Earth and Its Population

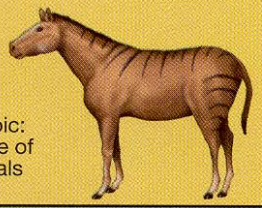
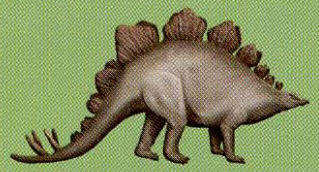
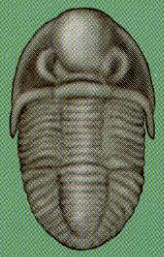
CVEN 3698

Engineering Geology

Fall 2016

Earth Statistics	
Mass (kg)	5.976e+24
Mass (Earth = 1)	1.0000e+00
Equatorial radius (km)	6,378.14
Equatorial radius (Earth = 1)	1.0000e+00
Mean density (gm/cm^3)	5.515
Mean distance from the Sun (km)	149,600,000
Mean distance from the Sun (Earth = 1)	1.0000
Rotational period (days)	0.99727
Rotational period (hours)	23.9345
Orbital period (days)	365.256
Mean orbital velocity (km/sec)	29.79
Orbital eccentricity	0.0167
Tilt of axis (degrees)	23.45
Orbital inclination (degrees)	0.000
Equatorial escape velocity (km/sec)	11.18
Equatorial surface gravity (m/sec^2)	9.78
Visual geometric albedo	0.37
Mean surface temperature	15°C
Atmospheric pressure (bars)	1.013
Atmospheric composition	
Nitrogen	77%
Oxygen	21%
Other	2%

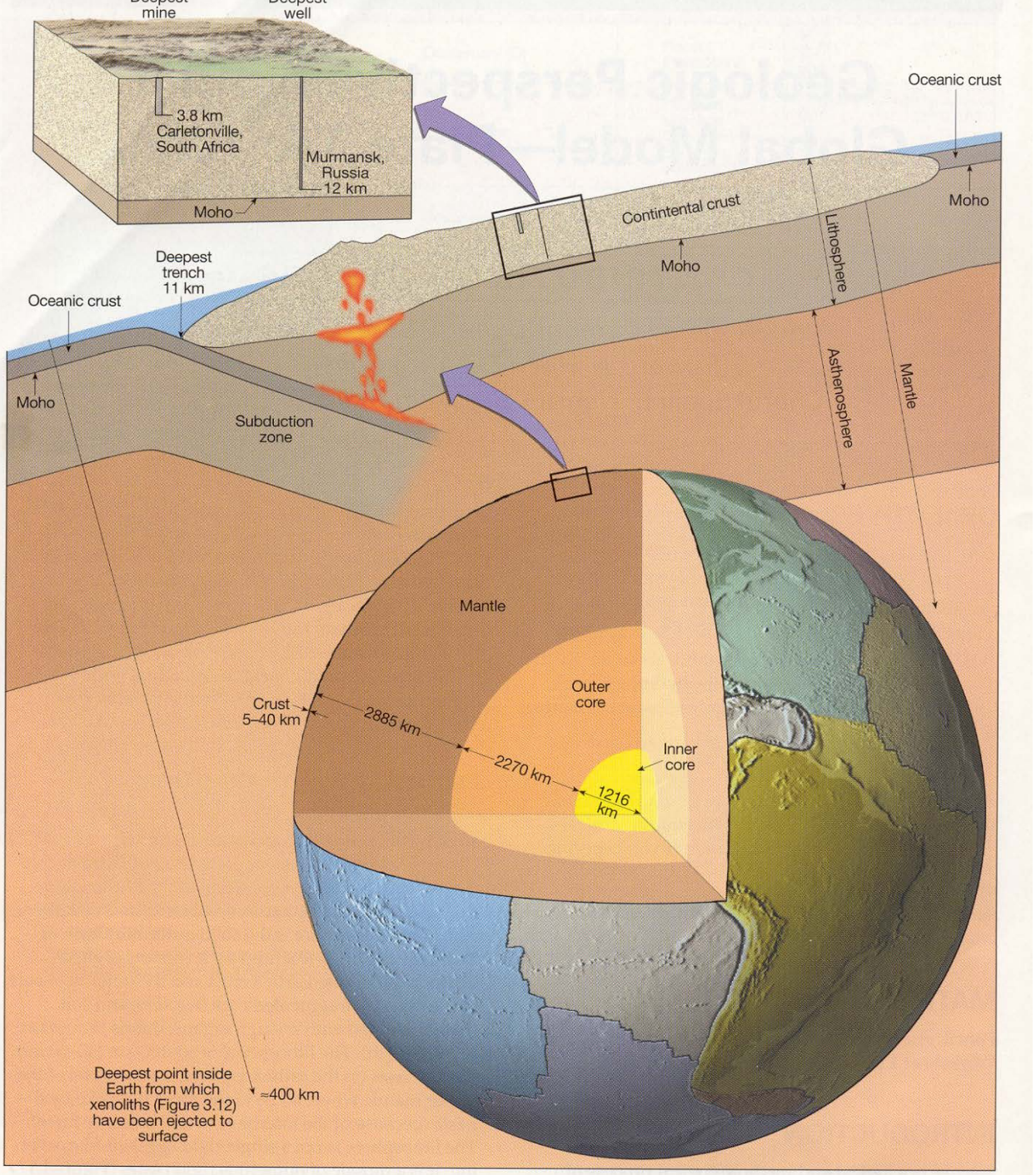
The Geologic Time Scale

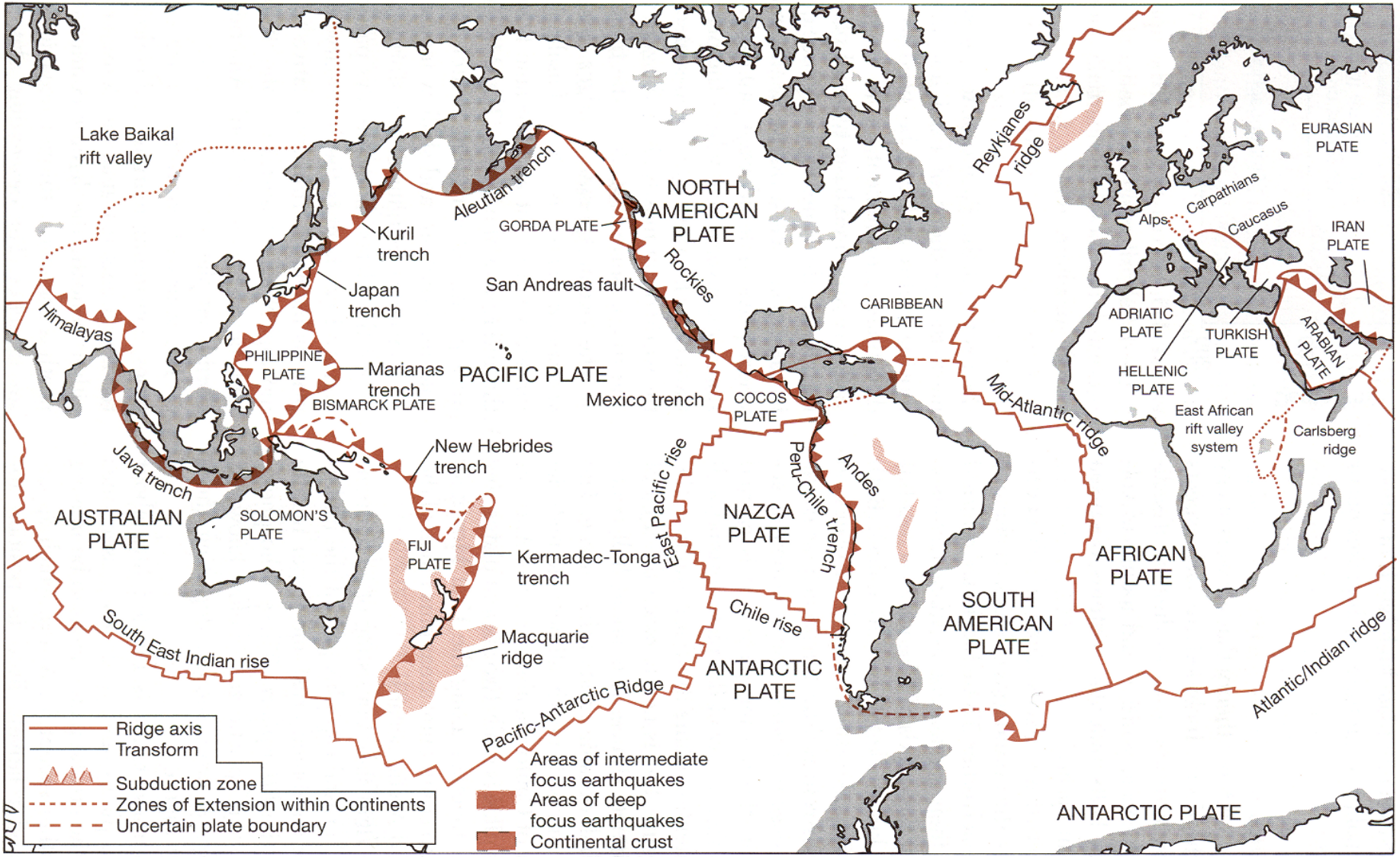
Eon	Era	Period**	Epoch		Approximate Ages (In millions of years)
Phanerozoic: The Eon of Visible Life	Cenozoic: The Age of Mammals 	Quaternary (Q)	Recent Pleistocene	Neogene*	1.6
		Tertiary (T)	Pliocene Miocene	Neogene*	24
			Oligocene Eocene Paleocene	Paleogene*	65
	Mesozoic: The Age of Reptiles 	Cretaceous (K)	Late Early		144
		Jurassic (J)	Late Middle Early		213
		Triassic (R)	Late Middle Early		248
	Paleozoic: The Age of Trilobites 	Permian (P)	Late Early		286
		Carboniferous (C)*: Pennsylvanian (IP)	Late Middle Early		320
		Carboniferous (C)*: Mississippian (M)	Late Early		360
		Devonian (D)	Late Middle Early		417
		Silurian (S)	Late Middle Early		445
		Ordovician (O)	Late Middle Early		495
		Cambrian (Ꞓ)	Late Middle Early		545
	Precambrian (PC)	Locally divided into Early, Middle, and Late			

If the history of our planet began at midnight on January 1:

- Feb. 10: First prokaryotic cell
- July 20: First eukaryotic cell
- Nov 20: Cambrian explosion
- Dec. 10: Dinosaurs appear
- Dec. 26: Dinosaurs disappear
- Dec. 28: First apes
- Dec. 31:

8:00 a.m.	Gorillas, cats, etc.
6:00 p.m.	Homo Habilis
11:23 p.m.	Archaic Homo Sapiens
11:56 p.m.	**Modern Homo Sapiens**…
11:58 P.M.	Cave Paintings

