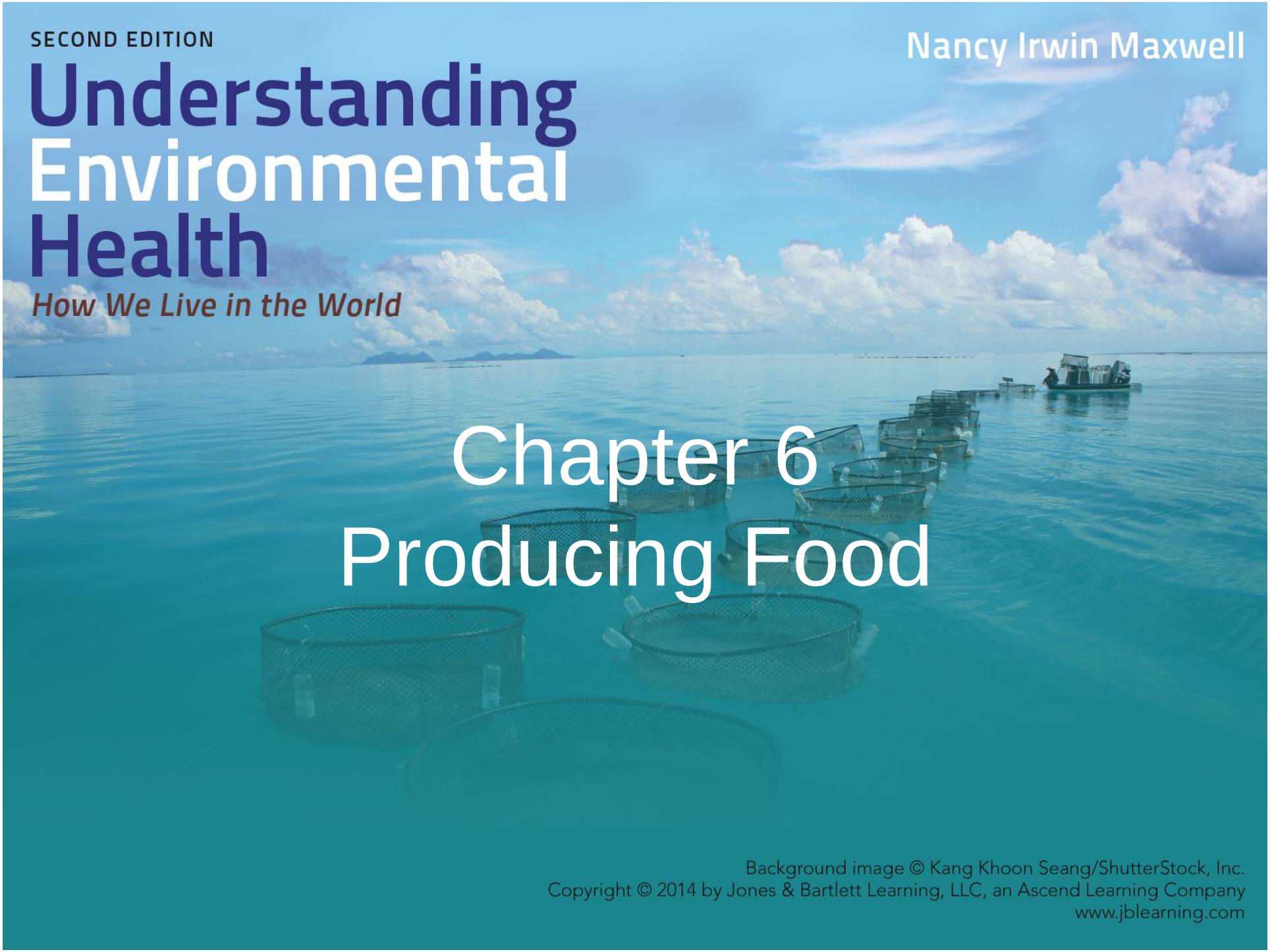

SECOND EDITION

Understanding Environmental Health

How We Live in the World

Nancy Irwin Maxwell

Chapter 6
Producing Food

6.1 Modern Crop Production Practices

6.2 Modern Livestock Production Practices

6.3 Impacts of Modern Agriculture on Global Climate

6.4 Modern Fishing

6.5 From Source to Table

6.6 Organic Farming and Locally Grown Foods

6.7 Regulation of Food and the Activities that Produce It

Introduction

- Key features of US agriculture today:
  - Few varieties of crops; grown in monoculture
  - Heavy reliance on chemicals and machinery
  - Subsidized by fossil fuels
  - Subsidized by fossil groundwater

Intensive Use of Fertilizers

Use of Chemical Pesticides

Integrated Pest Management

Genetically Modified Crop Plants

Use of Water for Irrigation

Mechanical Hazards to Workers

Nitrate contamination

- Extensive use of nitrate fertilizers
  - → 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

