ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

Jay Withgott • Scott Brennan

http://www.youtube.com/watch?v=7A4oAyKOGHg&feature=related

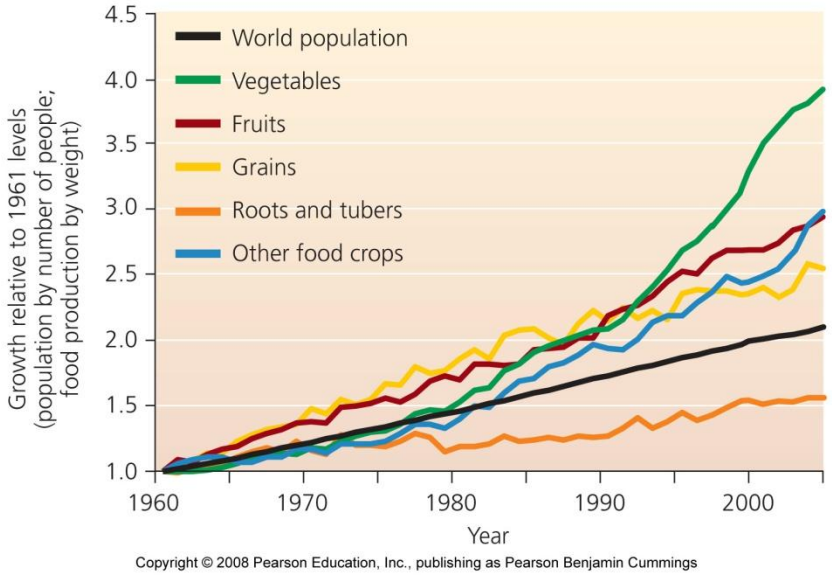
Ch 10

Agriculture, Biotechnology, and the Future of Food

Part 2: Environmental Issues and the Search for Solutions

PowerPoint® Slides prepared by
Jay Withgott and Heidi Marcum

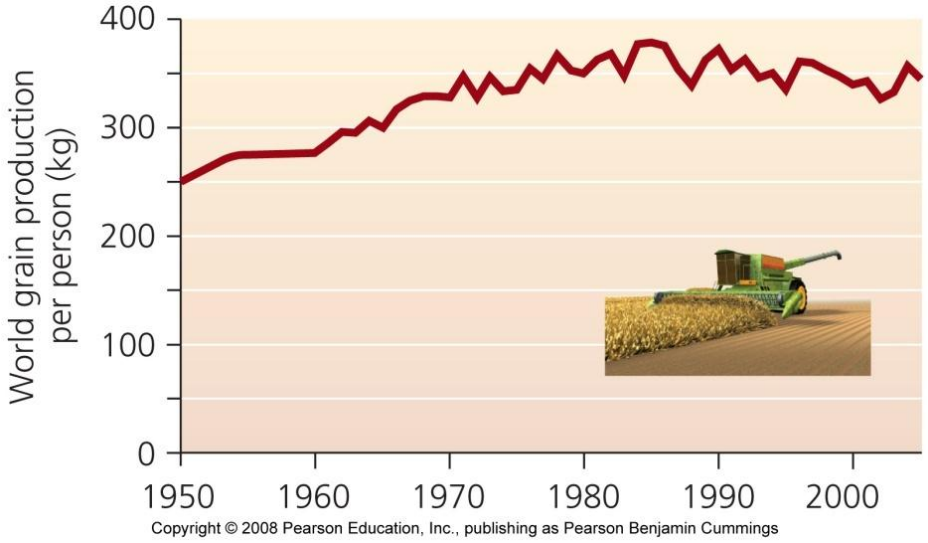
Today, we are producing more food per person



- Food production currently exceeds population growth
- We produce food through technology
  - Fossil fuels, irrigation, fertilizer, pesticides, crossbreeding
- Predictions of mass starvation in 1960s did not happen

Food security

- **Food security** = the guarantee of adequate and reliable food supply to all people at all times
- Fewer people today are hungry than in 1970
- We have reduced hunger by half since 1970
  - But, 850 million people still go hungry



Since 1985, world grain production has fallen by 9%

We face both too little and too much food

- **Undernourishment** = people receive less than 90% of their daily caloric needs
  - Mainly from economic reasons in developing countries
  - 31 million Americans are food insecure
- **Overnutrition** = receiving too many calories
  - In the U.S., 25% of adults are obese
  - Worldwide, more than 300 million people are obese
- **Malnutrition** = a shortage of nutrients the body needs
  - The diet lacks adequate vitamins and minerals

Quantity and quality of food is important

- **Kwashiorkor** = diets lacking protein or essential amino acids
  - Occurs when children stop breast-feeding
  - Bloated stomach, mental and physical disabilities
- **Marasmus** = protein deficiency and insufficient calories
  - Wasting or shriveling of the body

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The green revolution

- Dramatically increased per-acre yields
- Spread to the developing world in the 1940s with wheat, rice, corn
- Depended on large amounts of:
  - Synthetic fertilizers
  - Chemical pesticides
  - Irrigation
  - Heavy equipment

