses via action on sodium channels

Use of Pyrethrin Insecticides

- Generally have low concentrations of the active ingredient
- Used inside the home in aerosol cans, insecticide bombs, insecticidal pet shampoos, treatments for lice applied directly to humans, and mosquito repellents
- May be inhaled as a result of spraying and may be ingested in foods

Fungicides and Rodenticides

- Fungicides: many types of synthetic organic compounds used in agriculture, particularly for fruit or crops grown in wet conditions
- Rodenticides: early ones used inorganic metals to overwhelm the GI tract
  - Types of rat poisons: red squill causes heart paralysis and norbormide causes shock impairment of blood circulation
  - Often available as anticoagulant bait

Concern with Insect Resistance

- Akin to bacterial resistance, some pests may have a genetic makeup conferring tolerance (or resistance) to action of the pesticide
- Larger proportion of these “resistant types” survive after each application.
- Due to short life spans, speeds up evolutionary survival of the fittest.

Human Health Effects of Pesticides

- Difficult to study
  - Changing mix of chemicals
  - Workers lack information
  - Variation in practices, protective gear
  - Hard to disentangle acute and chronic effects
- Neurologic and reproductive effects
- Cancers

Disparities in Exposures and Impacts

- Pesticide production workers
- Farmers and their families
- Hired farmworkers
  - In U.S., mostly men, about half Hispanic, half foreign-born
  - Often inadequate protections, facilities, warnings
- In lower-income countries, more-hazardous pesticides may still be in use.

Integrated Pest Management

- Integrated refers to the use of multiple tactics
- Management goals are to suppress rather than wipe out pests.
  - Involves establishment of thresholds for action
    - Monitor, then act
  - Encourages the use of beneficial insects, pheromones, and changes to irrigation or crop rotation practices
- Hard to integrate IPM into large-scale, mechanized agriculture

Remember: There are Benefits of Modern Chemical Pesticides!

- Increase crop yields
- Fewer rodent problems
- Decrease major diseases

But, Also, Some Significant Drawbacks to Chemicals!

- Development of resistance
- Killing of beneficial species
- Persistent environmental contamination
- Concerns with residual contamination in food (linked with potential human health effects such as allergies, cancers, Parkinson's disease, etc.)

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Key Features of U.S. Agriculture Today

- Few varieties of crops; grown in monoculture
- Heavy reliance on chemicals and machinery
- Subsidized by fossil fuels

Nitrogen Contamination

- Extensive use of nitrate fertilizers
  - Leads to nitrites in groundwater
- Direct human health effect
  - Nitrites in water change hemoglobin to form that cannot carry oxygen
  - Causes methemoglobinemia (blue baby syndrome) in young infants

Genetically Modified Crop Plants (1 of 3)

- Rationale: increase global food supply
  - Crops that resist disease, repel pests, ripen faster, etc.
- Process
  - Isolate gene for desired characteristic
  - Using a loop of bacterial DNA, transfer this gene (transgene or biotech gene) into DNA of another species
- Two key concerns

Genetically Modified Crop Plants (2 of 3)

- Allergic reactions to GM foods
  - Allergens are proteins; chemical structure determined by DNA of species
  - Proteins of donor species present in transgenic plant
    - Thus, for example, allergenic protein from another plant species could occur in GM soybeans
  - Can't distinguish GM foods; can't prevent spread of GM plants in environment

Genetically Modified Crop Plants (3 of 3)

- GM foods and the spread of antibiotic resistance
  - Antibiotic resistance gene is coupled to transgene, in order to identify GM cells
  - Thus antibiotic resistance could spread through environmental gene-swapping[22,23]
    - In silos
    - In the gut of humans or other animals
    - In the field: recent evidence from canola plants[24]

Use of Water for Irrigation

- Irrigation accounted for 42% of U.S. water consumption in 2015[44]
- Substantial losses to evaporation
- Areas of concern:
  - Lower Colorado River, Rio Grande region
  - Central Plains and Southwest

Mechanical Hazards to Workers

- Fatal injuries
  - Approximately 250 fatal injuries per year in U.S. in 2017 and 2018 [47]
  - Often involving transport or equipment
  - Fatal injury rate in 2018 much higher than that in coal mining
- Nonfatal injuries; farmers report, etc.
  - Struck by objects/equipment; injuries to hands/feet; caused by human error, haste [50]

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Introduction

- In energy terms, eating meat is a luxury.
- Modern livestock production
  - Subsidizes feed crops with oil and chemicals
  - Emphasizes mechanization, large scale
  - Uses new feeding and veterinary practices

