Chapter 30: The Future of the Biosphere

Chapter Synopsis

Many of the ecological problems the earth is now experiencing are the result of too many people in too little space. There are still vast uninhabited areas, although many of these areas are also uninhabitable, like most deserts and the arctic. The early development of agriculture and the later development of industry resulted in the concentration of populations in localized areas. Not only must raw materials, food and water be provided to each population center, but the wastes of the people and their technology need to be disposed of properly. It is the latter that most frequently results in pollution problems. There just is not enough water, land, or air around these areas to dilute the wastes any longer.

The populations of the so-called "developing countries" are growing at a much faster rate than the rest of the world. Many of these areas are near the equator in the biologically-rich tropical rain forests. Unfortunately, these soils are very poor in quality and cannot sustain continual agriculture without expenditure of great quantities of energy and fertilizers, neither of which are readily available to poor countries. As a result, the rest of the world must attempt to distribute food to these people, but at what cost and to whom? The developed countries have succeeded in stabilizing their populations, but have attained such a high standard of living that in the near future one occupant of a developed country will use the same amount of resources available to five people living in a less-developed area.

The future of agriculture is highly dependent upon developing more nutritious food staples through technology. The Green Revolution of a decade ago attempted to solve many of these problems, but many of the crops that were developed were highly dependent on expensive machinery, pesticides, and fertilizer. Genetic engineering will likely improve many crops, but it cannot be the only solution. Some areas are just not fit for modern agriculture and must return to traditional methods of farming.

Nuclear power has the potential to release the world from all of the dangers and damage of fossil fuels. Many other problems have arisen in its wake, like those at Chernobyl and Three Mile Island. The greenhouse effect is another disaster in the making as carbon dioxide levels continue to rise. The destruction of the forests aggravates the condition as less carbon dioxide is converted back into oxygen with the existence of fewer plants. Although the oceans have a great capacity to store gases, especially carbon dioxide, there is little data indicating what will happen when the oceans reach their limit. Air and water pollution, acid precipitation, and altered ozone levels are also dangers that know no national boundaries. Industrial pollutants produced by one country are destroying vegetation literally half a world away. Determining the source of such pollution is often all but impossible. World-wide political legislation may be the only cure, but it may not come soon enough.

As cataclysmic as the Antarctic ozone hole may be, it has taken years for any world-wide political discussions regarding chlorofluorocarbons to even begin. Increased ultraviolet radiation significantly affects productivity in photosynthetic plankton as well as human health. In addition, the genetic variability of all ecosystems, especially the tropical rain forests, must also be maintained. Scientists have barely scratched the surface of the great variety of life on the entire earth. Ecologists must study what is left of the undisturbed areas to determine the lowest limits at which the rain forests and other communities retain their stability. It will do no good to have small patches of trees or grass in which all vital animal and plant life has disappeared.

Investigating all of these problems is the job of the environmental scientist. The process of solving them includes assessment, risk analysis, public education, and political action. It is all the more important that each individual be aware of the biological fate of the world. At the moment, there is no other world to inhabit when this one is gone. Earth is not disposable!

CHAPTER OBJECTIVES

- ä Describe the complications associated with increasing birth rates and the socioeconomic standards of developing countries.
- ä Describe the complications associated with the declining birth rate in developed countries coupled with the desire to increase the standard of living.
- ä Understand the effect of agriculture and the industrial revolution on overall human population and its distribution.
- ä Understand the future of agriculture, especially as related to the intentions of the Green Revolution.
- ä Understand the complications and consequences of nuclear power.
- ä Explain the greenhouse effect and its relationship to world climate and species survival.
- ä Describe various forms of pollution, their long-term consequences, and possible control through political legislation and biotechnology.
- ä Explain the concerns regarding the changes in ozone level in the upper and lower atmospheres.
- ä Understand the consequences of the destruction of tropical rain forests.
- ä Describe the five components of environmental problem solving.