The green revolution brought benefits and harm

- From 1900 to 2000, cultivated area increased 33%, while energy inputs increased 80 times!
- Positive effects on natural resources
  - Prevented some deforestation
  - Preserved biodiversity
- Negative effects on natural resources
  - Pollution
  - Erosion
  - Salinization
  - Desertification

Monocultures increase output, but at a cost

- **Monoculture =** a large expanse of a single crop
  - More efficient, increases output
  - Devastates biodiversity
  - Susceptible to disease and pests
- Narrows human diet: 90% of our food comes from 15 crop species and 8 livestock species

Armyworms easily defoliate monocultures

Biofuels affect food supplies

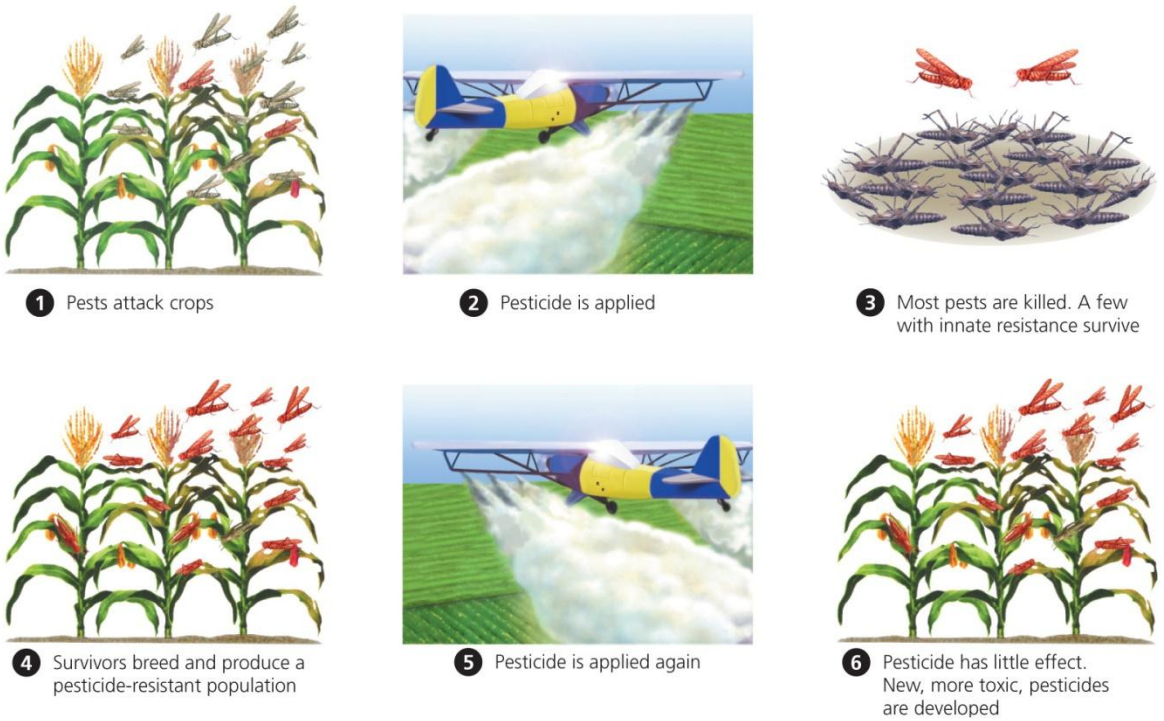
- Well intentioned efforts to promote renewable energy have unintended consequences
  - **Biofuels**: fuels derived from organic materials and used in internal combustion engines
  - **Ethanol** made from corn is the primary biofuel in the U.S.

Pests and pollinators

- **Pest =** any organism that damages valuable crops
- **Weed =** any plant that competes with crops
- **Pesticides** = poisons that target pest organisms
  - **Insecticides** = target insects
  - **Herbicides** = target plants
  - **Fungicides** = target fungi
- 400 million kg (900 million lbs.) of pesticides are applied in the U.S. each year
  - 75% of this is applied to agricultural land
  - Usage is increasing in developing countries

Resistance to pesticides

- Some individuals are genetically immune to a pesticide
  - They survive and pass these genes to their offspring
- Pesticides stop being effective
  - **Evolutionary arms race**: chemists increase chemical toxicity to compete with resistant pests



Biological control

Feeding the World

- **Biological control** (**Biocontrol**) = uses a pest's natural predators to control the pest
  - Reduces pest populations without chemicals
  - Cactus moths control prickly pear
  - **Bacillus thuringiensis (Bt)** = soil bacteria that kills many pests