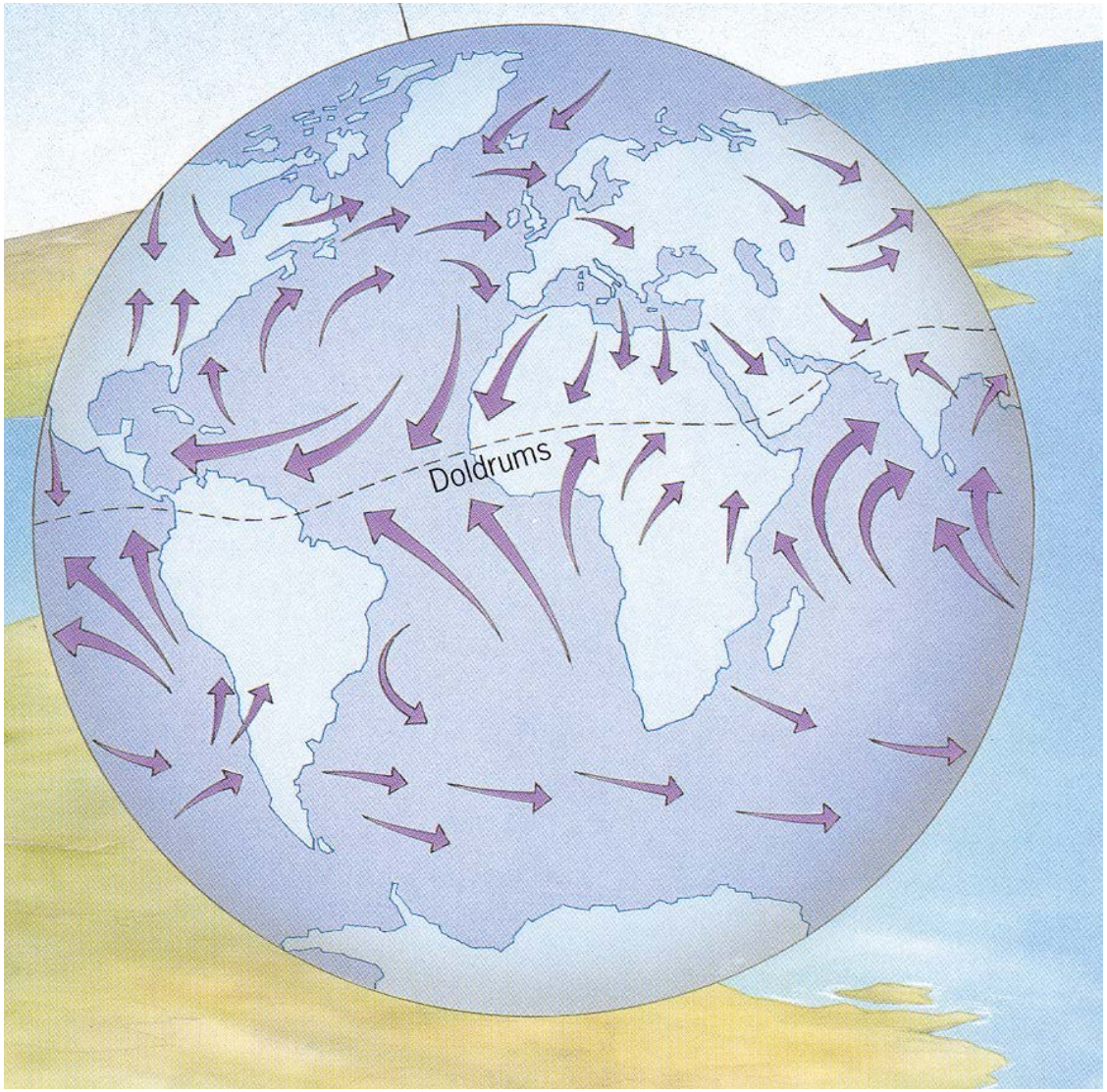

Deepest mine
Deepest well
3.8 km
Carletonville, South Africa
Murmansk, Russia
12 km
Moho
Oceanic crust
Continental crust
Moho
Lithosphere
Moho
Deepest trench 11 km
Oceanic crust
Moho
Subduction zone
Asthenosphere
Mantle
Mantle
Outer core
Crust 5–40 km
2885 km
2270 km
1216 km
Inner core
Deepest point inside Earth from which xenoliths (Figure 3.12) have been ejected to surface
≈400 km


Lake Baikal
rift valley
Aleutian trench
GORDA PLATE
NORTH
AMERICAN
PLATE
Reykjanes
ridge
EURASIAN
PLATE
Carpathians
Alps
Caucasus
IRAN
PLATE
Kuril
trench
Japan
trench
San Andreas fault
Rockies
CARIBBEAN
PLATE
ADRIATIC
PLATE
TURKISH
PLATE
ARABIAN
PLATE
Himalayas
PHILIPPINE
PLATE
Marianas
trench
PACIFIC PLATE
HELLENIC
PLATE
BISMARCK PLATE
Mexico trench
COCOS
PLATE
Mid-Atlantic ridge
East African
rift valley
system
Carlsberg
ridge
New Hebrides
trench
Java trench
East Pacific rise
Peru-Chile trench
Andes
AUSTRALIAN
PLATE
SOLOMON'S
PLATE
NAZCA
PLATE
AFRICAN
PLATE
FIJI
PLATE
Kermadec-Tonga
trench
Chile rise
SOUTH
AMERICAN
PLATE
South East Indian rise
Macquarie
ridge
ANTARCTIC
PLATE
Pacific-Antarctic Ridge
Atlantic/Indian ridge
Ridge axis
Transform
Subduction zone
Zones of Extension within Continents
Uncertain plate boundary
Areas of intermediate
focus earthquakes
Areas of deep
focus earthquakes
Continental crust
ANTARCTIC PLATE

Earth Processes

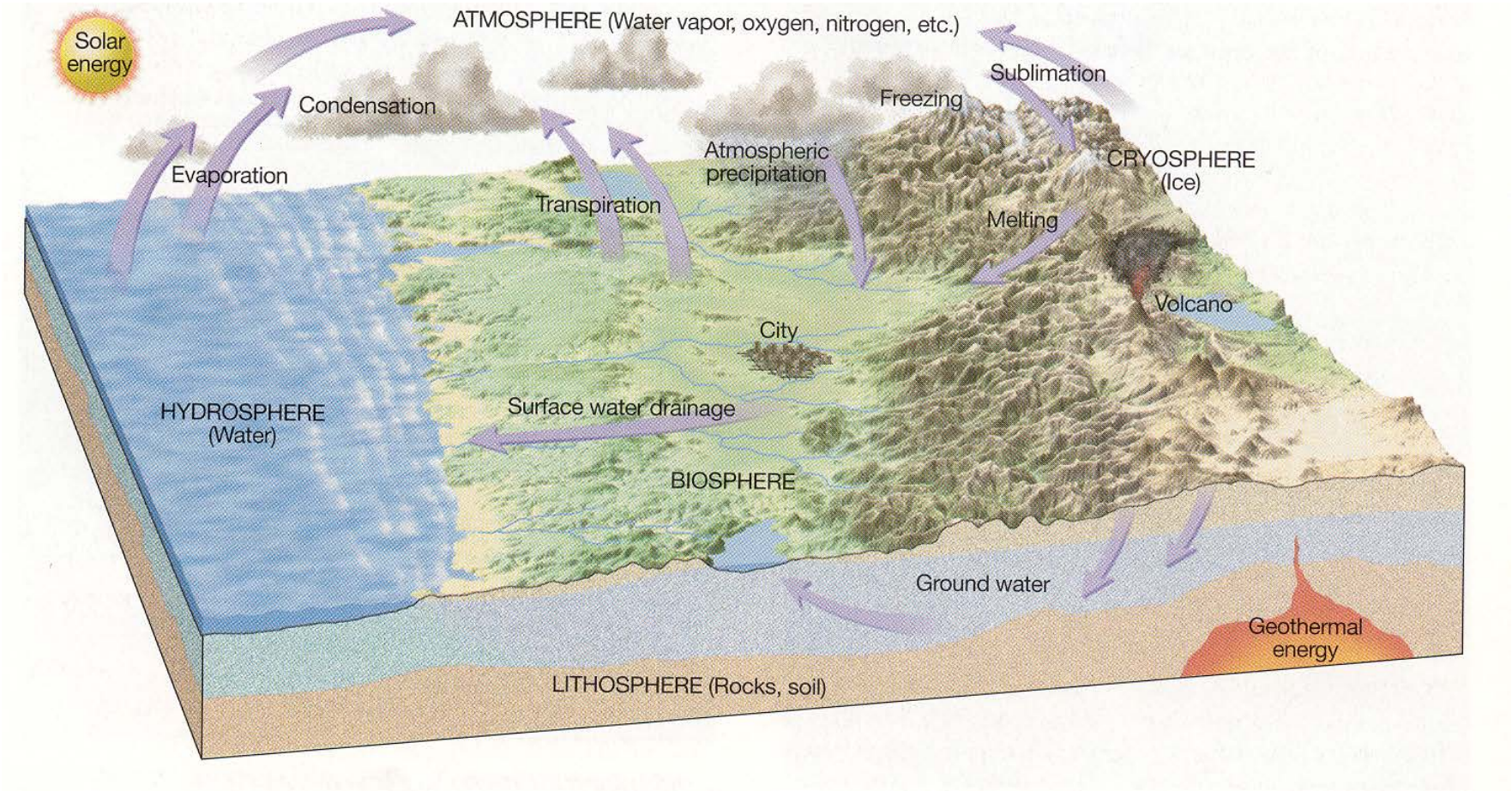
Melting, Evaporation, Freezing, Condensation, Sublimation, Dissolution, Vaporization, Reaction, Decomposition, Dissociation, Chemical Precipitation, Photosynthesis, Respiration, Transpiration, Evolution,…

Nature has created a 3 billion year old success story of life on Earth. This success is reflected in the way that life is diversified and organized to make the best use of the resources available.

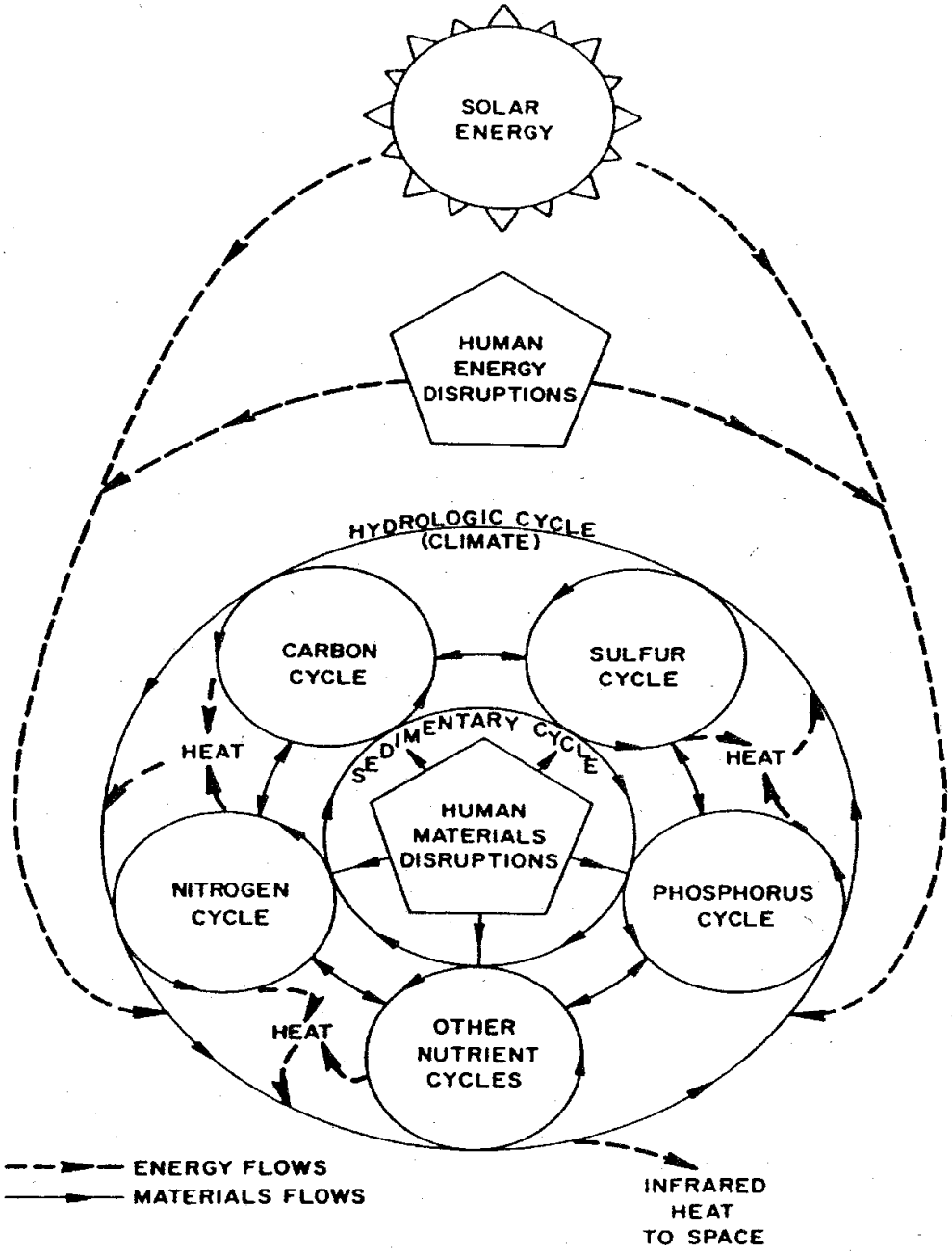


Moving Air in the Troposphere (0-18 km), From *Gaia* by James Lovelock (1991)

