

LECTURE OUTLINE – GEOGRAPHY 113 “HUMAN IMPACT ON THE ENVIRONMENT”

I. INTRODUCTION

A. Course **objectives**

1. **content** goal: we will ask “How are humans altering the world they live in?”
 - a. this is an example of a generic type of question in **science**
 - 1) science is the source of formal knowledge...and then of technology as well, as we apply the knowledge
 - 2) represents an ordinary human activity...inquiry, curiosity...
 - a) primitive people asked & answered questions about the sun, food, water, animals, health
 - b) you ask about the world when you get dressed to go outside, choose a way home, try to make a new computer program work
 - 3) science is an organized version of this activity
 - a) shared *standards* of evidence and proof
 - b) common intellectual *tools*: physics from Newton, e.g.
 - b. the question, in this course, is specific to aspect of the world: environmental science
 - 1) ecosystems
 - 2) human population
 - 3) resources
 - 4) pollution
2. **intellectual** goals of the course
 - a. this is not a course for geography or environmental studies majors...almost all students in this room are here to satisfy their BA science requirements
 - b. skills & perspectives of the course are meant to be general, of value for anyone:
 - 1) recognize elegance, power, coherence of broad organizing principles, and of mechanical explanation ... seeing how different problems share important characteristics that help us understand them.
 - 2) trust your own ability to observe the world, see problems, and seek solution—

“Anyone who conducts an argument by appealing to Authority is not using his intelligence, he is just using his memory.”

Leonardo.

*Stop this day and night with me and you shall possess the origin of all poems,
You shall possess the good of the earth and sun, (there are millions of suns left.)*

You shall no longer take things at second or third hand, nor look through the eyes of the dead, nor feed on the spectres in books,

You shall not look through my eyes either, nor take things from me,

You shall listen to all sides and filter them from your self.

Walt Whitman

- 3) know some facts about an interesting aspect of the world
3. topic is *concrete* to us all...our **environment**
 - a. we relate to it with ordinary activities: food, family, travel, purchases
 - b. and also with extraordinary activities: catastrophes, dramatic degradation, health impacts
- B. Approach will be **analytic & synthetic**, rather than merely descriptive
1. differences are this:
 - a. ask how the parts of this system work together (synthesis)
 - b. don't ask what's the biggest river in Nebraska (description)
 2. long-term value of **ways-of-thinking** exceeds any facts you would retain ...you can look up the facts in the encyclopedia
what you need to know in short term for the course isn't the facts
 3. *stuff* vs. *things* dichotomy ... you can look up all that **stuff**; remember the important **things**
you will do badly on the first exam if you know lots of stuff...you only need to know one number, for example, and it is 7 ... details later.
 4. if you know the **principles**, you can *reconstruct* the specifics
 - a. "the Reagan principle"
 - b. the meandering of streams, as an example...if you've seen one meander you've seen them all
- C. **Organization** of the course (see syllabus)
1. lecture, readings for material
 2. the purpose of the outlines
 3. quizzes & three exams...Why so many?
 4. help...office hours
- D. "**Environment**" — what does it mean?
1. we use it to describe a set of human concerns about:
 - a. cleanliness (litter, smog)
 - b. health (disease-causing or toxic pollutants)
 - b. nature (wildlife, natural ecosystems)
 2. to most people "environment" usually refers to the *human* environment; and what is *wrong* with it (although we should think of "wellness" as a goal, not just responses to pathologies)
 3. most people are interested in the environment in large part because of their **affection** for it — it is a source of beauty, peace, food, recreation, complexity, resources ... we should avoid the danger of seeing only "bad."

4. “environment” also a concept from biology — means “surrounding”
 - a. organisms inseparable from environment ... they are part of it, not within it. “**Ecosystem**” is the common term for situation of organism within its environment.
 - b. includes:
 - 1) “abiotic” (non-living) elements — light, heat, minerals
 - 2) “biotic” elements — other organisms ... ex: prey and predators
 - c. every organism changes its environment
 - 1) removes food
 - 2) adds wastes
 - d. may make other changes — ex: trees make shade & soil
5. The human environment *is* a biological environment:
 - a. except humans are much more powerful through technology .. interaction of technology & nature underlies most environmental problems
 - b. however we cannot suspend the laws of physics & principles of biology.

E. geography and environmental science

1. What is geography? ... This section is from the National Geography Standards, from NCGE & NGS ... aimed for K-12 students.
 There are 18 standards or goals which are grouped into six categories [themes] called "The six essential elements of geography." These six elements and the standards included under each of them are as follows:
 - a. The World in Spatial Terms
 Geography studies the relationships between people, places, and environments by mapping information about them into a spatial context. The geographically informed person knows and understands
 - b. Places and Regions
 The identities and lives of individuals and peoples are rooted in particular places and in those human constructs called regions.
 - c. Physical Systems
 Physical processes shape Earth's surface and interact with plant and animal life to create, sustain, and modify ecosystems.
 - d. Human Systems
 People are central to geography in that human activities help shape Earth's surface, human settlements and structures are part of Earth's surface, and humans compete for control of Earth's surface.
 - e. Environment and Society
 The physical environment is modified by human activities, largely as a consequence of the ways in which human societies value and use Earth's natural resources, and human activities are also influenced by Earth's physical features and processes.
 - f. The Uses of Geography
 Knowledge of geography enables people to develop an understanding of the relationships between people, places, and environments over time — that is, of Earth as it was, is, and might be.
2. what does it have to do with environmental science?

- F. optimism and the study of the environment:
1. it is a problem for many people to study only the bad parts of the environmental situation
 2. we should remember that people care about these issues because of their affection for and connections to the natural world
 3. focusing on how problems can be solved is useful in the short and the long run.

II. SYSTEMS & CYCLES

*“Why do we still have mountains? They are eroded everyday, so why aren't they gone?”
A general theory of stuff, to help us understand the world and its parts.*

- A. “**System**” as a concept: any part of the universe that we can think of as a *unit* is a system
1. value of the concept
 - a. helps us understand how parts of the environment interact with one-another
 - b. we also can understand properties of only *that* part
 2. underlying principle: *conservation of matter and energy* (**First Law of Thermodynamics**)
 - a. the first law: “energy [or matter] is neither created nor destroyed”
 - b. everything that went into the system is either still in there or has come out
 - c. matter and energy are *cycled*; never created nor destroyed
 - d. ...although energy is degraded, so it doesn't cycle so well (the Second Law of Thermodynamics)
- B. Natural systems tend to be in *balance*: relatively stable over the long run
1. we know that any system with an *outflow* (“Rivers take sediment from continents to the sea”) must have an *off-setting inflow* (“Something brings sediment back onto the land”)
 - a. formula: $I(\text{input}) = O(\text{output})$
 - b. the input always ends up as output
 - c. the output can only come from input
 2. *even if we cannot see it*, we should believe the return flow is there:
 - a. otherwise we would have run out of mountains (or whatever) a long, long time ago
 - b. we don't expect to see significant net change in a planet 5,000,000,000 years old within our paltry lifespans
- C. But *in the short run*, systems don't need to be in balance because of *storage*
1. it rains today, but the output (stream flow) doesn't happen immediately
 2. lakes, soil, groundwater, glaciers hold water between rainfall and runoff from the rivers
 3. $I = O + \Delta St$

4. the input can go to increase storage, or the output can come from decreasing storage, in the short run
 5. however, $\Delta St = 0$ in the long-run; all the water going into lakes will leave eventually
- D. It is not a coincidence that natural systems are stable, but rather an outcome of the fact that natural systems that are **homeostatic** – inherently resistant to change – survive, while others are destroyed. Key ideas in homeostasis:
1. **feedback**: the state of the system affects inputs or outputs
 2. **negative feedback**: an increase in storage will decrease input or increase output
 - a. example: thermostat: too much heat ($\uparrow St$ of heat) turns off furnace (\downarrow input of heat) or turns on air conditioner ($\uparrow O$)
 - b. very common in natural systems: animal population, stream flow, climate, physiological systems
 - c. physical analog to negative feedback: a marble in a bowl...rolls back into center of bowl when displaced (“perturbed”)
 3. **positive feedback**: more storage yields more input...yields more storage yields more input...(or less storage means less input ...)
 - a. continues until input (energy) is gone or system is broken...the positive feedback system destroys itself
 - b. ex: bonfire, earthen (or ice) dam, snow cover & temperature
 - c. self-destructive systems like this are uncommon in natural circumstances...for obvious reasons
 - d. positive feedback systems can be stable for a long time, until a **threshold** is crossed...a pile of firewood is stable until it crosses a certain temperature
 - e. physical analog of threshold: pop bottle on its neck; stable until it tips past a certain point
- E. The equilibrium state
1. If the state of a system is the difference between two opposite forces – average temperature balances the day's sunshine against night's cooling, e.g. – we should see the system find a balance which reflects equally the influence of the two factors
 2. this is the *optimum*: an intermediate value (of anything – the angle of a mountain slope, for example) toward which a system will tend
 3. the Goldilocks principle: “Not too hot, not too cold, but *juuuust* right”
 4. “optimum” doesn't necessarily mean “good”...the ecologically optimum number of mosquitoes is more than none
- F. Storage and **lag**
1. storage **smooths** out variation over a time (a big bank account smooths out changes in income)
 2. storage **delays** the response of the system to change (a lake fills and empties more slowly than a pond; a big truck speeds up or slows down later than a little one)
 3. the **time difference** between external change and internal response is called *lag*

Two Meditations — by John Barth 1972**Niagara Falls**

She paused amid the kitchen to drink a glass of water; at that instant, losing a grip of fifty years, the next-room-ceiling-plaster crashed. Or he merely sat in an empty study, in March-day glare, listening to the universe rustle in his head, when suddenly the five-foot shelf let go. For ages the fault creeps secret through the rock; in a second, ledge and railings, tourists and turbines all thunder over Niagara. Which snowflake triggers the avalanche? A house explodes; a star. In your spouse, so apparently resigned, murder twitches like a fetus. At some trifling new assessment, all the colonies rebel.