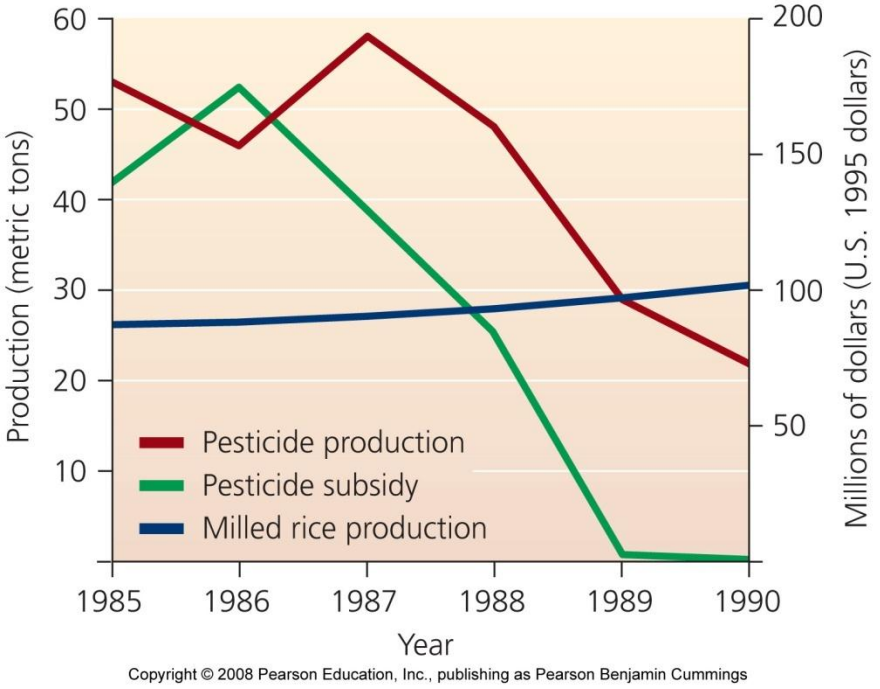
(b) After cactus moth introduction

Biocontrol agents may become pests themselves

- No one can predict the effects of an introduced species
- The agent may have "nontarget" effects on the environment and surrounding economies
  - Cactus moths are eating rare Florida cacti
- Removing a biocontrol agent is harder than halting pesticide use
  - Due to potential problems, proposed biocontrol use must be carefully planned and regulated

Integrated Pest Management (IPM)

- IPM uses multiple techniques to suppress pests
  - Biocontrol
  - Chemicals, when necessary
  - Population monitoring
  - Habitat alteration
  - Crop rotation and transgenic crops
  - Alternative tillage methods
  - Mechanical pest removal



Within 4 years of using IPM in Indonesia, rice yields rose 13%, and $179 million saved by phasing out subsidies

We depend on insects to pollinate crops

- Not all insects are pests; some are absolutely vital
  - 800 cultivated plant species rely on insect pollinators
- **Pollination** = male plant sex cells fertilize female sex cells
  - By wind or animals
- Pollinators include:
  - Hummingbirds
  - Bats
  - Insects

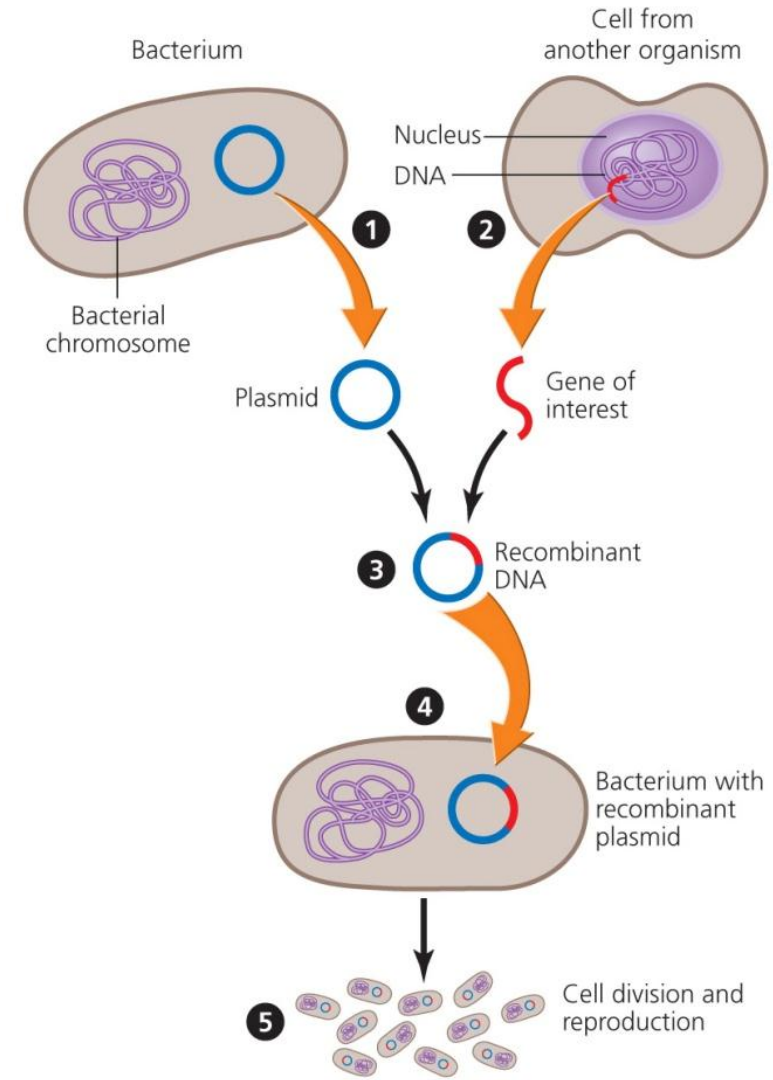
Flowers are evolutionary adaptations to attract pollinators