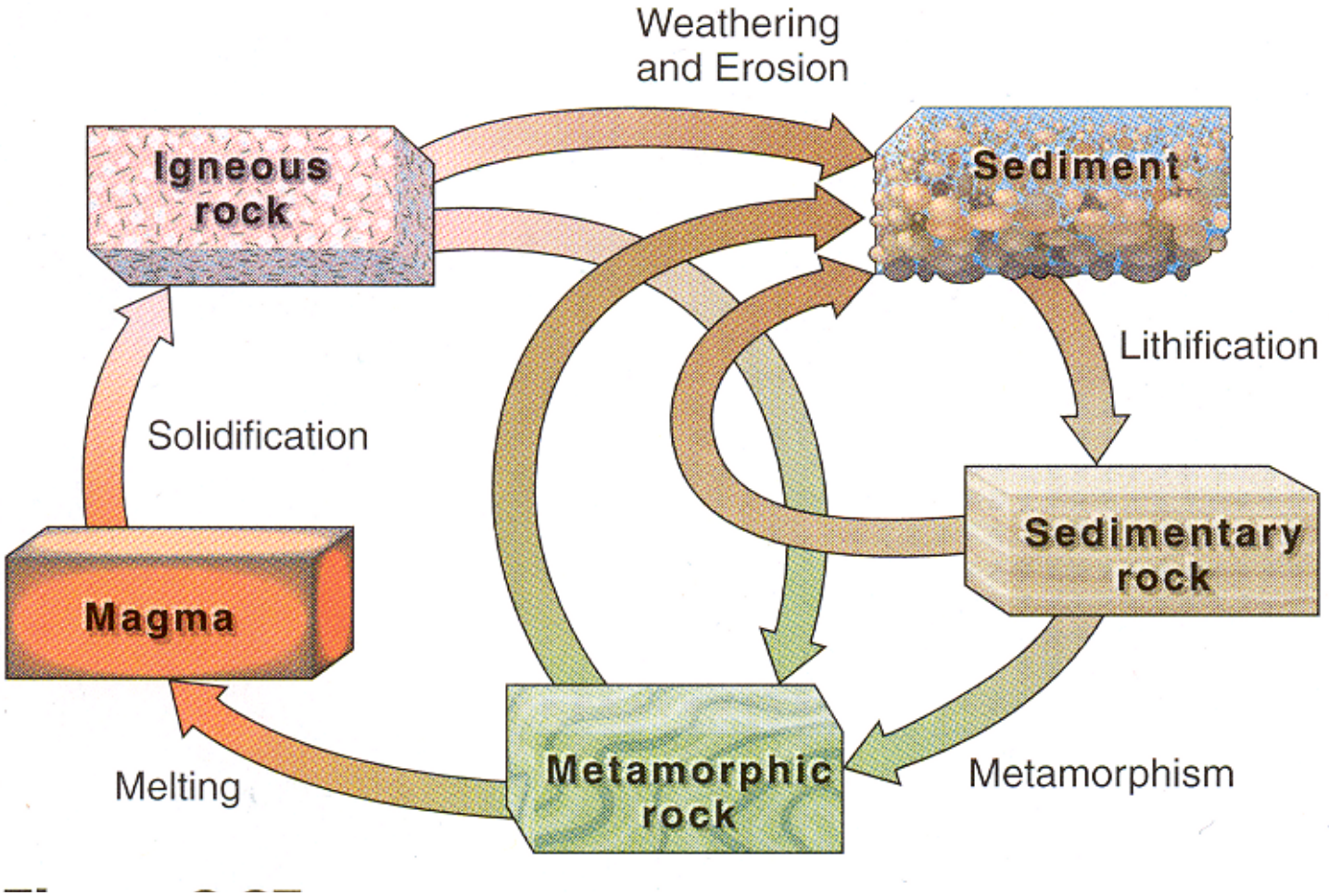
Hydrologic Cycle



From *Laboratory Manual in Physical Geology by* Busch et al., 1997.


SOLAR ENERGY
HUMAN ENERGY DISRUPTIONS
HYDROLOGIC CYCLE (CLIMATE)
CARBON CYCLE
SULFUR CYCLE
SEDIMENTARY CYCLE
HEAT
HEAT
HUMAN MATERIALS DISRUPTIONS
NITROGEN CYCLE
PHOSPHORUS CYCLE
HEAT
OTHER NUTRIENT CYCLES
ENERGY FLOWS
MATERIALS FLOWS
INFRARED HEAT TO SPACE


Bora Bora, Polynésie française, France. (S 16°30' O 151°44')
http://www.gannarthusbertrand.org



Geologic Cycle from *Physical Geology*, C. Plummer et al., 1996.

Remark

Humanity derives a wide array of crucial economic and critical life-support benefits from biodiversity and the natural ecosystems in which it exists. This is captured in the term “ecosystem services”.

Ecosystem Services

"Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life."

- Maintain biodiversity
- Produce goods
- Provide life-support functions
- Provide Intangible aesthetic and cultural benefits

G. C. Daily 1997

Ecosystem Services

Critical services valued at trillions of dollars annually, provided at no cost by Nature such as:

- Purification of air
- Global oxygen production (photosynthesis)
- Maintenance of O_2/ N_2 gas concentrations for *respiration*
- Purification of water (wetlands, sediments, underground)
- Cycling of nutrients
- Pollination of crops and natural vegetation

Ecosystem Services (2)

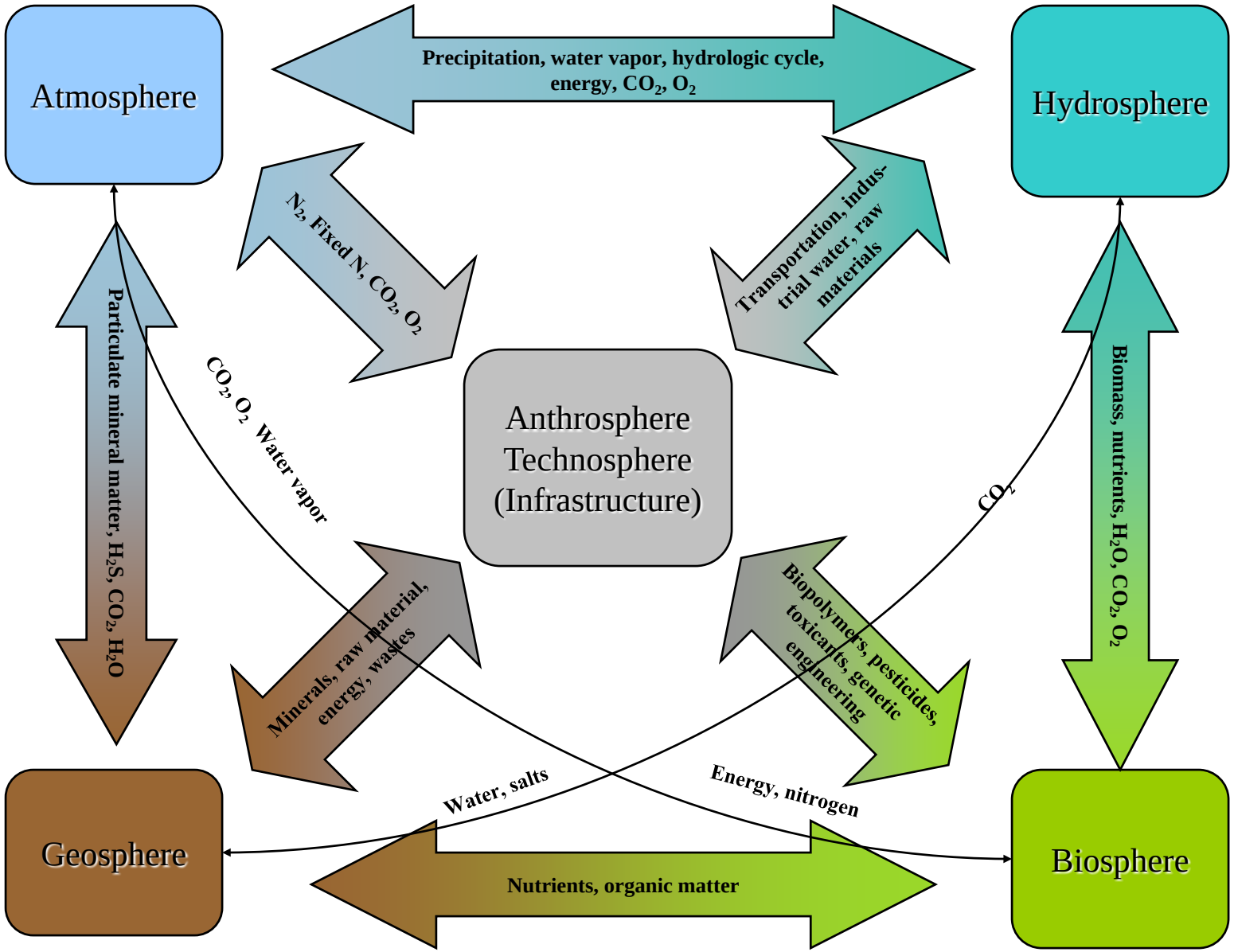
- Generation and renewal of soil and soil fertility (nitrogen fixers and detritus)
- Mitigation of floods (vegetations, river shape) and droughts
- Production of soils, preservation of top soils
- Regulation of climate and oceans
- Moderation of temperature extremes and force of winds and waves
- Detoxification and decomposition of wastes
- Control of the majority of agricultural pests
- Dispersal of seeds & translocation of nutrients
- Support of human cultures

“The human body is a dynamic field of energy. It is constantly participating in exchange with the larger of field of energy that surrounds it…

- 98% of the atoms in your anatomy were not there a year ago..
- bones are re-created brand new every three months..
- a new liver every six weeks..
- skin is new every month..
- a new stomach lining every four days..
- surface cells that actually come in contact with digesting food are renewed every five minutes..

Basically, your body completely re-creates itself down to the last atom over a period of four or five years”

(Deepak Chopra, 1995)



FROM: Figure 1.1, Industrial Ecology, Environmental Chemistry and Hazardous Waste, Stanley E. Manahan

What makes the anthrosphere?

- Structures used for dwellings
- Structures used for manufacturing, commerce, education, and other activities
- Utilities, including water, fuel, and electricity distribution systems and waste distribution systems, such as sewers
- Structures and facilities used for transportation, including roads, railroads, airports, and waterways constructed or modified for water transport

What makes the anthrosphere? (2)

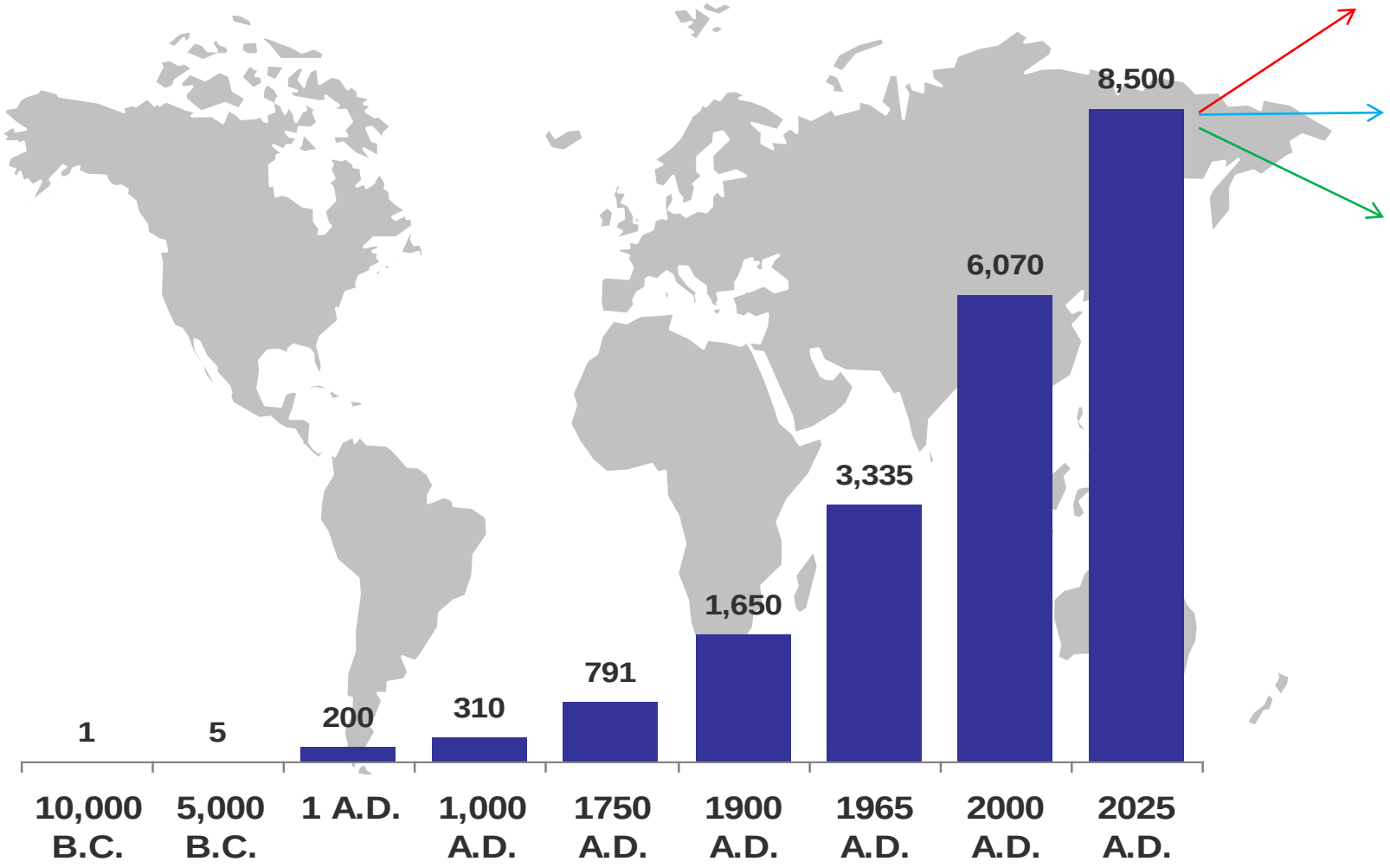
- Structures and other parts of the environment modified for food production, such as fields used for growing crops and water systems used to irrigate the fields
- Machines of various kinds, including automobiles, farm machinery, and airplanes
- Structures and devices used for communications, such as telephone lines or radio transmitter towers
- Structures associated with extractive industries