Intensive Use of Fertilizers

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Mechanical Hazards to Workers

Use of chemical pesticides

- Introduction
  - Pesticide = chemical used to kill pests
    - Active ingredient = the one intended to kill the pest
  - But what is a pest?
    - Not a biological category

Use of chemical pesticides

- Types of pesticides
  - Insecticides
    - Inorganic compounds
    - Pyrethrum
    - Organochlorine insecticides
      - DDT, chlordane, aldrin, dieldrin, heptachlor
      - Nerve toxins; low acute human toxicity
      - Persistent and bioaccumulative
      - Many banned in more developed countries; Stockholm Convention

Use of chemical pesticides

- Organophosphate insecticides
  - Nerve toxins; not persistent in environment
  - Acute toxicity to people varies widely
- Carbamate insecticides
  - Chemical action similar to organophosphates
  - Low acute toxicity to people
- Pyrethroid (pyrethrum-like) insecticides
  - Low acute toxicity to people
  - Used in some consumer products

Use of chemical pesticides

- Herbicides
  - Selective herbicides
    - Kill broad-leaved plants; do not kill plants in grass family (e.g., grain crops, turfgrass)
    - In military context, used to kill large plants that provide cover to enemy combatants
  - Nonselective herbicides—kill all plants
    - Example: Monsanto's Roundup
    - Roundup Ready genetically engineered soybeans

Use of chemical pesticides

- Fungicides—used in agriculture
- Rodenticides—often anticoagulant bait

- Limitations of pesticides
  - Resistance
    - Some pests resistant (genetic makeup)
    - Resistant individuals survive and breed

Use of chemical pesticides

- Ecosystem effects[1] →
  - Target pest resurgence
    - Killing of *predator of target pest* allows target pest population to rebound
  - Secondary pest outbreak
    - Killing of target pest allows population explosion among *pests normally eaten by target pest*

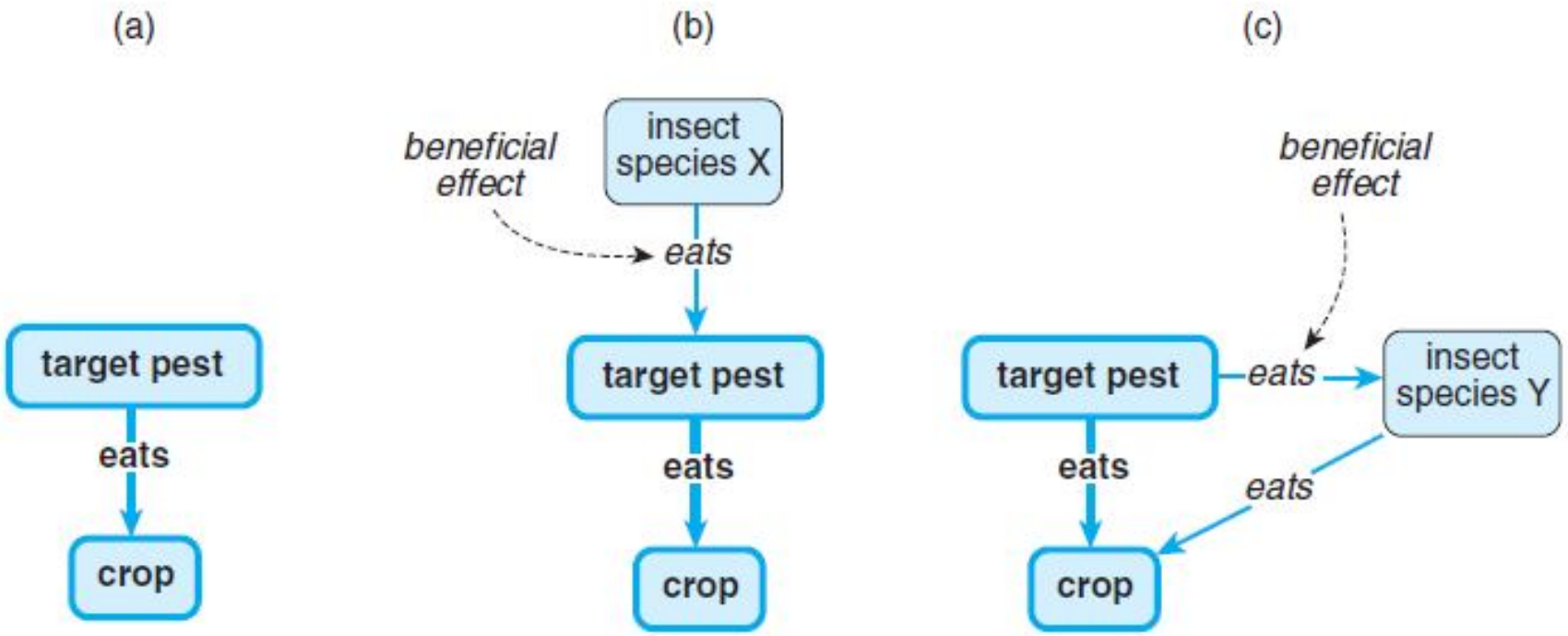

FIGURE 6.1 Unintended effects of the use of pesticides.

