FOOD, WATER, and ENERGY

December 8, 2014

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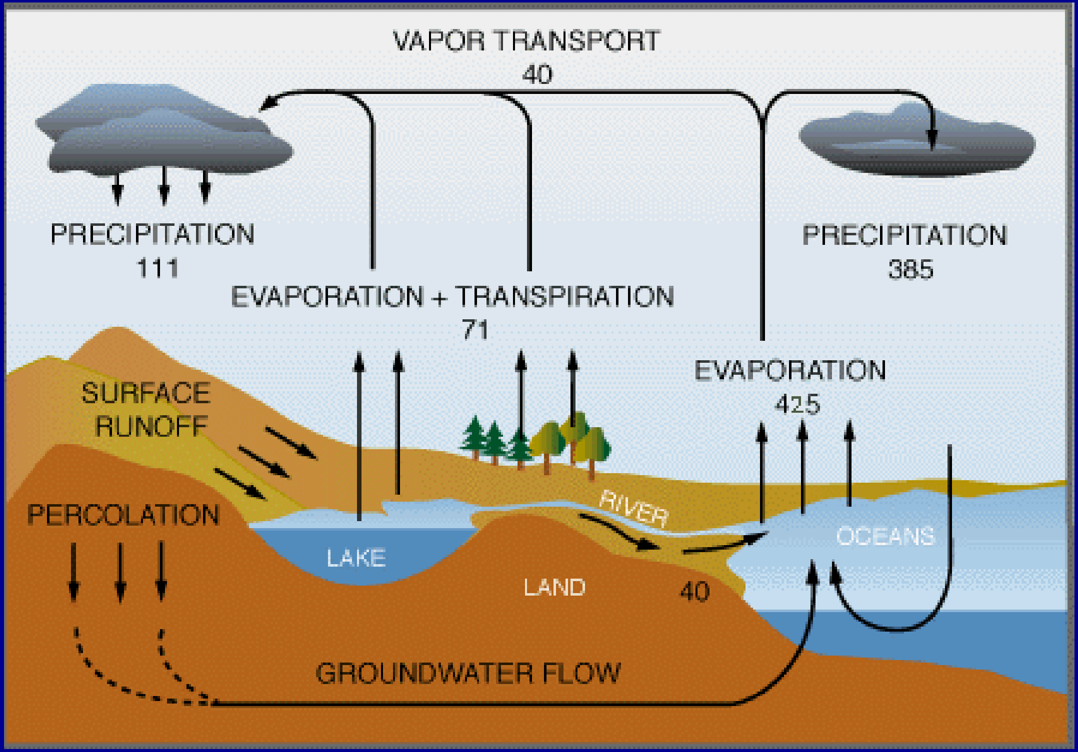
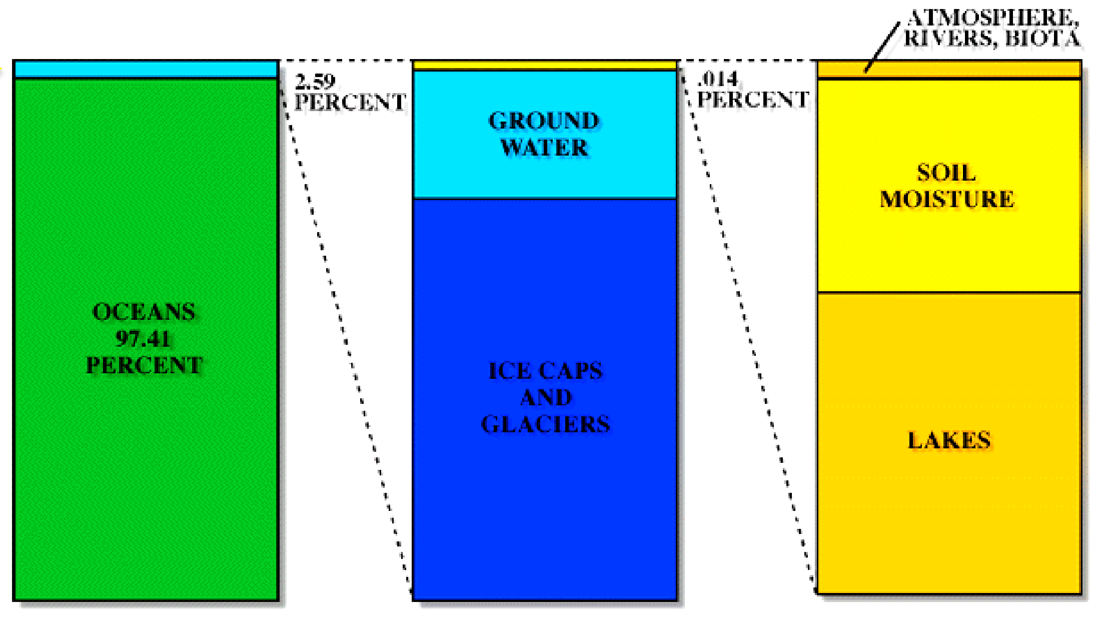
The Hydrologic Cycle



Water is moved close to the Earth's surface by solar energy, gravity, and the energy of the Earth's rotation

The amount of fresh water available for human use is a tiny percentage of the water on Earth



Water is a FULLY RENEWABLE resource!