People

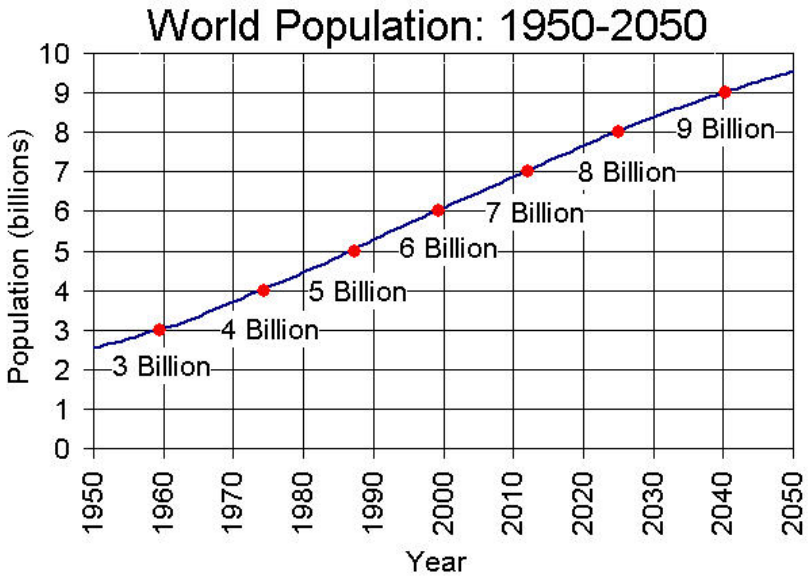
If we could shrink Earth's population to a village of 100 people:

- There would be 57 Asians, 21 Europeans, 14 from the Western World and 8 Africans
- 51 female and 49 male
- 70 non-white and 30 white
- 70 non-Christians and 30 Christians
- 50% of the world's wealth would be in the hands of 2 people from the US
- 80 would be living in substandard housing
- 70 are unable to read
- 50 suffer from malnutrition
- 1 would be near death and 1 near birth
- 1 would have college education

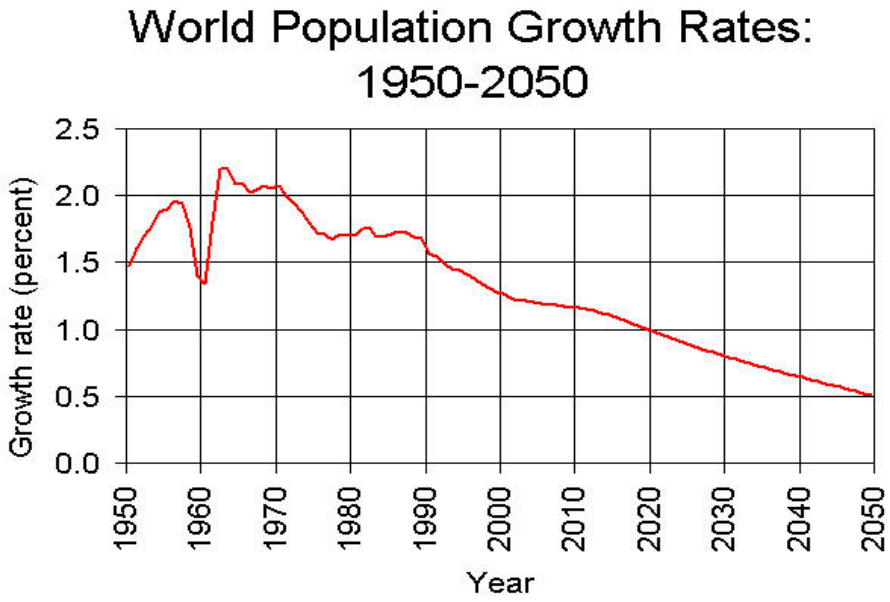
It is all about people…



World population in millions: wikipedia



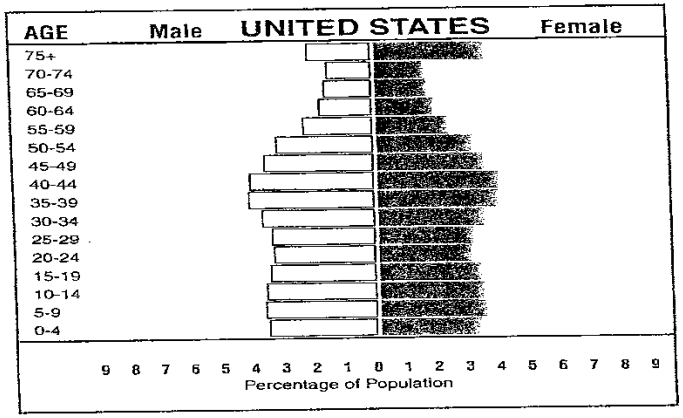
Source: U.S. Census Bureau, International Data Base, December 2008 Update.

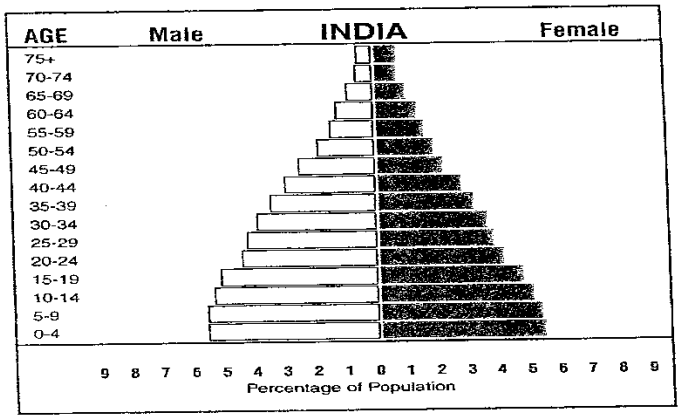


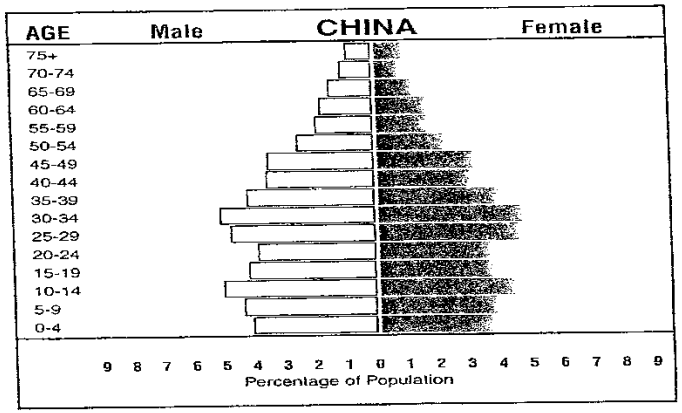
Source: U.S. Census Bureau, International Data Base, December 2008 Update.

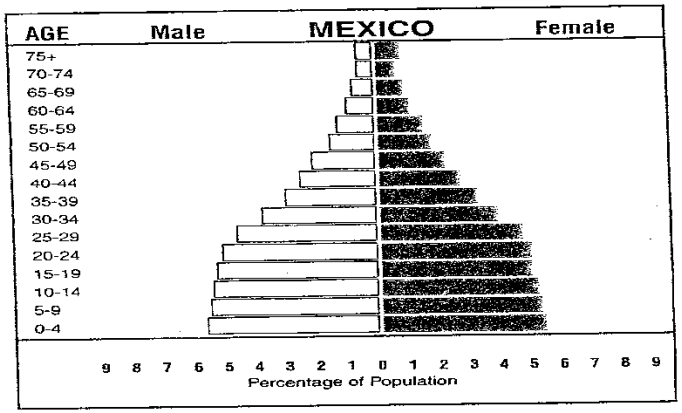
http://www.worldometers.info/world-population/

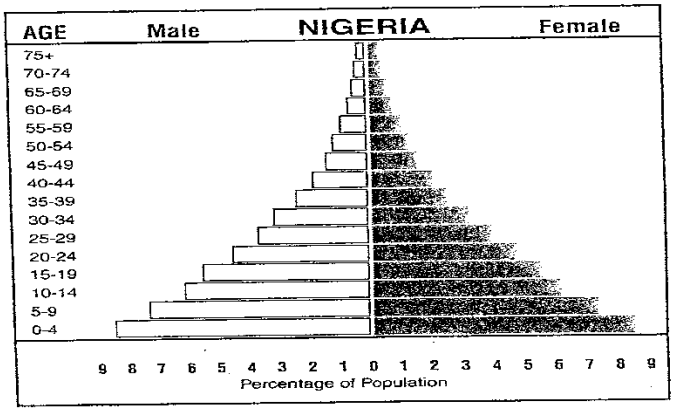
Power of the Pyramids—Sample Pyramids

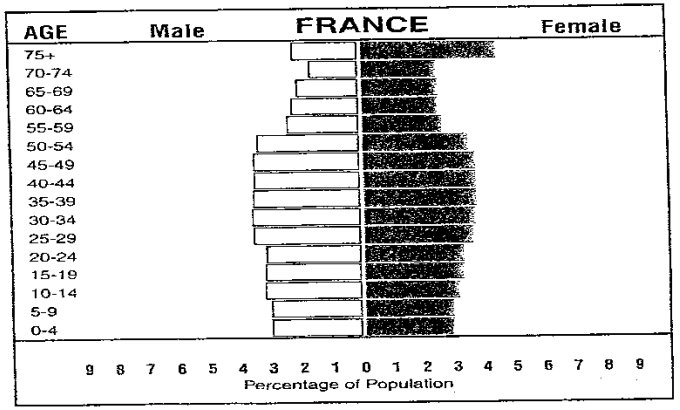










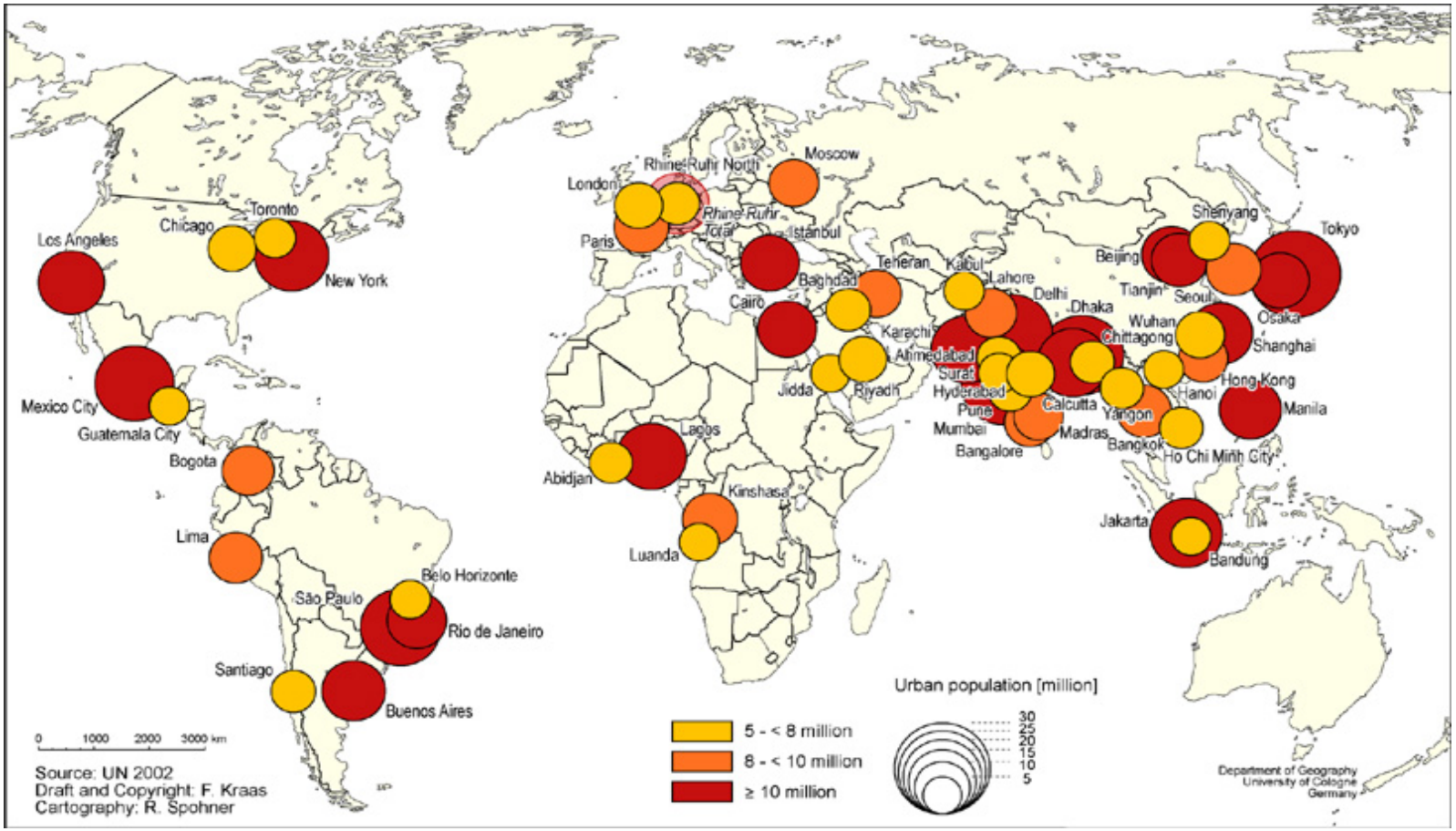


MEGACITIES

- Cities with population > 10 million
  - 5 (3 in developing world) in 1975
  - 26 (22 in developing world) by 2015
- World's population in cities
  - 30% in 1950
  - 50% in 2000
  - 60% in 2030