Conservation of pollinators is vital

- Native populations of pollinators have plummeted
- Honeybees pollinate more than 100 crops – 1/3 of the U.S. diet.
  - In 2006, hives died off
- To conserve bees:
  - Reduce or eliminate pesticide use
  - Plant flowering plants

Genetically modified organisms

- **Genetic engineering** = laboratory manipulation of genetic material
- **Genetically modified organisms** = organisms that have been genetically engineered by …
- **Recombinant DNA** = DNA created from multiple organisms



Genetic engineering has both benefits and risks

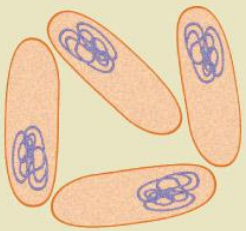
- Benefits of genetic engineering:
  - Increased nutritional content
  - Increased agricultural efficiency
  - Rapid growth
  - Disease and pest resistance
- Negatives of genetic engineering:
  - Risks are not yet defined or well understood
  - Protests from environmental activists, small farmers, and consumer advocates

Biotechnology is impacting our lives

- **Biotechnology =** the material application of biological science to create products derived from organisms
- **Transgenic organism** = an organism that contains DNA from another species
  - **Transgenes =** the genes that have moved between organisms
- Biotechnology has created medicines, cleaned up pollution, and dissolves blood clots

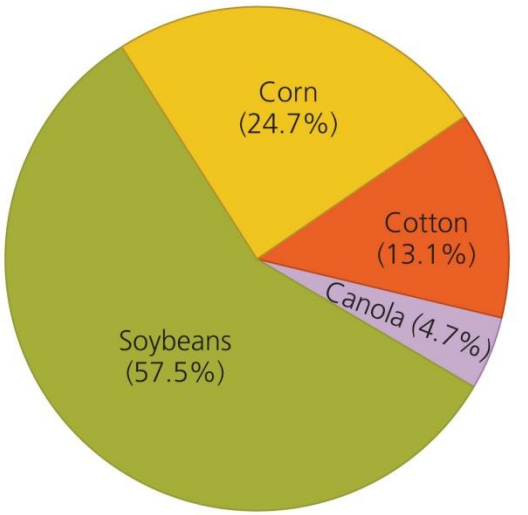
Some genetically modified foods

Several Notable Examples of Genetically Modified Food Technology

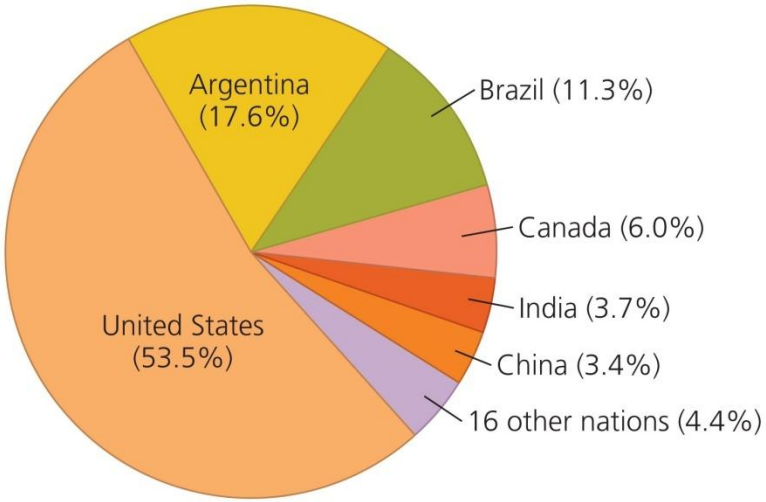
Food	Development
Golden rice 	Millions of people in the developing world get too little vitamin A in their diets, causing diarrhea, blindness, immune suppression, and even death. The problem is worst with children in east Asia, where the staple grain, white rice, contains no vitamin A. Researchers took genes from plants that produce vitamin A and spliced the genes into rice DNA to create more-nutritious "golden rice" (the vitamin precursor gives it a golden color). Critics charged that biotech companies hyped their product, which contains only small amounts of the nutrient and may not be the best way to combat vitamin A deficiency. India's foremost critic of GM food, Vandana Shiva, charged that "vitamin A rice is a hoax . . . a very effective strategy for corporate takeover of rice production, using the public sector as a Trojan horse." Backers of the technology counter that the nutritive value can be further improved and could enhance the health of millions of people.
Flavr Savr tomato 	By reversing the function of a normal tomato gene, the Calgene Corporation created the Flavr Savr tomato, which Calgene maintained would ripen longer on the vine, taste better, stay firm during shipping, and last longer in the produce department. The U.S. Food and Drug Administration approved the Flavr Savr tomato for sale in the United States in 1994. Calgene stopped selling the Flavr Savr in 1996, however, for several reasons, including problems with the technique and public safety concerns.
Ice-minus strawberries 	University of California–Berkeley researcher Steven Lindow removed a gene that facilitated the formation of ice crystals from the DNA of a particular bacterium, *Pseudomonas syringae*. The modified, frost-resistant bacteria could then serve as a kind of antifreeze when sprayed on the surface of frost-sensitive crops such as strawberries. The multiplying bacteria would coat the berries, protecting them from frost damage. However, early news coverage of this technique showed scientists spraying plants while wearing face masks and protective clothing, an image that caused public alarm.
Bt crops 	By equipping plants with the ability to produce their own pesticides, scientists hoped to boost crop yields by reducing losses to insects. By the late 1980s, scientists working with *Bacillus thuringiensis* (Bt) had pinpointed the genes responsible for producing that bacterium's toxic effects on insects, and had managed to insert the genes into the DNA of crops. The USDA and EPA approved Bt versions of 18 crops for field testing, from apples to broccoli to cranberries. Corn and cotton are the most widely planted Bt crops today. Proponents say Bt crops reduce the need for chemical pesticides. However, critics worry that the continuous presence of Bt in the environment will induce insects to evolve resistance to the toxins and that Bt crops might cause allergic reactions in humans. Another concern is that the crops may harm nontarget species. A 1999 study reported that pollen from Bt corn can kill the larvae of monarch butterflies, a nontarget species, when corn pollen drifts onto milkweed plants monarchs eat. Another study that year showed that the Bt toxin could leach from corn roots and poison the soil.