Concentrated Animal Feeding Operations (CAFOs) (1 of 5)

- A profile of CAFOs in the U.S.
  - 2010: 34.4 million cattle, 110 million hogs, 8.6 billion chickens slaughtered[54, 55]
  - Almost 20,000 CAFOs in the U.S. by end of 2017, with addition of 1400 new operations since 2010[56]
  - Production of beef, swine, and broilers concentrated in a few states

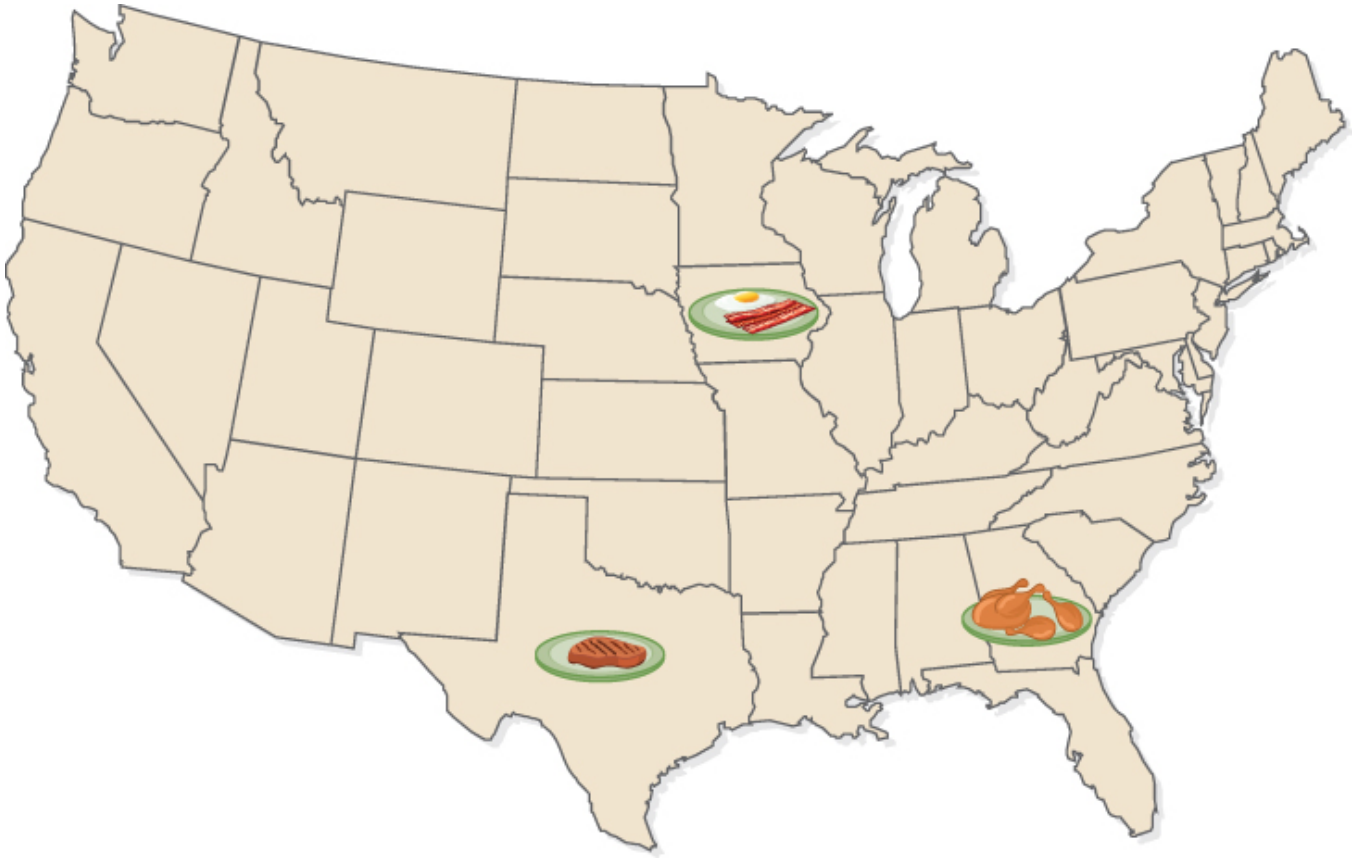

FIGURE 5.6 States in the U.S. with the largest CAFO production of beef, chicken, eggs or pork.