Use of chemical pesticides

- Human health effects of pesticides
  - Difficult to study
    - Changing mix of chemicals
    - Workers lack information
    - Variation in practices, protective gear
    - Hard to disentangle acute & chronic effects
  - Neurologic [2-4] & reproductive [5-11] effects; cancer [3, 12-19]

Use of chemical pesticides

- 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[20]
    - Often inadequate protections, facilities, warnings
  - In lower-income countries; more hazardous pesticides may still be in use

Intensive Use of Fertilizers

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Mechanical Hazards to Workers

Integrated pest management

- "integrated"[21]
  - Multiple tactics
  - Consistent with ecological principles
- "management"[21]
  - Suppress rather than wipe out pests
  - Set threshold for action, monitor, then act
  - Beneficial insects, pheremones, changes to irrigation or crop rotation practices
- Hard to integrate into large-scale, mechanized agriculture

Intensive Use of Fertilizers

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Mechanical Hazards to Workers

Genetically modified crop plants

- Rationale: increase global food supply
  - Crops that resist disease, repel pests, ripen faster . . .
- 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

- 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

- 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]

Intensive Use of Fertilizers

Use of Chemical Pesticides

Integrated Pest Management

Genetically Modified Crop Plants

Use of Water for Irrigation

Mechanical Hazards to Workers

Use of water for irrigation

- Irrigation = ~ 1/3 of US water consumption in 2005[25]
- Substantial losses to evaporation
- Areas of concern:
  - Lower Colorado River, Rio Grande region[26]
  - Central Plains and Southwest[27]

Intensive Use of Fertilizers

Use of Chemical Pesticides

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Genetically Modified Crop Plants

Use of Water for Irrigation

Mechanical Hazards to Workers

Mechanical hazards to workers

- Fatal injuries
  - Approx 300 fatal injuries per year in U.S. (2006-2010) [28]
  - Often involving transport or equipment
  - Fatal injury rate only slightly less than that in coal mining
- Nonfatal injuries; farmers report …
  - Struck by objects/equipment; injuries to hands/feet; caused by human error, haste [29]

6.1 Modern Crop Production Practices

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6.5 From Source to Table

6.6 Organic Farming and Locally Grown Foods

6.7 Regulation of Food and the Activities that Produce It

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 & veterinary practices

Concentrated Animal Feeding Operations

Slaughter and Meat Processing

Rendering of Animal Carcasses

Dairy Farming

Concentrated animal feeding operations

- A profile of CAFOs in the US
  - 2010: 34.4 million cattle, 110 million hogs, 8.6 billion chickens slaughtered[30,31]
  - About half of beef cattle and swine in CAFOs of 32,000 or more [32,33]
  - Production of beef, swine, and broilers concentrated in a few states