Delaware River Basin

Modern Water Treatment Centers

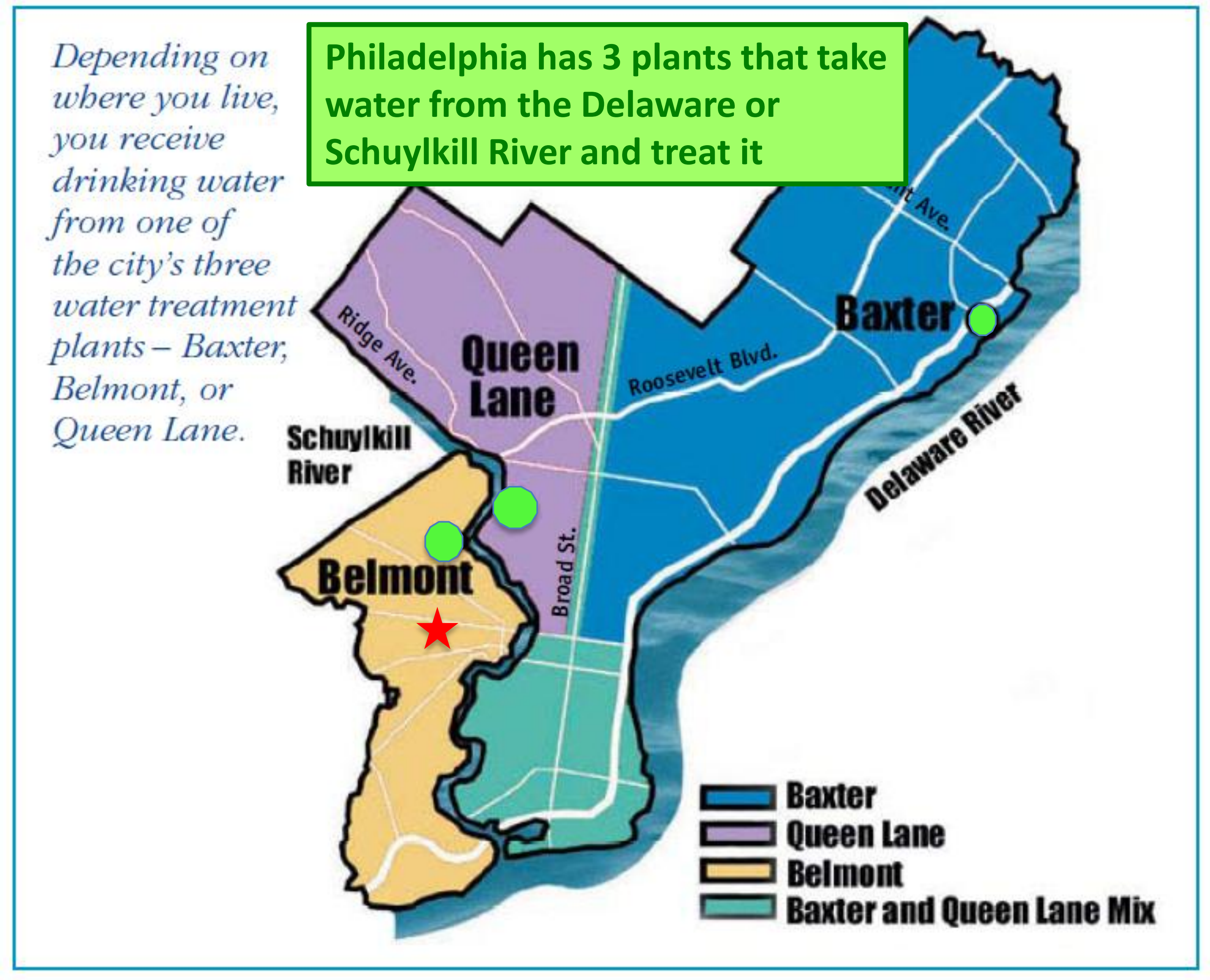
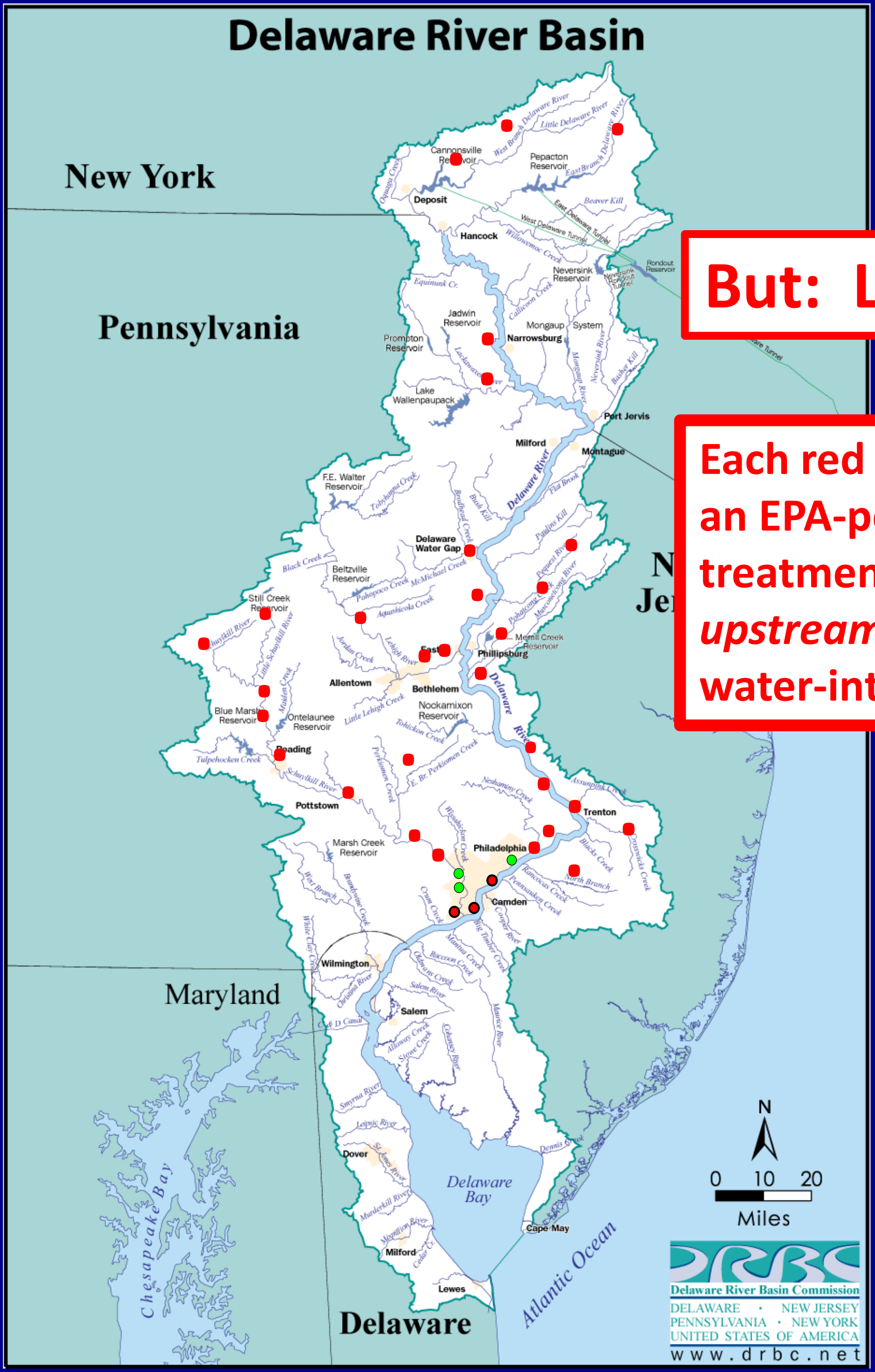


