Welcome to..

LA12 Environmental Science for Sustainable Development

Chicago, oblique aerial view north of downtown and Lake Michigan
(Photo by Kondolf)

Instructor:
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GSIs:
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NOTE: Classes at Berkeley start 10 minutes after the scheduled time

Course Structure

Weeks 1-9:

Unit 1. Environmental Science

Earth, energy, climate

Water

Urban forests & ecosystems

Food, soil, health

Lab exercises

Weeks 10-14:

Unit 2. Sustainability Strategies

Energy cycle

Urban infrastructure

Group term project

Course Structure

Lectures Tu & Th 1230 Pacific time ***online***
(lecture slides and recordings posted online)
Labs each week: Lab exercises, term project ***in person***
*Lab sections begin **next** week*
Bi-weekly quizzes, short tests after each unit

*Homework for next week: **3 things**:*
Review the syllabus and take the syllabus quiz any time between 1200 Monday and 1200 Tuesday (Pacific time)

Environmental Science autobiography (1-2pp) due Monday at 5pm

Watch the film ***An Inconvenient Truth*** before lab section

Today's Lecture:
Overview, Population, Ecological Footprint

Some key concepts

- Sustainability – what do we mean?
- Environmental impacts of humans related to population and rate of resource consumption/pollution
- Population growth rates and the demographic transition
- Global change (climate + direct human alterations)
- Ecological footprint

Major themes

- Energy/Earth Systems, Water, Ecosystems/Food, Sustainability
- Increased energy use, fossil fuels and impacts, alternative sources
- Increased demand for freshwater, human/ecol health
- Food production/distribution inefficiencies, impacts

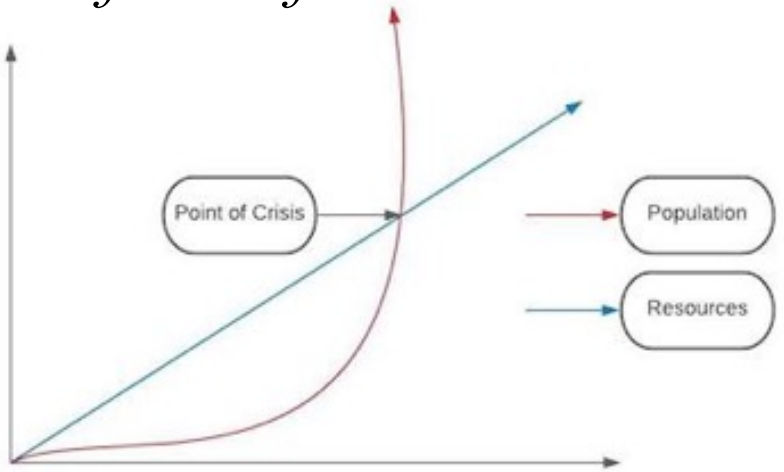
Population

The prophecy of Thomas Malthus (19thC)

- Humans need food
- "Passion between the sexes" remains strong, thus continued high birth rates
- Capacity of earth to produce food is limited
- Result: more people than food to support them

"Gigantic famine stalks in the rear, and with one mighty blow, levels the population with the food of the world."

Was he right or wrong?

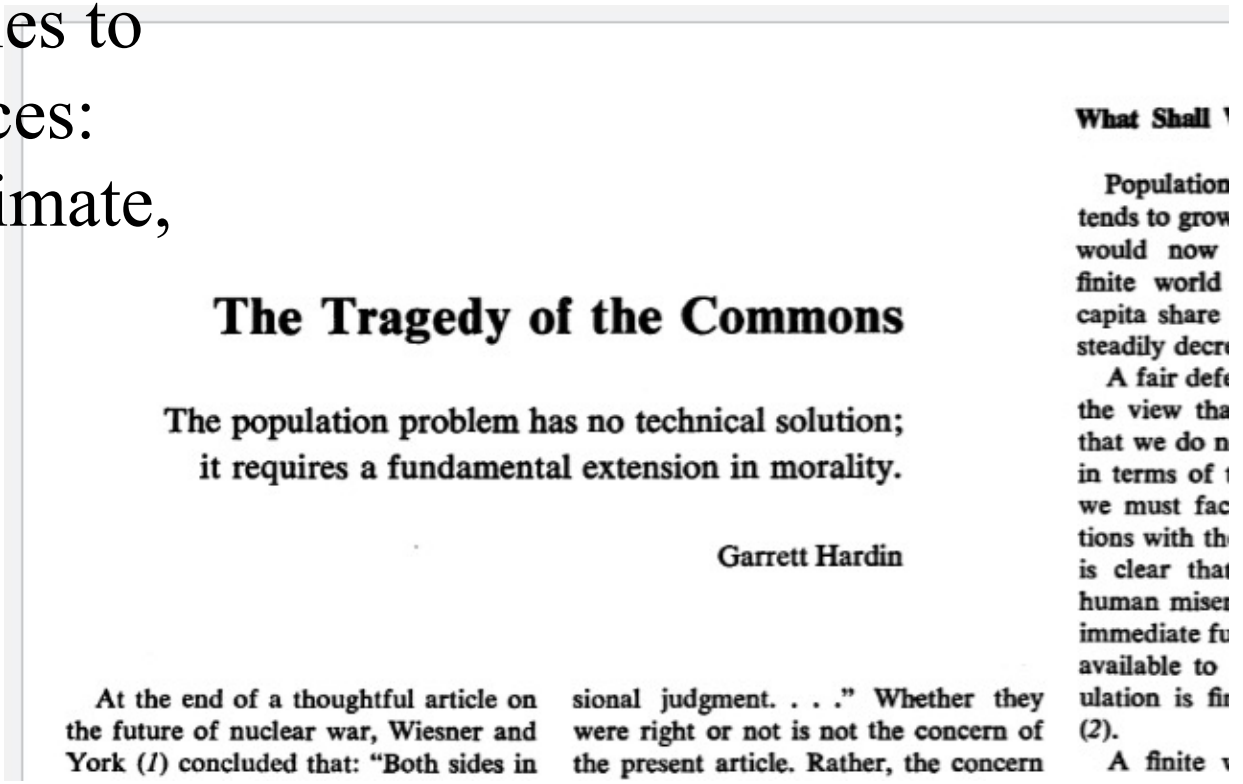


‘Tragedy of the Commons’

Individuals using a shared resource may over-exploit the resource through selfish action, resulting in loss of the shared resource. First proposed by WF Lloyd in 1833, using common pastures (‘commons’) as an example.

The principle applies to many other resources: fisheries, forest, climate, Etc

Garrett Hardin’s influential 1968 paper in *Science*



The Tragedy of the Commons

The population problem has no technical solution; it requires a fundamental extension in morality.

Garrett Hardin

At the end of a thoughtful article on the future of nuclear war, Wiesner and York (*1*) concluded that: “Both sides in

sional judgment. . . .” Whether they were right or not is not the concern of the present article. Rather, the concern

What Shall

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(*2*).
A finite

Some decisions make sense for the individual, but maybe not for larger society. Motor scooters (2-cycle engines!) in the parking lot at Sun Yat Sen University in Taiwan.

When human populations were small and dispersed, their impact on the landscape was minimal, human traces were minor

A Quichua garden (called a “chakra”) created by clearing a patch in the rainforest, planting vegetables among the downed trees to grow in the soil nutrients. Chakras were abandoned after several years, new ones cleared. Sustainable only with low population densities.

A Bedouin encampment in the Negev desert:
nomadic pastoral agriculture.
1000s of years of livestock grazing degraded the landscape.

Chicago, oblique aerial view north (Photo by Kondolf)

Contemporary western society: concentrated urban centers require massive inflow of resources from surrounding region.

Some past complex civilizations have collapsed.
e.g., the Mayan settlements of Tikal

With larger populations and increasing industrialization, human impacts on the environment have increased

Nicholas D. Kristof/The New York Times

In Jambi, Indonesia, schoolgirls in uniform walk home through the pervasive smoke from forest fires.

Asian Pollution Is Widening Its Deadly Reach

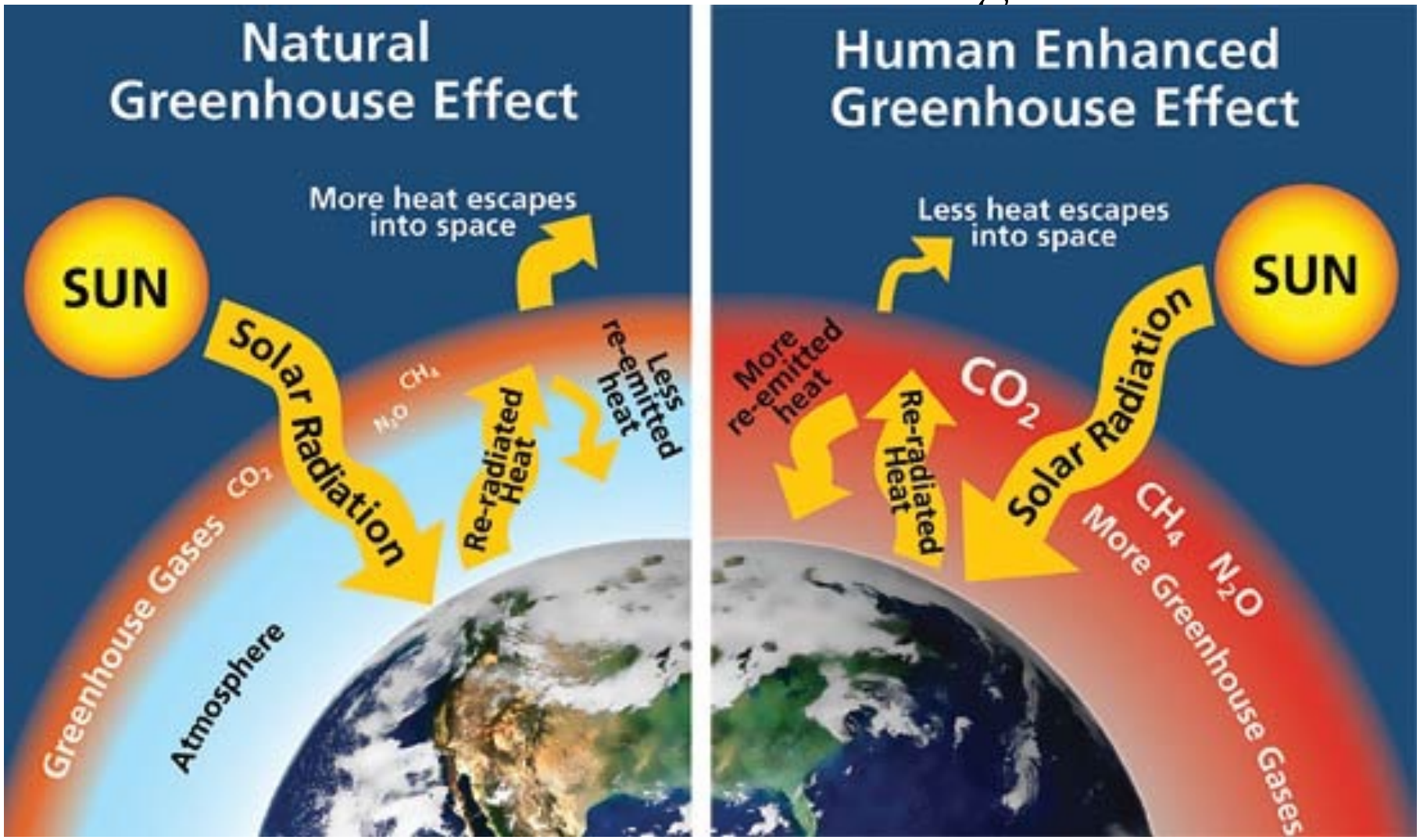
This is increasingly manifest especially in Asian megacities…
(as we'll see in the film *Under the Dome*)

Human effects on the environment are now global in scale:

Greenhouse gases (GHGs) and climate change
Resulting sea level rise
Depletion of ozone
Acid rain
Greater climatic extremes:
- Water shortages
- More intense storms
- Heat waves

Ecosystem damage

CO2 and climate change



The greenhouse effect and its intensification by increasing greenhouse gases (some are also 'ozone depleting chemicals') in the atmosphere are presented in detail in the film *An Inconvenient Truth* and elsewhere.