Water – Waste – Food – Energy -
Transportation – Land Use - IT

Mega-cities 2015



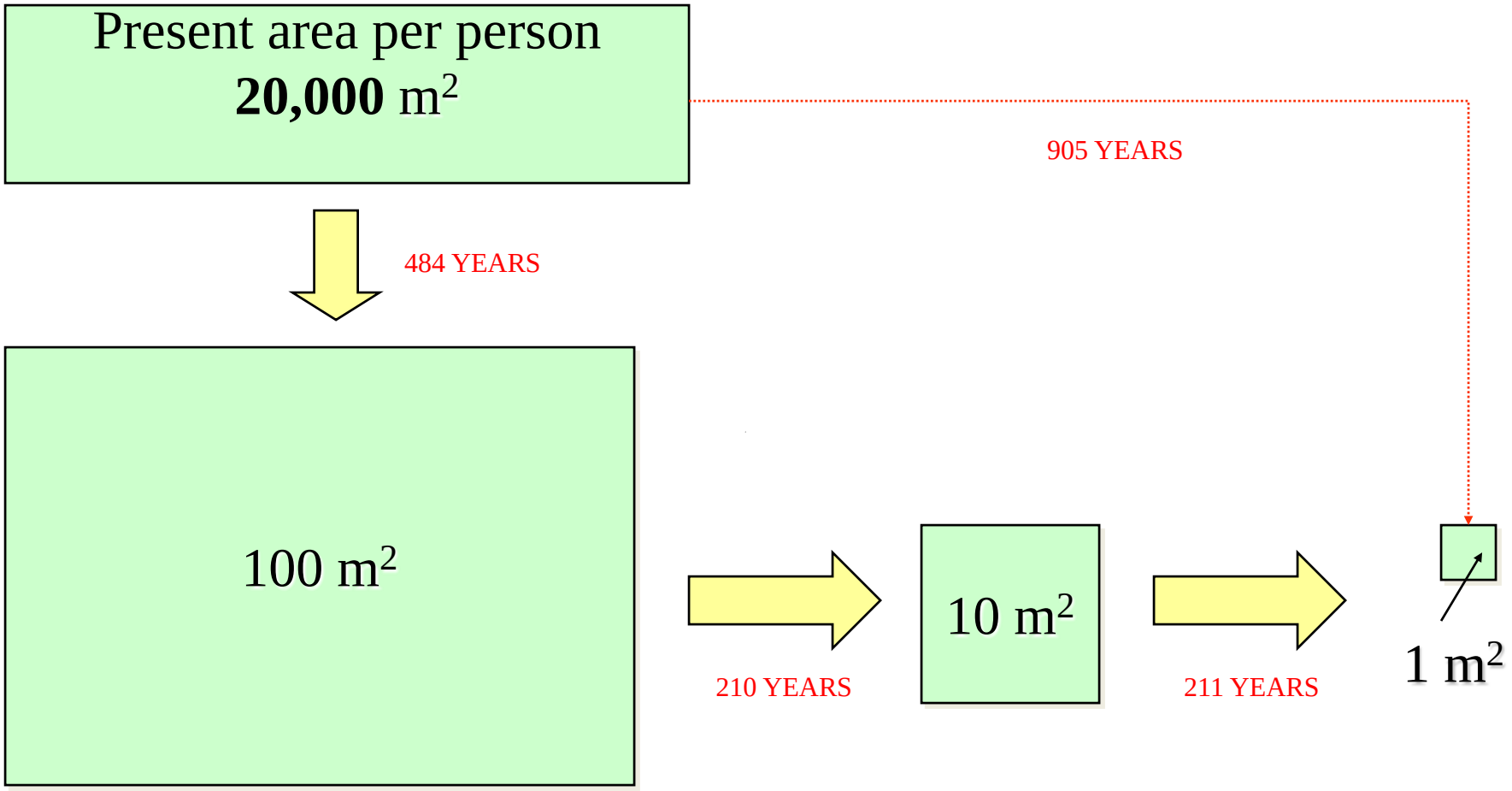
For instance, let N_o be a certain initial quantity and let x be the percentage increase of that quantity per year. A year later, the quantity will be $N_o (1+10^{-2}x)$. After a period of t years (and assuming the same percentage increase during that period), it will be equal to

$$N = N_o (1+10^{-2} x)^t = N_o \, e^{\lambda t}$$

$$\lambda = \ln (1+10^{-2} x) \quad .$$

Let T be the doubling time, i.e. the time is takes for N to be equal to $2N_o$.

$$T = (\ln 2)/\lambda$$

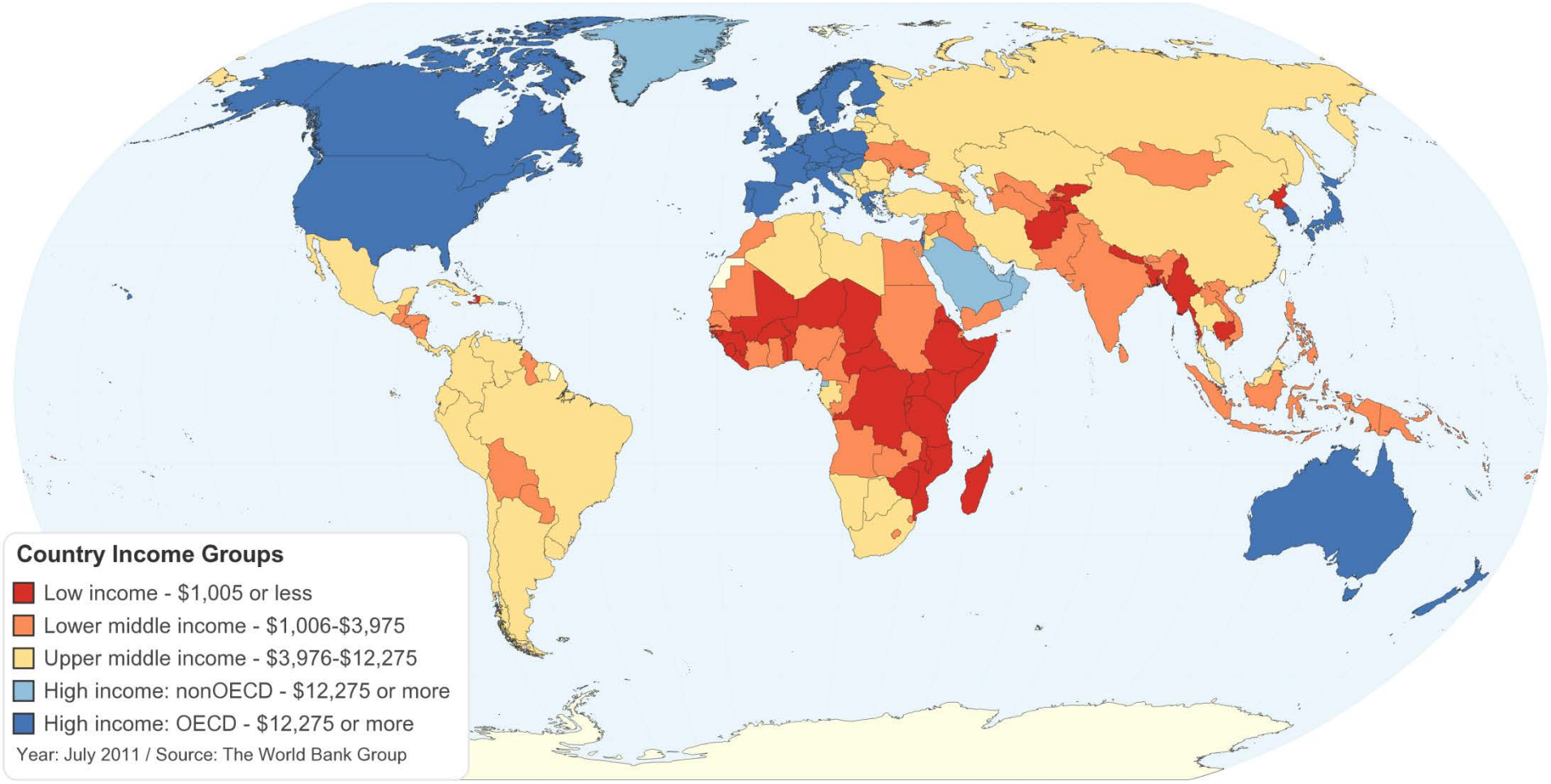


Land area of the Earth = 150×10^{12} m^2

Initial Population = 7.0×10^9

Annual Percent Increase = 1.1%

World Bank Income Groups



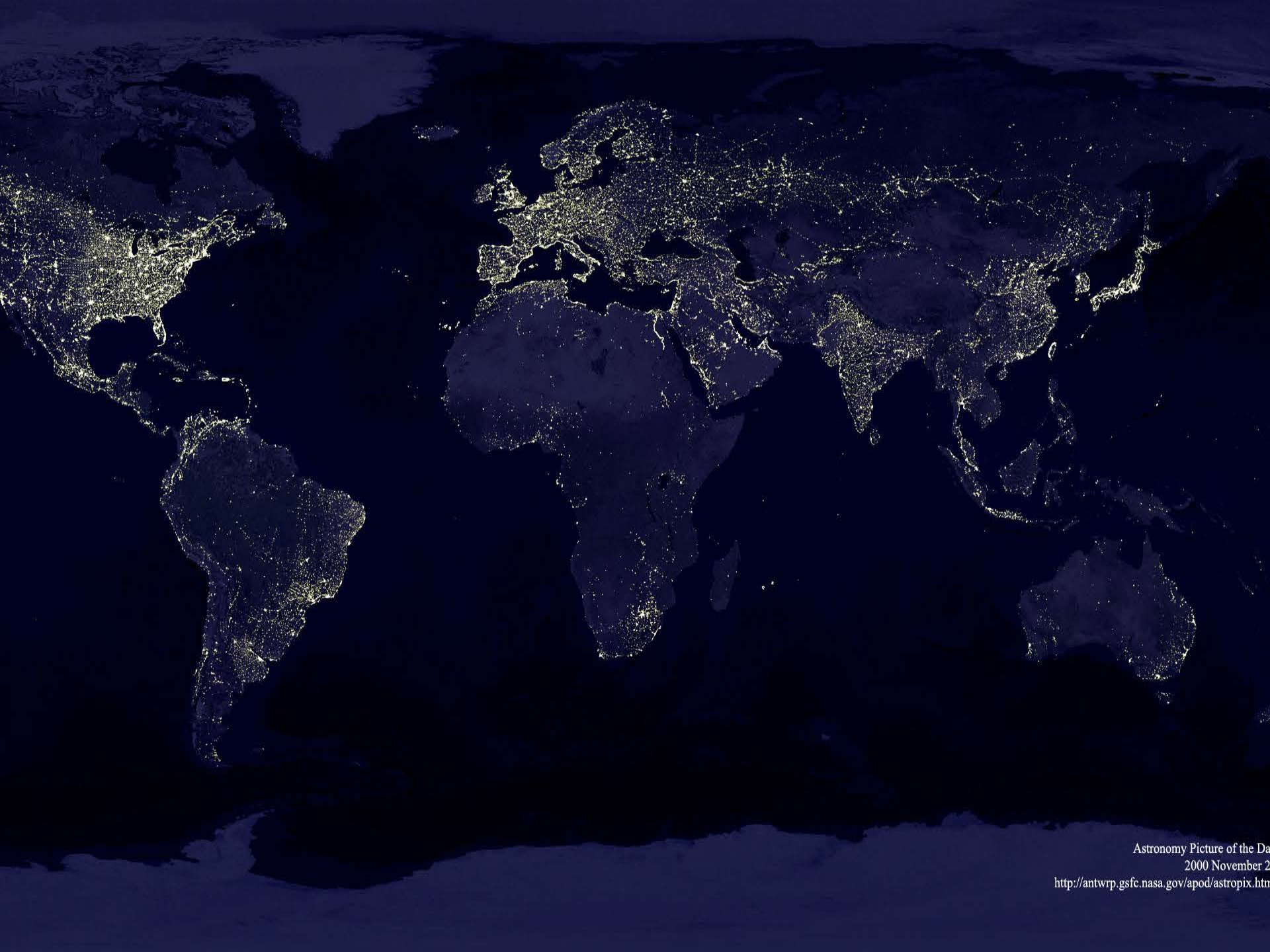
LICs: 35 countries
LMICs: 56 countries

UMICs: 54 countries
HICs: 70 countries

- 0.78 billion lack clean water
- 2.5 billion lack adequate sanitation
- 2.4 billion are at risk with malaria
- 2.0 billion with no access to low cost essential medicines