Image: PWD

Wastewater Treatment Centers

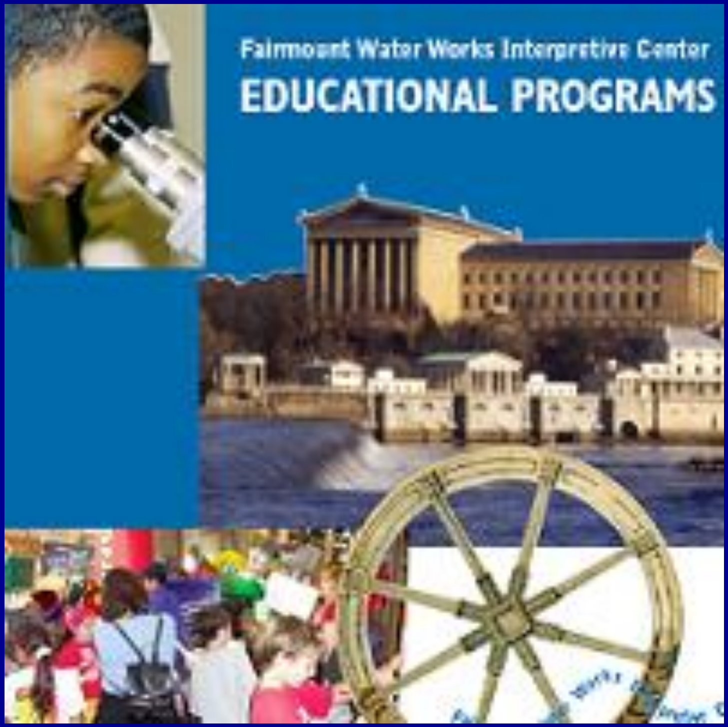
Image: PWD



But: Look upstream!

Each red dot is the location of an EPA-permitted wastewater-treatment discharge facility *upstream* from Philadelphia's water-intake sites

The Fairmount Water Works Interpretive Center



Hidden River

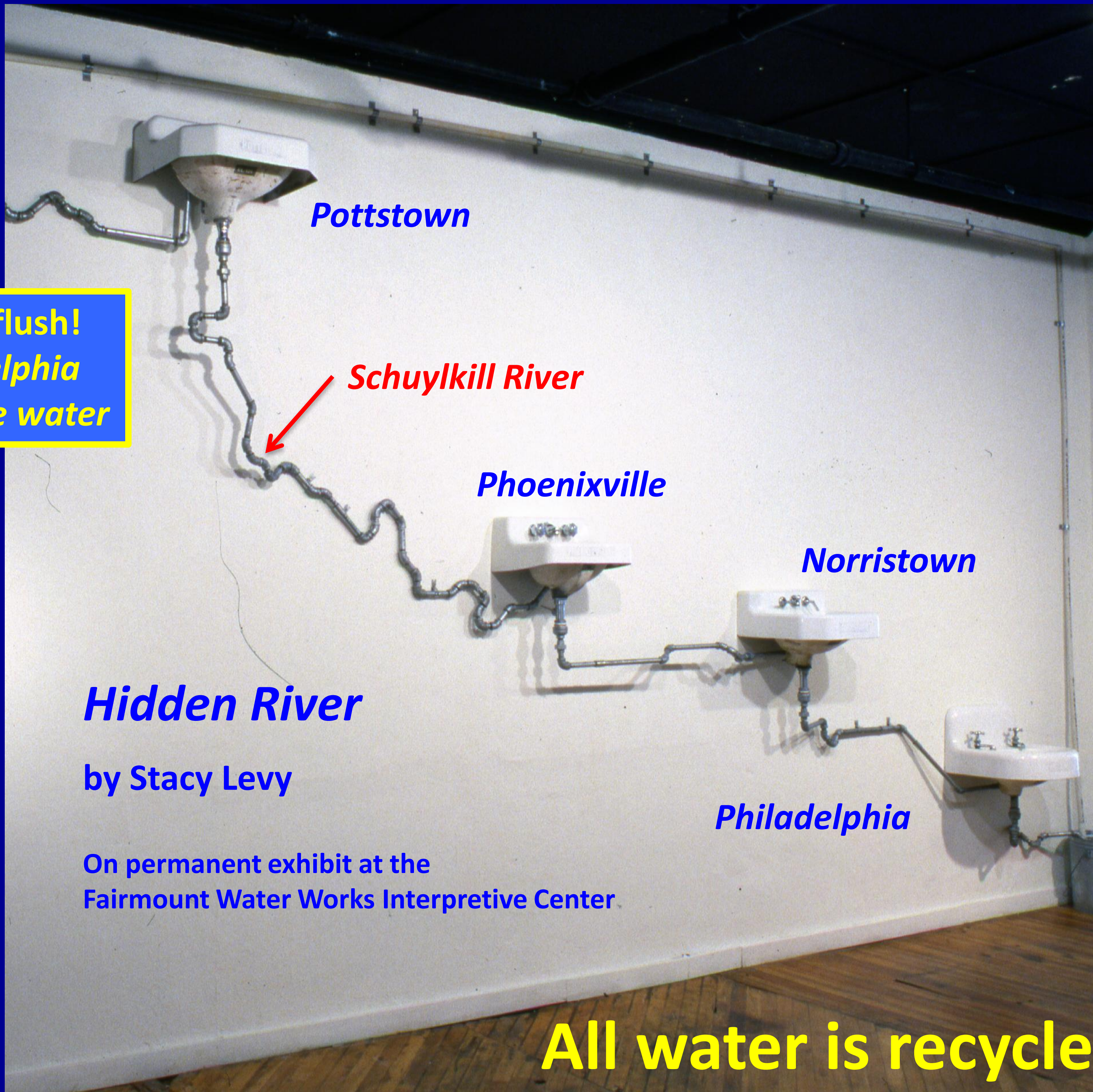
by Stacy Levy

On permanent exhibit at the
Fairmount Water Works Interpretive Center

Reading


Pottstown
Schuylkill River
Phoenixville
Norristown
Philadelphia
Hidden River
by Stacy Levy
On permanent exhibit at the
Fairmount Water Works Interpretive Center