KEY TERMS

biodiversity
biological magnification
conservation biology
environmental scientist
global warming
greenhouse effect
groundwater
hydroponics
megareserves
ozone
topsoil

CHAPTER OUTLINE

30.0 Introduction

I. HUMANITY VERSUS THE EARTH

A. Effects of Human Population Visible at Great Distance fig 30.1

B. Population Impacts the Environment
1. Total population of the earth in 1995 reached 5.7 billion
2. More people consume more food, water, energy, and raw materials
3. More people create greater amount of waste

30.1 The world's human population is growing explosively

I. A GROWING POPULATION

A. The Present Situation
1. World population is nearly 6 billion
2. Global birth rate for last 300 years: 30 per year per 1000 people
3. Present rate decreased slightly to 25 per 1000
   a. Decreased death rate from 29 to 13 per 1000 people per year
   b. Net increase in annual population rate

4. Population increasing at rate of 1.4% per year
   a. Will double population in 39 years
   b. Annual increase of 77 million per year
   c. 210,000 new people every day, 140 every minute
   d. Estimate population of 6 billion by 2000 AD
   e. Expected stabilization at 8.5 to 20 billion by next century

B. The Future Situation
1. Localization of human populations in year 2000 fig 30.2
   a. 60% in tropical or subtropical regions
   b. 20% in China
   c. 20% in developed or industrialized nations
2. Rate of growth
   a. Industrialized countries at 0.3% per year
   b. Developing countries (excluding China) at 2.2% annually
3. Variable world age structure affects population growth
   a. Industrialized nations: 20% of population under 15 years
   b. Developing countries have nearly twice as many people under 15 years
   c. Populations of developing countries continue to increase at faster rate fig 30.3
   d. Industrialized nations will constitute smaller portion of the global population

C. Population Growth Rate Starting to Decline
1. Estimates of population in 1995 less than expected
   a. Growth rate in 1965 to 1970 at 1.4% per year
   b. Actual growth in 1998 at 1.48%
   c. Increase in 77 million per year compared to 53 million in 1960s
2. U.N. attributes decline to family planning efforts, increased status of women
   a. Substantial monies spent on family planning
   b. Opposition would rather spend it on education, improving economy
   c. U.N. reports an increase in education levels after reduction in family size
3. Countries progressing to slow their growth rates
4. Population may stabilize sometime in the next century
5. Quality of life dependent on stabilizing world's population
   a. Wealthiest 20% of populations consume 86% of resources and emit 53% of CO_2
   b. Poorest 20 % consume 1.3% of resources and emit 3% of CO_2
6. Humanity's future dependent on building a sustainable world
   a. Depends on limiting population growth
   b. Depends on reducing amount of per capita resource consumption

30.2 Improvements in agriculture are needed to feed a hungry world

I. THE FUTURE OF AGRICULTURE

A. Immediate World Challenge to Produce More Food
1. Food production increased by 2.6 times since 1950
   a. Expanded at greater rate than population
   b. Most cultivatable land already in use
   c. Topsoil lost from agricultural land
2. Prospects for increased agricultural productivity

B. Finding New Food Plants
  1. Major crops have been cultivated for thousands of years
    a. Half of all human energy requirements fulfilled by rice, wheat, corn
    b. 100 kinds of plants provide over 90% of calories
    c. Need to explore properties of plants among 250,000 known species fig 30.4
  2. Identify new crops, especially in tropics
    a. Few new plants cultivated since 1800
    b. Examples: Rubber and oil palms
  3. Crops selected for ease of growth

C. Improving the Productivity of Today's Crops
  1. Improvement needed in tropical and subtropical regions
    a. People cannot be fed on exports from industrial nations
    b. Industrial nations contribute 8% of own production
  2. Improvement of strains via Green Revolution: 1950-1970
    a. Ten-fold increase in Mexican wheat production
    b. Food production in India outpaced population growth
    c. China became self-sufficient in food production
  3. Limitations of Green Revolution
    a. Agricultural techniques require great energy output
    b. Extensive use of costly pesticides and herbicides
    c. U.S. wheat production requires 1000 times more energy than farming in India
  4. Present solutions
    a. Improve production of current crops
    b. Fully apply traditional means of plant breeding and selection fig 30.4