Lake Erie

The wisdom to recognize and halt follows the know-how to pollute past rescue. The treaty's signed, but the cancer ticks in your bones. Until I'd murdered my father and fornicated my mother I wasn't wise enough to see I was Oedipus. Too late now to keep the polar cap from melting. Venice subsides; South America explodes. Let's stab out our eyes. Too late: our resolve is sapped beyond the brooches.

III. ENERGY.

All life — all action anywhere — depends on energy; it is one of the fundamental concepts in science

- A. **Energy** drives every temperature change, chemical reaction, change in motion, source of light.
1. Natural work includes wind, heat, erosion, soil development, plant and animal life, rain, stream flow, decomposition of chemicals
 - a. Energy arrives in sunlight, wind, streams, plants, food, heat.
 - b. Nothing happens without a source of energy
 - c. we should pay attention to where that energy comes from in order to understand nature.
 2. Artificial work includes heat, light, manufacturing, transportation, chemical fabrication
 - a. Energy arrives as fuel, electricity, animal work, etc.
 - b. Nothing happens without a source of energy
 - c. we should pay attention to where that energy comes from in order to understand society.
- B. The laws of **thermodynamics** ... the theory behind how energy is used
1. First Law of Thermodynamics: Energy is neither created nor destroyed; “No free lunch”.

- a. Because of the First Law, we can treat energy as “stuff” ... energy accounting works as though energy were material.
 - b. Common units for energy are **calories** ... amount of energy needed to heat one gram of water one degree Celsius.
2. Second Law of Thermodynamics: Use of energy degrades it toward lower value, less usable, less “pure” energy (finally to uniform heat), thereby eliminating the energy’s utility (although the energy is still there) ... You cannot make a perpetual motion machine.
- a. Entropy is the concept of disorder that the degraded energy represents. We can extend the idea to include material — pure material (iron ore, for example) contains less entropy. Any change (mixing, e.g.) increases the entropy.
 - b. One form of energy can be turned into another & back again (1st Law), but there is an energy loss in each change (2nd Law).
 - c. All energy ends as heat... the “heat death” of the universe will come; everything will be lukewarm & brown (material ends up mixed—purity is expensive & rare).

IV. BIOLOGICAL PRODUCTIVITY

The engine that drives the ecosystem of which we are part

- A. All energy to support life on earth comes from the *sun*; energy “*cascades*” through the ecosystem ... passes from one user to another; used once by each.
- B. Energy is “*fixed*” by **photosynthesis**: the key reaction for life on earth.
 1. the equation: $6\text{H}_2\text{O} + 6\text{CO}_2 + \text{solar energy} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.
 2. $\text{C}_6\text{H}_{12}\text{O}_6$ represents “fixed carbon” ... carbon-carbon and carbon-hydrogen bonds containing more energy than the carbon-oxygen bond.
 3. only [well, almost only] *green plants* do photosynthesis.
- C. **Respiration** is the reverse process, which releases energy from the fixed carbon:
 1. *opposite* of photosynthesis: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \longrightarrow \text{H}_2\text{O} + 6\text{CO}_2 + \text{biological energy}$.
 2. done by all living things.
 3. equivalent to combustion: you burn sugar and release work same as a steam engine would.
- D. **Biomass** is the general term for fixed carbon.
 1. we’ll use it as a measure of *energy content*: two slices of bread is twice the biomass of one & twice the energy ... note that we are using *mass* as a measure of *energy*.
 2. the biomass content of an ecosystem—which may be the product of many years of growth—is the *standing crop*.
- E. **Productivity** is the rate of biomass production
 1. typically measured as grams of fixed carbon / meter² / year.

2. productivity limited by supply of *nutrients, water, sun* ... ranges between 3 g/m²/yr (desert) and 4000 g/m²/yr (tropical coral reef).
 3. *Limiting factors* suppress productivity – lack of rain in the desert, etc.
 4. Net primary productivity is plant productivity minus plant respiration.
- F. **Ecology** is the interaction between the organisms in the environment ... different species can be predators, prey, competitors, symbionts, etc.
- G. Animals are **consumers**; live only off of (ultimately) plant biomass.
1. herbivores eat plants ... primary consumers
 2. carnivores eat animals; secondary consumers.
 3. and decomposers eat whatever is left after whatever happens
 4. energy *cascades* through system – each level receives from the previous
- H. The *productivity of animals* is far *lower* than the productivity of plants ... say, 10%.
1. plant energy *dispersed* by animal life processes ... feeding, warmth, movement.
 2. Second Law of Thermodynamics would have predicted this: less available energy after the “use” in consumption.
 3. concept: the **trophic pyramid**: each level has a fraction the productivity of the level below it (although the standing crop can be higher than in the layer below).
 4. the **productivity of top carnivores** of long food chains (sharks, for example) is *very low*; square miles of grass support one lion.
- I. Necessary ecological concept for understanding prey & predators ... and much else:
1. **r-selected** organisms (“disturbance tolerators”):
 - a. *reproduce rapidly, invest little* into each “propagule”, *make many*, each with *little defense* or food to grow on.
 - b. respond well to **fluctuating environment** but not competitive in stable environment.
 - c. examples: flies, rats, weeds ... “r” stands for *rate* in an ecologists’ equation (or rapid, or rat?).
 2. **K-selected** organisms:
 - a. *reproduce slowly, invest much* in each off-spring (it is *large at birth*, long gestation, *defensive, slow to maturity*) ... favor **stable environments**.
 - b. examples: elephants, trees, large carnivores, humans, cactus.
 - c. K-selected organism favored in *competitive* or *stressed* environments (forests or deserts).
 - d. both *pioneer* and *climax* vegetation should be K-selected.
- J. **Nutrients** are *cycled* within the ecosystem:
1. the *same* phosphorus may be used by a tree today as 5000 years ago at the same spot (the same sunlight cannot).
 2. soil is the *short-term* (1000 year) pool of nutrients; good soils are those that cycle well: accept, hold, & release nutrients and water.

3. **decomposers** are organisms which break down dead tissue, release nutrients for another plant.
4. nitrogen, carbon, (water?) are atmospheric pools ... fast cycling after loss. Nitrogen must be “fixed” before it is available to plants.
5. phosphorus, calcium, potassium, iron, etc are in geologic pools ... as long as 100,000,000 years between loss of the nutrient from the land to the sea and reappearance on land through erosion, uplift, weathering.

V. HUMANS IN THE ENVIRONMENT

It is important to see how we resemble, and how we differ from, other animals.

- A. *Humans are animals.* We have the same needs as other animals.
 1. animal requirements which humans have: food, etc.
 2. tens of millions of years ago, primates were affected by adaptations during our arboreal (tree-dwelling) period ... predisposed us to be social, familial visual, vocal, tool-handling, etc.
 3. humans evolved in Africa over the last million years; became taller, verbal, and tool-using
 4. much more recently (40,000 years?), environmental differences fostered evolution of superficial differences we see as race—pigment, hair, body build ... all environmental responses
- B. *Humans are more than animals.* We have *culture*, which animals don't.
 1. culture: learned adaptation
 - a. increase our range and density because of what we *know*
 - b. includes technologies: fire, elevators
 - c. includes social adaptations: language, insurance
 2. result of culture: humans cover the earth
 - a. the great migrations to everywhere
 - b. habitation in many environments: desert, rainforest, tundra
 - c. efficient resource use: 100's of foods
 - d. civilization: cities, writing, monumental architecture
- C. Because of our *culture* humans have thousands of times more ability to change—damage or improve—the non-human environment than we once did.
 1. The story of environmental impact is the story of technology.
 2. “ $I = f(PAT)$ ” as a simple construction of this
 - a. I, human impact (“the ecological footprint”)
 - b. ... is some function of
 - c. P, population
 - d. A, their affluence
 - e. and T, the level of technology they bring to their lives

VI. THE HUMAN POPULATION

Is over-population the root environmental problem?