Biotechnology is changing our world

- GM foods become big business
- Most GM crops are herbicide resistant
  - Farmers apply herbicides to kill weeds, and crops survive
  - Most U.S. soybeans, corn, cotton, and canola are genetically modified



(a) GM crops by type



(b) GM crops by nation

Globally, more than 10 million farmers grew GM foods on 102 million ha of farmland, producing $6.15 billion worth of crops

What are the impacts of GM crops?

- As GM crops expanded, scientists and citizens became concerned
  - Dangerous to human health
  - Escaping transgenes could pollute ecosystems and damage nontarget organisms
  - Pests could evolve resistance
  - Could ruin the integrity of native ancestral races
  - Interbreed with closely related wild plants

Supporters make the following points:

- GM crops pose no ill health effects
- They benefit the environment by using less herbicides
- Herbicide-resistant crops encourage no-till farming
- GM crops reduce carbon emissions by needing fewer fuel-burning tractors and sequestering carbon in the soil by no-till farming

Critics argue that we should adopt the **precautionary principle** = don't do any new action until it's understood

The GM debate involves more than science

- Ethical issues plays a large role
  - People don't like "tinkering" with "natural" foods
  - With increasing use, people are forced to use GM products, or go to special effort to avoid them
  - Multinational corporations threaten the small farmer
  - Research is funded by corporations that will profit if GM foods are approved for use
  - Crops that benefit small, poor farmers are not widely commercialized

The GM industry is driven by market considerations of companies selling proprietary products

GMO producers are suing farmers

Farmers say that "[they] are being sued for having GMOs on their property that they did not buy, do not want, will not use, and cannot sell"

- Monsanto has launched 90 lawsuits against 147 farmers, winning an average $412,000 per case
  - Monsanto charged farmer Percy Schmeiser of Canada with using its patented GM seeds without paying for them
  - Schmeiser charged the seeds blew onto his field from the neighbor's adjacent field
  - The courts sided with Monsanto, saying Schmeiser had violated Monsanto's patent

Nations differ in their acceptance of GM foods

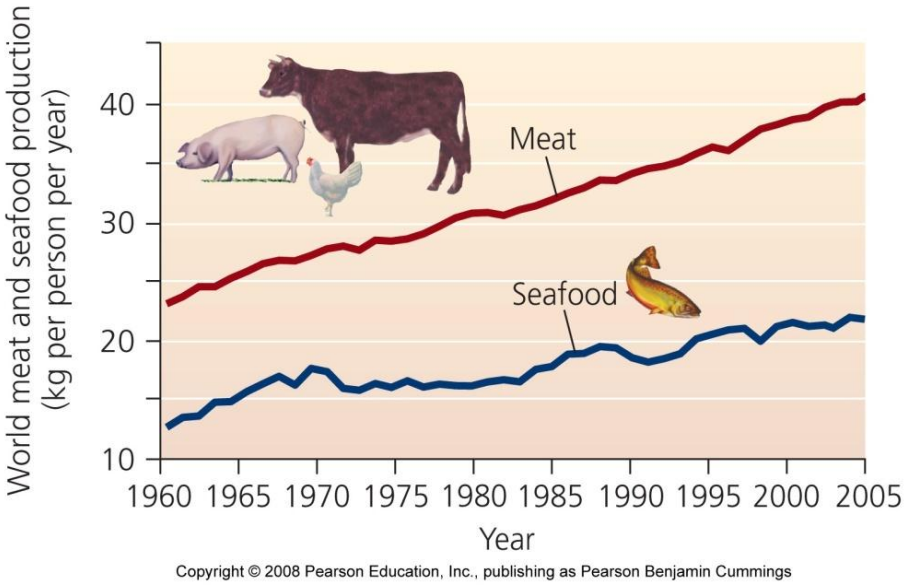
- Europe opposed GM foods
  - The U.S. sued the European Union before the World Trade Organization, charging that the European Union was hindering free trade
  - Brazil, India, and China approve GM crops
  - Zambia refused U.S. food aid, even though people were starving, because some seeds were genetically modified