Global warming well explained in the 2006 film *An Inconvenient Truth*

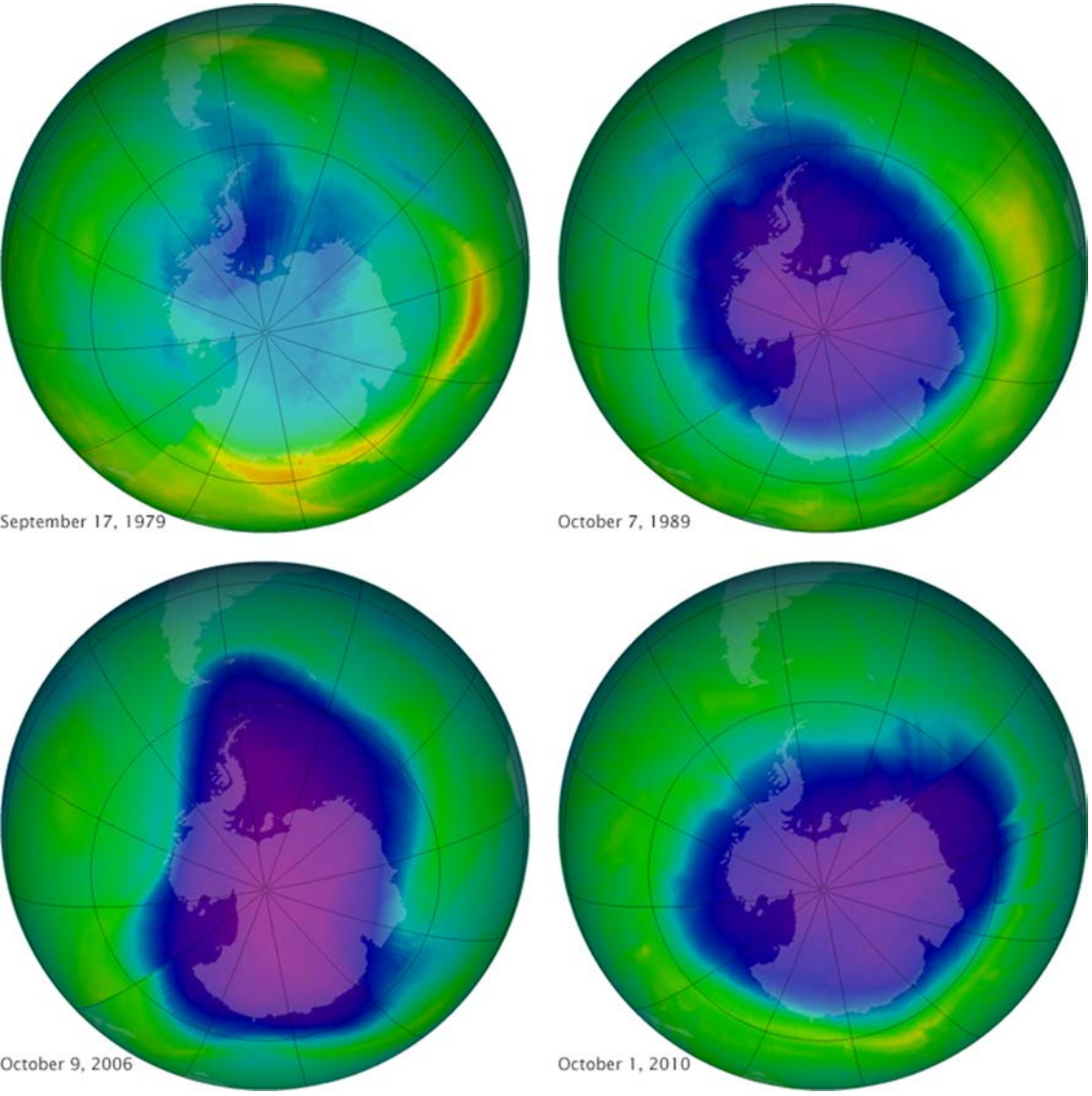
Watch it before your lab session next week.

Good explanations.
Also an important film culturally, politically, and historically.
Very influential to many people.

Ozone Layer

- **The ozone layer is located in the stratosphere, 10 to 50 kilometers above Earth's surface.**
- **This blanket of gas absorbs the sun's UV radiation, which can damage DNA, cause skin cancer, etc.**

The Hole In the Ozone Layer



Ozone measured in “Dobson Units” (DU)

Prior to 1979, scientists had not observed concentrations below 220 DU.

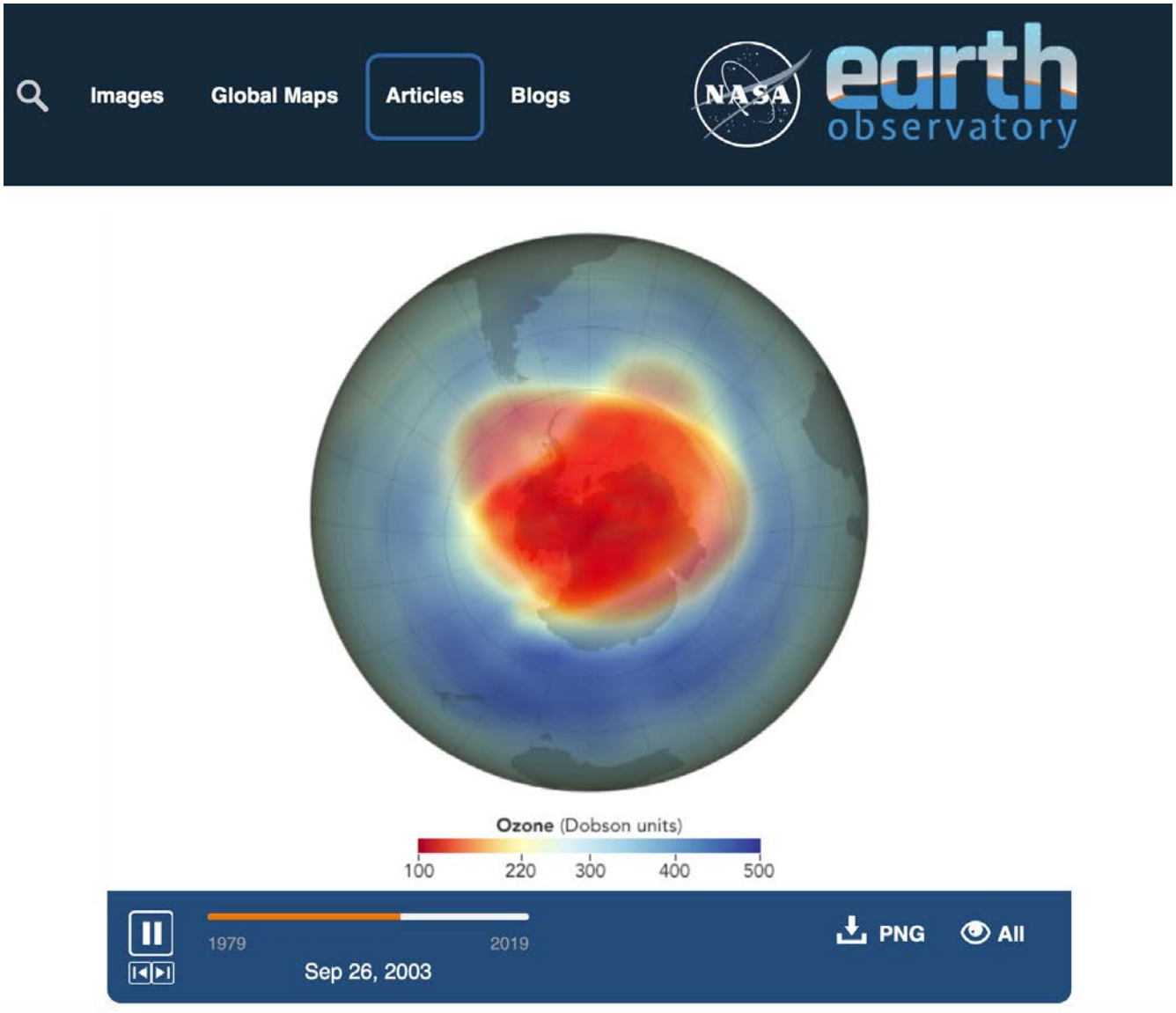
In 1985, scientists found a ‘hole’ in the ozone above Antarctica caused by ozone-depleting chemicals such as CFCs.

Ozone concentrations below 100 DU have been common since 1991.

https://ozonewatch.gsfc.nasa.gov/monthly/SH.html

Montreal Protocol

- The 1987 **Montreal Protocol**, an international agreement, banned the use of these ozone depleting chemicals, and significantly dropped the level of ozone-depleting chemicals in the atmosphere.
- As a result, the “hole” over Antarctica has been shrinking!

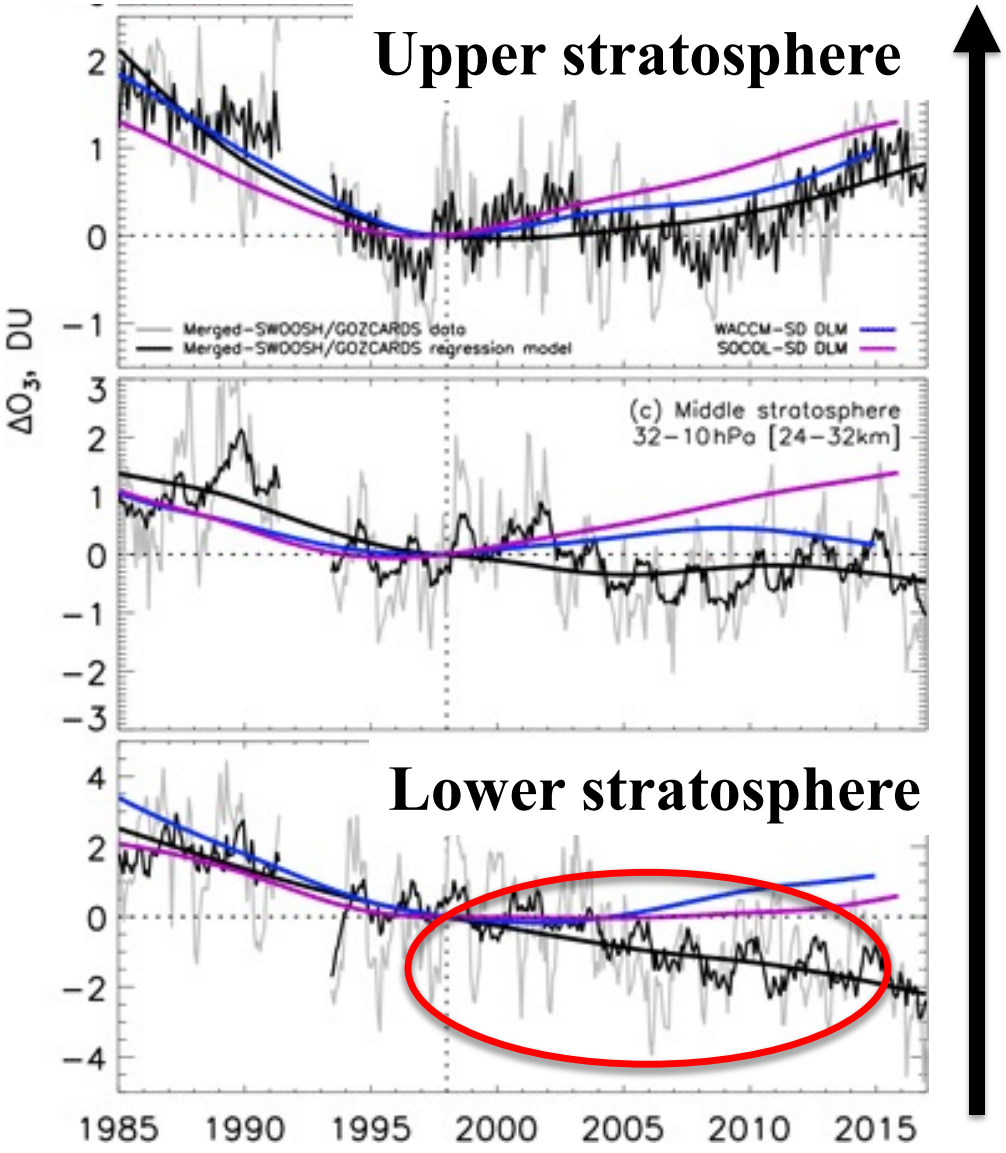


Watch the evolution of the ozone hole over Antarctica at *https://earthobservatory.nasa.gov/world-of-change/Ozone*