- A. The general issue:
1. people make environmental problems.
 2. more people make more problems.
 3. some problems “emerge” once population cross certain thresholds.
 4. the population is now increasing rapidly ... as are environmental problems.
- B. How to talk about population ... some statistics
1. **population** — the number of people in a given place
 - a. Is this an environmental important factor?
 - b. Is a country with more people always worse off?
 - c. What other factors are important? Population *density*, for example
 2. *growth rate* — population change per year, in percent
 3. *crude birth rate* — births per thousand people per year
 4. *crude death rate* — deaths per thousand people per year
 - a. “crude” differentiates these rates from age-adjusted rates: births per thousand women between 15 and 45, for example
 5. $GR = (BR - DR)/10$ (+ net immigration, which is usually close to 0)
 - a. means all change in population is birth (+), death (-), or migration
 - b. dividing by ten is only to change a per-thousand to a percent
 - c. expressed as a percent change per year, like an interest rate
 - d. a high GR can be caused by a high BR or a low DR or both
- C. Exponential growth
1. a constant percent growth — 3.5%, for example — is *not* a constant amount of increase (or decrease)
 2. each year increases previous year's population by 3.5%, and *increases the increase*
look at what happens to 100,000,000 people over three years at 3.5% growth (which is the same as multiplying by 1.035):

$$100,000,000 * 1.035 = 103,500,000$$
 growth is 3,500,000

$$.. (100,000,000 * 1.035) * 1.035 = 107,122,500$$
 .. growth is 3,622,500

$$... ((100,000,000 * 1.035) * 1.035) * 1.035 = 110,871,788$$
 ... growth is 3,749,288
 3. See why it's called ‘exponential growth’?
3 years’ growth, $((100,000,000 * 1.035) * 1.035) * 1.035$ is the same as $100,000,000 * (1.035)^3$
 4. lesson: constant percent increase means that a population **increases at an increasing rate**

5. a meaningful (and powerful) statistic: *doubling time*
 - a. length of time until population is twice a given level
 - b. constant for a given growth rate
 - c. value is approximately $0.7/GR \times 100\%$... a 10% GR yields 7 year doubling time
 - d. note that doubling time is less than $1.0/GR$ (10% GR yielding 10 year doubling time) because of compounding (like compound interest)
 6. description of phenomenon: the *J-shaped curve*
 7. can reach *any* size population we wish to name — 100 billion? 2000 billion? — (“the biotic potential is unlimited”)
 8. Philosophical note: Exponential growth is only a *heuristic* — a simple, informative model, not a firm prediction — it is a way to understand the world but not to predict the future. We’ll see more heuristics.
- D. Importance of population growth, beyond mere increase in size
1. Age structure
 - a. demonstrated with a *population pyramid* — a histogram (graph of number versus category) of age groups
 - b. shows history of when growth or decline happened in that population
 - c. helps predict future growth ... numbers of new mothers, e.g.
 - d. illustrates dependency ratio ... percent non-working people
 - e. disproportionate investment required for children's needs ... schools, hospitals, dairy, e.g.
 2. Increasing needs ..
 - a. economy must expand to stay constant
 - b. more jobs needed for incoming workers
- E. How does a country **lower its death rate** ... that is, why do people die and how can it be prevented?
1. *causes*: infant mortality, infectious diseases, famine
 2. *prevention*: sanitation, inoculation, disaster relief
 3. simple, cheap medical (*technological*) intervention
- F. How does a country **lower its birth rate** ... that is, why do people have children and when will they stop?
1. *value* of children in a sick, poor, agricultural circumstance
 2. *cost* of children in a healthy, rich, industrial circumstance
 3. slow, expensive *social and value changes* needed
- G. The demographic transition ..
1. a change happens between high constant BR & high variable DR and a low constant DR and low variable BR as a country develops
 2. it is *easy* for a country to lower its DR, and hard to lower its BR .. DR drops years earlier
 3. the time between the two events is the time of fastest population growth

4. the poorer the country, the longer the transition will take
5. “the best way to lower the GR of a poor country is to make the country rich”
6. .. but ...remember $I = PAT$... rich people have more impact

VII. OVERPOPULATION

- A. **Biological definition: exceeding carrying capacity**
1. carrying capacity: maximum *stable* population density
 2. consequences of exceeding it:
 - a. starvation, predation, illness, “reproductive dysfunction”
 - b. environmental degradation ... overgrazing
 3. result: approximate equilibrium (although populations will fluctuate above & below)
- B. Human, cultural version: Rev. Thomas Malthus ... the **Malthusian** theory
1. “the passion between the sexes shall continue unabated” (the biotic potential is unlimited)
 2. human population shall grow at a geometric rate, as 4, 9, 16, 25, 36 (exponential, actually, 4, 8, 16, 32, 64)
 3. food supply will increase linearly, as 2, 3, 4, 5, 6 (nobody knows why he thought that ... but surely there are limits to growth of food production)
 4. population will exceed food supply, eventually
 5. resulting in famine, pestilence, or warfare
 6. unless we choose a “negative check” ... “*virtue*”
- C. **Neo-Malthusianism:** a more modern statement of this ... widely held by the biologists who were important early on in the 20th Century American environmental movement. (*Darwin* read Malthus and recognized the significance of excess births for all animals)
1. human population has the potential to exceed its carrying capacity
 2. starvation is inevitable
 3. many other environmental problems are direct & indirect results of over-population
 - a. resource depletion
 - b. pollution
 4. population control must be the *first* priority in environmental maintenance
 5. we are already well past carrying capacity ... hunger and environmental degradation are apparent
- D. **Anti-Malthusianism:** economists (and others) know that humans are more than just animals. (*Marx* read Malthus and recognized that there must be more to the ability of the land to support people than just its qualities: different modes of production, e.g.
1. “carrying capacity” is culturally varied ... 250,000,000 modern Americans where 2,000,000 Native Americans lived 500 years ago; which is the carrying capacity

2. more people is much more ability to produce food — group work (irrigation dams, e.g.) and innovation (steam power, e.g.) — and people are good, anyway
 3. the hunger we see is a product of human choices ... economic systems, wealth, warfare
 4. pollution is not created directly by people; dependent upon level of technology: one American produces as much pollution as ten Chinese
 5. Malthusianism can disguise racism — should we discourage reproduction of brown & black people more than white people?
 6. we have never been any good at predicting the future, knowing what productivity will be, for example.
- E. Environmental ethics in a densely populated world
1. What is ethics?
 2. An ethical tool: the ecological footprint.
 3. “Cowboy economy” ... our footprints don’t overlap (from Kenneth Boulding)
 4. “Spaceship economy” ... we breath each others exhalate.

<i>Man's march to the summit — Kenneth Boulding, 1955</i>	
<p><i>The Conservationist's Lament</i></p> <p>The world is finite Resources are scarce Things are bad And will be worse</p> <p>Coal is burnt And gas exploded Forests cut And soils eroded</p> <p>Wells are drying Air's polluted Dust is blowing Trees uprooted</p> <p>Oil is going Ores depleted Drains receive What is excreted</p> <p>Land is sinking Seas are rising Man is far Too enterprising</p> <p>Fire will rage With man to fan it Soon we'll have A plundered planet</p> <p>People breed Like fertile rabbits People have Disgusting habits</p>	<p><i>Technologist's Reply</i></p> <p>Man's potential Is quite terrific You can't go back To the Neolithic</p> <p>The cream is there For us to skim it Knowledge is power And the sky's the limit</p> <p>Every mouth Has hands to feed it Food is found When people need it</p> <p>All we need Is found in granite Once we have The men to plan it</p> <p>Yeast and algae Give us meat Soil is almost Obsolete</p> <p>Man can grow To pastures greener Till all the earth Is Pasadena</p>
<p><u>Moral:</u> The evolutionary plan Went astray By evolving Man</p>	<p><u>Moral</u> Man's a nuisance Man's a crackpot But only man Can hit the jackpot</p>

VIII. POPULATION CONTROL

- A. The issue: too many people is a problem; it also creates or aggravates other problems
- B. *Technical* aspects of the solution are simple: contraception, abortion, abortifacants, etc., are well developed technology (although liability laws have discouraged development of new kinds of birth control in U.S.)
- C. *Human* aspects of problem are intractable:
 - 1. moral or religious objections ... use of abortion as birth control or sex choice, e.g.
 - 2. male self-image, domination (who makes decisions, who sees the problems more closely)
 - 3. individual liberties ... Chinese systems of strict legal limit on number of children does *work*; do we want it here?
 - 4. labor requirements, old-age maintenance, etc. (demographic transition issues)
- D. This contradiction is the *Tragedy of the Commons*, a recurring block to us solving environmental problems. Garret Hardin gave it that name and this formulation: "*The best choice for the individual may be the worst choice for the group*"
 - 1. The "commons" is a common grazing land in traditional European society (e.g., the Boston Commons) ..
 - a. by extension a commons is any "free" but finite resource (fisheries, clean water, park benches)
 - b. called a 'common property resource' — accessible by all with no owner.
 - 2. If it is over-grazed, it will degrade and support *less*
 - 3. To the *whole group*, the optimal number of cows will be, for example, 5 per person
 - 4. To each individual, the optimal number of cows will be dozens and dozens.
 - 5. If each individual makes his/her choice freely, the commons will be degraded.
 - 6. That's why we need laws, or ethics, or religions, or families, or whatever makes us operate toward the interests of all.
 - 7. Central idea: the market – the idea that prices come from the interaction of supply and demand, and bring all the crucial information about consumption to consumers (that is, we can buy it if we can afford it).