Reading



Please flush!
Philadelphia needs the water

Hidden River

by Stacy Levy

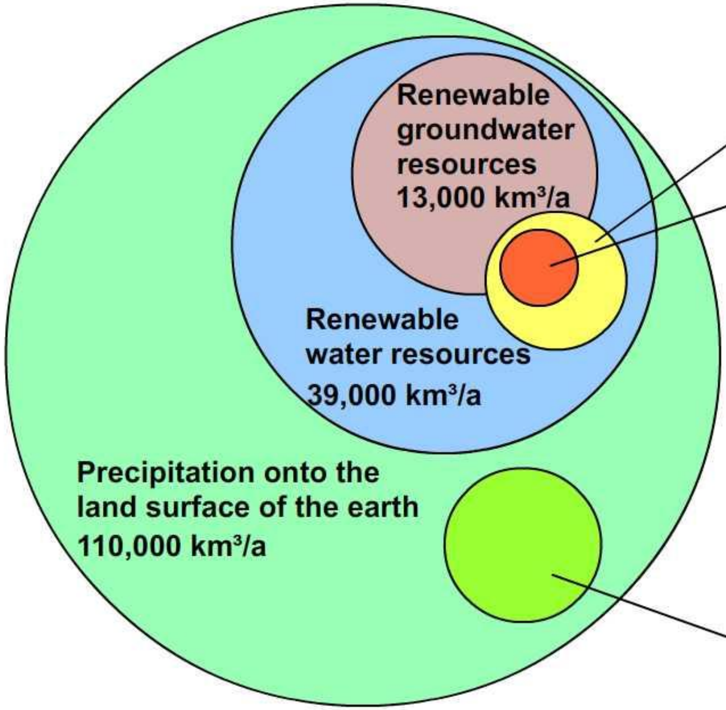
On permanent exhibit at the
Fairmount Water Works Interpretive Center

All water is recycled!!

Singapore's "newater"

Recycled sewage represents 25% of Singapore's drinking water, and 35% of the drinking water of Windhoek

GLOBAL WATER "USE"



Water withdrawals 4,300 km^3/a (35% from groundwater)

Consumptive use 1,400 km^3/a (40% from groundwater)

Water use sector	Withdrawals	Groundwater	Consumptive use
Irrigation *	3,200 km^3/a	42%	1,200 km^3/a
Thermal power plants	530 km^3/a	0%	10 km^3/a
Households	330 km^3/a	36%	50 km^3/a *
Manufacturing	260 km^3/a	27%	110 km^3/a
Livestock	27 km^3/a	0%	27 km^3/a

***we waste 30%**

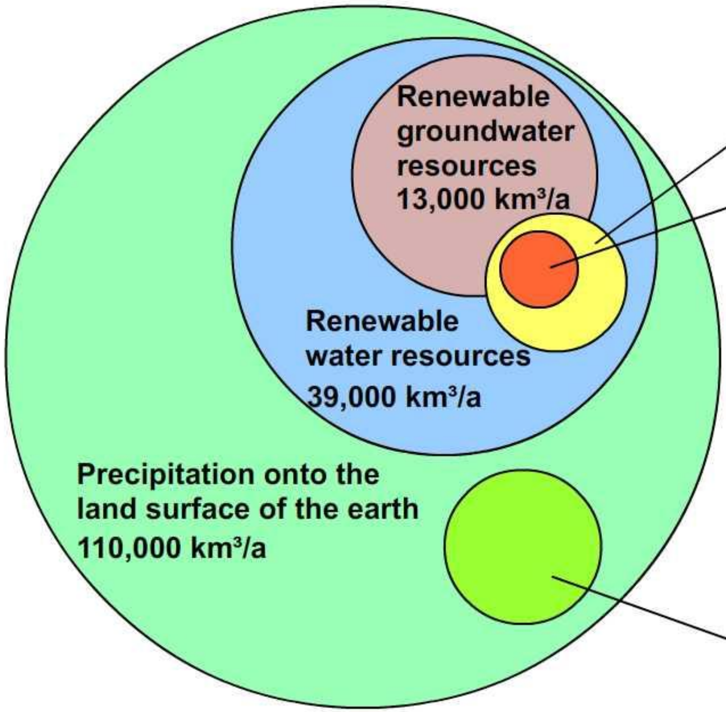
*** 7 m^3/person/yr**

Green water use 5,300 km^3/a (evapotranspiration of precipitation on cropland)

Precipitation onto land surface = ~110,000 km^3/yr *(green circle)*
~55,000 km^3/yr are re-evaporated, or transpired by plants
~55,000 km^3/yr flow, eventually, to the ocean, via surface runoff or groundwater *(blue and brown circles)*

Humankind intercepts, for "use", 4,300 km^3, or ~4% of that flow
75% of that use is for irrigated agriculture

GLOBAL WATER "USE"