BUT

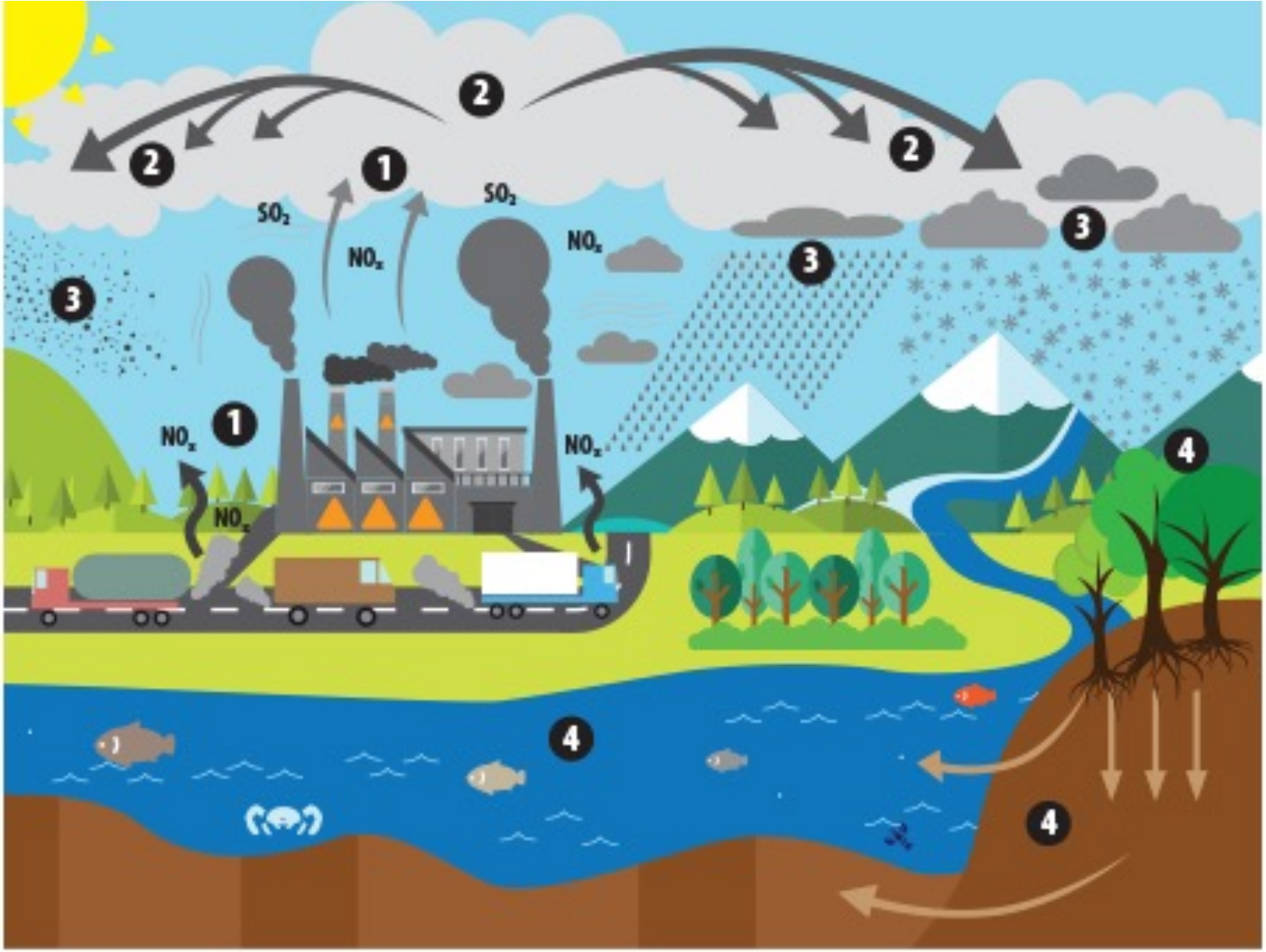
While the upper ozone layer is recovering, the ozone in the lower stratosphere continues to decrease (though at a much lower rate) (Ball et al., 2018)

The cause of this is unknown.



Acid Rain

Fossil-fuel power plants, industry, and vehicles emit:
Sulfur dioxide SO2, *nitrous oxides* Nox
These react with H2O, O2 to form *sulfuric and nitric acids,*
which are carried downwind to fall as acid rain.



This image illustrates the pathway for acid rain in our environment:
(1) Emissions of SO_2 and NO_x are released into the air, where (2) the pollutants are transformed into acid particles that may be transported long distances. (3) These acid particles then fall to the earth as wet and dry deposition (dust, rain, snow, etc.) and (4) may cause harmful effects on soil, forests, streams and lakes.

Source: EPA.gov

Water Resources

Increased development and population results in increasing use of water resources, environmental discharges to water, degradation of aquatic ecosystems. Today, over 800 million people don't have access to clean water.

Deforestation

https://www.sciencenews.org/article/tropical-forests-have-flipped-sponges-sources-carbon-dioxide

Clear-cutting tropical forest ecosystems – not only damages ecosystem, flora and fauna, but can also flip a carbon “sink” to a carbon “source”

Solid waste

Recycling helps but there's a *lot* of plastic out there, much non-recyclable.

China recently stopped accepting waste plastic, throwing US recycling into chaos.

Bales of plastic are piled at a Recology facility in San Francisco. (Alana Semuels / The Atlantic)

Again, it's not only how many people but also how big an impact per person. In the US, we use a lot of plastic

The city of Cairo: around 20M, growing rapidly

Due both to births and to immigration from rural areas

Until recently, the Sphinx was in the desert many miles outside the limits of Cairo.

But today, it's nearly engulfed by expanding urbanization of Cairo

Cultural and religious resistance to population control: Families prize their children, and in Egypt, religious leaders preach against population control as a western plot to limit Arab populations.

But it's difficult for the country to support such a growing population. Half of the national budget goes to subsidize food imports.

The Global Village

Shrinking the Earth's population to 100 people, with all existing ratios remaining the same: 57 Asians, 21 Europeans, 14 Western Hemisphere (North & South), and 8 Africans

-- 70 non-white; 30 white

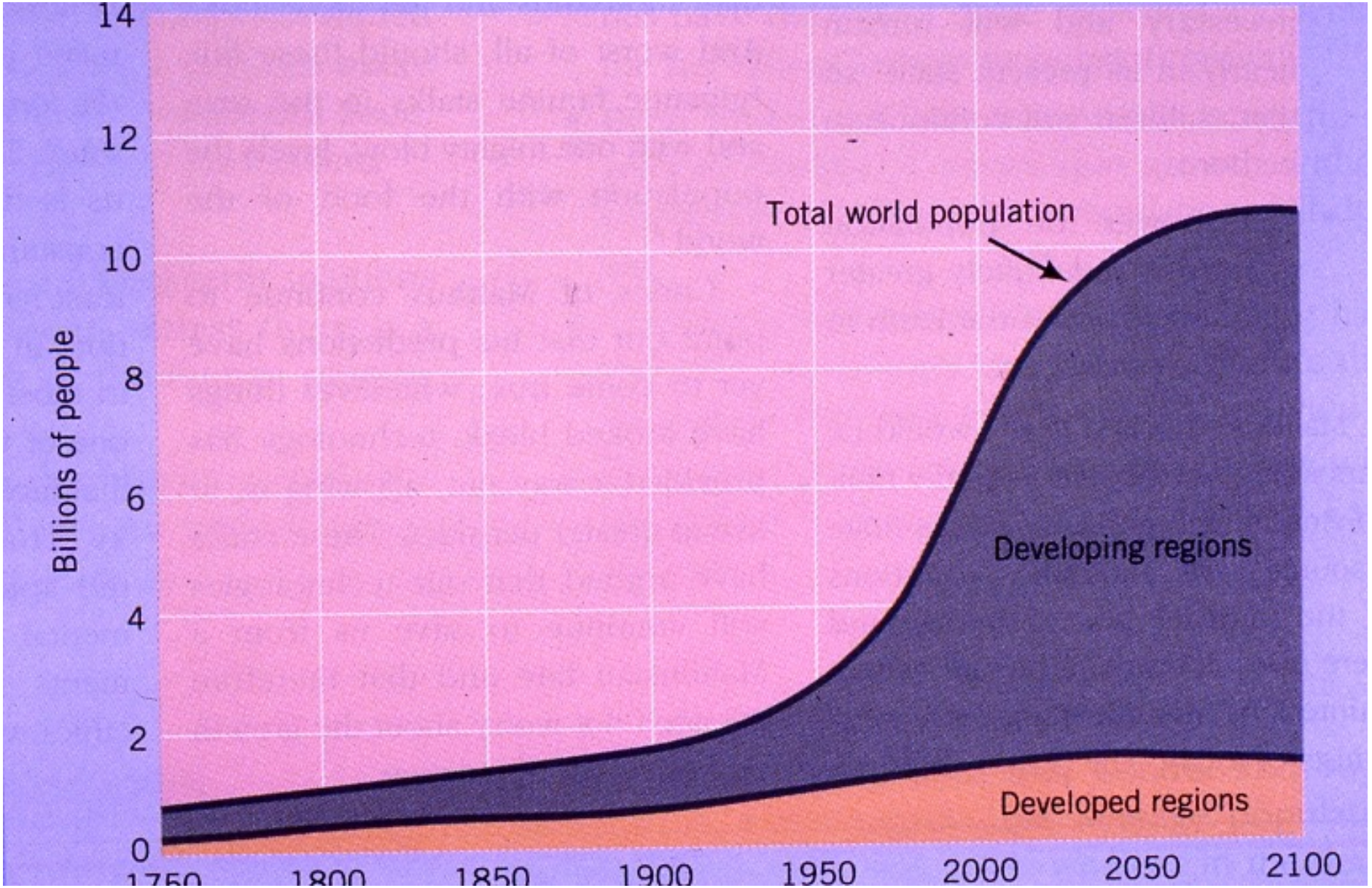
-- 70 non-Christian

-- Only 1 has a university education

-- 70 unable to read

-- 50 suffer from malnutrition

-- 80 live in sub-standard housing



The big increase in population is in developing countries, countries least equipped to support large populations