 IX. AGRICULTURE IN HUMAN HISTORY

- A. Purpose ... feed *more* people by **increasing (human) carrying capacity** of an area
- B. Operation ... **control limits of environment** (water, nutrients, pests, etc.) and breed plants adapted to those limits
- C. **Origin** (important to understanding the requirements and the problems of agriculture)
 - 1. **Paleolithic** (“old stone age”) subsistence was hunting-gathering ... like another animal
 - a. example: the !Kung bushmen of Namibia
 - b. One of the harshest environments in the world: Kalahari Desert
 - c. !Kung subsistence: 15 hours a week gathering mongongo nuts
 - d. !Kung healthy, long-lived; environment stable and reliable
 - 2. **Neolithic**: origins of *domestication* ... plants and animals with higher productivity and useful traits (wool, big seeds, simultaneous ripening, etc.)
 - a. with agriculture: Mexican peasants (for example)
 - b. sixty-hour work weeks, little protein, more disease, vulnerability to political subjugation
 - 3. Why make the switch? We were better off before.
 - a. Key element in !Kung system was *population density* at about one-third carrying capacity
 - b. Methods of maintaining population levels were traumatic: infanticide, late marriage, years-long abstinence, protracted nursing
 - c. Lose control of population density and intensification, domestication inevitable
 - d. Key to agriculture is that a little more labor is always a little more food; a little more hunting is not always a little more food
 - e. Neolithic began, all over world, after settlement had expanded into every corner of the globe, and every ecological niche ... the planet was “full”
- D. Conclusion about role of agriculture in human evolution:
 - 1. increased carrying capacity dramatically
 - 2. increased work-per-unit-food even more dramatically
 - 3. we cannot go back to gathering mongongo nuts unless most people die
 - 4. agriculture permitted civilization, buildings, and writing (and war, kings, and peasantry)
 - 5. and, we shall see, it is the most widespread negative impact on the global environment

X. MODERN AMERICAN AGRICULTURE

The most productive — and most destructive — food system ever known

- A. General **ecological** circumstance.
1. *simplify* ecosystems (to remove what we don't use & stop competition).
 2. favor “*super-weeds*” ... r-selected plants ... the right qualities for crops.
 3. decrease limiting factors
 4. provide *protection* from competitors & predators.
- B. Systems & cycles view: an *unstable* system.
1. goal is an **output** (food) ... therefore not inherently stable.
 2. *net inputs* (fertilizer, etc.) must mean a net output (**pollution**).
 3. **weeds & crops** are a *temporary* stage in any ecosystem ... r-selected, thus
 - a. unstable
 - b. poor cycling
 - c. poor protection
 4. soil erosion, etc., **degrading** future agricultural potential.
- C. The processes of agriculture:
1. **plow** ... turn over topsoil.
 - a. *why?* remove weeds (+ improve seedbed).
 - b. *side-effects*: dramatic, rapid, near-permanent soil loss because atmospheric energy is exerted directly on the soil (rain-drops, streamlets, wind).
 - c. *preventing problems*: decrease amount of uncovered soil (no-till) or decrease stream energy across fields (strip-cropping, contour plowing, terraces).
 2. **fertilize** ... add inorganic mineral nutrients (P, N, K, Ca) not present in soil or lost from soil after erosion.
 - a. *why?* increase productivity; replace lost nutrients.
 - b. *side-effects*: costly; limited supply (non-renewable); encourages pollution “downstream” (eutrophication, as in Chesapeake) and “upstream” (where produced).
 this is an ‘externality’ to the market ... the cost of polluting someone else’s stream doesn’t hurt the farmer’s profit.
 - c. *preventing problems*: decrease soil erosion; recycle nutrients more effectively (manure management).
 3. plant **hybrids** ... giant, defenseless, very thoroughly domesticated plants, in extensive plots (monoculture).
 - a. *why?* grow faster; utilize fertilizer effectively; tastier; economies of scale.
 - b. *side-effects*: vulnerable to pests—dramatic failures like the potato famine; reliant on farmers & inputs and cost; permanent loss of diversity.
 - c. *preventing problems*: mix crops; rotate crops; preserve diversity; accept lower productivity.

4. **pesticides** ... chemical poisons for weeds and insects.
 - a. *why?* plants are more vulnerable; insects (not us) consume 40% of biomass in natural communities; chemicals are very cheap.
 - b. *side-effects:* often *less* productivity after a few years
 - 1) insects evolve resistances very fast, as non-resistant ones are killed
 - 2) more toxic up food change; preferentially kill our friendly insects before enemies.
 - 3) persistent poisons potentially dangerous to humans, mammals, birds (Agent Orange).
 - c. preventing problems:
 - 1) use natural enemies (support previous ecosystem; import natural predators);
 - 2) limit pesticide use to times when pests are obvious (integrated pest management);
 - 3) use non-toxic controls (traps; pheromones)
- D. Summative critique of modern American agriculture:
 1. unstable
 2. inefficient in
 - a. land use
 - b. food quantity per input
 - c. resources: energy, chemicals, water
 3. polluting
 4. expensive
 5. ... but very effective in getting you and me a good, rich, healthy diet.

XI. FEEDING THE NEXT BILLIONS

Food production for the future

- A. Premise: the present world population is undernourished, and there will be still more people in the future. How will they be fed?
- B. Evidence: the Famine. What causes intense food shortages?
 1. not enough total food?
 2. environmental degradation?
 3. low income?
 4. too many people?
 5. failures of the market?
 6. collapse of social, economic, political, transportation system?

- C. Can American-style agriculture feed the world? Its strengths here are weaknesses elsewhere:

Interlude: what does “efficient” mean about agriculture? It should be lots of output per unit input ... but is that food per *land* input? Per *capital* input? Per *material* input (fuel, water, etc.)? Per *hour of labor*?

1. American agriculture minimizes labor inputs, through profligate use of land, fuel, chemicals, capital ... poor nations have much labor but little land, fuel, chemicals, capital.
 2. American agriculture overcomes instability by buying transporting food (so we don't get famines), and changing inputs ... poor nations can suffer disasters if crops fail or decrease
 3. American-style agricultural technology acts to disrupt many aspects of the food system in poorer countries:
 - a. land tenure systems
 - 1) landlords kick peasants off land and hire them to farm it
 - 2) wage-labor decreases access to food)
 - b. economic development
 - 1) debt is necessary [to buy hybrids, fertilizer, fuel]
 - 2) excess labor (underemployed labor) becomes unemployed and migrates to the city)
 - c. ecology (people are dependent on many parts of agri-ecosystem ... fish, e.g., which get poisoned or degraded)
 - d. nutrition (single crop — rice — displaces higher protein lentils, etc.; higher productivity needed mean more protein)
 - e. stability (widespread use of a single cultivar [crop type] encourages catastrophic pest infestation)
 - f. flexibility (cannot return to old system after investment in pumps, tractors; crops cannot be grown on *moderate* levels of inputs)
- D. The converse: what can Americans learn from Third-world agriculture:
1. increase efficiency by utilizing what would otherwise be waste (“detritus”)
 2. decrease pollution through the same means ... waste was pollution
 3. more labor means higher efficiency and less degradation (use all the land; repair damage early)
 4. recognize non-economic value of farmland
 - a. use land appropriately to its qualities and its permanent value
 - b. make decisions according to the interests of the seventh generation
 5. meat is *very* inefficient (25% or less) and inhumane ... vegetarian USA could feed an extra billion
- E. Can we increase the area under cultivation?
1. only a little bit ... *most* soil is inappropriate to food production
 2. we can breed new crops — drought resistant, or tree crops — for problem environments

3. if we do so, it is at cost of organisms already there (rainforest, e.g.)
- F. The oceans will save us?
1. the open oceans are a desert
 - a. the nutrients sink below the thermocline
 - b. fish are concentrated in shallow waters or areas of upwelling
 2. we eat high on the trophic ladder in the sea, and are thoroughly over-fishing already
 3. we *can* harvest lower on the pyramid (kelp, krill) or “farm” (choose and manage species) ... but this will displace existing populations

XII. RESOURCES

What the environment gives us to use.