Preserving crop diversity: insurance against failure

- Preserving native variants protects against crop failure
  - Monocultures are vulnerable, so wild relatives contain genes that could provide resistance to disease and pests
- We have already lost a great deal of genetic diversity in crops
  - Wheat varieties in China dropped from 10,000 (1949) to 1,000 (1970s)
- Market forces discourage diversity in food's appearance
  - Consumers prefer uniform, standardized food

Eating animal products has significant impacts

- As wealth and commerce increase, so does consumption of meat, milk, and eggs
  - Global meat production has increased fivefold
  - Per capita meat consumption has doubled



Domestic animal production for food increased from 7.3 billion in 1961 to 20.6 billion in 2000

Feedlot agriculture

- **Feedlots** (**factory farms**) = also called **Concentrated Animal Feeding Operations (CAFOs)**
  - Huge warehouses or pens designed to deliver energy-rich food to animals living at extremely high densities
  - Over ½ of the world's pork and poultry come from feedlots

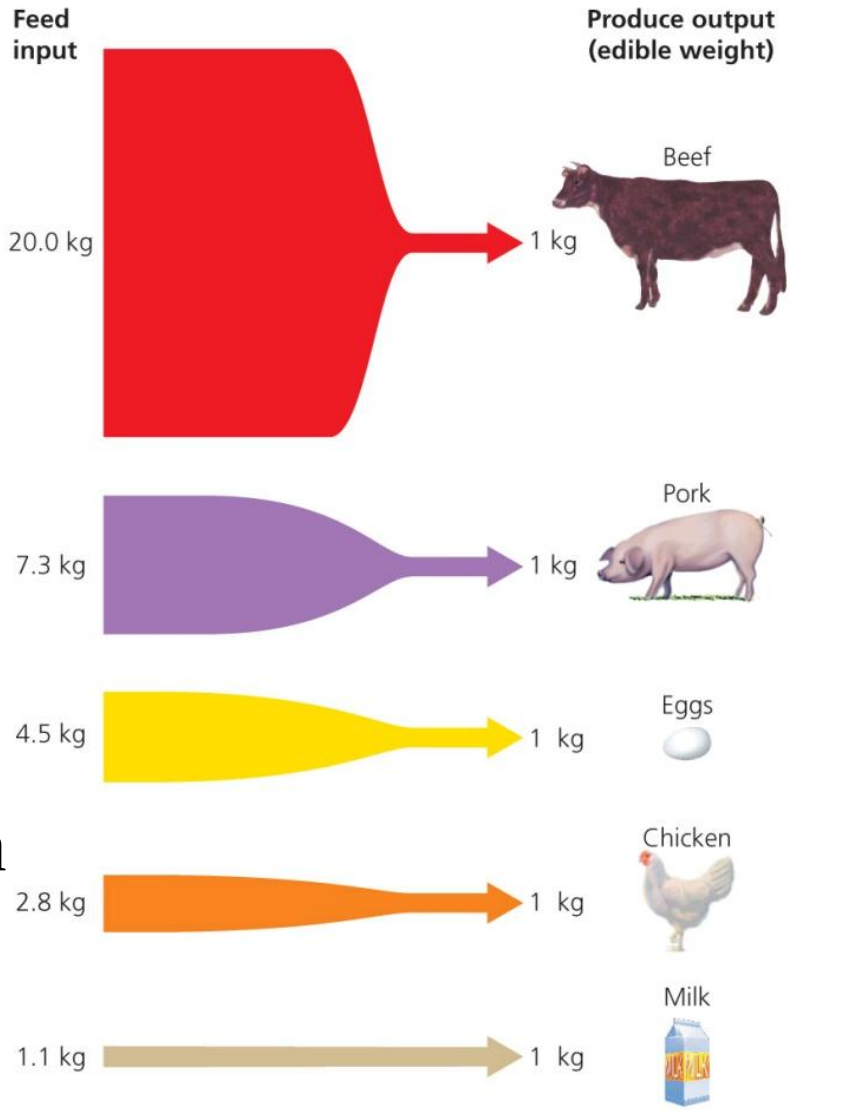
Debeaked chickens spend their lives in cages; U.S. farms can house hundreds of thousands of chickens in such conditions