Data from U.S. Department of Agriculture. National Agricultural Statistics Service. Cattle: Final Estimates 1999–2003. 2004. Available at: http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb989.pdf; U.S. Department of Agriculture, National Agricultural Statistics Service. Livestock Operations: Final Estimates 1998–2002. 2004. Available at: http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb1002.pdf; U.S. Department of Agriculture, National Agricultural Statistics Service. Poultry Production and Value: Final Estimates 1998–2002, 2004. Available at: http://usda.mannlib.cornell.edu/usda/reports/general/sb/sb994.pdf. All accessed April 19, 2008.

Concentrated Animal Feeding Operations (CAFOs) (2 of 5)

- Conditions of animal confinement[59]
  - Feedlots, paved or unpaved (cattle) →
  - Enclosed houses, slotted floors (swine) or bedding (broilers), mechanical ventilation
  - Ground and pelletized feed
  - Ammonia, hydrogen sulfide, dusts
  - Respiratory problems largest single cause of death in cattle and swine before slaughter

FIGURE 5.7 Cows study the photographer from the fringes of a mass of cattle in this CAFO.

Courtesy of Cathryn Dowd

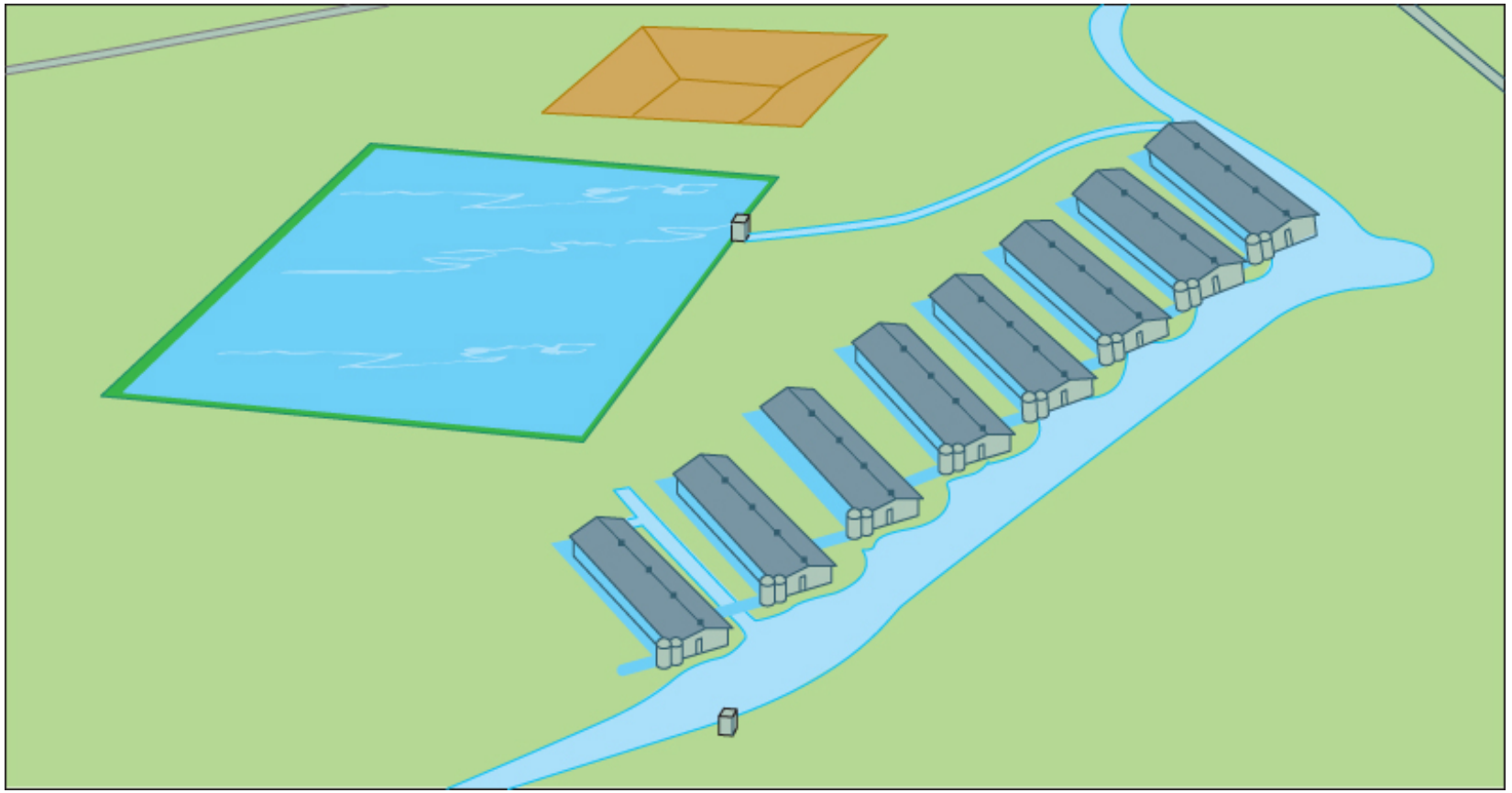

FIGURE 5.8 This sketch shows a typical layout for a hog CAFO, with a series of barns and an associated manure lagoon. A large operation might consist of several such units.