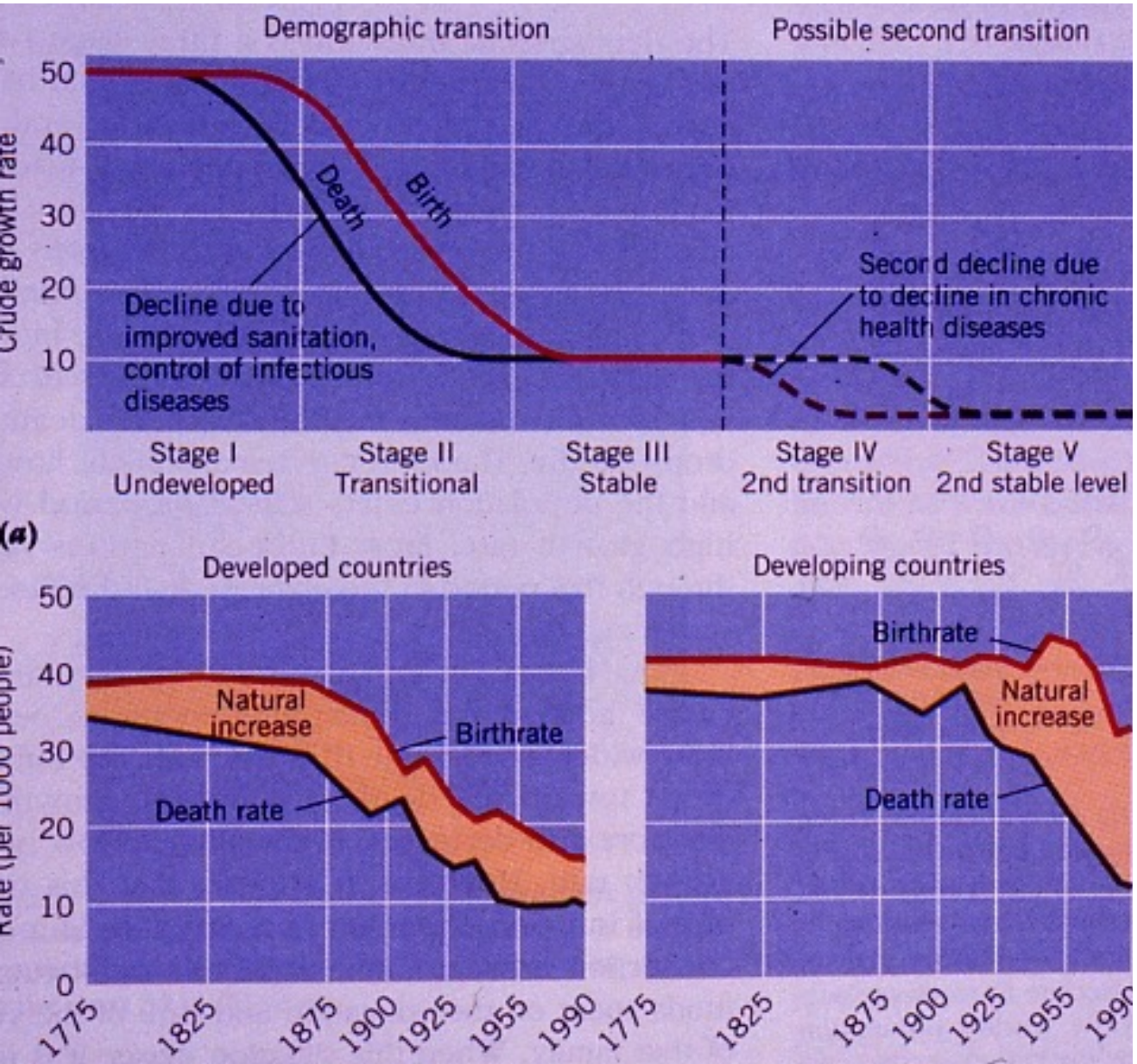
Equation for population change

$$P2 = P1 + (B-D) + (I - E)$$

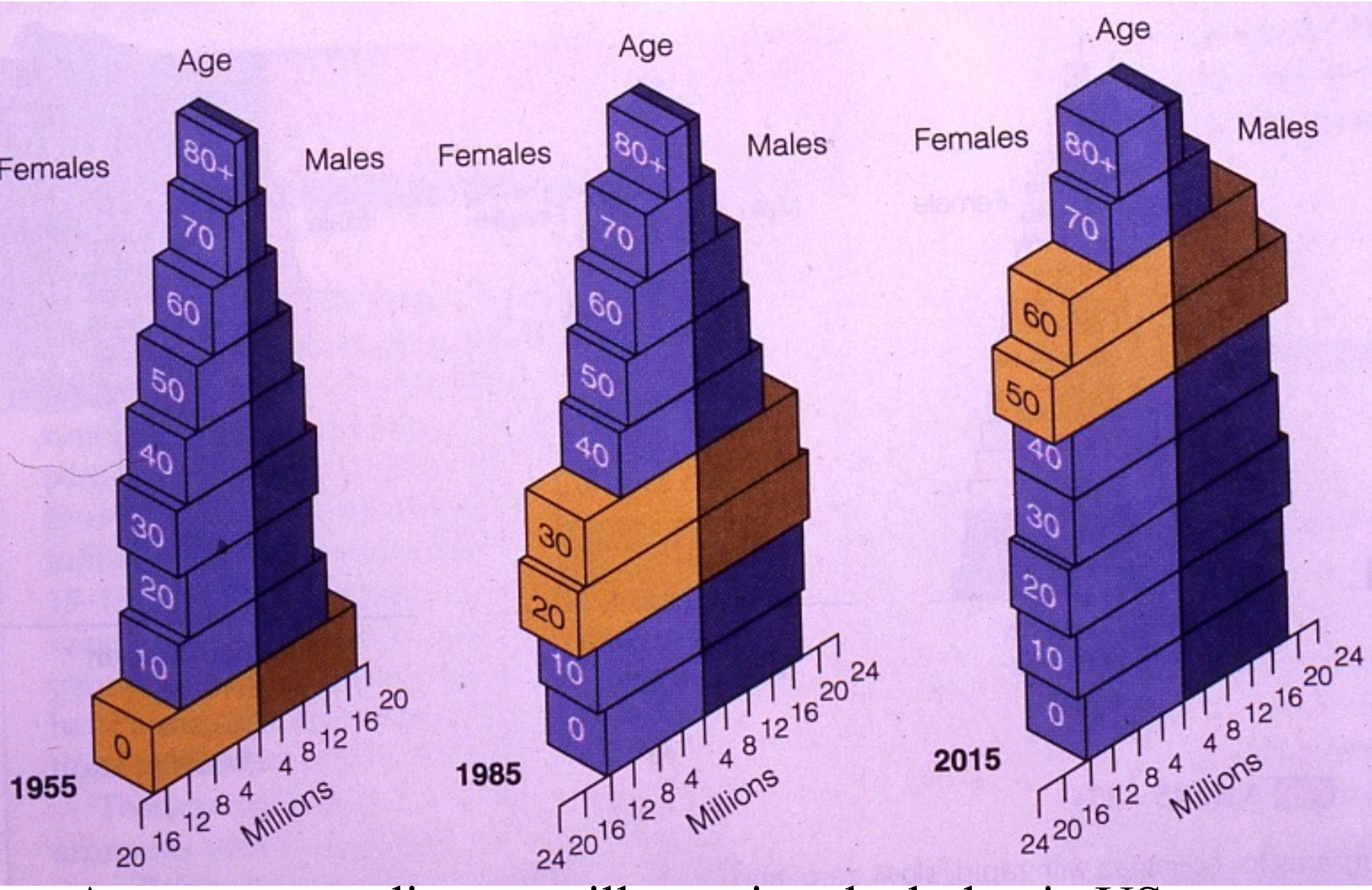
P1 and P2 are populations at time 1, 2
B = births
D = deaths
I = immigration
E = emigration

The Demographic Transition

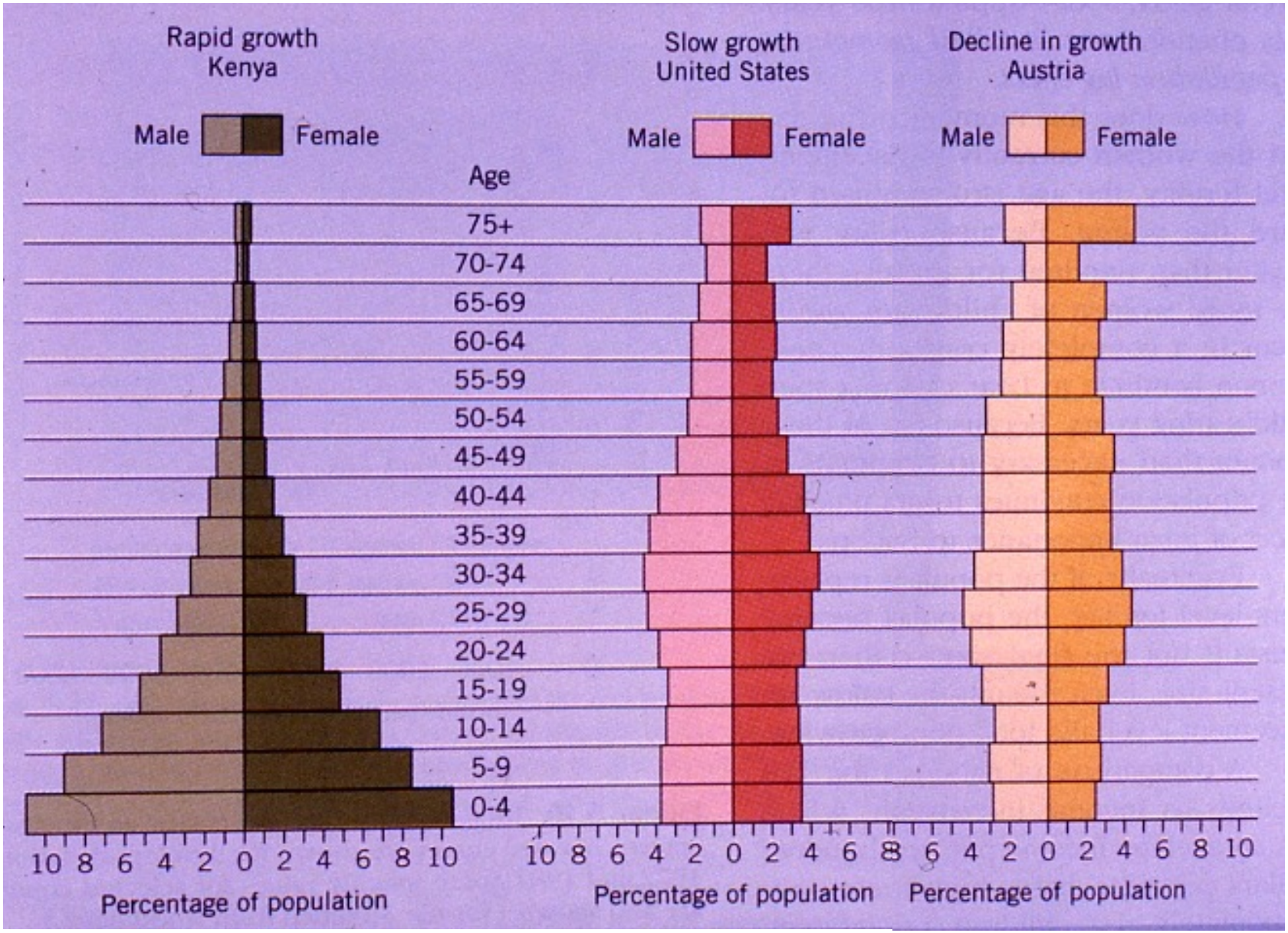
as countries go from developing to developed



As nations develop, improved nutrition and medical care first causes the death rate to decrease, while the birth rate is still high. Then evenutally, couples have fewer children, but invest more in each child.