- A. Concept ... material in the environment of use to us—Culturally defined ... value of materials different to different peoples, different times
- B. Renewable vs. non-renewable resources ... a fundamental (but vague) distinction
1. all resources are produced by natural processes (of course) and essentially all natural processes still work at some rate, so all resources are technically renewable
 2. renewable: rate of production approximates our use rate / human life span ... 100 year forest regrowth
 3. non-renewable: natural production much slower than use (100,000,000 years for oil)
 4. mineral resources are the usual type of non-renewable resources

XIII. MINERAL RESOURCES:

Minerals ... the standard example of non-renewable resources

- A. Value of mineral resources is in their concentration
1. a fundamental tendency for material in the natural world is toward disorder ... called “entropy”, and it always increases
 2. only energy can increase material order (at the cost of the entropy—the useable quality—of the energy)
 3. it is far more than 1000 times more difficult to obtain a gram of gold which is 1/999th of 1000 grams of rock than that which is 51% of 2 grams of rock
 - a. the last bit is always the hardest to get
 - b. example: the first Easter egg is easy to find, the last is hardest
 - c. note that in the 51% gold case you can throw away millings (already-processed ore) which are better than 1/999th gold (the ore in the second case)
 4. if nature do not make a highly concentrated ore, then we have to, and our energy is more expensive than nature’s

- B. Natural processes concentrate ores
 - 1. all such processes take energy ... examples:: stream sorting, chemical precipitation ... ground water or hydrothermal sulfide deposits
 - 2. all such processes are rare, and rarely preserved — organic material must be buried without oxygen, not over heated, brought near surface (coal) or trapped beneath impermeable layers (oil, gas)
- C. We use the best (most concentrated) resources first. Of course.
 - 1. the set of **resources** (all of the iron, e.g.) are divided into
 - a. **reserves** (those of commercial value in concentration or in accessibility) ... reserve will increase or decrease as price changes
 - b. **known reserves** are those we can find
- D. stages in resource exploitation:
 - 1. early price drop, with better technology, economies of scale, more exploration
 - 2. price rises, from depletion ... supply & demand; more cost to extract
 - 3. increased efficiency, recycling ... cause it pays now
 - 4. finally, substitution, with
 - a. another non-renewable resource of lesser value
 - b. a renewable resource which is now commercially feasible because prices are higher
- E. Role of recycling:
 - 1. postpone depletion
 - 2. prevent price increases which cost everybody money
 - 3. make money from resource
 - 4. decrease waste-stream

XIV. ENERGY & ENERGY RESOURCES

The “ultimate resource” ... can replace, expand, or clean any other resource

- A. Importance of topic
 - 1. high energy use underlies “modernity” ... industrial economies
 - a. per capita energy use correlated with income
 - b. example of modern agriculture
 - c. impact of oil embargo, Persian Gulf war
 - 2. energy a limited resource
 - a. fossil fuels (coal, oil, natural gas) are **non-renewable** — natural production rate essentially zero ... they **will** run out
 - b. renewable energy resources (solar energy, hydroelectric power, wind energy) produced at lower rates than we like to use
 - c. efficiency with which we use resources can vary greatly, can change impact and rate of depletion

3. energy production and use has severe and widespread impact
 - a. mining coal, oil spills
 - b. air pollution .. smog in cities
 - c. acid rain affecting 1000's of square miles of forest
 - d. "Greenhouse effect" will change global climate
- B. Non-renewable resources
1. processes which are making (for example) coal work very slowly ... 1,000,000 times slower than we use it
 2. examples: oil, coal, natural gas, uranium
 3. depletion curve — use must decrease (and price increase) as supply exhausted (especially easily recovered supply)
 4. substitute resource will be needed, which will be more expensive (at least at first)
- C. Renewable resources
1. old as fire .. wood was first renewable fuel
 2. examples: wood (or other biomass), sun, wind, water, dung
 3. supply unlimited, if we can wait (that is, rate-limited, not supply-limited)
 4. larger capital requirements vs. lower production costs
- D. Conservation
1. choose not to use extra energy, instead of finding new energy?
 2. cheapest energy "source" ... power companies now investing in home insulation (to save fuel) rather than in new plants
 3. savings projected far into the future (which is good *and* bad)
 4. "end-use" design matches quality of energy to use ... heat is cheap (due to second law of thermodynamics ... energy use degrades it to less useable, lower quality energy)
 5. co-generation .. "waste" heat can be used; analogy to trophic levels: some food is left in the ecosystem after fancier users are done.
 6. counter-argument: more energy production means more economic growth
- E. Pollution from extraction:
1. degraded land and disrupted settlement (ex.: Shamokin & other anthracite towns): destroyed vegetation, acid drainage, boom-and-bust economies
 2. oil spills, especially on the ocean and in coastal waters ... serious damage in critical environments
- F. Total cost of energy use: Premise: the *price* we pay directly for energy is a small part of the *total cost*
1. The market provides a price for energy ... what are the components of that price?
Dollar costs for renergy:
 - a. price ... goes to labor, land owners, new investment, dividends & interest
 - b. see also "energy content" of manufactured goods ... aluminum, plastics, transportation

2. “Total cost” is the market cost (price you pay at the pump) plus some hidden costs.
 - a. Environmental costs:
 - 1) dollar costs: lost fisheries or lumber
 - 2) plus a “multiplier” — lost fishery jobs also decrease boat sales
 - 3) non-dollar costs: (“incommensurables”) ... dead birds
 - a) what's a dead sea otter worth? The \$35,000 Exxon spent on them? A zoo can buy one for \$750.
 - b) plus ecosystem effects — fewer salmon mean fewer bears
 - c) hard to measure, but maybe 50,000 “excess deaths” from SO₂ (mostly people already sick ... very young or old)
 - 4) uncertain, but possibly extreme, future damage: greenhouse effect causing extinction of half the species on earth?
 - 5) Example of ANWR ... how to choose?
 - b. Social costs, etc. ... military protection for Persian Gulf, tax breaks

XV. AIR POLLUTION

By-product of modernity; example of vulnerability

- A. Almost all air pollution from fossil fuel use: SO₂, CO₂, NO_x, HC
- B. Severe health risk ... 50,000 deaths per year from coal-fired power plants?
- C. Acute local impacts: “smog” in a city where input is very high
- D. Regional impacts down wind from industrial regions from acid rain
 1. SO₂ and NO_x from combustion, makes acid rain
 2. kills trees, lakes
 3. varies according to “resilience” of local environments (buffering capacity)
 4. delayed impact, as buffering is depleted, or as organisms age, or as other disruptions (storms, e.g.) amplify effect
 5. most acidic rain in nation in central Pennsylvania
- E. Global impacts from carbon dioxide (and a few other gases) ... see above

XVI. HUMAN-INDUCED CLIMATE CHANGE

The biggest human impact ever?

- A. History —
 1. it is clearly the case that climate have changed in the past.
 - a. New York City was under *glacial ice*, 18,000 years ago;
 - b. the previous interglacial provided a subtropical climate here.

2. data: geologic deposits (glacial till, soil, coastlines); biological evidence (pollen, fossils); geochemical traces
- B. Causes—What drives changes.
1. external forces ... planetary cycles & asteroids
 2. internal (internal to the atmosphere) forces ... are we one?
 3. Lots of feedback makes it unpredictable.
- C. Temperature response of atmospheric system ... example of accelerated Greenhouse effect.
1. CO₂ slows cooling through atmosphere
 2. concentration rising: 270 ppm in 1800, to 360 now
 3. globe may be as much as 10°C warmer in 2100?
 4. melt ice caps, shift rainfall zones, extinct ecosystems
 5. most severe impact on least powerful population (like any catastrophe)
- D. Complexities:
1. there is direct driving:
 - a. more CO₂ higher temperature.
 - b. reach a **new equilibrium** state.
 2. but negative feedback pervades system.
 - a. more CO₂ means faster uptake by natural sinks (ocean, vegetation).
 - b. higher temperature means higher evaporation, means more clouds, means less sun.
 3. and some positive feedback, too ...
 - a. warming releases CO₂ & methane from tundra, ocean
 - b. less snow means more insolation at high latitudes, means less snow ...
- E. Uncertainty: we don't know what's going to happen.
1. predictability is very low; we don't know much about conditions so different from present ones ("Our models are poorly calibrated for extreme conditions").
 2. the best models provide a wide range of possible outcomes, dependent of certain parameters we cannot yet measure precisely (cleanliness of the snow cover, amount of methane to be released in the Arctic).
 3. it is nearly certain that the details of our models will change dramatically in the next few years, as they has in the past few years, as we learn more.
 4. some rational scientists* expect very little temperature response to the response ... more negative feedback than positive, for example.
- * ... but fewer scientists doubt the visible, significant impact each year.
- F. Overall response of atmosphere to higher temperature.
1. higher temperature shifts weather bands poleward ... Kansas gets Texas' weather; Sahara becomes Tropical wet-dry while Italy becomes Sahara.
 2. temperature change greater at higher latitude (direct insolation a lower % of total heat).