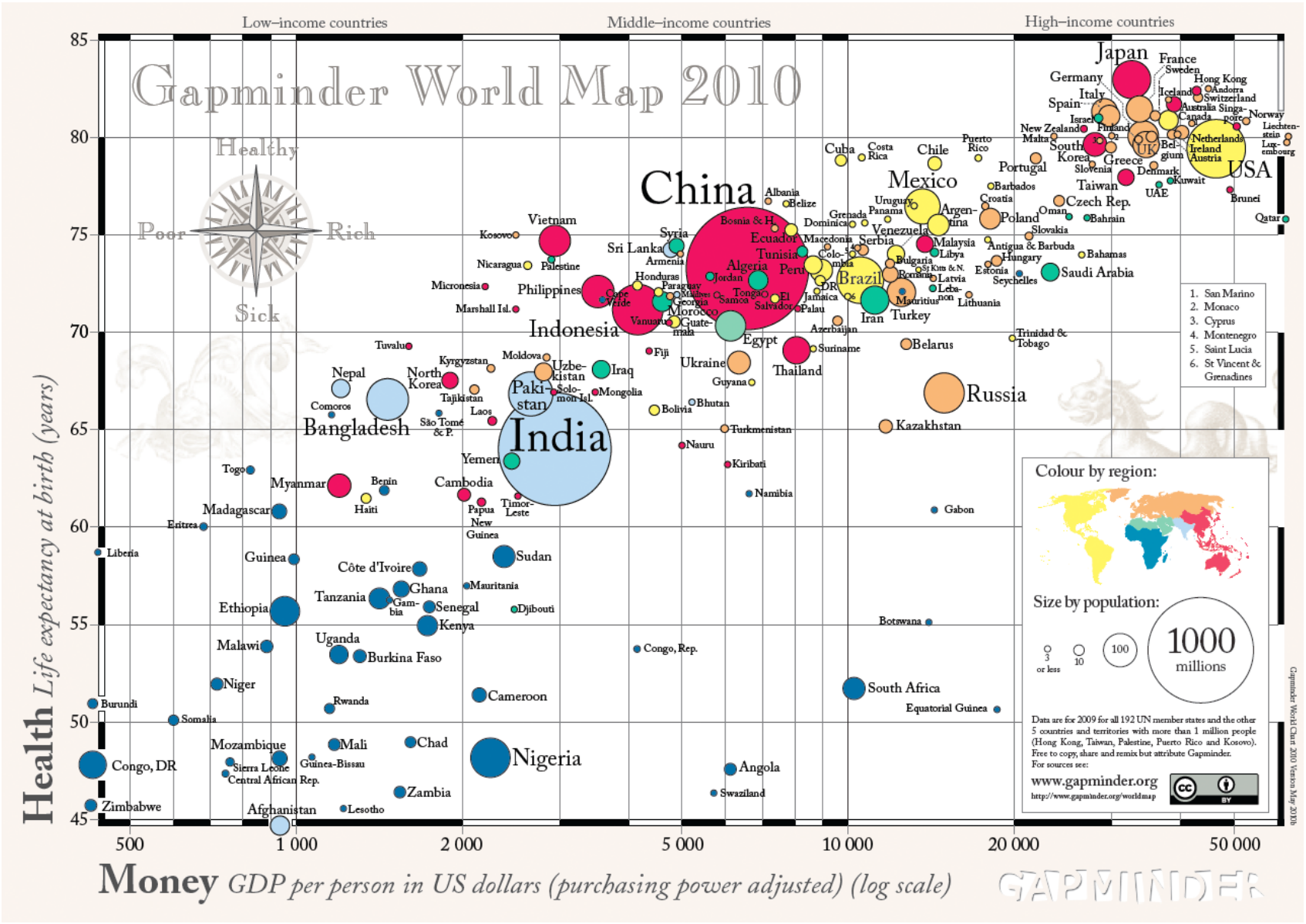
Why Engineering for the Developing World?

- 1.2 billion lack adequate housing
- 1.6 billion have no access to electricity
- 1.3 billion are illiterate
- 1.8 billion live in conflict zones, in transition, or in situations of permanent instability

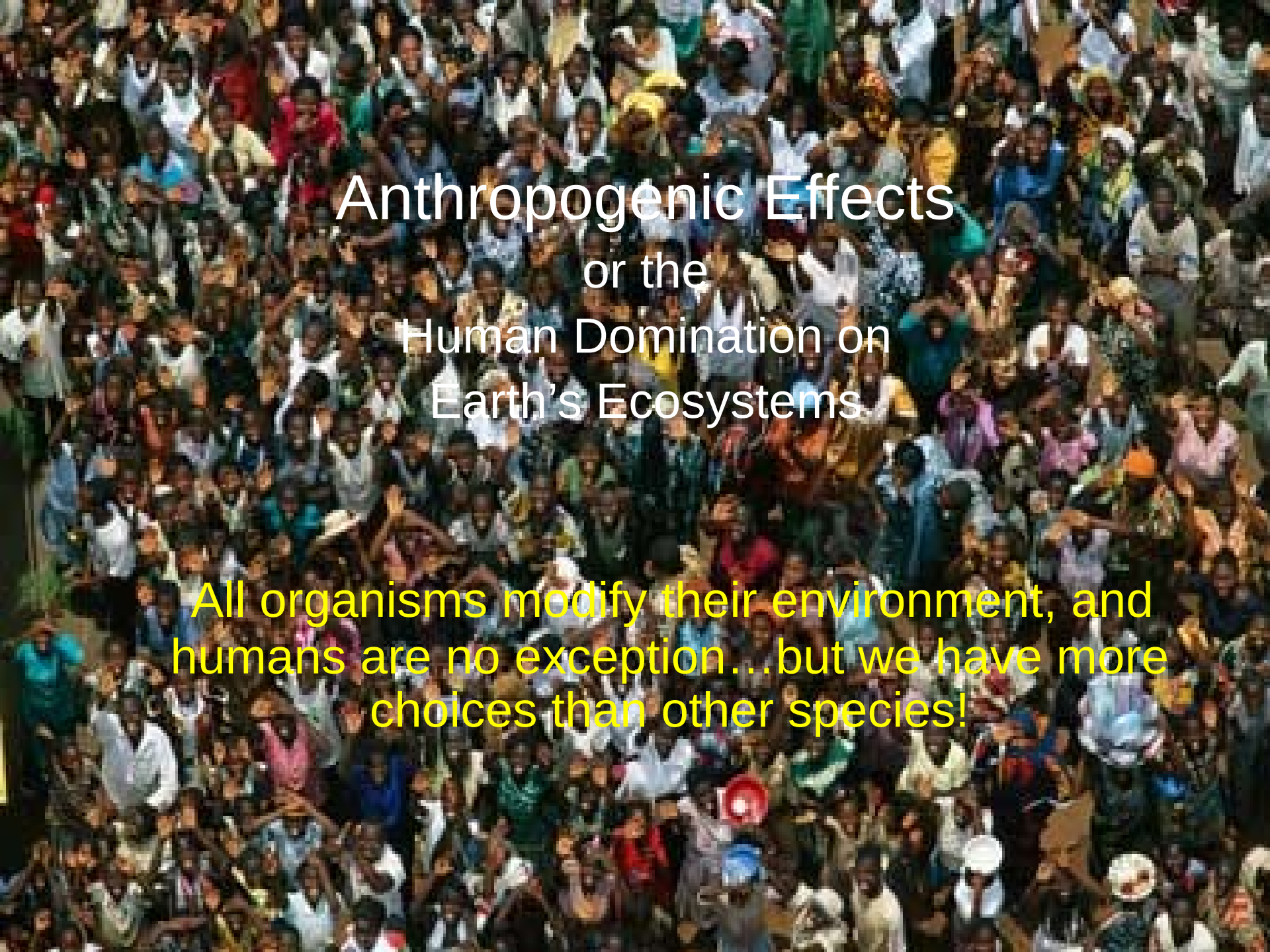

Astronomy Picture of the Da
2000 November 2
http://antwrp.gsfc.nasa.gov/apod/astropix.htm

Different Challenges

- In the developed world, the challenge is to consume less and more intelligently and be respectful of natural and human systems.
- In the developing world, the challenge is to ensure that proposed economic solutions address the basic needs of people and are good to the environment



[Gapminder World]