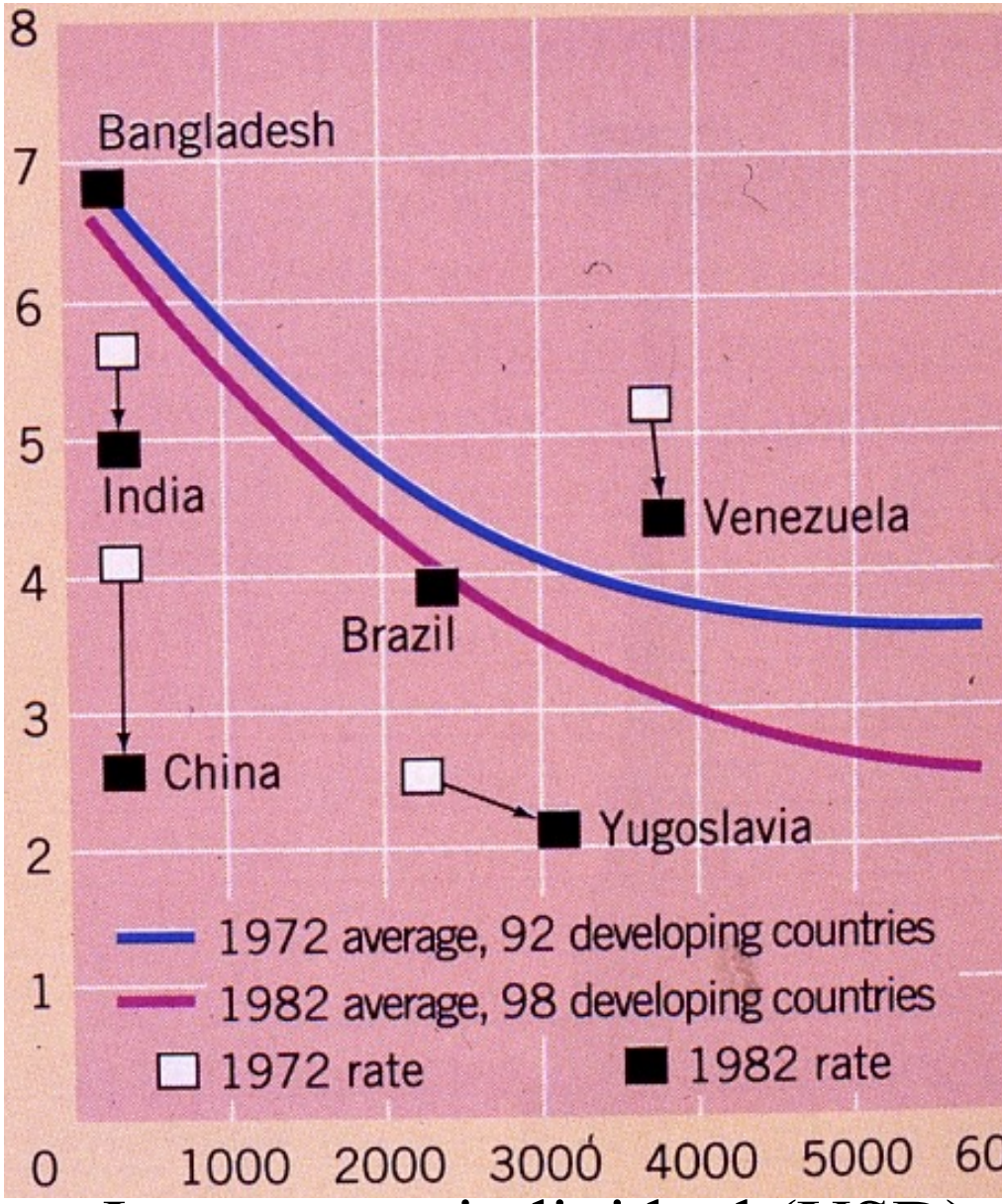


Age-structure diagrams illustrating the bulge in US population from the 'baby boom' after WW2



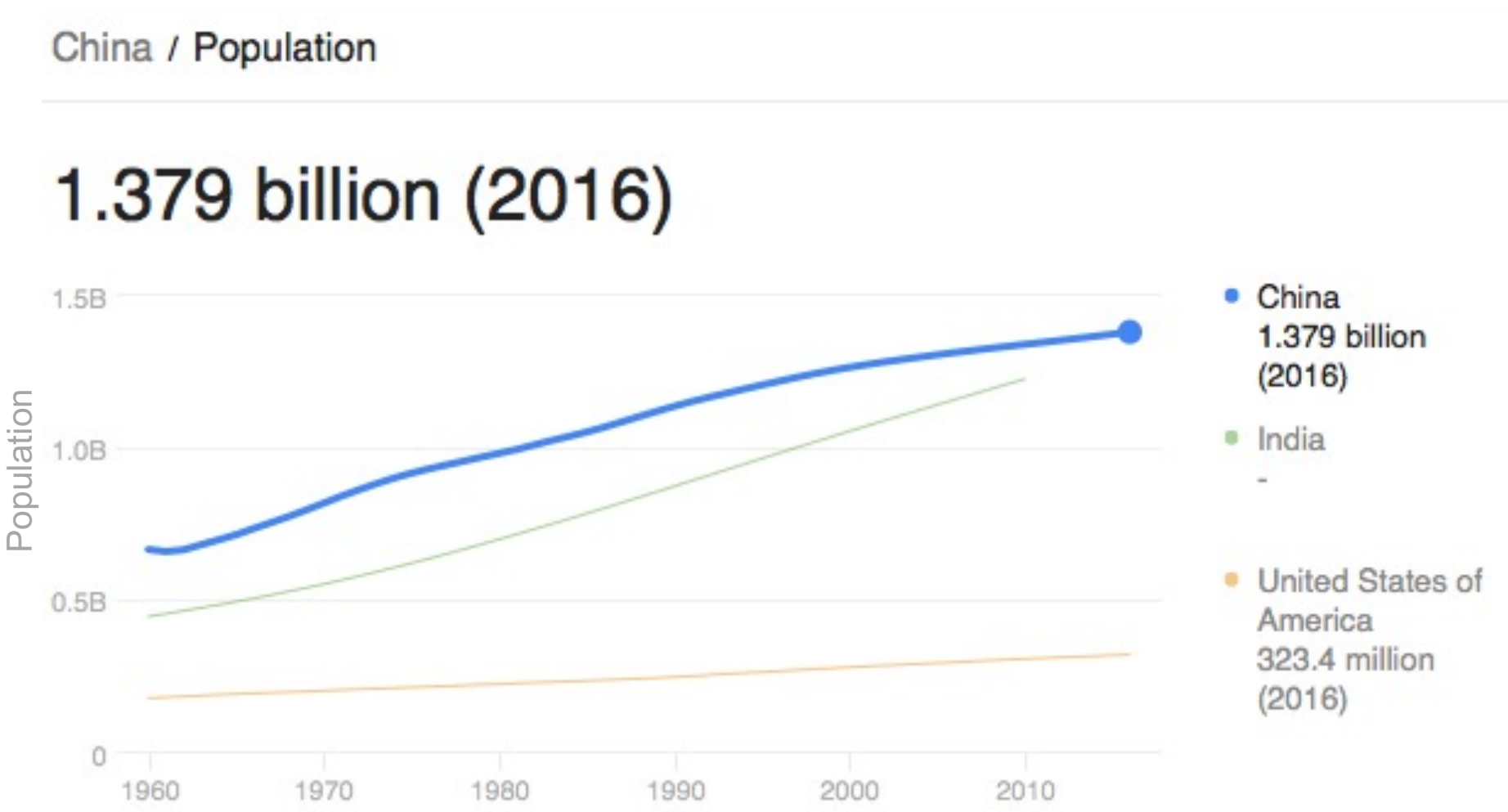
Characteristic age structures of developing countries and developed countries.

As per capita income (a surrogate for development) rises, fertility rate normally goes down.



While there are reasons that governments would like to limit population growth, it is difficult to do in practice. Only China, with its strong central government and enormous existing population (1.4B) has imposed limits on families.

Poster in Chungching, China, extolling the virtues of the one-child family.

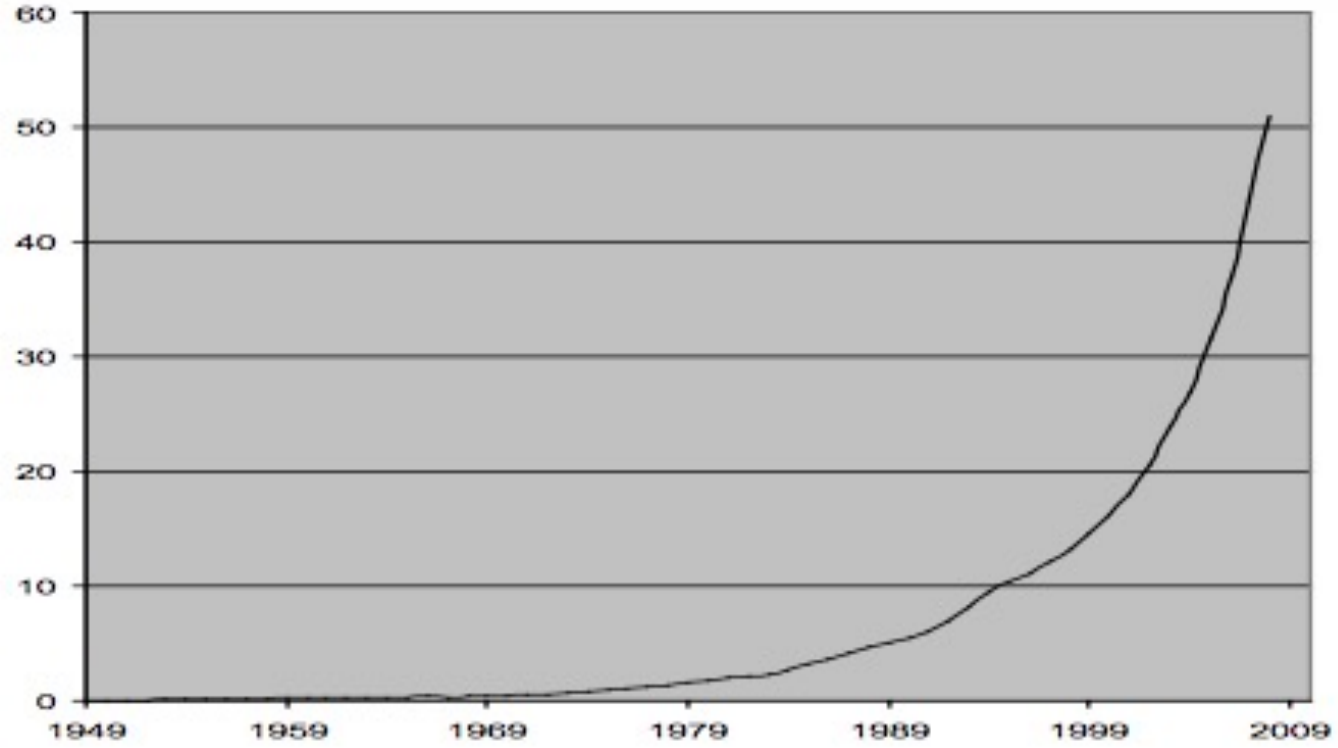


As a result, population growth in China has been much slower than that of countries like India.