Concentrated Animal Feeding Operations (CAFOs) (3 of 5)

- Environmental impacts of CAFOs
  - Methane (belching cattle) contributes to global climate change
  - Cattle and swine wastes stored in lagoons, sprayed on fields, released to water
    - Nitrogen loading → nitrates in groundwater
    - Manure in surface water → drop in dissolved oxygen, fish kills

Concentrated Animal Feeding Operations (CAFOs) (4 of 5)

- Routine administration of antibiotics to food animals
  - Lifelong at low doses to promote growth
  - Same antibiotics used to treat illness in people, farm animals, pets
  - Foodborne illness: bacteria that contaminate meat at slaughter may be resistant
  - Broader issue: resistant bacteria in waste enter "global web of bacterial genetics"[72]
- 80% of all antibiotics produced in 2015 used for agricultural purposes[71]

Concentrated Animal Feeding Operations (CAFOs) (5 of 5)

- Health impacts of CAFOs to workers and neighbors
  - Workers: fatal injuries, ammonia and organic dust, manure pits
  - Neighbors: odors of manure, dead fish, ammonia, hydrogen sulfide (rotten egg)

Slaughter and Meat Processing (1 of 2)

- Animals stunned, bled, cut into parts

- Hazards to workers[49, 78 - 84]
  - Acute injuries (knife injuries, slips/falls)
  - Repetitive strain injuries
  - Zoonotic illnesses
  - Respiratory irritation
  - Noise, heat or cold
  - Some evidence of cancer risk

Slaughter and Meat Processing (2 of 2)

- Source of foodborne illness in consumers
  - Fecal matter can contaminate animal flesh on fast-moving production line
  - Poultry: *Salmonella*, *Campylobacter*
  - Beef: *E. coli* O157:H7

Rendering of Animal Carcasses (1 of 4)

- Background
  - Animal carcasses after slaughter are enormous waste-handling problem
  - Rendering as recycling: converts carcasses into two useful products
    - Meat-and-bone meal (fed to cattle)
    - Tallow
  - Rendering was the source of prion diseases transmitted in food