The benefits and drawbacks of feedlots

- The benefits of feedlots include:
  - Greater production of food
  - Unavoidable in countries with high levels of meat consumption, like the U.S.
  - They take livestock off the land and reduces the impact that they would have on it
- Drawbacks of feedlots include:
  - Contributions to water and air pollution
  - Poor waste containment causes outbreaks in disease
  - Heavy uses of antibiotics to control disease

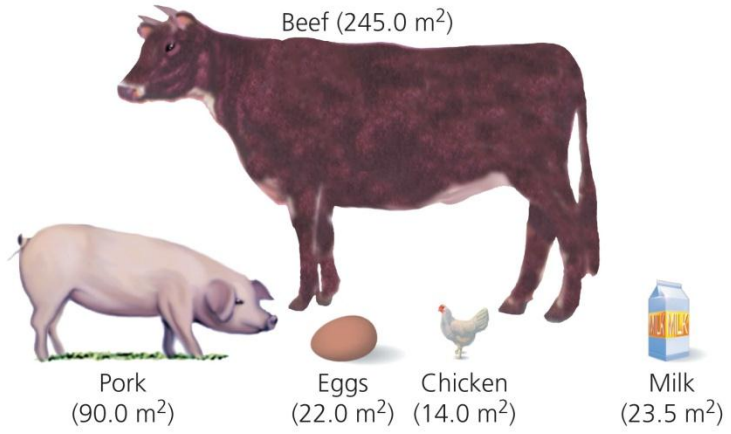
Energy choices through food choices

- 90% of energy is lost every time energy moves from one trophic level to the next
- The lower on the food chain from which we take our food sources, the more people the Earth can support.
- Some animals convert grain into meat more efficiently than others

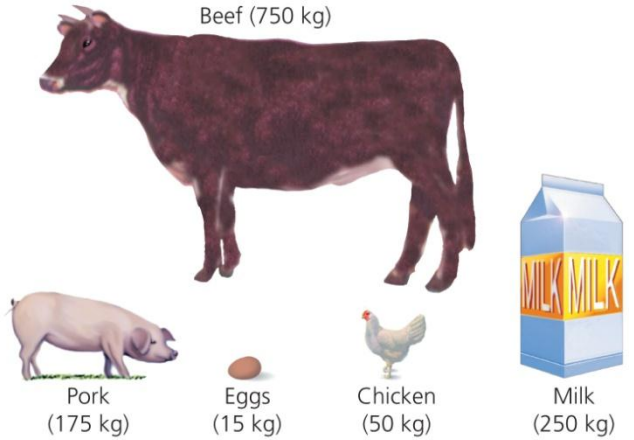


Environmental ramifications of eating meat

- Land and water are needed to raise food for livestock
- Producing eggs and chicken meat requires the least space and water
  - Producing beef requires the most



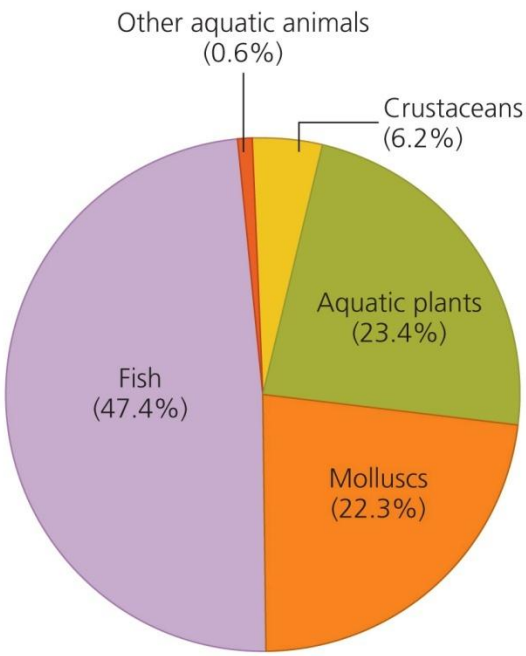
(a) Land required to produce 1 kg of protein



(b) Water required to produce 1 kg of protein

When we choose what to eat, we also choose how we use resources

Aquaculture

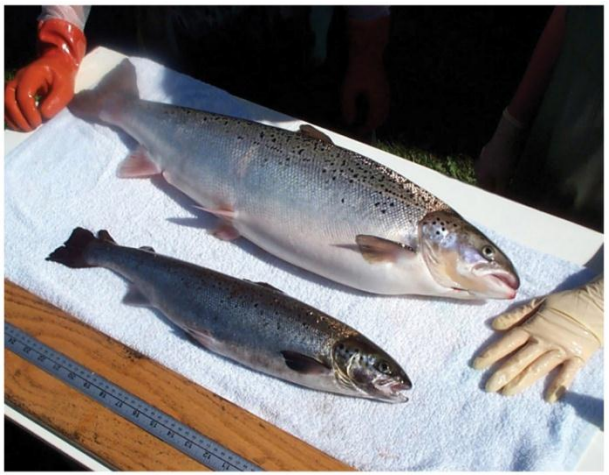


(a) World aquaculture production by groups

- World fish populations are plummeting
  - Technology and increased demand
- **Aquaculture** = raising aquatic organisms for food in a controlled environment
  - Aquatic species are raised in open-water pens or land-based ponds