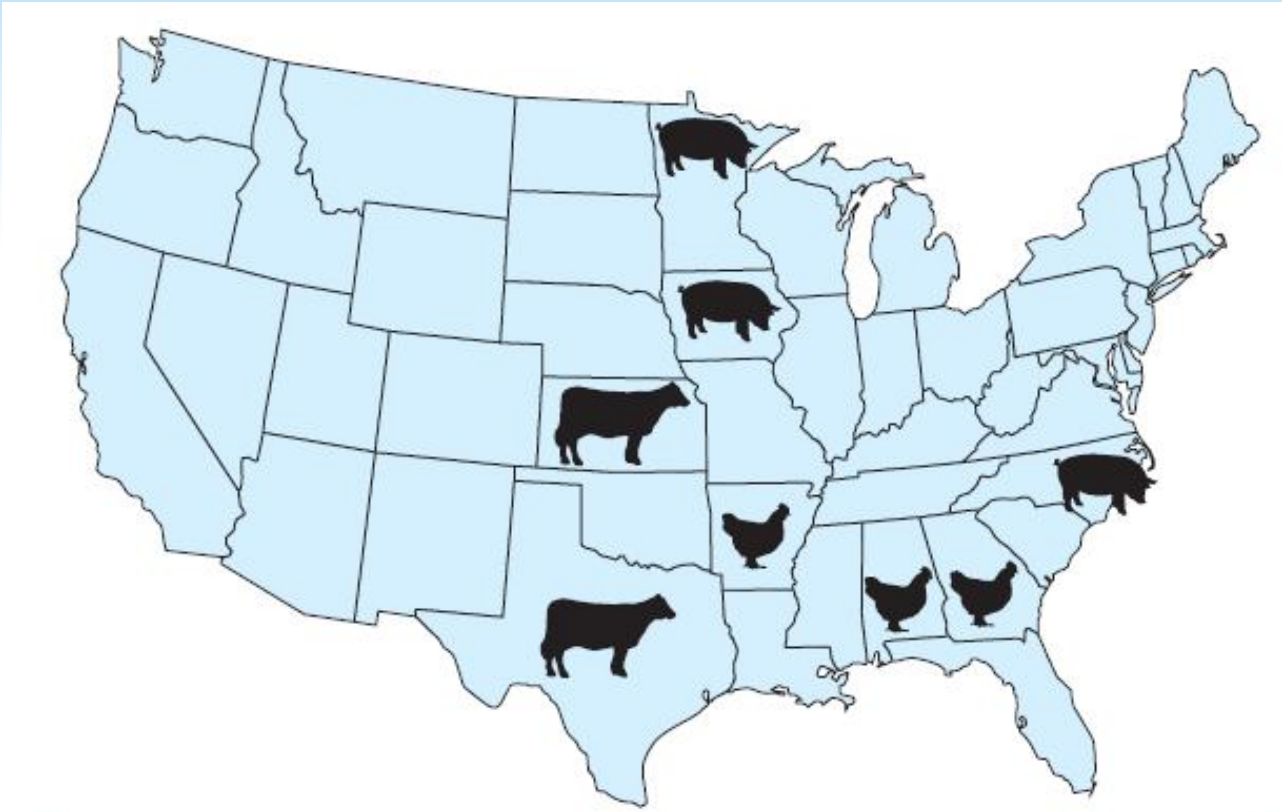

FIGURE 6.5 Concentration of beef cattle, swine, and broiler production in states in the Midwest and South.

Sources: 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

- Conditions of animal confinement[34]
  - Feedlots, paved or unpaved (cattle) →
  - Enclosed houses, slotted floors (swine) or bedding (broilers), mechanical ventilation
  - Ground & pelletized feed
  - Ammonia, hydrogen sulfide, dusts
  - Respiratory problems largest single cause of death in cattle and swine before slaughter

FIGURE 6.3 Cows study the photographer from the fringes of a mass of cattle in this CAFO.

Source: © 2008 Cathryn Dowd. Used with permission.