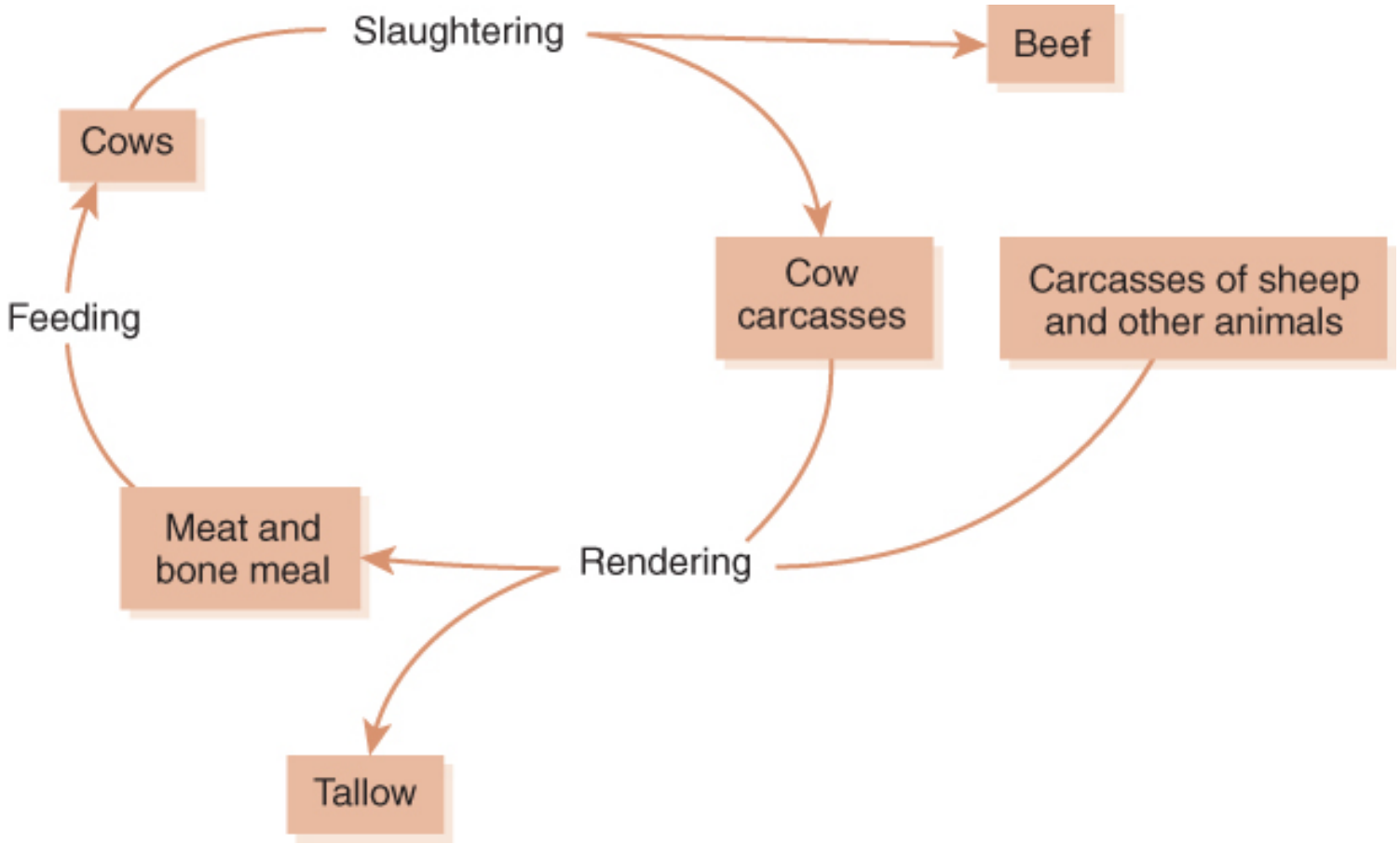

FIGURE 5.10 The rendering cycle

Rendering of Animal Carcasses (2 of 4)

- Familiar prion diseases
  - Creutzfeldt-Jakob disease (sporadic)
  - Scrapie in sheep
  - Diseases in other ruminants
- Two novel prion diseases
  - Documented two new prion diseases:
    - Bovine spongiform encephalopathy
    - Variant Creutzfeldt-Jakob disease

FIGURE 5.11 A cow afflicted with BSE struggles to stand up.

Courtesy of CDC public Health Image Library. ID# 5438. Content providers: CDC/Dr. Art Davis. Available at: http://phil.cdc.gov/phil/home.asp. Accessed October 29, 2012

Rendering of Animal Carcasses (3 of 4)

- Potential transmission cycle was documented:
  - Eating beef as a risk factor for vCJD
  - Study of slaughtering showed that neural matter could contaminate meat.
  - Prions survive both rendering of carcasses and cooking of meat.

Rendering of Animal Carcasses (4 of 4)

- The origins of the BSE epidemic
  - How did the first cow get BSE? Two likely answers:
    - Sporadic case of BSE occurred in cow; remains were rendered
    - Prion from sheep with scrapie became able to infect cows
  - Then: amplification through rendering
  - Analogy: kuru in New Guinea

U.S. Safeguards Against BSE

- Ban on importing animals/animal products from countries affected by BSE
- Feed bans:
  - First, ruminant feed ban: ban on feeding *ruminant protein* to ruminants
  - Then, mammalian feed ban = ban on feeding *mammalian protein* to ruminants
    - Practical challenges of segregated rendering
- BSE surveillance in U.S.: four cases to date

Dairy Farming

- Consolidation into larger operations [90]
  - Less likely to be family-owned, to grow own feed, to raise own heifers
- Dairy cattle[93]
  - Regular injection of recombinant bovine growth hormone (genetically engineered)
  - Increases milk production

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Occupational Hazards of Fishing

- For 2006–2010, annual fatality rate for fishermen 4x that for coal miners[96]
- Alaskan fleet (1990s): annual fatality rate 119 per 100,000 FTE, nearly all males[95]
  - Sinking or capsizing of ship
  - Drowning, hypothermia: man overboard; 20% unobserved
  - Crushing by equipment
- Similar patterns in East Coast waters