D. Genetic Engineering to Improve Crops
  1. Resistance to specific herbicides results in better weed control
  2. Develop plants to grow where they could not grow before
  3. Desirable traits introduced into crop plants
    a. Modified rice high in ascorbic acid and iron
    b. Plants tolerant to irrigation with salt water
    c. Can fix nitrogen and carry out C_4 photosynthesis
    d. Produce substances to deter pests and disease
  4. Genetically modified (GM) crops are controversial
    a. Concern about loss of genetic diversity
    b. Potential harm to nearby insects
    c. Influence of seed companies
  5. Must determine if risks outweigh benefits
  6. Provides tremendous potential to improve crop plants

E. New Approaches to Cultivation
  1. "No-till" agriculture conserves topsoil
  2. Use of hydroponic agriculture problematic
  3. Resources of oceans are not inexhaustible
    a. Reduce over fishing of specific areas
    b. Develop new microorganism-based foods: *Spirulina*

30.3 Human activity is placing the environment under increasing stress

I. NUCLEAR POWER

A. Chernobyl Incident
1. One of four reactors exploded in April 1986
   a. Emergency safety systems shut off
   b. Power surge precipitated the explosion
2. Released over 100 megatons of radioactivity
   a. Millions of times greater than Three Mile Island
   b. Significant human exposure to radiation
   c. Death due to radiation poisoning

B. The Promise of Nuclear Power
1. Fossil fuels no longer cheap sources of energy
2. Nuclear power could provide new source
3. Undesirable side effects to burning fossil fuels
   a. Produces sulfur, principal cause of acid rain
   b. Produces carbon dioxide, primary greenhouse gas
4. New problems associated with nuclear power
   a. Safe operation of power plants
   b. Disposal of radioactive wastes and safe decommission of power plants
   c. Prevention of terrorism and sabotage
5. Important to develop other alternative energy sources
   a. Includes solar and wind energy
   b. Improve efficiency of electrical appliances

II. CARBON DIOXIDE AND GLOBAL WARMING

A. Changing Concentrations of Gases in Atmosphere
1. CO_2 maintains world temperature 25° higher than without it
   a. Traps heat-producing infrared light
   b. Creates greenhouse effect fig 30.5
2. Seven times more CO_2 locked in fossil fuels than in atmosphere
   a. Preindustrialized atmosphere had 260 to 280 ppm CO_2
   b. Increased from 315 to 340 ppm in 25 years since 1958
3. Global warming results from increased CO_2
   a. Mean global temperature increased 1° since 1900
   b. Level of CO_2 could double by 2035
   c. Warming exacerbated by trace gases
      1) Include nitrous oxide, methane, ozone, chlorofluorocarbons
      2) Effects similar to CO_2
4. Ancillary problems
   a. Rising sea levels
   b. Leads to global climate changes, shift of desert and agricultural regions

III. POLLUTION

A. Rhine River as an Example
1. Fire in chemical warehouse washed chemicals into river
   a. Deadly mercury and pesticides killed fish and plants
   b. Water became unsafe to drink
2. River slowly cleaned itself

B. The Threat of Pollution
  1. Results from industrial by-products
    a. Plastics cannot decompose
    b. Efforts being made to develop new microorganisms are so far unsuccessful
  2. Agricultural pollution
    a. Widespread use of pesticides, herbicides, fertilizers
    b. Toxic chemicals remain in ecosystems
      1) Chlorinated hydrocarbons banned in U.S.
      2) Biological magnification: Toxins concentrate in the food chain fig 30.6

IV. ACID PRECIPITATION

A. Mechanism for Production of Atmospheric Acids
  1. Sulfur compounds produced when coal burned
  2. Effects seen far from where acids are produced
    a. Mixes with atmospheric water to produce sulfuric acid fig 30.7
    b. Acid dispersed by winds high up in atmosphere

B. Biological Consequences
  1. Death of thousands of fresh-water lakes
    a. pH below 5.0 is usually life-threatening
    b. Seepage into groundwater
  2. Destruction of forests fig 30.8
  3. Expensive to capture and remove emissions
    a. Polluter and recipient far apart
    b. Neither wants to pay for problems
  4. Success of Clean Air Act in U.S.