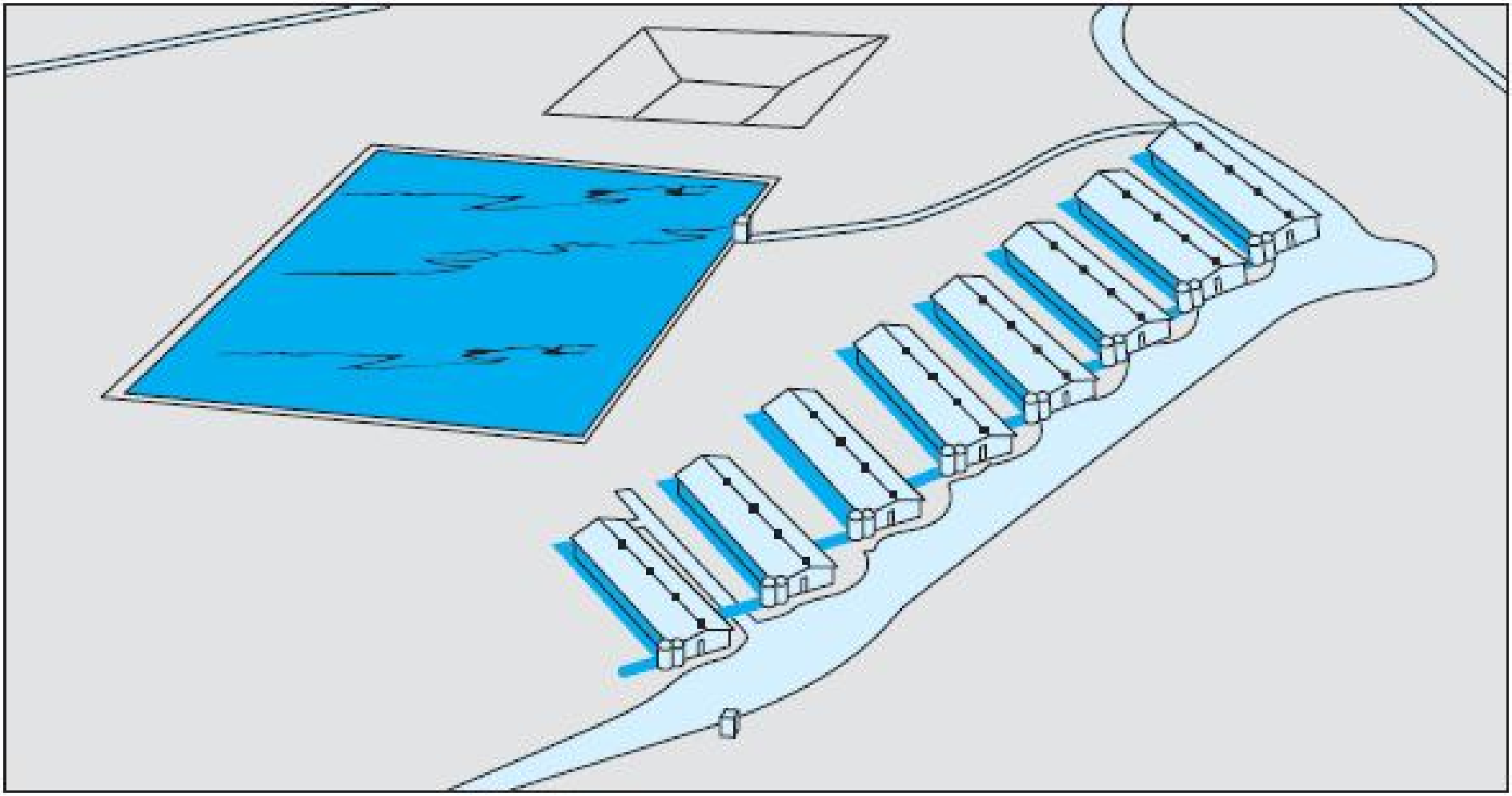

FIGURE 6.4 This sketch shows a typical layout for a hog CAFO, with a series of barns and an associated manure lagoon. A large operation might consist of several such units.

Concentrated animal feeding operations

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

Concentrated animal feeding operations

- Health impacts of CAFOs to workers and neighbors
  - Workers: fatal injuries, ammonia and organic dust; manure pits [28,6,35-37]
  - Neighbors: odors of manure, dead fish, ammonia, hydrogen sulfide (rotten egg)[38]

Concentrated animal feeding operations

- 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"[39]
- Administration of steroid hormones[40]
  - increase growth rate
  - produce meat with less fat and more lean mass

Concentrated Animal Feeding Operations

Slaughter and Meat Processing

Rendering of Animal Carcasses

Dairy Farming

Slaughter and meat processing

- Animals stunned, bled, cut into parts
- Hazards to workers[41-47]
  - 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