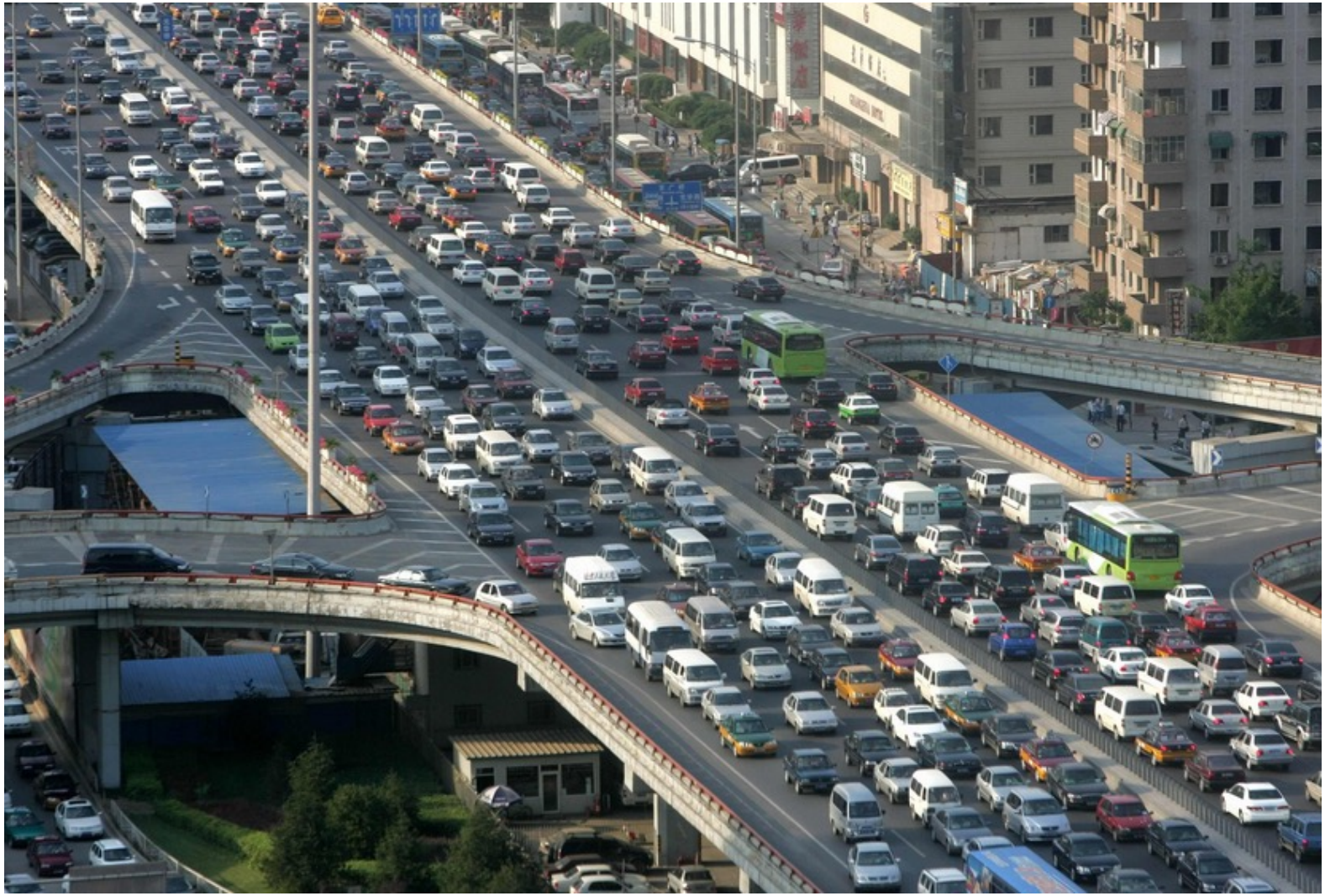
In Chinese cities, population is densely concentrated. Formerly, most people got around on foot, bicycle, or public transit.

Formerly, the streets of Chinese cities were filled with bicycles. This was a sustainable way to get around! But…..

Private cars in China (millions)

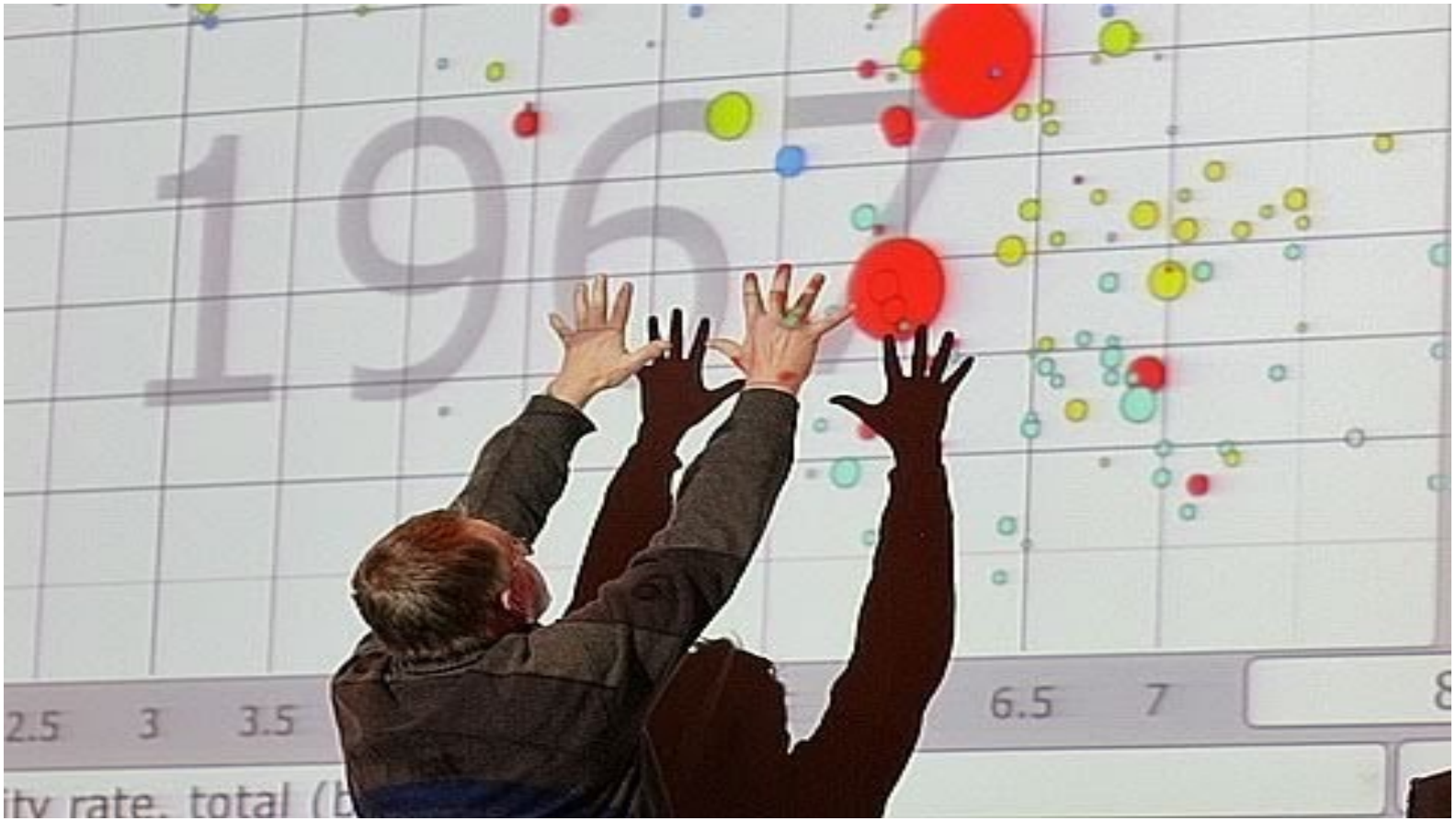


But it's changing – ***fast***. Private car ownership increased from less than 1M in 1970 to over 50M in 2008, and of course, it's still rising fast. By this year, there were projected to be nearly 240M cars in China, making it the world's biggest car market, surpassing the US.



The result: traffic jams. (Beijing)

Update on global population: changes in infant mortality rates, incomes, etc. presented by Hans Rosling, a Swedish scientist who presents data very effectively)

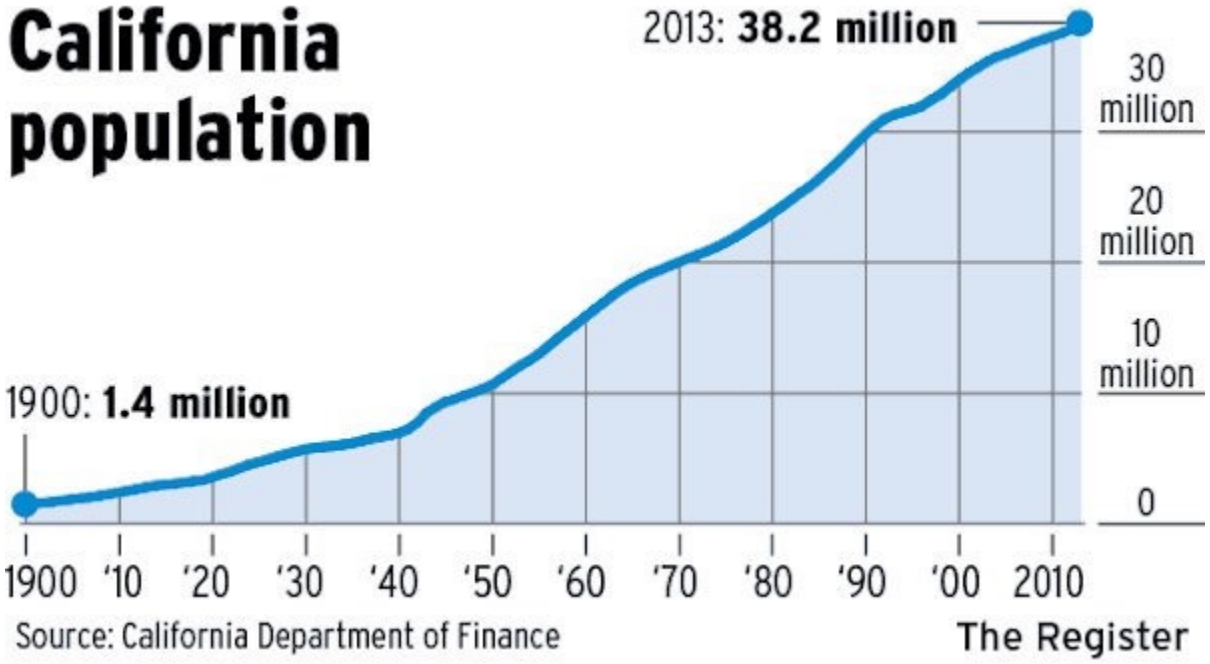


https://www.youtube.com/watch?v=hVimVzgtD6w

Urban form has a tremendous influence on the success of mass transit, use of bicycles, etc. Where population density is high, you can support mass transit.

Where population density is low, as is the case in most of the US (even so-called “cities”), transportation is mostly by automobile. As a result, the environmental footprint of each American is much larger than that of residents of most other nations.

And urban sprawl continues to extend into previously undeveloped lands.



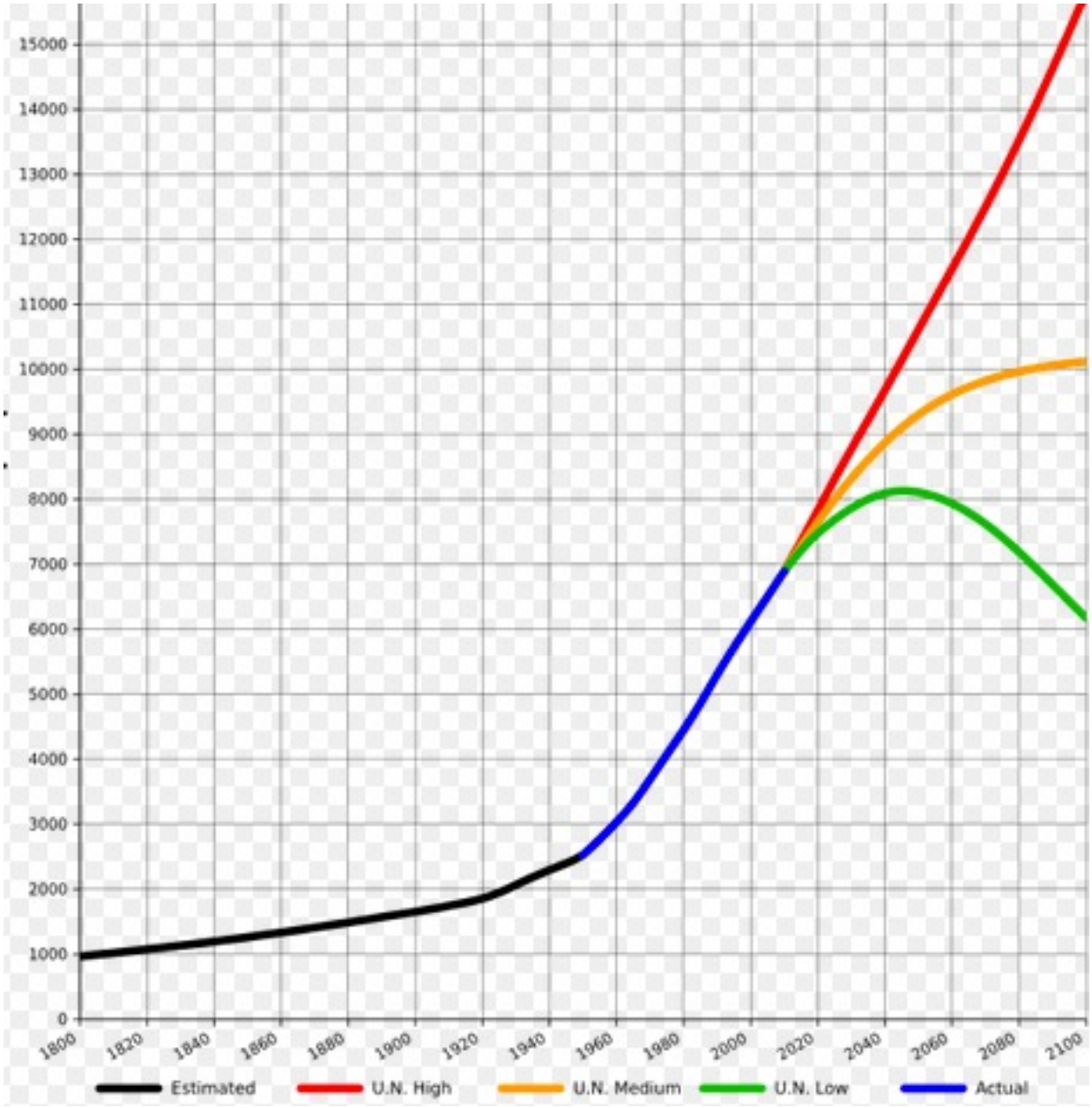
- 2000 census: 34 million
- 2010 census: 37.3 million
- 2017 census: 39.5 million
- 2050 projection: 52.7 million