V. THE OZONE HOLE

A. Visible to Electronic Equipment over Antarctica fig 30.9
  1. Hole is nearly the size of the U.S.
    a. Thinning of ozone layer first appeared in 1975
    b. Presence of hole coincides with Antarctic spring
  2. Cause of ozone hole attributed to chlorofluorocarbons (CFCs)
    a. Chemicals used in cooling, fire extinguishers, and styrofoam
    b. CFCs reduce O_3 ozone molecule to O_2 gas
  3. Global agreements to halt CFC production
    a. Problem will get worse before it gets better
    b. Quantity currently in lower atmosphere will reach upper atmosphere in later years
  4. Ozone layer protects life from harmful UV rays from sun
  5. Life appeared only after oxygen layer became sufficiently thick to generate ozone
  6. Biological consequences of loss of ozone layer
    a. Increased ultraviolet light penetration
    b. Increases incidence of human skin cancers

VI. DESTRUCTION OF THE TROPICAL FORESTS

A. Rain Forests Are Rapidly Disappearing
  1. Rain forests are biologically richest biomes
    a. Other forests with better soils destroyed for agriculture long ago
    b. Rain forests now destroyed even though soils are poor

2. Undisturbed rain forests occupy only 5.5 million square kilometers
    a. Area about two-thirds the size of U.S. (Without Alaska)
    b. Represents half the original size of the rain forests
3. 160,000 square kilometers clear cut each year
    a. Additional loss due to shifting cultivation, gathering firewood, cattle ranching
    b. Equal to the size of Indiana per year
    c. At the present rate they will be gone in 30 years

B. A Serious Matter
1. Loss of biodiversity
2. Damage to complex, productive ecosystem
    a. Need to change from one-use to continuous agriculture fig 30.10
    b. Natural resources not available for use again
3. Biologists must learn more to sustain agriculture in tropical regions

30.4 Solving environmental problems requires individual involvement

I. ENVIRONMENTAL SCIENCE

A. Attempts to Find Solutions to Environmental Problems
1. Studied by environmental scientists
2. Applied science associated with ecology, geology, meteorology, social sciences

B. Solving Environmental Problems
1. Assessment
    a. Gathering information
    b. Construct model of situation
    c. Use model to predict future events
2. Risk analysis
    a. Analyze environmental impact
    b. Evaluate potential for solving problem
    c. Determine adverse effects of solution
3. Public education
    a. Address problem in terms the public can understand
    b. Present alternative actions
    c. Explain costs and results of various choices
4. Political action
    a. Choice made through elected officials
    b. Difficult to implement if problems are multinational
5. Follow-through
    a. Monitor results of environmental actions
    b. Evaluate and improve initial analysis and modeling

C. Individuals Can Make the Difference
1. The Nashua River
    a. New England river severely polluted by mills
    b. Declared ecologically dead in 1960s
    c. Stoddart approached state to set apart a greenway along river, rejected
    d. Formed Nashua River Cleanup Committee
    e. Led, in part, to Massachusetts Clean Water Act of 1966
    f. Industrial dumping banned, river recovering

2. Lake Washington
   a. Freshwater lake east of Seattle
   b. Sewage discharged into lake in 1940-1950s
   c. Effluent thought to be harmless
   d. Actually fertilized lake, promoted growth of blue-green algae
   e. Algae expected to deplete deep lake's oxygen supply, kill lake
   f. Sewage rerouted to dumping in sea
   g. Lake now clean