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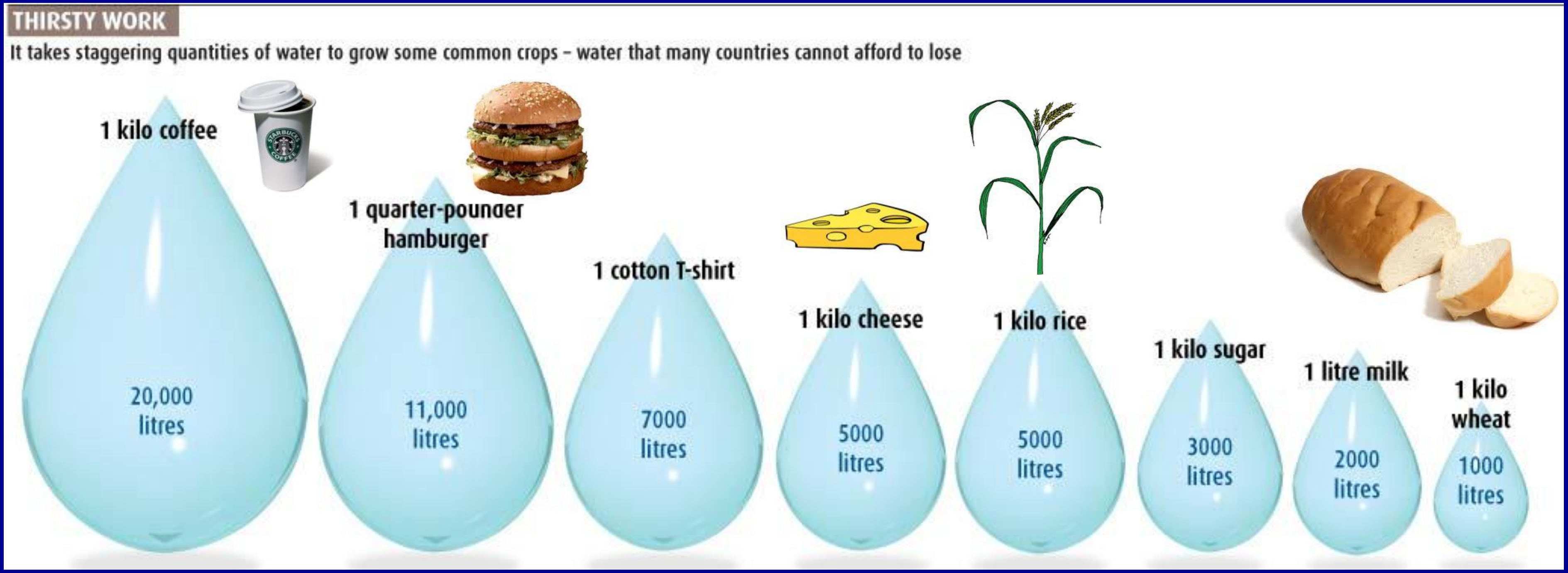
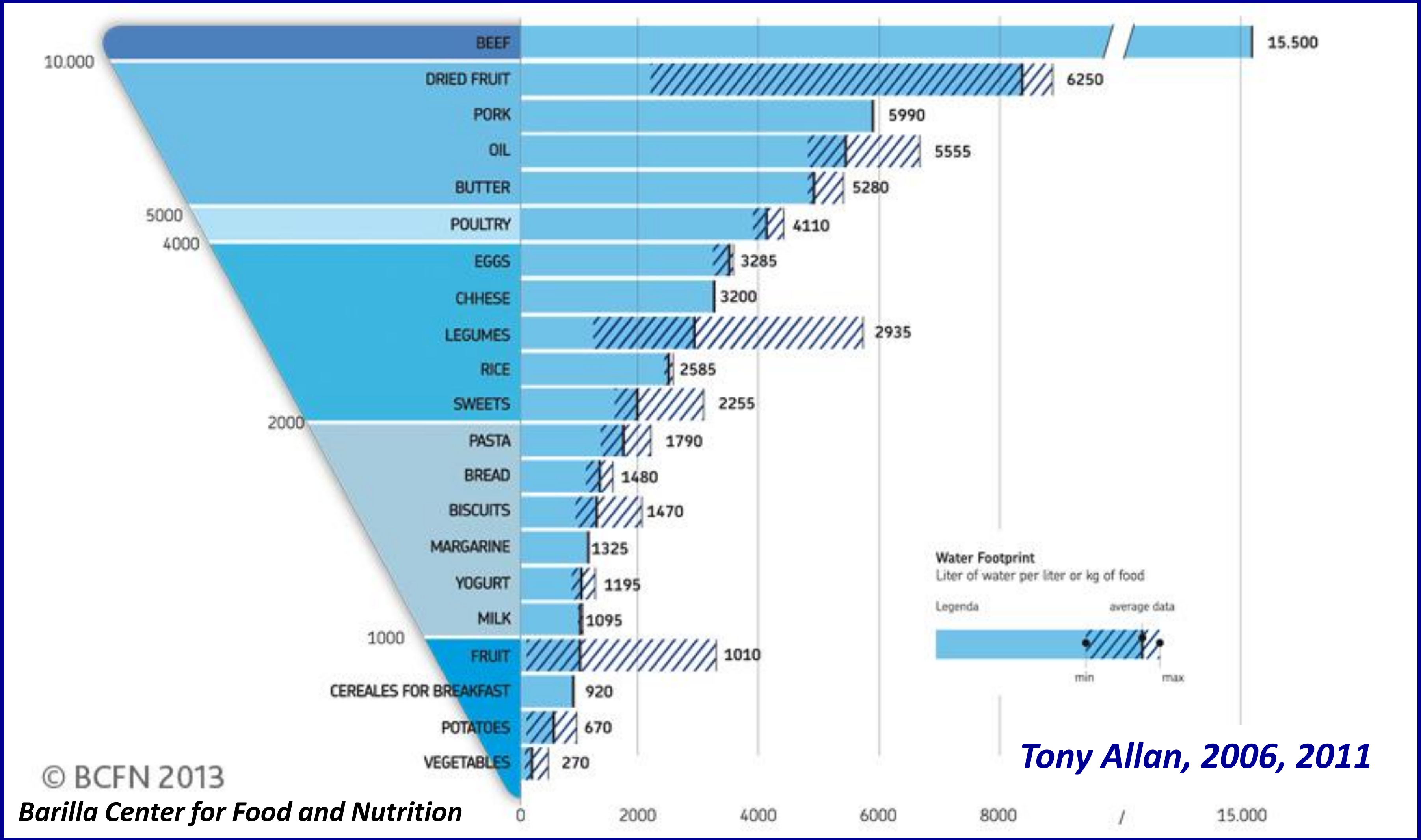
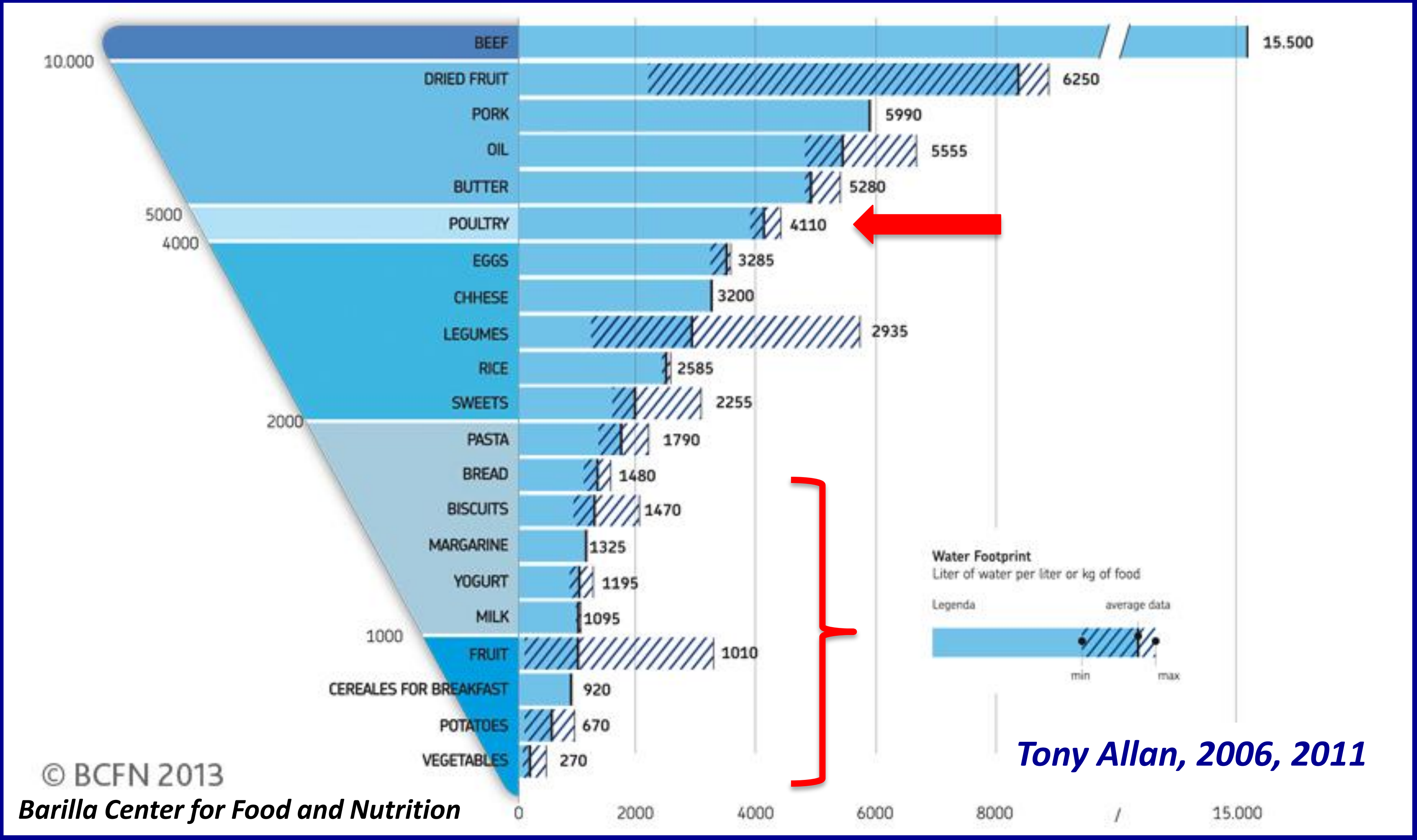
“Virtual”, or embodied water