- 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

Concentrated Animal Feeding Operations

Slaughter and Meat Processing

Rendering of Animal Carcasses

Dairy Farming

Rendering of animal carcasses

- 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

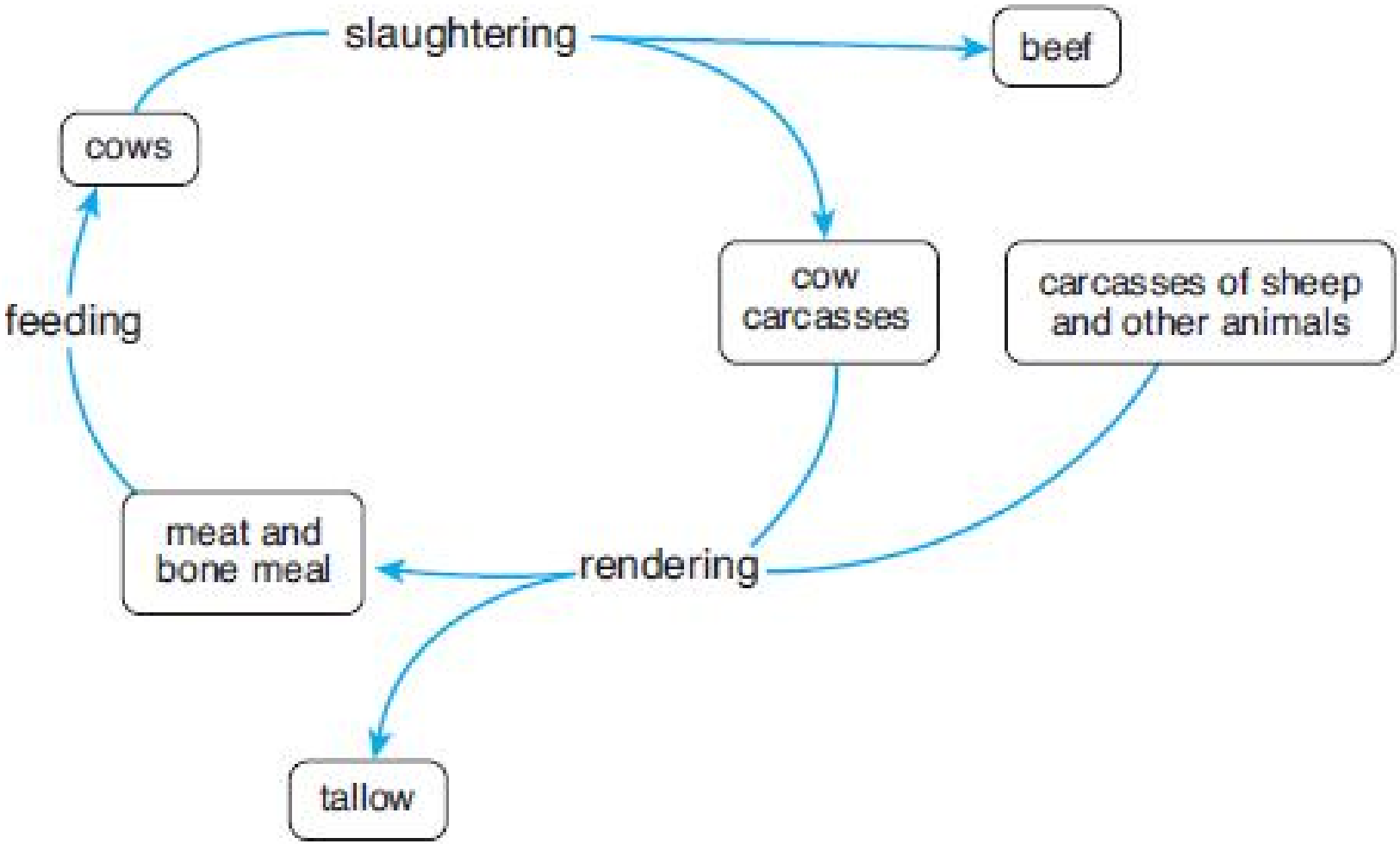

FIGURE 6.6 The rendering cycle.

Rendering of animal carcasses

- 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 6.7 A cow afflicted with BSE struggles to stand up.

Source: Reprinted 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

- Potential transmission cycle was documented:
  - Eating beef as a risk factor for vCJD
  - Study of slaughtering showed that neural matter could contaminate meat[48]
  - Prions survive both rendering of carcasses and cooking of meat

Rendering of animal carcasses

- 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

Rendering of animal carcasses

- Human illness in the United Kingdom
  - Epidemic appears to be ending
  - But some possibility that these deaths represent a genetically susceptible subgroup[49]