3. storms, monsoons more intense ... more heating.
 4. most are reluctant to say whether change has begun ... variation is inherent in system ... but a consensus is growing
 5. indirect outcomes: coastal flooding, collapse of agriculture, extinctions, storms.
- G. A policy nightmare: How do we respond politically to a problem that might-or-might-not give us incomparably bad problems?

XVII. BIODIVERSITY

A. What is it?

1. Biological diversity: the relative diversity among organisms present in different ecosystems.
 - a. genetic diversity - diversity of genes within a species. Important to the stability of a species: “evolutionary bottlenecks” of cheetahs, Amish
 - b. species diversity - diversity among species — diversity of populations of organisms and species, but also the way these organisms function.
 - c. ecosystem diversity - diversity at a higher level of organization. In each ecosystem, living organisms are part of a whole, they interact with one another, but also with the air, water, and soil that surround them.

B. Where does it come from?

1. Biodiversity is the result of 3.5 billion years of evolution.
2. Until the emergence of humans, the Earth supported more biodiversity than in any other period in geological history.
3. Estimates of global species diversity vary from 2 million to 100 million species, with a best estimate of somewhere near 10 million.

C. Benefits of biodiversity

Ethics is the set of reasons we use to choose an action ... why we do what we do.

1. in this sense, ‘ethics’ doesn’t mean what we think ‘ethical’ means ... ‘right’ be some particular standard. Criminals robs and cheat because it is appropriate within their ethical universe.
2. Why is anything important? The interaction / conflict of human and non-human values:
 - a. instrumental value — something is an instrument for me to use (an ‘anthropocentric’ perspective
 - b. intrinsic value — the value of an organism is defined beyond my relationship to it.
3. one approach to ethics is to ask what entity is at the center of a descision – me, my children, my dog, all people?
4. one simple structure –

ETHICAL REALM↓ / SCALE→	individual	aggregate
human	<i>egocentric</i>	<i>ethnocentric</i>

non-human	<i>biocentric</i>	<i>ecocentric</i>
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5. could also differentiate self / others, animate / inanimate, young / old, etc.
6. consider 'the market' as an ethical structure ...
7. Ecological role of biodiversity (borrowed / adapted from Wikipedia)
 - a. Species provide function to an ecosystem. They can capture and store energy, produce organic material, decompose organic material, help to cycle water and nutrients throughout the ecosystem, control erosion or pests, fix atmospheric gases, or help regulate climate.
 - b. Ecosystems also provide various supports of production for humans (soil fertility, pollinators of plants, predators, decomposition of wastes...) and services such as purification of the air and water, stabilization and moderation of the climate, decrease of flooding, drought and other environmental disasters. These functions are important for ecosystem function and human survival.
 - c. Research suggests that a more diverse an ecosystem is better able withstand environmental stress and consequently is more productive.
 - 1) The loss of a species is thus likely to decreases the ability of the system to maintain itself or to recover from damage or disturbance.
 - 2) An ecosystem with high biodiversity may have a greater chance of adapting to environmental change. The more species comprising an ecosystem, the more stable the ecosystem is likely to be.
8. Economic role of biodiversity "The biodiversity is the one of the bigger wealths of the planet, and nevertheless the less recognized as such." E.O. Wilson.
 - a. For humans, biodiversity a resource for daily life. E.g., 'crop diversity'
 - b. Biodiversity is a reservoir of resources
 - 1) biodiversity provides food : crops, livestock, forestry, and fish
 - 2) 70 % of the promising anti-cancer drugs come from plants in the tropical rainforests.
 - c. Eco-tourism: biodiversity is a source of economical wealth for many areas,
 - d. The majority of species have yet to be evaluated for their current or future economic importance.
9. Ethical role of biodiversity
 - a. biodiversity is to be a mirror of our relationships with the other living species, an *ethical* view with rights, duties, and education.
 - 1) If humans consider species have a right to exist, they cannot voluntarily cause their extinction.
 - 2) biodiversity is also part of many cultures spiritual heritage (see *indigenous people* and *cultural diversity*).
 - b. the 'market' provides no value for nature beyond the instrumental
10. Scientific role of biodiversity
 - a. Each species can gives a clue as to how life evolved
 - b. biodiversity helps scientists understand how life functions and the role of each species in sustaining ecosystems.
 - c. A *biodiversity hotspot* is a region with many *endemic* species
 - 1) Usually in areas of historically limited human impact and are generally very productive.
 - 2) Most of these hotspots are located in the *tropics*.

- 3) Human activity in many of these areas is increasing dramatically.
- 4) coral reefs, mangroves, e.g.
- 5) Brazilian rainforest is said to represent 1/5 of the world biodiversity, with 50,000 plant species, 5,000 vertebrates, 10-15 million insects, millions of microorganisms, etc.

D. How is biodiversity threatened?

1. The majority of biologists believe that a mass extinction is under way.
 - a. estimates rates range from a handful to upwards of 200 species a day lost
 - b. most scientists believe that the rate of species loss is greater now than at any time in human history- with extinctions occurring at rates hundreds of times higher than *background extinction* rates.
 - c. Some studies show that about one of eight known plant species is threatened with *extinction*.
 - d. Every year, between 17,000 and 100,000 species vanish from our planet . This figure indicates *unsustainable* ecological practices, because only a small number of species come into being each year.
 - e. Some people say that up to 1/5 of all living species could disappear within 30 years.
2. Nearly all say that the losses are due to human activities, in particular destruction of plant and animal habitats.
 - a. An increasing number of studies indicate that elevated rates of *extinction* are being driven by human *consumption* of organic resources.
 - b. While most of the species that are becoming extinct are not food species, their *biomass* is converted into human food when their *habitat* is transformed into *pasture, cropland and orchards*.
 - c. 40% of the Earth's biomass is tied up in *livestock and crops*.
 - d. An *ecosystem* decreases in stability as its species are made extinct; the global ecosystem faces collapse if it is further reduced in complexity.
3. Biodiversity and size bias

The vast majority of Earth's biodiversity is microbial, and that contemporary biodiversity science is "firmly fixated on the visible world" Microbial life is very much more metabolically and environmentally diverse than multicellular life On the tree of life ... visible life consists of barely noticeable twigs. This should not be surprising — invisible life had at least three billion years to diversify and explore evolutionary space before the 'visibles' arrived".

E. Extinction – the extreme case of biodiversity loss

1. loss (death) of gene pool of a species ... not just an individual, like when we die
 - a. a species is a population which can interbreed ... the basic “kind” of organism
 - b. a lesser version: loss of genetic diversity within a species ... corn, tigers
2. Significance: irreplaceable ... that combination of genetic material will never occur again; it is the creation of the billions of deaths that drive evolution
3. The big picture, over time:
 - a. extinctions occurred repeatedly through out geologic history ... at most period ends ... Cretaceous-Tertiary (dinosaurs, etc.), Jurassic (the big one), Pleistocene-Holocene (mammoths, etc.)
 - b. specific causes identified or presumed for each: climate, sea-level, asteroid

XVIII. CAUSES OF BIODIVERSITY LOSS

A. Ecological adaptations

Necessary ecological concept for understanding prey & predators ... and much else:

1. r-selected organisms (“disturbance tolerators”):
 - 1) reproduce rapidly, invest little into each “propagule”, make many, each with little defense or food to grow on.
 - 2) respond well to fluctuating environment but not competitive in stable environment.
 - 3) examples: flies, rats, weeds ... “r” stands for rate in an ecologists’ equation (or rapid, or rat?).
2. K-selected organisms:
 - 1) reproduce slowly, invest much in each off-spring (it is large at birth, long gestation, defensive, slow to maturity) ... favor stable environments.
 - 2) examples: elephants, trees, large carnivores, humans, cactus.
 - 3) K-selected organism favored in competitive or stressed environments (forests or deserts).
 - 4) both pioneer and climax vegetation should be K-selected.
3. Essentially all threats to biodiversity favor the r over the K-selected organisms:

B. Direct killing or collecting

1. hunting ... food, trophies ... the lure of the almost extinct
2. commerce ... whales, chimpanzees, sea otters
example: whaling
3. predator control ... wolves, bears, coyotes, eagles

C. Pollution

1. DDT & food chain (osprey, pelicans)
ex: bald eagle
2. eutrophication (like Lake Baikal)
ex: humpback whales & red tide

D. Habitat loss

1. rainforest most obvious example ... 1 acre/second
2. also here (bison, cougar), everywhere ... we cut our forests long ago
3. size of remaining plots significant ... must be enough to support large animals
4. climate change as a driving force?
ex.: coral reef

E. Exotics

Environmental changes — from thoughtless causes — that will outlast the human species