Projections of an >50 million people by 2050! Where will these additional people live? Can we meet their needs for food, water?

Carrying Capacity:

What is the maximum number of people that the earth could sustain?

World population (Millions)



Earth reached 7.6 billion popuation in 2018.

What trajectory for the future?

Key differences in environmental impact

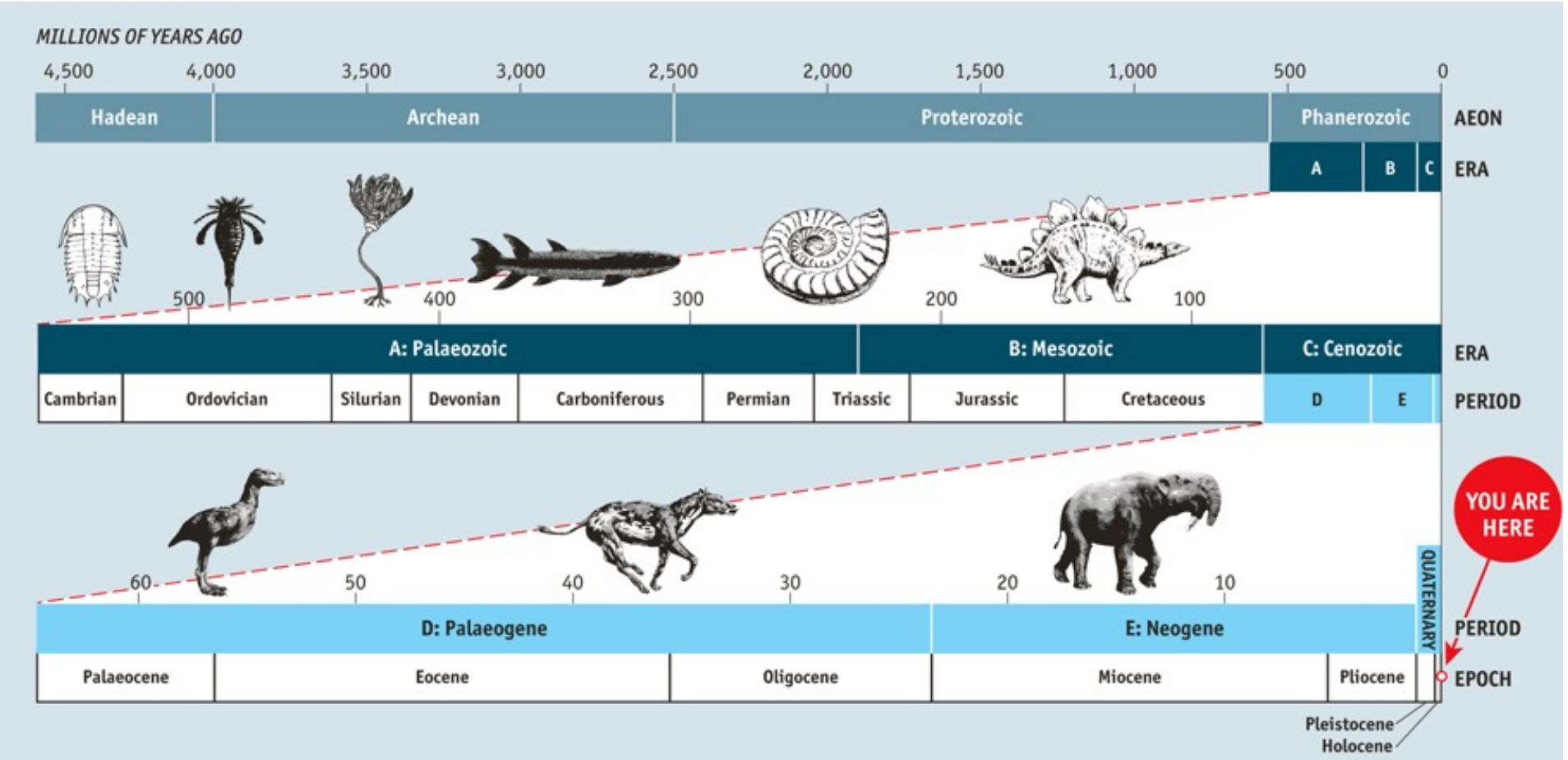
1. Population density
2. Resource consumption
3. Efficiency of energy generation
4. Types and cleanliness of energy generation

The leaf-blower as a symbol of American energy use
(and lack of exercise!)

Dependence on the gasoline-powered automobile

“The Anthropocene”

Proposal to designate the current period, when human activity is the dominant influence on the environment, as Anthropocene. (usually taken to have started in the 19th century)



Times Scales

Human disturbance of the landscape now greater than natural processes of earthquakes, hurricanes, fires, landslides, river transport. We have altered flood patterns, flattened mountains, dredged land…

Human experience is limited in space and time.

It's hard for us to believe earthquake, tsunamis, etc, will occur. Thus we are unprepared for these events.

Table 1 Time scales of natural hazards and human perception (roughly approximated time scales based on reported return periods for natural hazards and other sources)

Natural hazard	Time scale (years)	Human perception	Time scale (years)
Earthquake and tsunami, Japan[a]	450	Human life[e]	70
Strike-slip earthquake, Hayward Fault, California[b]	50–100	Typical planning horizon for real estate development[f]	5–10
Hurricane, New York area[c]	25–50	Term of office, elected official[g]	2–4
Hurricane, southeast Florida[c]	5–7		
Major fire[d]	5	Government budget[h]	1
Cold weather in northeast/Midwest US[d]	2	Attention span of media[i]	0.02

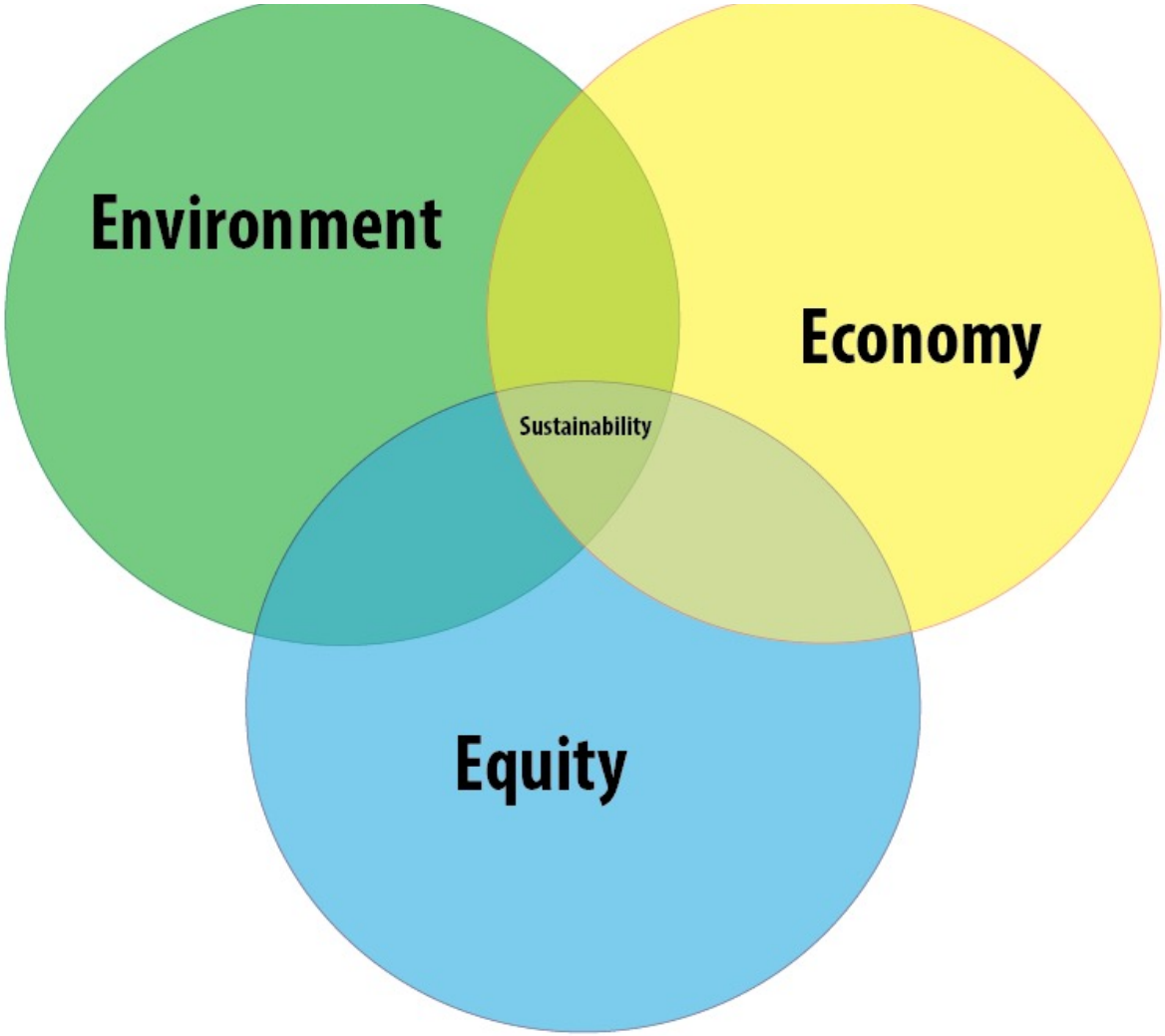
From Kondolf & Podolak 2013, *Space and Time Scales in Human-Landscape Systems*

Sustainability: What do we mean?