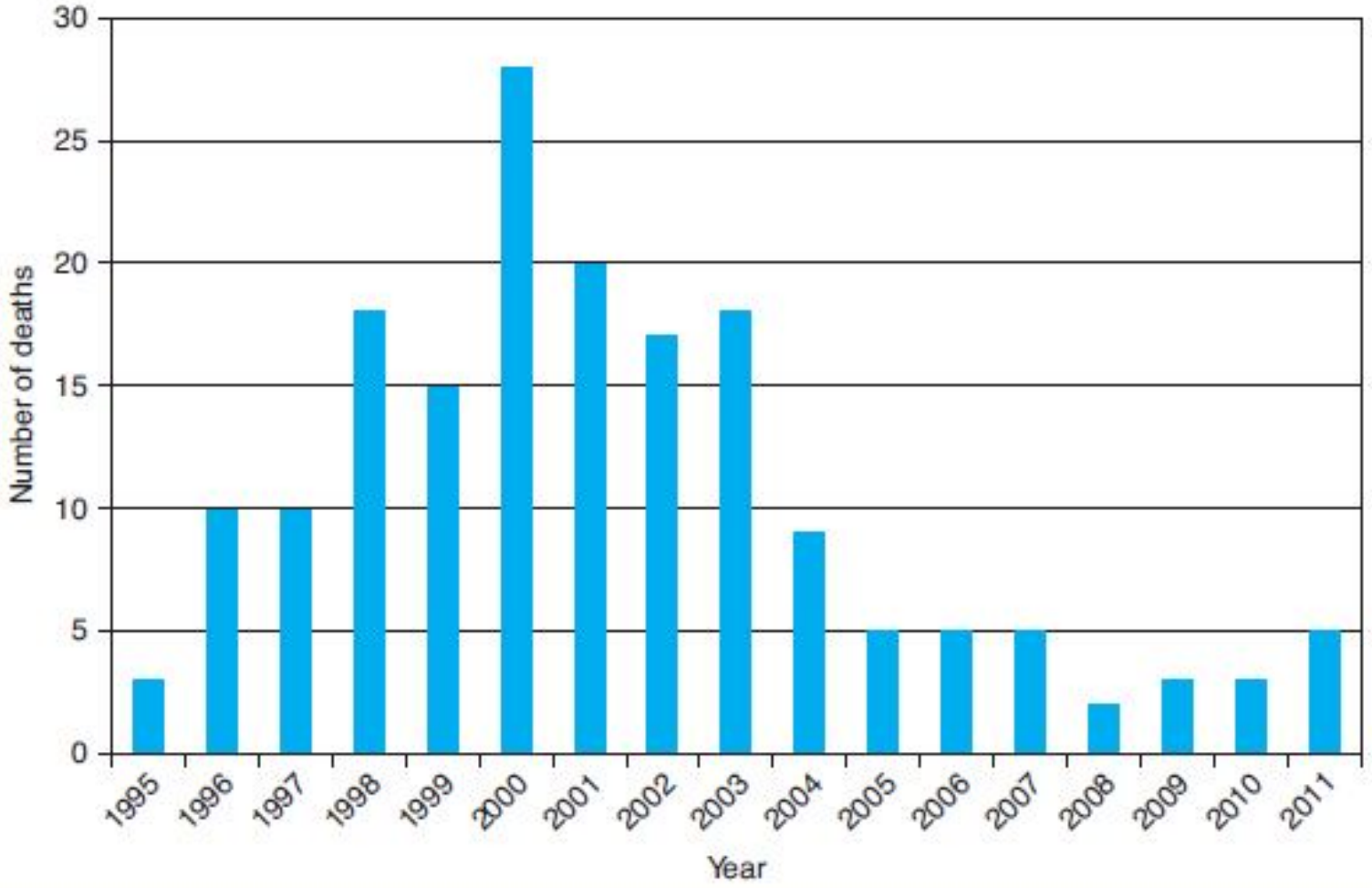

FIGURE 6.8 Deaths from variant Creutzfeldt-Jakob disease in the United Kingdom, 1995–2011.

Source: Data from National Creutzfeldt-Jakob Disease Surveillance Unit. Creutzfeldt-Jakob Disease Surveillance. Available at: www.cjd.ed.ac.uk/figures.htm. Accessed April 23, 2012.

Concentrated Animal Feeding Operations

Slaughter and Meat Processing

Rendering of Animal Carcasses

Dairy Farming

Dairy farming

- Consolidation into larger operations [50]
  - Less likely to be family-owned, to grow own feed, to raise own heifers[51]
- Dairy cattle[52]
  - Regular injection of recombinant bovine growth hormone (genetically engineered)
  - Increases milk production

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6.7 Regulation of Food and the Activities that Produce It

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

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Declining Wild Stocks and Growth of Fish Farms

Occupational Hazards of Fishing

Declining wild stocks and growth of fish farms

- Typical timeline for marine fishery →
  - 1950: >90% of world's fisheries undeveloped or developing[53]
  - 2000: < 10% undeveloped or developing; ~20% collapsed[53]
- Rapid growth in fish farming
  - PCBs, dioxins, DDT higher in farmed than wild-caught salmon [54]