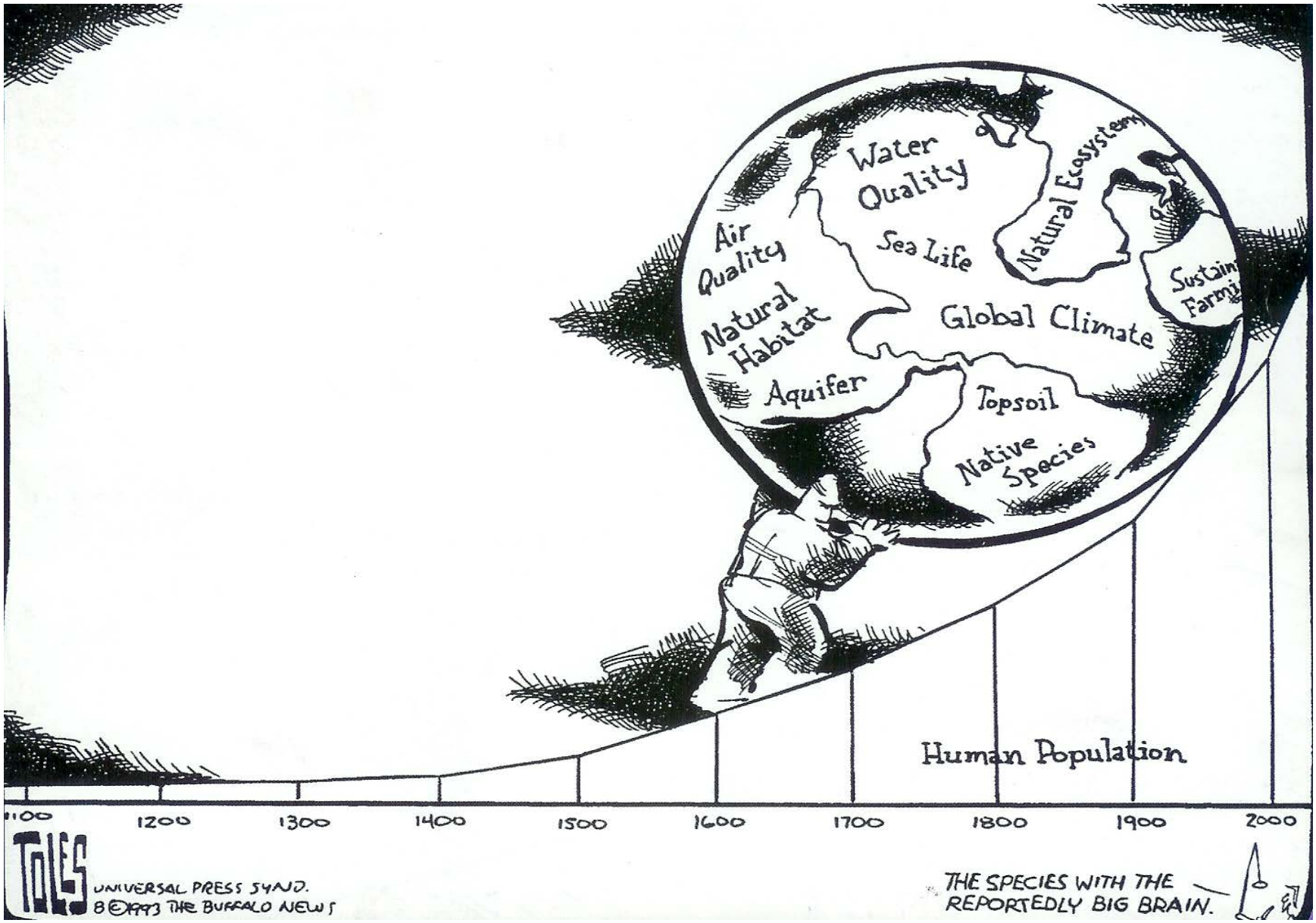
Anthropogenic Effects

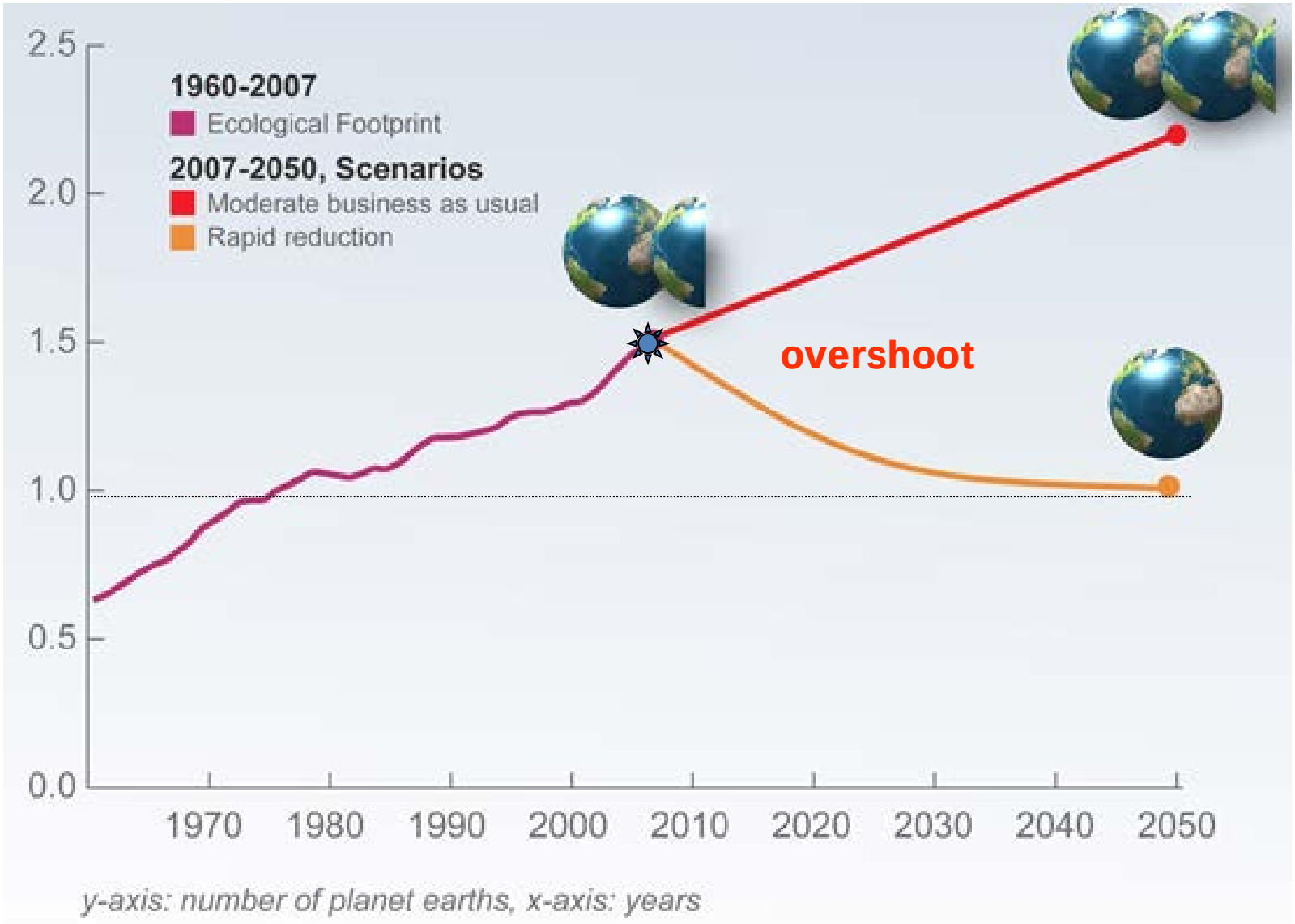
or the

Human Domination on

Earth's Ecosystems

All organisms modify their environment, and humans are no exception…but we have more choices than other species!


Water Quality
Natural Ecosystems
Air Quality
Sea Life
Natural Habitat
Global Climate
Aquifer
Topsoil
Native Species
Human Population
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
TOLES
UNIVERSAL PRESS SYND.
©1993 THE BUFFALO NEWS
THE SPECIES WITH THE REPORTEDLY BIG BRAIN.


2.5
2.0
1.5
1.0
0.5
0.0
1960-2007
Ecological Footprint
2007-2050, Scenarios
Moderate business as usual
Rapid reduction
overshoot
1970
1980
1990
2000
2010
2020
2030
2040
2050
y-axis: number of planet earths, x-axis: years

How do *all* humans under such constraints can have fulfilling lives, meet their basic needs, and live with dignity without degrading the eco-systems and services in the future?

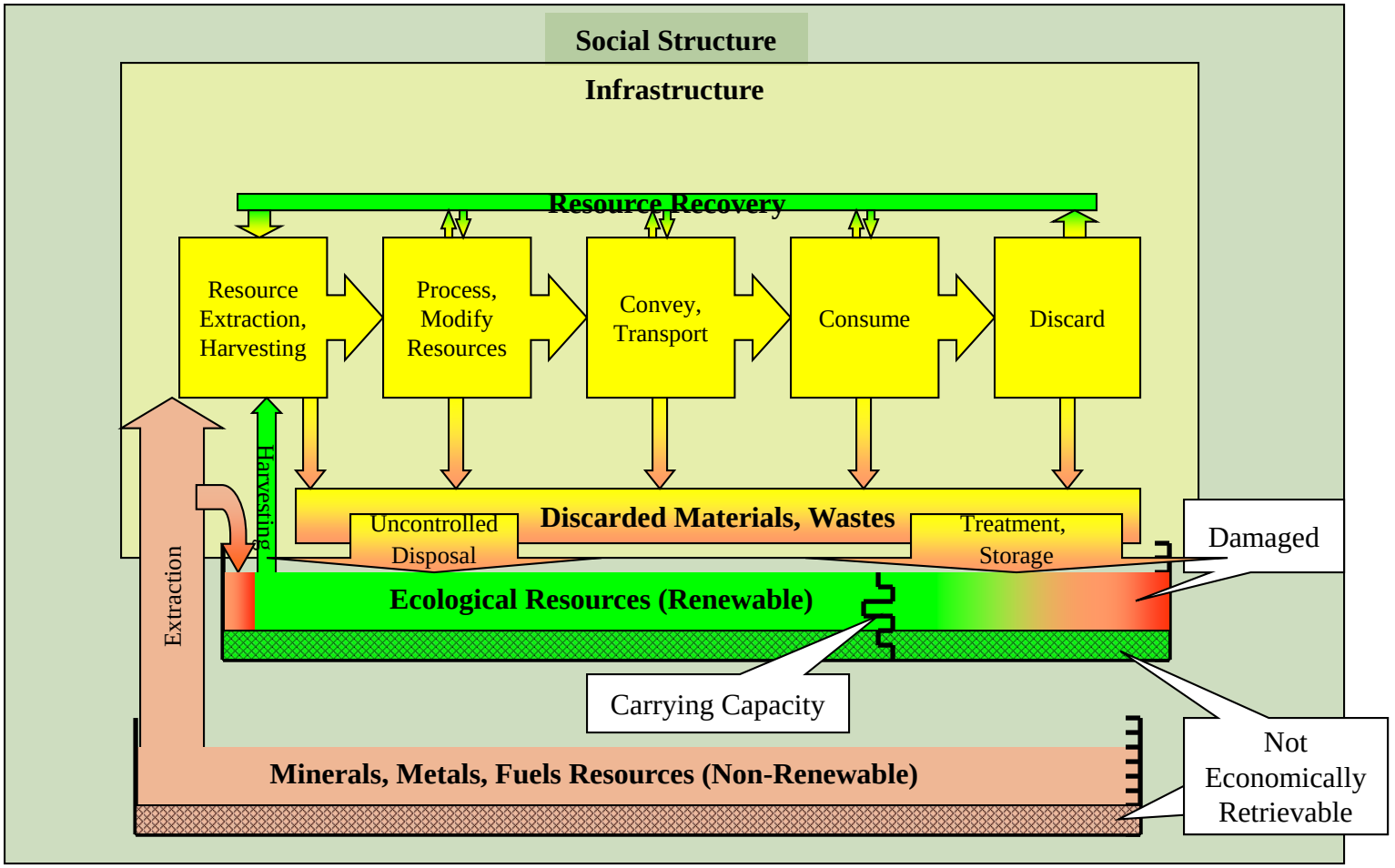
Waste

“Pollution is nothing but the resources we are not harvesting. We allow them to disperse because we've been ignorant of their value.” (Buckminster Fuller)

“Our present industrial economy is an immature ecosystem.” (Hawken, 1993)

Production-Consumption Model

Cradle to Grave (Take – Make – Waste)



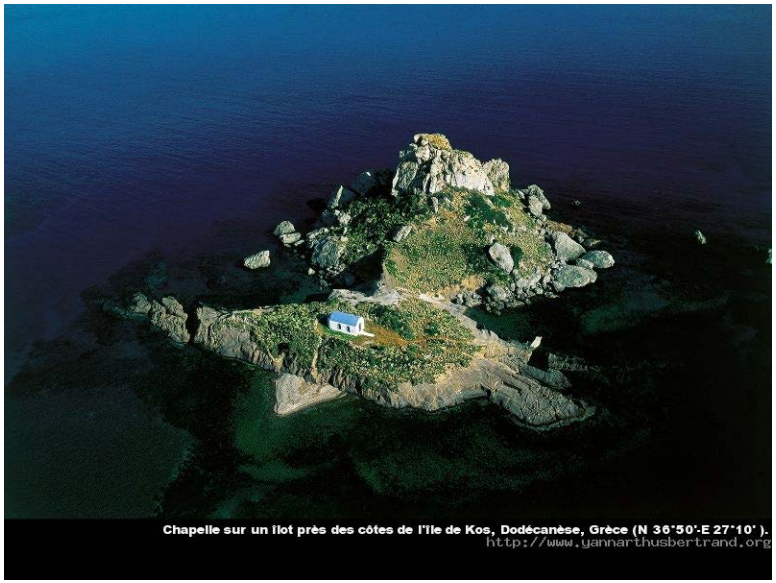
Adapted from D. Roberts and W. Wallace

Sustainability and Sustainable Development – Questions?

- Do we have a clear definition of sustainability and sustainable development?
- What represents a sustainable system, structure or community?
- Can sustainability be possibly quantified?
- Is sustainability just another one of those contemporary “buzzwords”?

Sustainability

The word “sustainability” comes from “sustain” which comes from a Latin word “sustenere” that means to hold up and prolong, to keep in existence, to endure and withstand.



What do we want/need to sustain?

Preservation of activities that humans can derive their sense of well-being from:

- The natural environment (air, water, land, biota)
- The human race and its basic organizations (family, individuals, communities). Critical issues are body, mind, soul
- The built environment (facilities, infrastructure systems)
- Production systems (goods, products, services)
- Resource base (different types of capital)

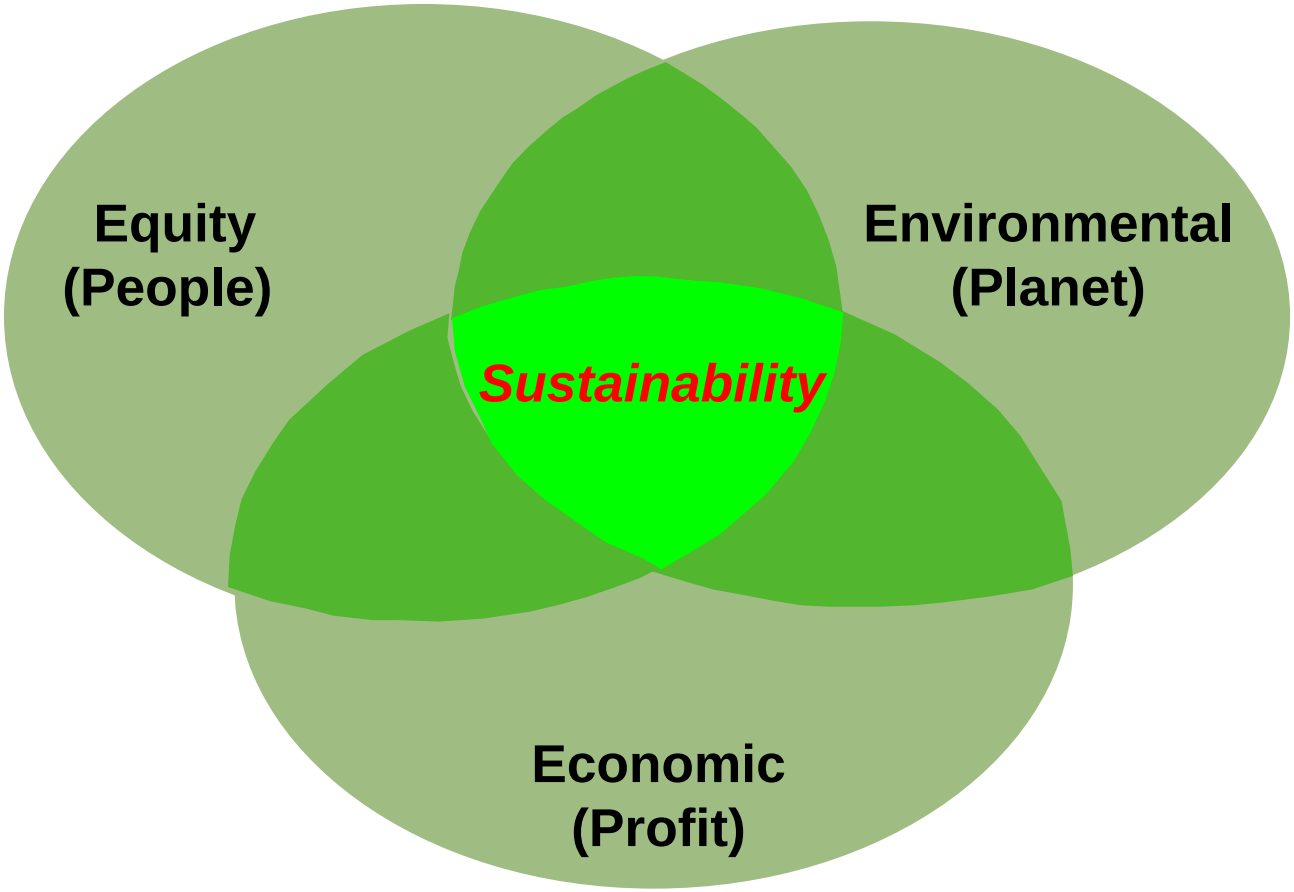
With two additional levels of complexity

- Spatial scale of sustainability

  (site, local, state, regional, national, global footprint, etc.)