Declining Wild Stocks and Growth of Fish Farms

- Typical timeline for marine fishery
  - 1950: >90% of world's fisheries undeveloped or developing[97]
  - 2000: <10% undeveloped or developing; ~20% collapsed
- Rapid growth in fish farming
  - PCBs, dioxins, DDT higher in farmed than wild-caught salmon [99]

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Impacts of Modern Agriculture

- Agriculture is the planet's dominant environmental threat.
  - Consumes a large portion of the earth's land surface, destroying habitats
  - Uses up freshwater and pollutes oceans
  - Emits greenhouse gases

Agriculture's Global Footprint

- 40% of the earth's land surface, not including Greenland or Antarctica, covering much of the *best* land
- Agricultural practices since the last ice age have disrupted ecosystems dramatically, transforming 70 percent of grasslands, half of the savannas, and more than a quarter of tropical forests.
- Agriculture's footprint on the earth's surface is 60 times that of urban pavements and buildings.[102]

Agricultural Water Pollution

- Irrigation uses 70 percent of freshwater withdrawals
- Pollutes both fresh and marine water supplies with fertilizer runoff and CAFO wastes
  - Both contribute to eutrophication that results in enormous hypoxic *dead zones* at the mouths of several of the world's major rivers[102]

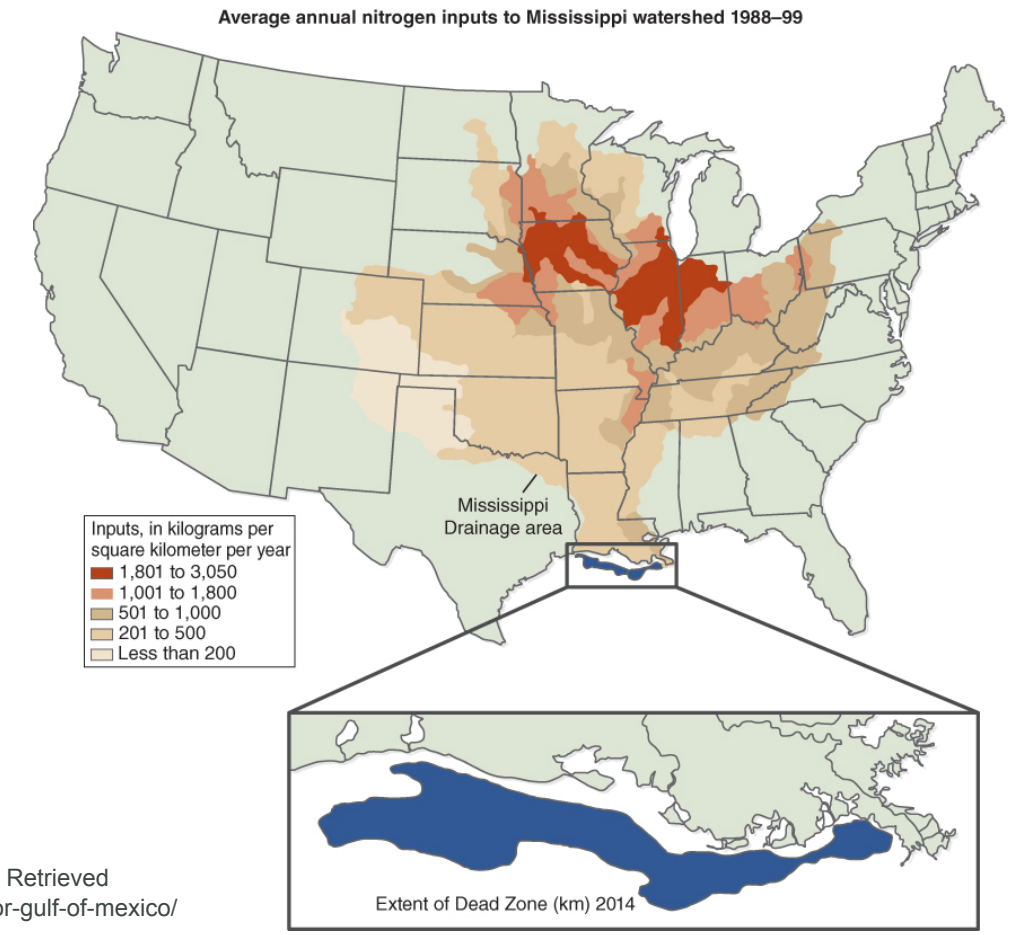

FIGURE 5.12 Gulf of Mexico dead zone.