1. definition — organisms introduced into environments where they are not native

- a. familiar and apparently benign examples: pigeons, starlings, dandelion, corn, Norway rat
 - b. a permanent change in the world
 - c. will survive for tens of millions of years (if anything does)
 - d. our longest-lasting environmental effect?
 - e. We expect exotics to be r-selected: travel well, spread rapidly
ex.: snake-head, Spartina
2. Four dramatic problems with exotics:
- a. Problem I: human disturbance favors a shift to r-selects organisms (including exotics)
 - 1) examples: weeds and pests that have developed and moved around with agriculture: Med fly, dandelion, bindweed
 - 2) these become ubiquitous, problems everywhere as we “average” the genes of the world
 - b. Problem II: introducing “unmatched” organisms ... those with no natural enemies
 - 1) examples: Japanese beetles, Gypsy moth, kudzu, fire ants, Africanized bees
 - 2) eventually predators can be introduced (or develop locally), but population explodes first
 - c. Problem III: introducing diseases to populations without defenses
 - 1) examples: smallpox and measles into New World killed more native people than did Europeans, SARS, Dutch elm disease, Newcastle's disease, Chestnut blight
 - 2) can (& will) extinct species long before defenses can evolve ... this is a slow process (decay & threshold)
ex: distemper & seals in Europe
 - d. Problem IV: the competitive disadvantage of island biota
 - 1) small number of species evolve poorly into many niches on islands
 - 2) predatory pressure weak, so defenses are, too.
 - 3) “continental” biota will consume or out-compete the islanders
 - 4) examples: deer in New Zealand, half of Hawaii's birds are extinct, pigs, goats, & mongoose in Hawaii & Caribbean
ex.: Hawaii
3. rates of interchange are increasing
4. ecological side-effects
- a. collapse of food chain
ex.: orcas and sea otters
 - b. symbiotic species ... the dodo, acacia and ants

XIX. EXTINCTION

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 - 2. specific causes identified or presumed for each: climate, sea-level, asteroid
- D. The big picture, now:
 - 1. > 1,000,000 species described
 - 2. 2x - 10x presumed undescribed ... how would we know how many?
 - 3. ninety-percent(?) of species in tropical forests ... 1/3 are coleopterans (beetles)
- E. Human impact, the numbers ...currently 1000x “background” rate?

XX. WILD RESOURCES

We are dependent, in various ways, on wild organisms. We are rapidly, thoroughly, and irreversibly damaging the ecological foundation of that part of our environment

- A. Harvesting living things ...
 - 1. fish, trees are examples
 - 2. in this case we depend on natural productivity ... existing forests, natural reproduction ... this is hunting and gathering, like the !Kung
 - 3. clearly can be a “renewable” resource ... have been used for 1000's of years
 - 4. What happens as rate of use increases? (That is, what is over-fishing or -cutting?)
 - a. at low rates — harvesting mimics natural losses; may increase vigor (like wolves strengthening caribou herds)
 - b. higher —
 - 1) marginal productivity decreases (in a limited lake, 200 fishermen don't catch twice as much as 100)
 - 2) harvest rates exceed growth & replacement rates;
 - 3) ecosystem changes forced up or down food chain
 - 4) “standing crop” (existing population of fish, trees, etc.) can postpone this effect ... a threshold to our observation
 - c. higher still —

- 1) marginal productivity is negative (more fishermen catch fewer fish)
 - 2) population collapses (remove adults & reduce off-spring production)
5. new technology makes this worse and increases ancillary ecological impact
 - a. drift nets, super-ships ... “strip mine” the ocean ... deplete surface species completely; chew up bottom structure
 - b. whole-tree harvest, clear-cutting removes all habitat, nutrients, ground cover
 6. this is literally the Commons (fish in the ocean), and we see here the Tragedy ... I'll catch all I can, and everyone will suffer
 7. response to the “Commons” problem
 - a. privatize (wood lots versus government land)
 - b. legislate (fishing season, size, and technology limits)
 - c. exert moral force (Greenpeace, boycotts)
 - d. educate (sportsman clubs)
 - e. offer incentives (debt-for-nature, cost-sharing of habitat planting)
 - f. empower the market (bidding for licenses, leases)
- B. Managing wild resources: how do we minimize damage?
1. maximum sustained yield ... harvest at flat top of the curve (or do we want the steepest part of the curve, before serious ecological problems start, while marginal productivity is still high?)
 2. shift down trophic ladder to increase efficiency ... harvesting krill versus harvesting whales (although harvesting whales is currently more efficient [like using cows to harvest fodder]... and this would take the whale's food)
 3. “farm” fish (or trees) — select species, manage food supply (or nutrients and competitors), harvest at lower energy cost (compared to traveling 1000's of miles in a boat) ... but this has environmental problems of any farming ... ex: eutrophication of Puget Sound; introduced diseases; exotic fishes
 4. protect limited productive areas ... near-shore and estuarine areas have more nutrients (compared to desert of open ocean) ... also (for the same reasons) most vulnerable to pollution

XXI. EXOTICS

Environmental changes — from thoughtless causes — that will outlast the human species

- A. definition — organisms introduced into environments where they are not native
- B. familiar and apparently benign examples: pigeons, starlings, dandelion, corn, Norway rat
- C. a *permanent* change in the world
 1. will survive for tens of millions of years (if anything does)
 2. our longest-lasting environmental effect?

- D. We expect exotics to be r-selected: travel well, spread rapidly
- E. Four dramatic problems with exotics:
1. Problem I: human disturbance favors a shift to r-selects organisms (including exotics)
 - a. examples: weeds and pests that have developed and moved around with agriculture: Med fly, dandelion, bindweed
 - b. these become ubiquitous, problems everywhere as we “average” the genes of the world
 2. Problem II: introducing “unmatched” organisms ... those with no natural enemies
 - a. examples: Japanese beetles, Gypsy moth, kudzu, fire ants, Africanized bees
 - b. eventually predators can be introduced (or develop locally), but population explodes first
 3. Problem III: introducing diseases to populations without defenses
 - a. examples: smallpox and measles into New World killed more native people than did Europeans, SARS, Dutch elm disease, Newcastle's disease, Chestnut blight
 - b. can (& will) extinct species long before defenses can evolve ... this is a slow process (decay & threshold)
 4. Problem IV: the competitive disadvantage of island biota
 - a. small number of species evolve poorly into many niches on islands
 - b. predatory pressure weak, so defenses are, too.
 - c. “continental” biota will consume or out-compete the islanders
 - d. examples: deer in New Zealand, half of Hawaii's birds are extinct, pigs, goats, & mongoose in Hawaii & Caribbean
- F. rates of interchange are *increasing*

XXII. ENVIRONMENTAL HEALTH

Finally it is how the environment protects our health that matters most to us as individuals

- A. General idea:
1. much of health & sickness is environmental, and always has been
 2. much of our interest in the environment is about its possible effect on our health
 3. three topics: ecology of vectors & contagion, human settlement, toxins in the environment
- B. ecology of disease ... germs are organisms & have an ecology like others do
1. vectors (e.g., “tropical diseases”)
 - a. mosquitoes & malaria ... ecologic action: draining swamps, as response
 - b. Lyme disease & ecology of dogs ... exotics carrying diseases ... farm animals, e.g., beavers and giardiasis?
 2. “Travelers disease” ... others' intestinal flora doesn't match your defenses

3. genetic forces responding to environmental forces ... race (q.v.), sickle-cell anemia, lactase deficiency
- C. human settlement ... how we live increases our exposures
1. contagion ... living close together is dangerous
 - a. *most* sickness is from improper water supplies ... very much a product of population density
 - b. cholera, plague, small pox are diseases of civilization
 - c. episodes of “Asian” flu ... from Chinese pigs? ... illustrate spread
 - d. smaller population protected
 2. hunger-related diseases result of settlement (density).
- D. Health effects of pollutants
1. toxins
 - a. some chemicals we release into the environment are poisonous, doing direct damage to human tissues ... kidney, liver, nerves, skin, reproductive organs
 - b. examples: lead, pesticides, mercury, TCE, PCB, etc.
 - c. toxicity related to dose ... more is worse
 - d. exposure is significant variable ... lead poisoning in inner-city children
 - e. from paint, exhaust, water pipes
 - f. low-grade neurological damage (cf. decline of Roman empire)
 - g. some chemicals (heavy metals, pesticides) *cumulative poisons* ... stays in the body
 - h. *biological amplification* increases concentration of poisons up food chain ... example: toxins accumulate in fishes from sediment at Minamata [Hg], James River [kepone], Hudson River [PCB], ocean tuna? [Hg], Columbia River [radiation], etc.
 2. carcinogens
 - a. some chemicals that we release into the environmental induce physiological damage that causes or promotes uncontrolled cell proliferation — cancer
 - b. psychologically important environmental impact
 - c. many (most) people carry personal tragedies from cancer
 - 1) a major tool against industrialization
 - 2) Delany clause prohibits any carcinogens in food additives, no matter what the trade-off
 - d. *pattern* of cancer implies environmental causes ... bad water, air, etc.
 - e. specific chemicals, exposures are linked to cancer in humans (they are *carcinogens*): smoking, asbestos, radon, formaldehyde, etc.
 - f. animal models suggest more: Ames test, rodents
 - g. identifying impact of carcinogens on humans is currently almost impossible, for four reasons:
 - 1) Are there thresholds below which carcinogens have no effect; that is, what is the shape of the tail of the dose-response curve? If so, we need not control low exposures as carefully as high exposures.