World Commission on Environment & Development – the 'Brundtland Commission' of the UN (1987)

- Defined Sustainable Development as development that meets the needs of current generations **without compromising the ability of future generations to meet their own needs**
- Human-centered: Conservation of plants and animals as resources to meet future human needs
- 'Sustainable development' is a controversial term, often criticized

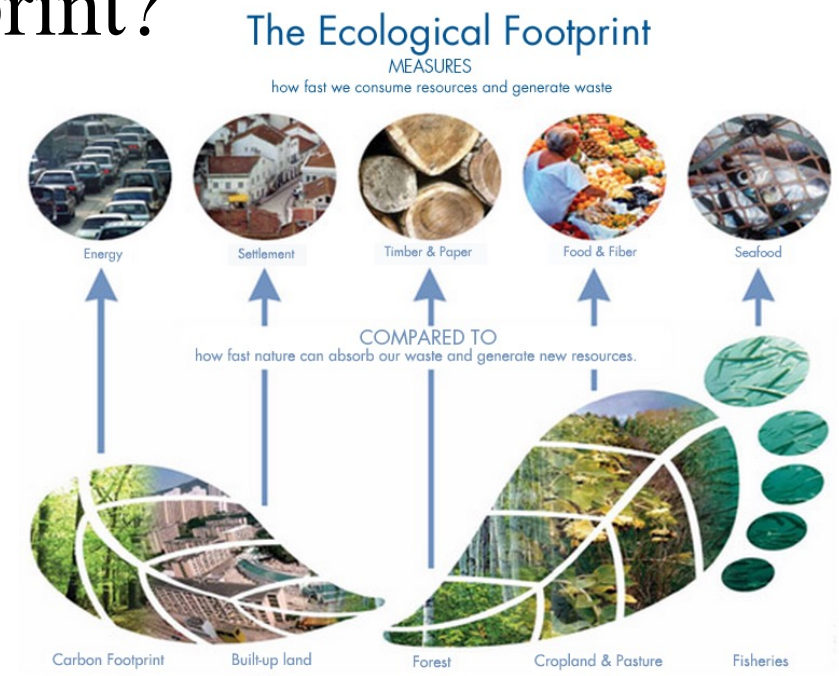
Sustainability Triangle – The Three E's



A New Field proposed: "Sustainability Science"

- Deals with coupled human-environment systems
- Increasingly focused on problem-solving
- Some basic research, some applied, some use-inspired basic research (eg, Louis Pasteur)

What is ecological footprint?

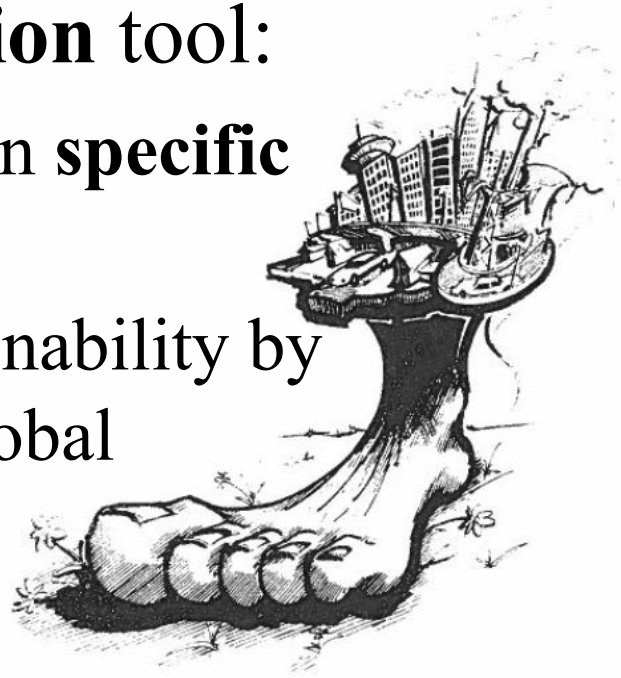


Global Footprint Network
Advancing the Science of Sustainability

Concept developed by Rees and Wackernagel, University of British Colombia, in early 1990s.

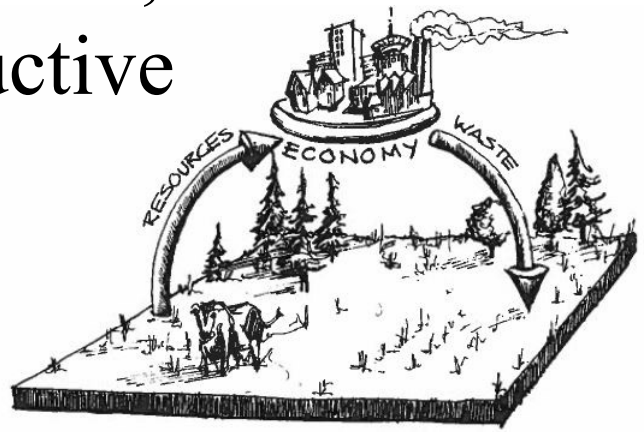
What is the Ecological Footprint?

- The Ecological Footprint is both a **measurement** and a **communication** tool:
  - Enables sustainability to be defined in **specific** and **measurable** terms
  - Enables people to **understand** sustainability by linking their personal impact with global ecological capacity.



What is the Ecological Footprint?

- **Measures** how much biologically productive land & water area humanity uses to produce the resources it consumes and absorb waste it generates, using prevailing technology and resource management, whenever on earth those bioproductive areas are located.



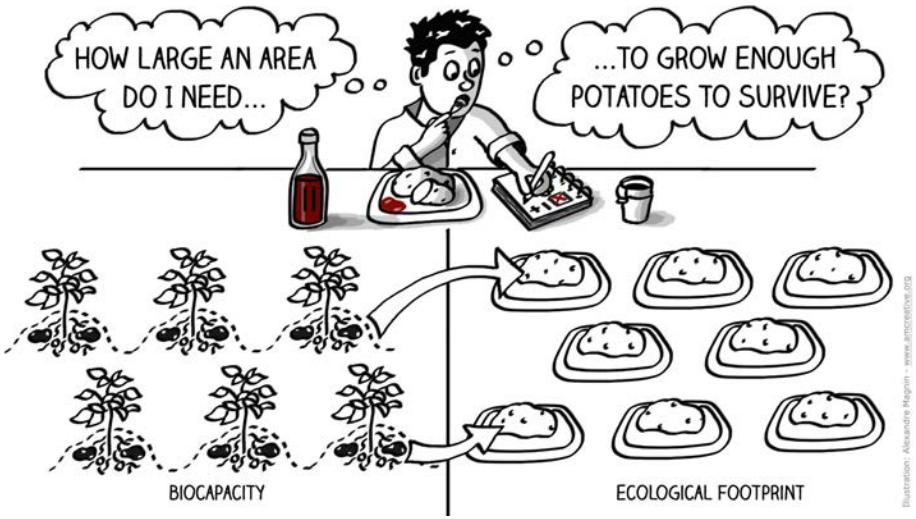
What is the Ecological Footprint?

- Impact = Population x Affluence x Technology

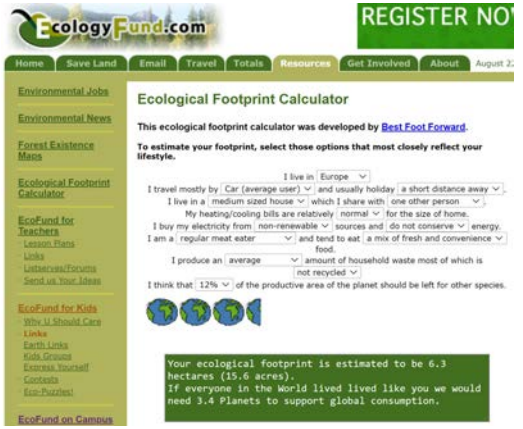
- Footprint of a nation of humanity (I) =
  - Number of people consuming (P) x
  - Average amount of goods and services an average person consumes (A) x
  - Resource intensity of these goods and services (T)
- We can track most resources people consume and wastes they generate
- Most resource and waste flows can be converted into biologically productive area required to maintain these flows

What "Footprint" means

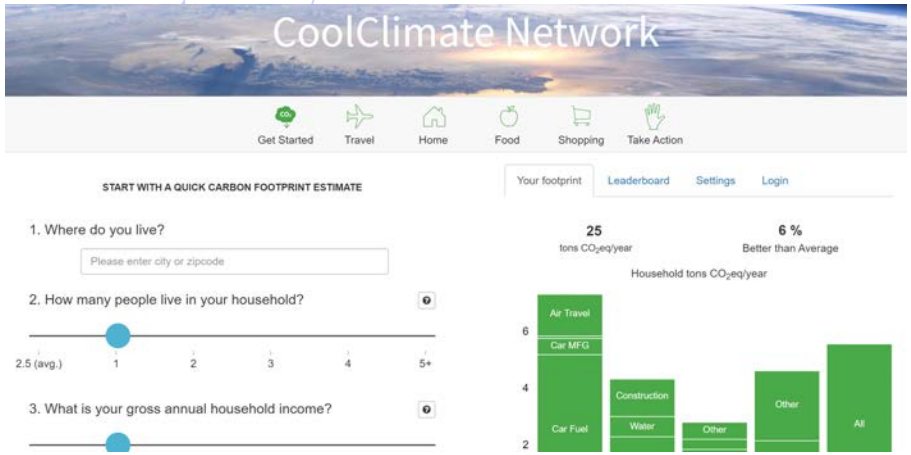
- Footprint is **NOT** a general term for "environmental impact"…
  - I.e., tonnes of carbon emitted is **NOT** the "carbon footprint"
  - …**surface** area of planet needed to sequester CO2 emissions and maintain a stable climate IS the carbon footprint



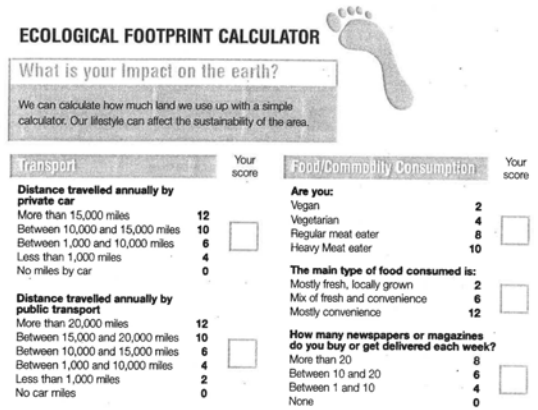
https://www.footprintcalcula



http://www.ecologyfund.com/ecology/res_bestfoot.html



https://coolclimate.berkeley.edu/calculator



https://www3.epa.gov/airnow/workshop_teachers/calculating_carbon_footprint.pdf

Environmental Footprints

- The **ecological footprint** measures how much biologically productive land & water area humanity uses to produce the resources it consumes and absorb waste it generates.

- The **carbon footprint** is a measure of the amount of greenhouse gases produced and emitted into the atmosphere by the activities of an individual, group of people, or nation.

- The **water footprint** is a measure of water use by individual, community, or country (measured in cubic meters of water per year).

For next week:

Take ***syllabus quiz*** between Monday 1200 - Tuesday 1200

Write ***environmental science autobiography*** (by Mon 5pm)

Watch ***An Inconvenient Truth*** before your lab section

Attend lab in person

Lab includes a carbon uptake exercise and an overview tour from the top of the Social Science Building on campus

Summary – 1of 2

- Increasing human populations has led greater impacts on the environment: air pollution, global warming, depletion of ozone, acid rain, smog, health impacts
- Equation for population growth: P2 = P1 + (Birth-Death) + (Immigration – Emigration)
- As countries go from developing to developed, improved nutrition and medical care reduces child mortality, then eventually couples have fewer children and invest more in each child. This causes a "demographic transition" – age structures of developing vs. developed countries vary significantly. More young people in developing countries (fast growth); More older people in developed countries.
- Where population density is high, you can support mass transit. Where population density is low (in most of US), transport is mainly individual (in the US, by car).
- This is one reason the environmental footprint of each American is larger than that of people in other countries.

Summary – 2 of 2

- Key factors that result in differences in environmental impacts: population density, resource consumption, efficiency of energy generation, types and cleanliness of energy generation
- Carrying capacity: maximum number of people that the earth can sustain
- Sustainability: different definitions in different fields. For our purposes, the Bruntland commission's (1987) definition is most useful: *development that meets the needs of current generations without compromising the ability of future generations to meet their own needs*
- The 'sustainability triangle' concept illustrates the potential benefits of combining disparate perspectives : ***environment, equity, economy***
- Environmental footprints: Ecological, Water, Energy