The benefits and drawbacks of aquaculture

- Benefits:
  - A reliable protein source
  - Sustainable
  - Reduces fishing pressure on overharvested wild fish stocks
  - Energy efficient



- Drawbacks:
  - Diseases can occur, requiring expensive antibiotics
  - Reduces food security
  - Large amounts of waste
  - Farmed fish may escape and introduce disease into the wild

Sustainable Agriculture

- Industrial agriculture may seem necessary, but less-intensive agricultural methods may be better in the long run
- **Sustainable agriculture** = does not deplete soil, pollute water, or decrease genetic diversity
- **Low-input agriculture** = uses smaller amounts of pesticide, fertilizers, growth hormones, water, and fossil fuel energy than industrial agriculture
- **Organic agriculture** = Uses no synthetic fertilizers, insecticides, fungicides, or herbicides
  - Relies on biological approaches (composting and biocontrol)

A standardized meaning for "organic"

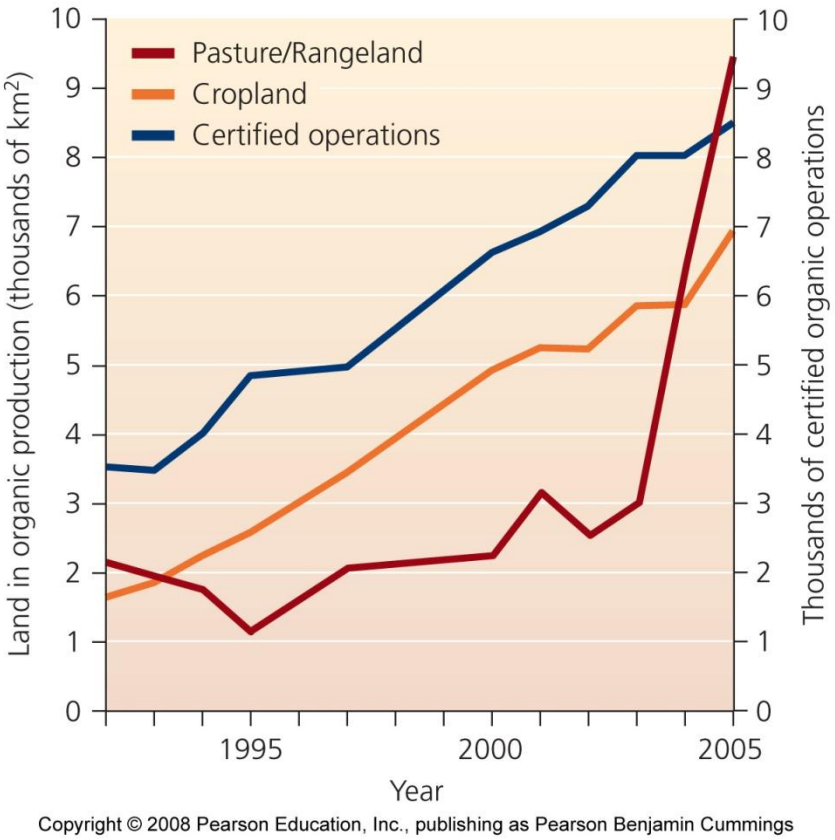
- People debate the meaning of the word "organic"
  - Organic Food Production Act (1990) establishes national standards for organic products
  - The USDA issued criteria in 2000 by which food could be labeled organic
  - Some states pass even stricter guidelines for labeling

The National Organic Standards Board wrote:

"Organic agriculture… is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony… Methods are used to minimize pollution from air, soil, and water… the primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and people."

The market for organic food is increasing

- Sales increased 20%/year in Canada and the U.S. from 1989-2005
  - Expanded by a factor of 40 in Europe
- Amount of land for organic farming is increasing
  - 10-35%/year in the U.S. and Canada
  - In 2005 the U.S. had 1.7 million acres of organic cropland and 2.3 million acres of organic pastureland



The benefits of organic farming

- For farmers:
  - Lower input costs, enhanced income from higher-value products, reduced chemical costs and pollution
  - Obstacles include the risks and costs of switching to new farming methods and less market infrastructure
- For consumers:
  - Concern about pesticide's health risks
  - A desire to improve environmental quality
  - Obstacles include the added expense and less aesthetically appealing appearance of the product

The U.S. doesn't financially support organic farmers

- In 1993, the European Union adopted a policy to support farmers financially during conversion to organic farming
- The U.S. offers no such support
  - Organic production lags in the U.S.
  - Farmers can't switch, because they can't afford the temporary loss of income
  - In the long run, organic farming is more profitable
  - 2008 Farm Bill set aside $112 million over five years for organic agriculture

Locally supported agriculture is growing

- In developed nations, farmers and consumers are supporting local small-scale agriculture
  - Fresh, local produce in season
- **Community-supported agriculture** = consumers pay farmers in advance for a share of their yield
  - Consumers get fresh food
  - Farmers get a guaranteed income (farmer's markets)