Reproduced from Workboat Staff, NOAA sees very large 'dead zone' for Gulf of Mexico, 2019, Retrieved https://www.workboat.com/news/coastal-inland-waterways/noaa-sees-very-large-dead-zone-for-gulf-of-mexico/

Agriculture and climate

- Nitrous oxide
  - Produced by bacteria from nitrates
- Methane
  - Anaerobic digestion (belching cattle) or decomposition (manure in lagoons, crop residues in rice paddies)
- Both are more potent greenhouse gases than CO_2
- Lots of CO_2, too, due to reliance on fossil fuels for crop production and global distribution of food

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Food Defects and Food Additives (1 of 2)

- Food defects
  - Inevitable contaminants at low levels
  - Mold, insect fragments, rodent hairs, etc.
- Food additives
  - Preservatives, sweeteners, flavor enhancers, fat replacers, nutrients, etc.

Food Defects and Food Additives (2 of 2)

- FDA sets Food Defect Action Levels
  - Maximum acceptable level of specific *food defects* (insect parts, rodent hairs, etc.)
- FDA approves *food additives,* sets limits and labeling requirements (since 1958)
  - Exempt from approval: substances already considered safe in 1958; substances on evolving GRAS (generally regarded as safe) list
  - No additive can be approved if shown to cause cancer (Delaney Clause)

Irradiation of Food

- Purpose: to kill microbes
  - Effective against insects, parasites, bacteria; *not* viruses, prions, bacterial spores, bacterial toxins [57]
  - Late in processing to prevent recontamination
- Negatives[108, 109]
  - Substitutes late-stage process for upstream prevention
  - May destroy nutrients
  - Creates new (radiolytic) chemicals

“Traceability” in the Modern Food Supply System

- Traceability and recall are important, but problematic.
- Examples:
  - *E. coli* O157:H7 in ground beef
    - Rapid distribution from large slaughterhouses to many grocery and fast food chains nationwide
  - Genetically modified corn
    - Cannot segregate GM corn in processing and transport; many parties involved

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Local Foods and Organic Farming

- Renewed interest in locally grown foods and organic foods
  - Locally grown foods: farmers' markets and community gardens
  - Organic farming:
    - Sustainable; maintains and builds soil
    - Rejects synthetic pesticides and commercial fertilizers
    - Small but growing percentage of U.S. agriculture

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Introduction

- Key players
  - USDA regulates safety and labeling of most *meat and poultry*
  - EPA responsible for managing effects of *pesticides* on human health
  - FDA responsible for safety, nutritional value, and labeling of most foods *other than meat and poultry*
    - Related to concerns *other than pesticides*

Pesticides

- Must be registered with (licensed by) EPA for specific use(s)
  - If used as instructed, “reasonable certainty of no harm” to people; and will not pose “unreasonable risks to the environment”[62]
- Pesticide tolerance: maximum residue allowed in human food

Genetically Modified Food Plants

- No separate regulatory structure
  - USDA: evaluates whether GM plants in field could harm other plants
  - EPA: registers pesticides and sets food tolerances for pesticides produced by GM plants
  - FDA: responsible for food safety (e.g., allergenicity of new proteins in GM foods); to date, no *required* procedures or labeling *requirements* specific to GM foods

Humane Slaughter of Food Animals

- Humane Methods of Slaughter Act (1978)
  - USDA has veterinarian and slaughter line inspector at each federally inspected slaughterhouse
  - Mandated methods for slaughter are incorporated in HAACP system (see later)

Inspection and Grading of Meat

- Carcasses are *inspected for wholesomeness*, with stamped approval
- Individual cuts of meet are *graded based on marbling*
- New voluntary certification process for labeling beef as *grass-fed*

Conservation and Management of Fisheries

- Magnuson-Stevens Fishery Conservation and Management Act
  - Addresses:[63]
    - Overfishing of regional ocean fisheries
    - Environmental degradation of fisheries
    - Accidental catching of other species

Organic Foods

- Organic Foods Production Act
  - Standards for production and handling of foods labeled as organic
  - Products from certified growers can carry organic seal

FIGURE 5.15 The USDA organic seal.