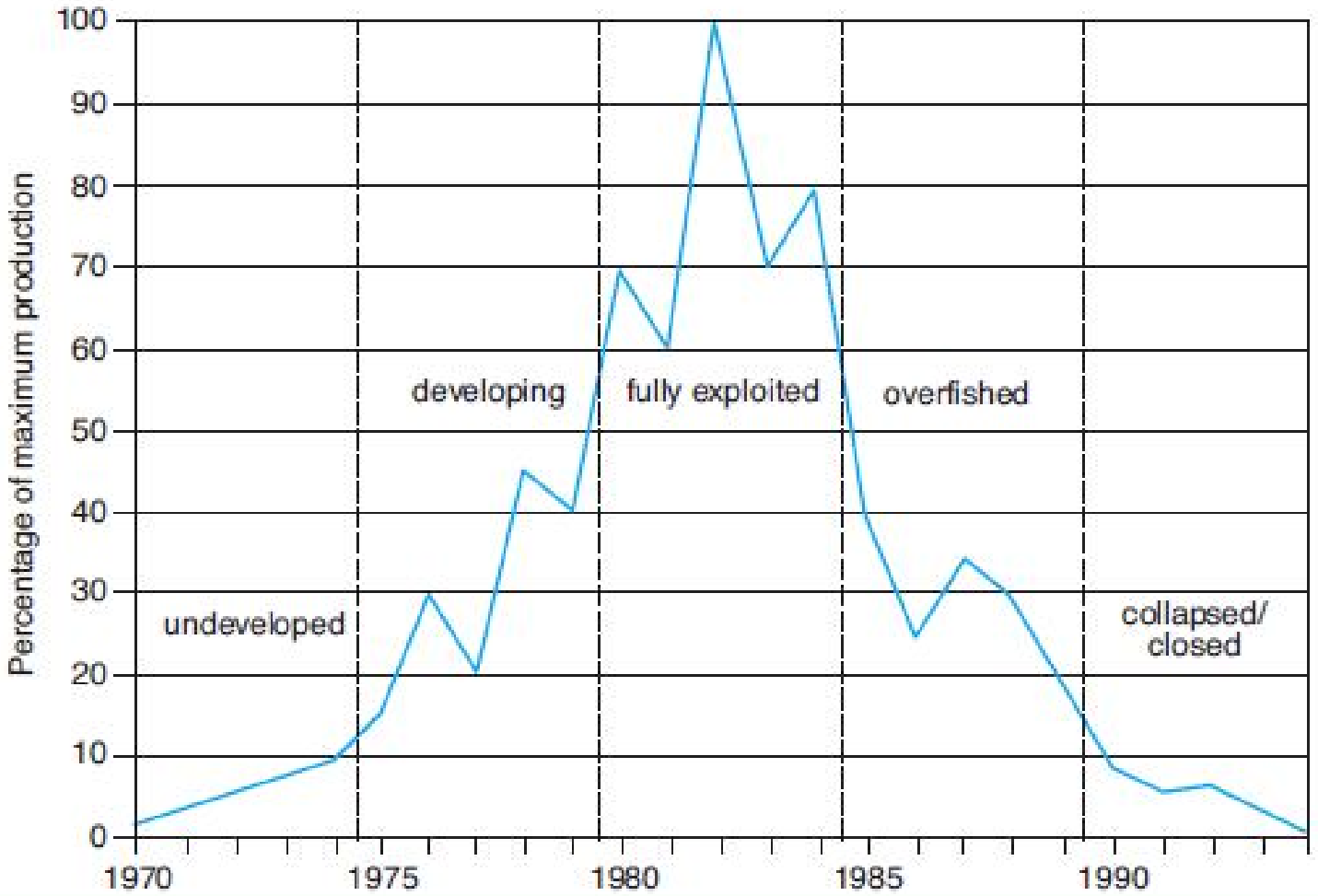

FIGURE 6.10 The typical time course of a hypothetical marine fishery.

Source: Data from Froese R, Kesner-Reyes K. *Impact of Fishing on the Abundance of Marine Species.* Presented at: International Council for the Exploration of the Sea Annual Science Conference; 2002; Copenhagen.

Declining Wild Stocks and Growth of Fish Farms

Occupational Hazards of Fishing

Occupational hazards of fishing

- For 2006-2010, annual fatality rate for fishermen 4X that for coal miners[28]
- Alaskan fleet (1990s): annual fatality rate 119 per 100,000 FTE, nearly all males[55]
  - Sinking or capsizing of ship
  - Drowning, hypothermia—man overboard; 20% unobserved
  - Crushing by equipment
- Similar patterns in East Coast fleet (2000s)[56]

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Food Defects, Food Additives, and the Irradiation of Food

"Traceability" in the Modern Food Supply System

Food defects, food additives, and the irradiation of food

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

Food defects, food additives, and the irradiation of food

- 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[57-59]
    - Substitutes late-stage process for upstream prevention
    - May destroy nutrients
    - Creates new (radiolytic) chemicals

Food Defects, Food Additives, and the Irradiation of Food

"Traceability" in the Modern Food Supply System

"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

6.1 Modern Crop Production Practices

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6.5 From Source to Table

6.6 Organic Farming and Locally Grown Foods

6.7 Regulation of Food and the Activities that Produce It

Organic and local foods

- Renewed interest in organic & locally grown foods
  - Organic farming:[60,61]
    - Sustainable; maintains & builds soil
    - Rejects synthetic pesticides & commercial fertilizers
    - Small but growing percentage of US agriculture
  - Locally grown foods—farmers' markets and community gardens

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Introduction

- Key players
  - USDA regulates safety & 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 below)

Inspection and grading of meat

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

US 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.:4 cases to date

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 & handling of foods labeled as organic[64]
  - Products from certified growers can carry organic seal

Source: U.S. Department of Agriculture, Agricultural Marketing Service. National Organic Program: USDA Organic Seal. Available at: www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?&template=TemplateA&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPOrganicSeal&description=The%20Organic%20Seal&acct=nopgeninfo. Accessed December 7, 2012.

Food safety

- 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[65] →

Food safety

- 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

- 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

Food defects and additives

- 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)

Food defects and additives

- FDA has approved irradiation of several foods at specific doses
- Irradiated food must be so labelled and carry radura symbol

Source: Morehouse K. Food irradiation: The treatment of foods with ionizing radiation. *Food Testing Anal*. 1998;4(3):9, 32, 35.

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