Steel: 6 liters/kilogram
Microchips: 16,000 liters/kilogram



Virtual water in food: liters of water/kg of food



Virtual water in food: liters of water/kg of food

>3,300 brands of bottled water are now available worldwide

Despite their brave assertions of pristine purity, all represent recycled water

In 2009:

Americans spent $21 billion on bottled water
All water utilities in the USA spent $29 billion on renovation and maintenance of their facilities

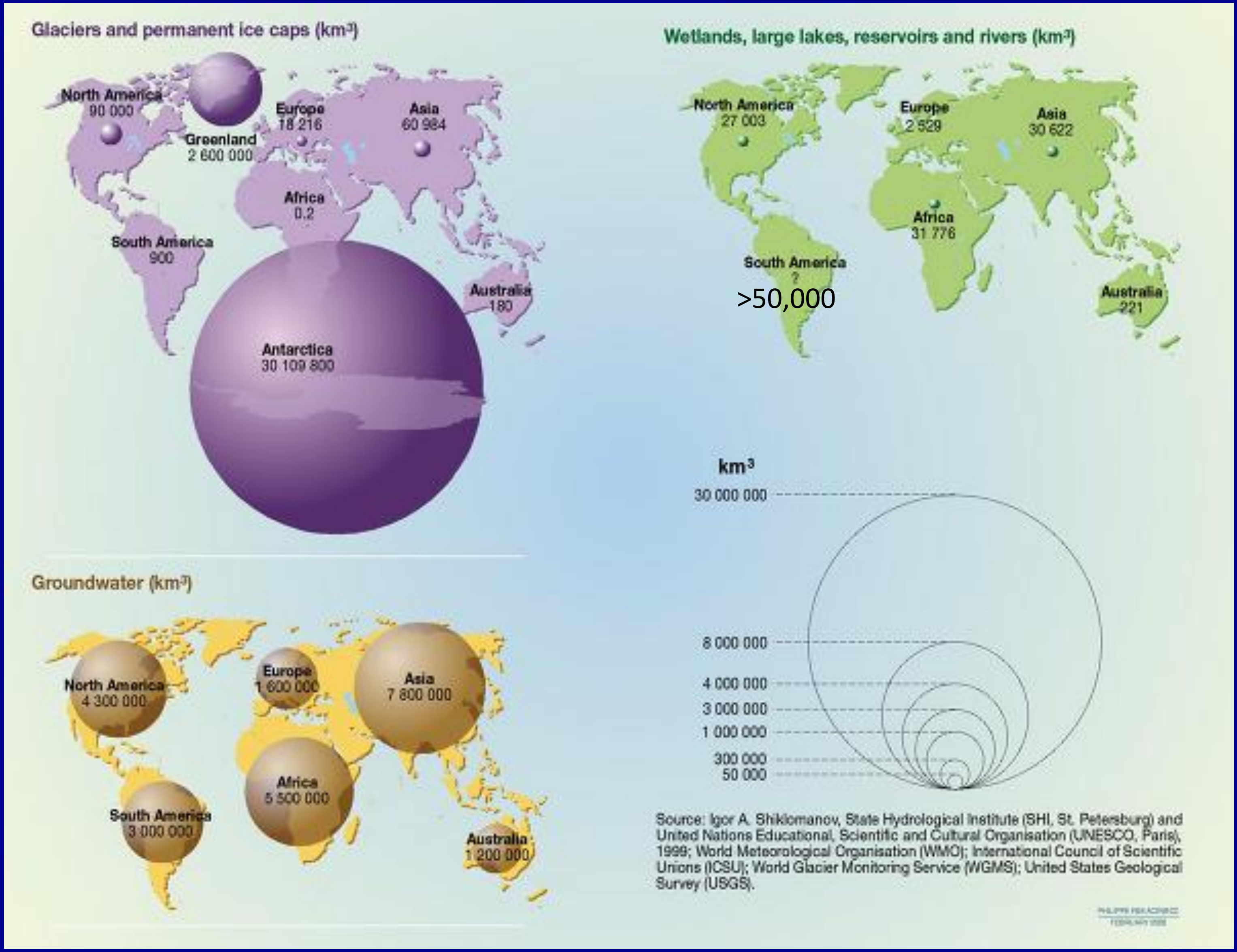
One 500 ml bottle of water cost $1.25
Thus, one m^3 of bottled water cost $2,500
One m^3 of treated water delivered to an American household by a public water utility cost $0.75

That is a markup of 3,333X!