- Temporal scale of sustainability

  (today, 1 yr., 1-5 yr., 5-10 yr., etc.)

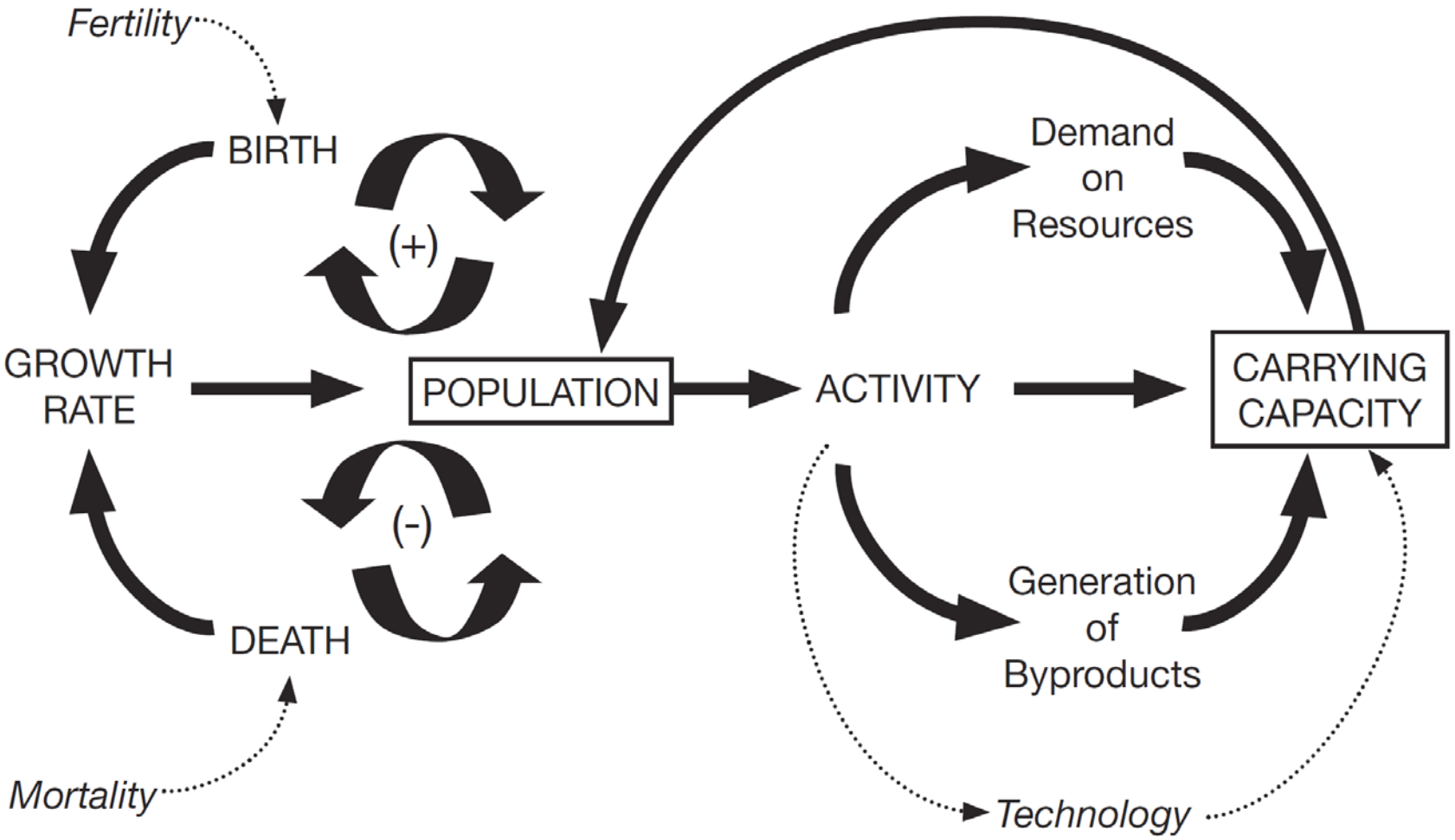

Equity
(People)
Environmental
(Planet)
Sustainability
Economic
(Profit)

Sustainability

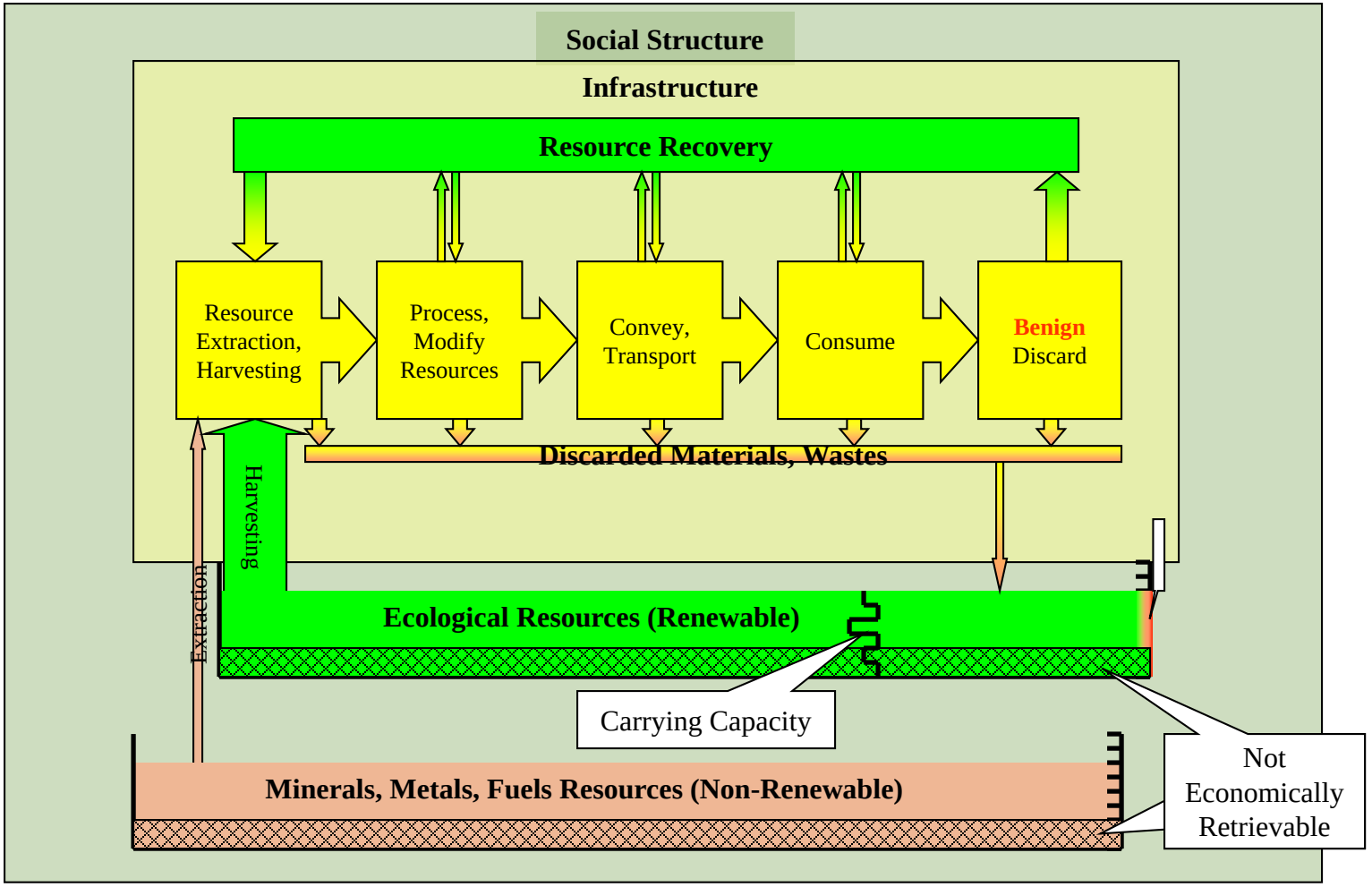
"A dynamic equilibrium in the processes of interaction between a population and the carrying capacity of an environment such that the population develops to express its full potential without adversely and irreversibly affecting the carrying capacity of the environment upon which it depends."

Michael Ben-Eli (2011)

Dynamic Equilibrium



Cradle to Cradle



Take → Make

Waste

"Nature does not have a design problem. People do"

Sustainable Development

"Sustainable development is the challenge of meeting human needs for natural resources, industrial products, food, transportation, shelter, and waste management while conserving and protecting environmental quality and the natural resource base essential for future development."

(Policy Statement, ASCE TAC Subcommittee on Sustainability, 2001)

Sustainable Development Projects

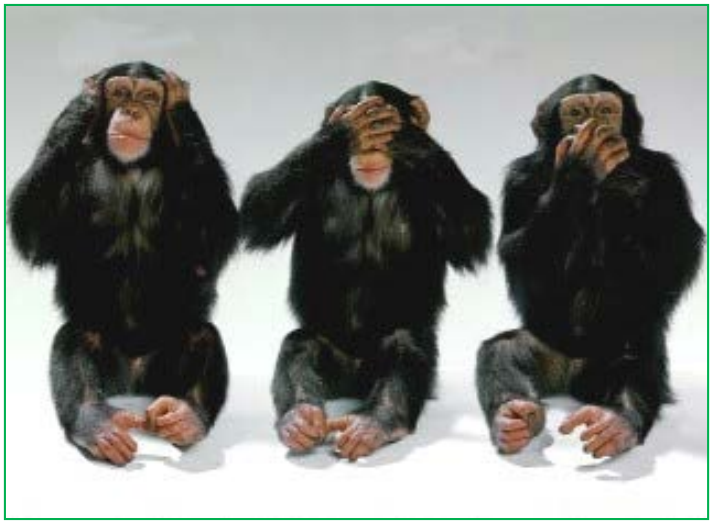
- Take responsibility for their effects on the natural world by doing no harm and not diminishing the diversity of its systems
- Create structures and systems of durability and long term utility whose ultimate use or disposition will not be harmful to current and future generations
- Change the conversation by educating all stakeholders involved
- Deliver efficient and resource-conserving solutions that reduce consumption, energy use, distribution costs, economic concentration, soil erosion, atmospheric pollution and other forms of environmental damage
- Consider what they take, make and waste
- Deliver solutions that work in harmony with the assimilative and regenerative capacity of the Earth's systems

“Design is a signal of intention”

. William McDonough

“The significant problems we face cannot be solved by the same level of thinking that created them.”

Albert Einstein



Old Mindset:

- Linear
- Earth made for humans
- Violent (brute force)
- Control nature
- Short time frames
- Earth is a limitless source and sink for waste
- Technology is omnipotent
- Doing well
- Extractive processes
- Waste as waste
- Externalize externalities
- Benefits for a few
- Creates waste

New Mindset:

- Cyclical, Systemic
- Humans made for Earth
- Caring and restoring
- Emulate nature, work with
- Longer time frames
- Earth is finite source or sink

- Technology as solution
- Doing good by doing well
- Renewable processes
- Waste as resources
- Internalize externalities
- Benefits all
- Creates value

"Thus the task is not so much to see what no one yet has seen, but to think what nobody yet has thought about that which everybody sees"

Arthur Schopenhauer