- 2) Which animal models are appropriate for humans? Guinea pigs and rats respond differently by a factor of 1000's to dioxin ... we don't know at all about humans
- 3) Background carcinogen levels may be very high ... 1 g per day of natural carcinogens from plant pesticides?
- 4) Statistical methods cannot identify significant increases in a very rare event ... we are measuring "excess deaths" above 'background'. A relatively large clustering of a rare event, or a small increase in a common event, can be mere chance.

XXIII. RISK

It matters how dangerous environmental changes are ... it matter more how dangerous we think environmental changes are.

A. The risk concept:

1. we *make decisions*, to *avoid* or *accept* environmental (and other) situations because we are concerned that they will hurt us physically, economically, or psychologically
2. thus our behavior can be thought of as choosing (or rejecting) *risks*
3. our responses to risk are *very* different for different risks of the same magnitude (that is, two things with equal chance of harming you are not equally scary)

B. Measuring risk

1. necessary before we can compare them scientifically
2. insurance companies do it all the time: *probability* (from previous experience) x magnitude of loss ... your car insurance
3. for health (sorry ... this is pretty clinical-sounding):
 - a. chance of death
 - b. loss of *years* of life, or quality of life
 - c. in law: loss of life-time earnings (rich people's live are worth more?), or "pain and suffering" ... \$1,500,000,000?
 - d. a (facetious) concept: the "micromort": what you get from an activity which increases your chance of dying by 1 in 1,000,000.
 - 1) 1.4 cigarettes, 6 minutes in a canoe, 150 miles in a car, 1000 miles in a jet, 1 pint of wine, 40 tablespoons of peanut butter
 - 2) ignores length of life lost, but permits us to compare mortal risks

C. How can we measure the value of a human life?

1. obviously it is valuable beyond price, *but* ...
2. people will "sell" micromorts
 - a. increase in pay to take an equivalent job with increase risk
 - b. comes to about \$4.80 per micromort, equals \$4,800,000 per life
 - c. the last micromort is worth more than the first, of course ...
3. investment to avoid loss-of-life ... standard (& inevitable) engineering decision

- a. a million dollars was a rule-of-thumb a few decades ago
- b. but Ford got into trouble over the pinto for using a number
- 4. (but this is statistical ... we cannot easily stop paying for a real person)
- D. When do we value micromorts more highly (that is, what risks *seem* biggest)?
 - 1. high regret (large or very noticeable losses at one time) — plane crashed
 - 2. involuntary — living next to a chemical plant
 - 3. hidden — chemicals, radiation
 - 4. dreadful — cancer, nuclear war, environmental collapse
 - 5. not helpful — unlike medicines, e.g.
 - 6. new — renting a car with bad brakes, versus not fixing my own
 - 7. unfamiliar
- E. What is the effect of this on policy?
 - 1. decisions are conservative, favor specific people, ignore voluntary risks,
 - 2. rational consideration of trade-offs not possible under many situations ... \$40,000,000 / micromort for hazardous waste cleanup?

XXIV. SUSTAINABILITY

Can we assure that future generations get opportunities like those we had?

- A. Definition of sustainability:
 - 1. Standard definition: “The ability to meet present needs without compromising those of future generations”.
 - 2. comparative ethical perspective
 - seventh generation
- B. Practical limits of the idea
 - 1. the physical problem .. any change or use is a future loss
 - 2. the cultural problem .. do we know what they want
- C. Sustainability as a societal endeavor:
 - 1. we cannot solve isolated pieces of a broad problem.
 - 2. sustainability has social, economic, as well as environmental components
 - 3. topical closure: an environmental choice exists within a cultural system, and cannot be considered independently; sustainability of this system underlies the human future.

XXV. FINAL THOUGHTS

... On The Human Environment

- A. Why go on? Isn't it hopeless?
 - 1. Yeah, but it always was. We've been about-to-be-overpopulated since Malthus, about-to-run-out-of- petroleum since 1965, and so forth. There's time.

2. Organisms in the environment may be more resilient and adaptable than we can imagine. Trees grow in cracks in the sidewalk; humans thrive in Calcutta.
 3. The world is new to each newborn. We see an open, natural world in the forest or fields that have been drastically altered since 200 years ago; what will our children see?
 4. Humans may pass, but the earth abideth forever. There will be shadbush blooming in the mountains in 10,000 years if we figure out how to live sustainable or if we finish ourselves off. (Is this cheering you up yet?)
 5. If we are depressed it is because we love the world and its beauty; depression isn't a reason to stop.
- B. Understand what is particular about human responses to these problems. We see specific aspects of human psychology that moderate our responses:
1. "tragedy of the commons" affects our abilities to think of the needs of others
 2. a billion years of evolution prepares us to fear quick, personal harm – a tiger, stinking water – but not slow, indirect, subtle harm – ozone depletion, carcinogens, lost of biodiversity, too many babies.
 3. .the scale of human life means we don't even see some problems:
 - a. the slow .. soil erosion
 - b. the distant in time or place (hazardous wastes, starvation in Africa)
 4. "risk perception" minimizes some problems & increases others:
 - a. nuclear accidents and cancer are scary, extinction isn't.
 - b. reasons to not change may exceed concerns about significant risks: staying in Centralia, or living on a floodplain
 5. the more people around, the more reluctant we are to act as individuals: It's someone else's problem.
 6. we'll solve the easy, obvious, cheap, annoying, local problems first.
- C. How do we solve environmental problems?
1. Understand what is particular about these problems.
 - a. Limits to our understanding of global change:

(Adigest from Stern, Paul C., et al., Global environmental change: understanding the human dimension, ©1992, National Academy Press.)

The earth has entered a period hydrological, climatological, and biological change that differs from previous episodes of global change in the extent to which it is of human origin. Human and environmental systems meet in two places: where human actions proximately cause environmental change, that is, where they directly alter aspects of the environment, and where environmental changes directly affect what humans value.

Humans threaten to alter the global climate by releasing so-called greenhouse gases.

CFCs already in the atmosphere are expected to cause significant reduction in stratospheric ozone over a period of several decades.

Human activities are decreasing biological diversity on land, in fresh waters and the seas, in industrialized and developing nations, from the coldest inhabited lands to the tropics.

Large physical and biological systems exhibit a number of characteristics that present a number of challenges to those endeavoring to understand them. They require advances in scientific concepts, theories, and methods beyond those typical of existing disciplines.

Complex interdependencies exist both within and between environmental systems. Changes in one part of the earth's environment can have effect in surprising places.

Global environmental systems frequently exhibit nonlinear responses. Mathematical models of global processes demonstrate that, under certain conditions, small perturbations in environmental systems can have large effects.

Environmental systems can undergo irreversible changes. The clearest example is the extinction of species.

Long lag times are common in environmental systems. CFCs released into the atmosphere migrate into the stratosphere, where they are broken down by sunlight over a period of decades to centuries.

Global environmental changes can result from the interactions of local systems with each other and with larger-scale systems. Understanding of the biosphere may need to be built up from knowledge of smaller spatial scales, such as ecosystems or biomes.

These characteristics of the global environment present serious challenges for scientific research. The nature of the global environment also raises doubts about the value of existing scientific disciplines for understanding global change.

2. HUMANS AND ECOSYSTEMS (Quotes are from G. Tyler Miller):

- a. "The ecosystem is not only more complex than we think, it is more complex than we can ever think."
- b. "Everything and everyone are all interconnected. Function within the ecosystem with a sense of cooperation rather than domination."
- c. "Everything we have has come from the earth or the sun. We cannot sustain ourselves by depleting the earth's capital.
- d. "We can never throw something away, we can only through it somewhere else."
- e. The biotic potential is unlimited; we can expand enough to exceed any limit.
- f. Higher levels of consumption create higher levels of trouble.

D. What can a person do? What is the nature of the problem?

1. Engineering: what technology would help?
2. Policy: how do we help the common good?
3. Ethical: why do people act as they do?
4. Research: what do we know?
5. Educational: what should others know?
6. Economic: how can resources be available?

7. Narrative: how can people come to understand their world more clearly
- E. Ask whether we have the ethical framework to address the problems:
What rights do animals have? What rights does a tree have? How does Christianity regard the environment? What do other peoples teach us about the world? Are animals more important than the ecosystem they are in?
- F. And then the politics
... in which realm, environmental concerns on but one of the competing issues: hunger, fairness, strategic and economic security must also “win”. But that’s another course.