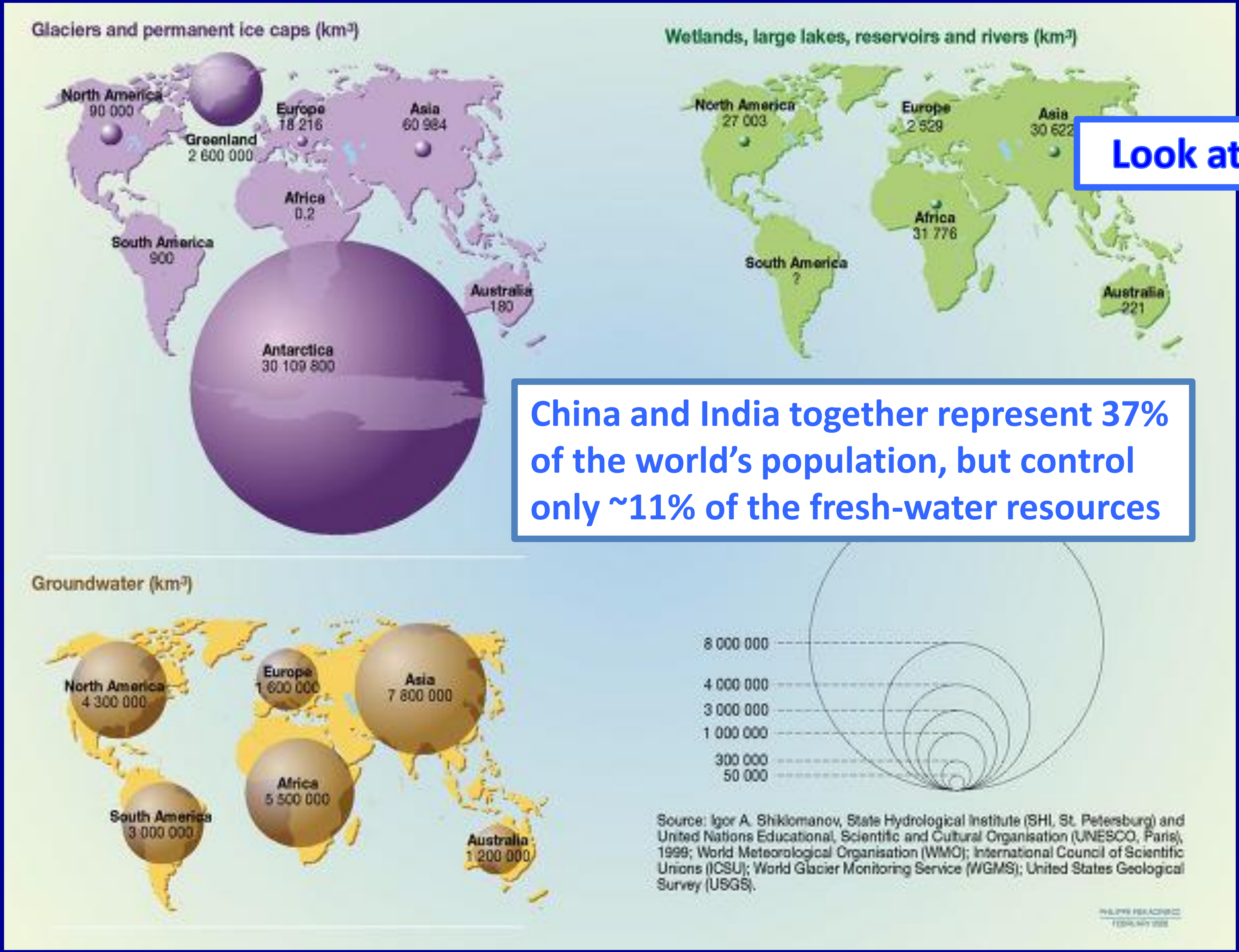
Public water utilities are beginning to wonder why they bother to deliver safe water to American households. This is an insidious risk.

If you insist on using bottled water in the USA, please buy it from those companies who bottle and sell tap water already purified by municipal utilities. EPA trumps FDA.

(After 2010, bottled-water use in the USA has begun to decline)