Basic Levers for Food Safety

- Time and temperature: “Keep it hot, or keep it cold, or don’t keep it.”
- Temperature: danger zone is 40ºF to 140ºF
- Time: lag phase and log phase in growth of bacterial population

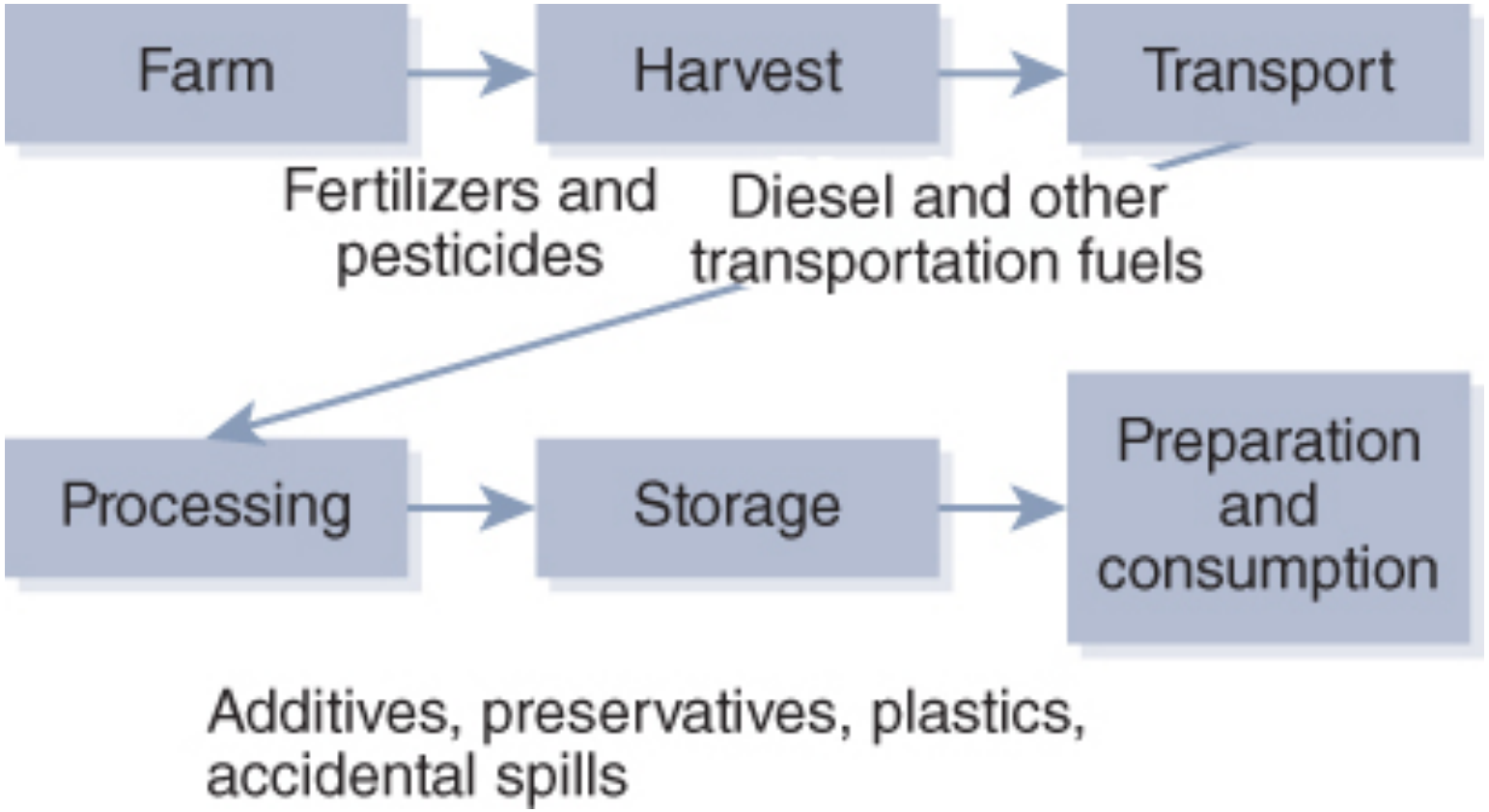

FIGURE 5.17 Farm to table system.

Food Safety (1 of 2)

- Regulatory focus on controls upstream in food supply (vs. food safety in home or restaurant)
- Traditional approach: hands-on inspection (“poke and sniff”)

Current Emphasis on Hazard Analysis and Critical Control Point (HAACP) Approach

- Identify potential hazards
- Identify critical control points in production
- For each critical control point, establish:
  - Measures to prevent hazard
  - Procedures to monitor these measures
  - Corrective actions in event of failure
- Establish procedures to ensure system is working
- Establish recordkeeping systems

Food Safety (2 of 2)

- HAACP pro and con:
  - Pro: Science-based HACCP approach can be much more effective than “poke and sniff”
  - Con: Inspectors evaluate industry’s HAACP systems rather than inspecting food itself