II. PRESERVING NONREPLACEABLE RESOURCES

A. Destruction of Nonreplaceable Resources in U.S.
   1. Topsoil
   2. Groundwater
   3. Biodiversity

B. Topsoil
   1. U.S. is among most productive of agricultural regions due to fertile soils
      a. Much of Midwest was once extensive prairie
      b. Substantial topsoil accumulated over countless generations
      c. Rich soil once extended down several feet
   2. Lost at a rate of several centimeters per decade
      a. Loss through repeated tilling of soil to eliminate weeds
      b. Rain washes away most of topsoil
   3. Utilize new approaches to reduce intensive cultivation
      a. Genetically engineer crops resistant to weed-killing herbicides
      b. Terrace areas via contour farming to recapture topsoil fig 30.11

C. Groundwater
   1. Groundwater is water trapped within porous rock, in aquifers
   2. Originated from seepage of glaciers during last ice age
   3. Large portion of water wasted for nonproductive activities
   4. Great deal also polluted by poor disposal of chemical wastes

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

Present Malthus' ideas on the maximum population capacity of the earth and how it relates to our present situation. Compare our "throwaway" society to one that interacts with nature more wisely, not overutilizing resources or creating more wastes than the environment can handle. Consider the prospect of feeding the hungry versus teaching them how to feed themselves. Is the latter always possible or even advantageous?

Consider the means we possess to preserve plant and animal life. This has been a function of zoos and botanical gardens, although secondary to their entertainment value. Technology now enables us to freeze various cells, gametes, and embryos with apparently little damage. Is it worthwhile to save what we can this way and hope that at some future date the various forms of life can be reconstructed? What are the flaws of this method? (Consider coevolution and how well an organism is able to survive without its complex habitat.)

Discuss why it is more important to save the tropics than any of the other biomes, primarily in relation to species diversity.

Although CFC propellants no longer stream from spray cans, they still leak from discarded refrigerators, air conditioners, and various chemical processes.

Discuss engineering bacteria to degrade pollutants (plastics, oil spills). Include the many safeguards that are added to prevent potential disaster in terms of degradation of desired materials (insulation, plastic containers, housing products, natural oil reserves) in addition to the wastes and toxins. So much of what we use is made of some form of plastic – a totally unnatural product that is *not* biodegradable. Most people don't realize that a plastic jug or fishing line will be intact hundreds of years from now.

The topics presented in this chapter are the regular fare of newspapers, magazines, and television. Since the last edition of this textbook, many localities have enacted more stringent air and water pollution controls and have begun recycling paper, plastics, cans, and glass. Many citizens mulch garden and lawn wastes, and restrict their use of pesticides, herbicides, and fertilizers. Volunteer groups clean up parks, beaches, and waterways. Who would have guessed 5 years ago that a magazine called *Garbage* would thrive and that consumers would want to buy paper towels made from recycled paper? Such ecological activities are in vogue and will hopefully become permanent lifestyle changes in all of us. A necessary accompaniment to these activities is education, perhaps of adults more so than small children. The young children know that we adults will probably never see the culmination of the environmental problems our wasteful attitudes have caused — but they will!

VISUAL RESOURCE:

Photos of the various forms of pollution and the effect on living organisms can be quite sobering. Especially graphic are those that show birds strangled by the plastic webs that hold six packs of cans, plastic garbage bags floating in mid-ocean, and toxic dumps.

Collect your home and/or office garbage for several days and bring it into class. Sort and weigh it by type (cans, paper, glass, organics, and so forth). Suggest that your students do the same. They may realize that they produce more waste than they thought they did.

Rent the movie *Medicine Ma*n starring Sean Connery. Connery's character is engaged in research in the rain forest looking for a chemical cure for cancer based on stories of the indigenous peoples. To spoil the story : he thinks the compound is an isolate from an epiphytic plant, but it turns out that the compound is associated with the ants that inhabit the plant. Of course he finds this all out after the area in which he is working is destroyed by fire and a road-building crew!