Distribution of fresh water by continent

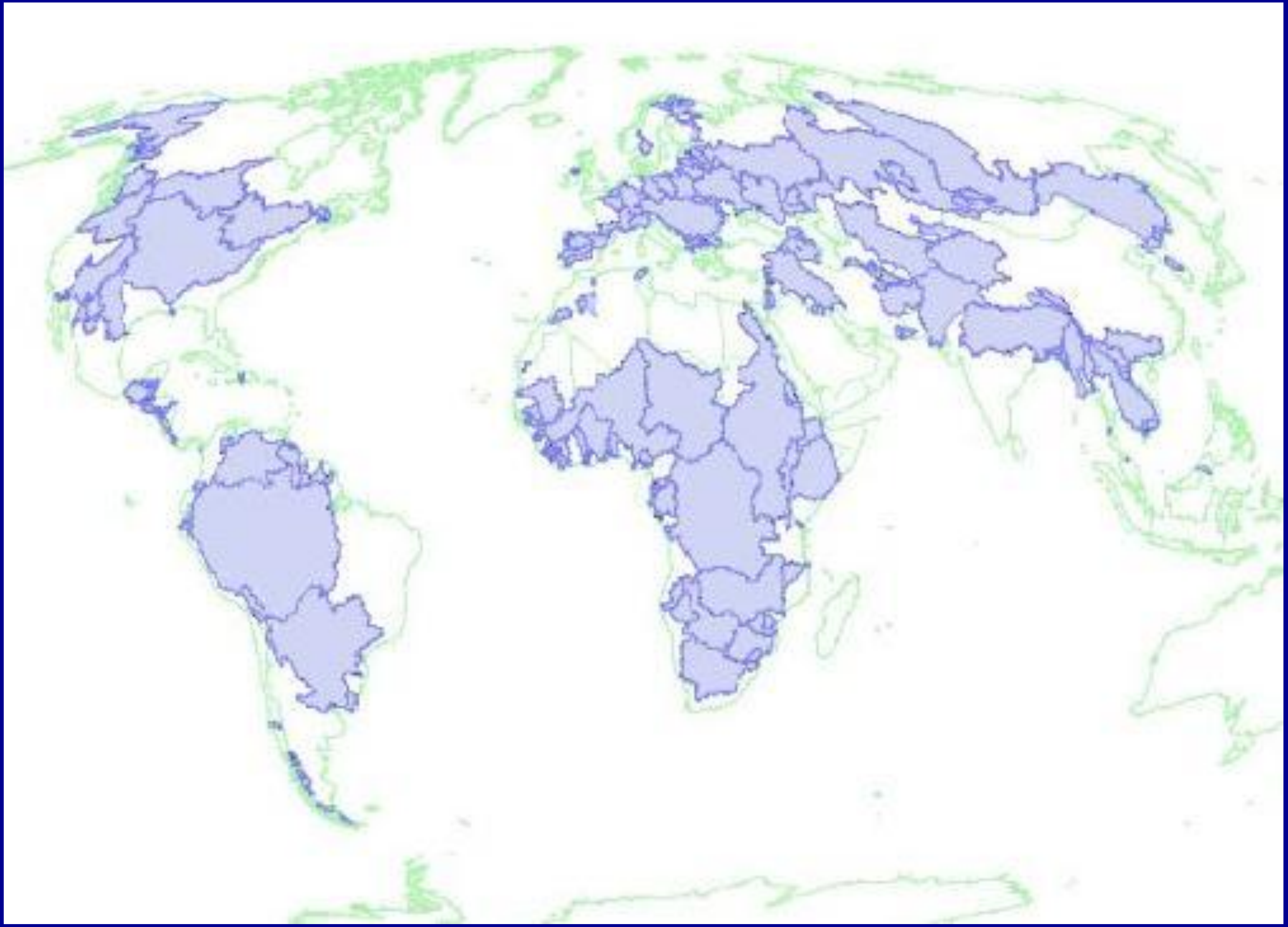


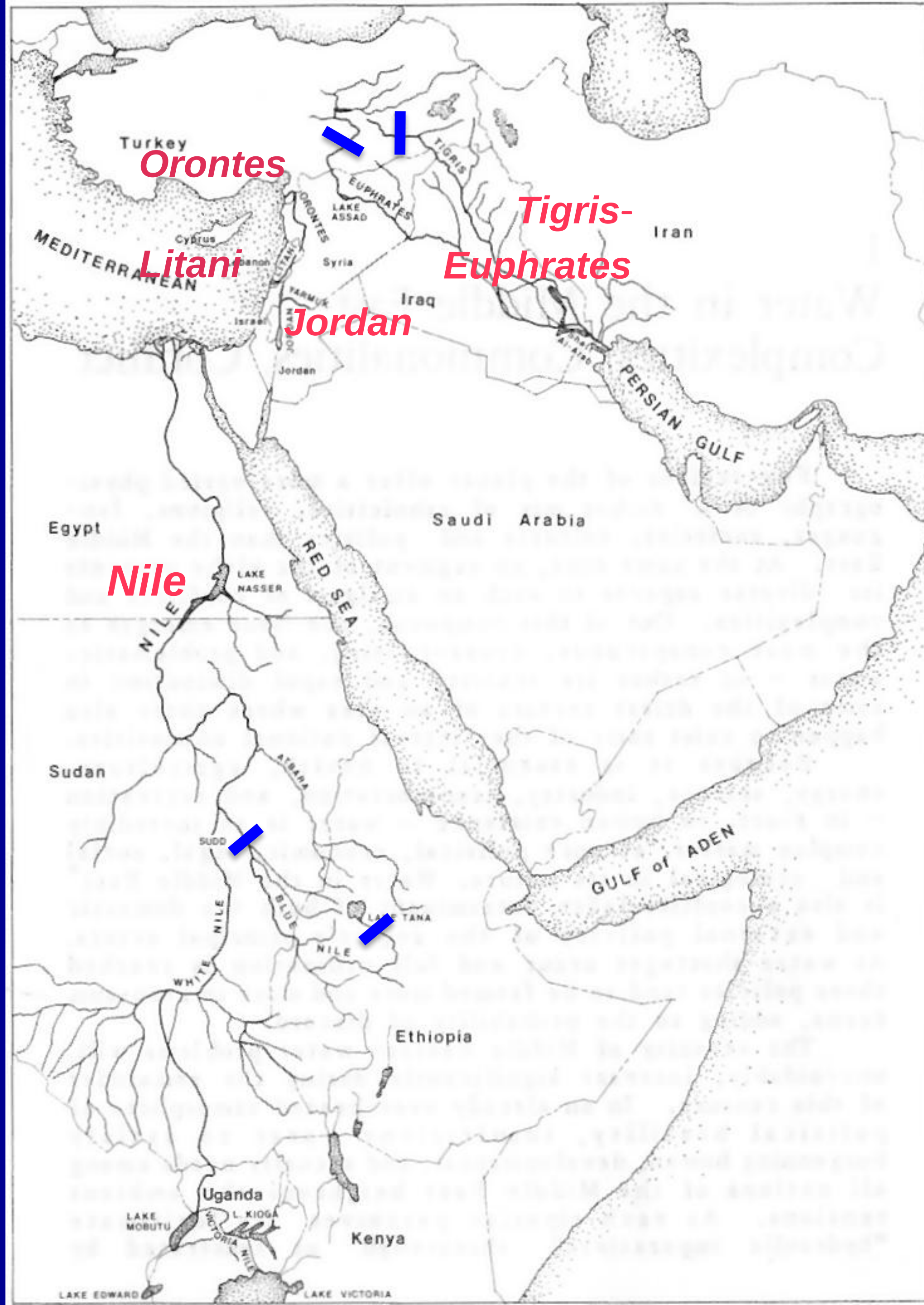
Look at Africa!

China and India together represent 37% of the world's population, but control only ~11% of the fresh-water resources

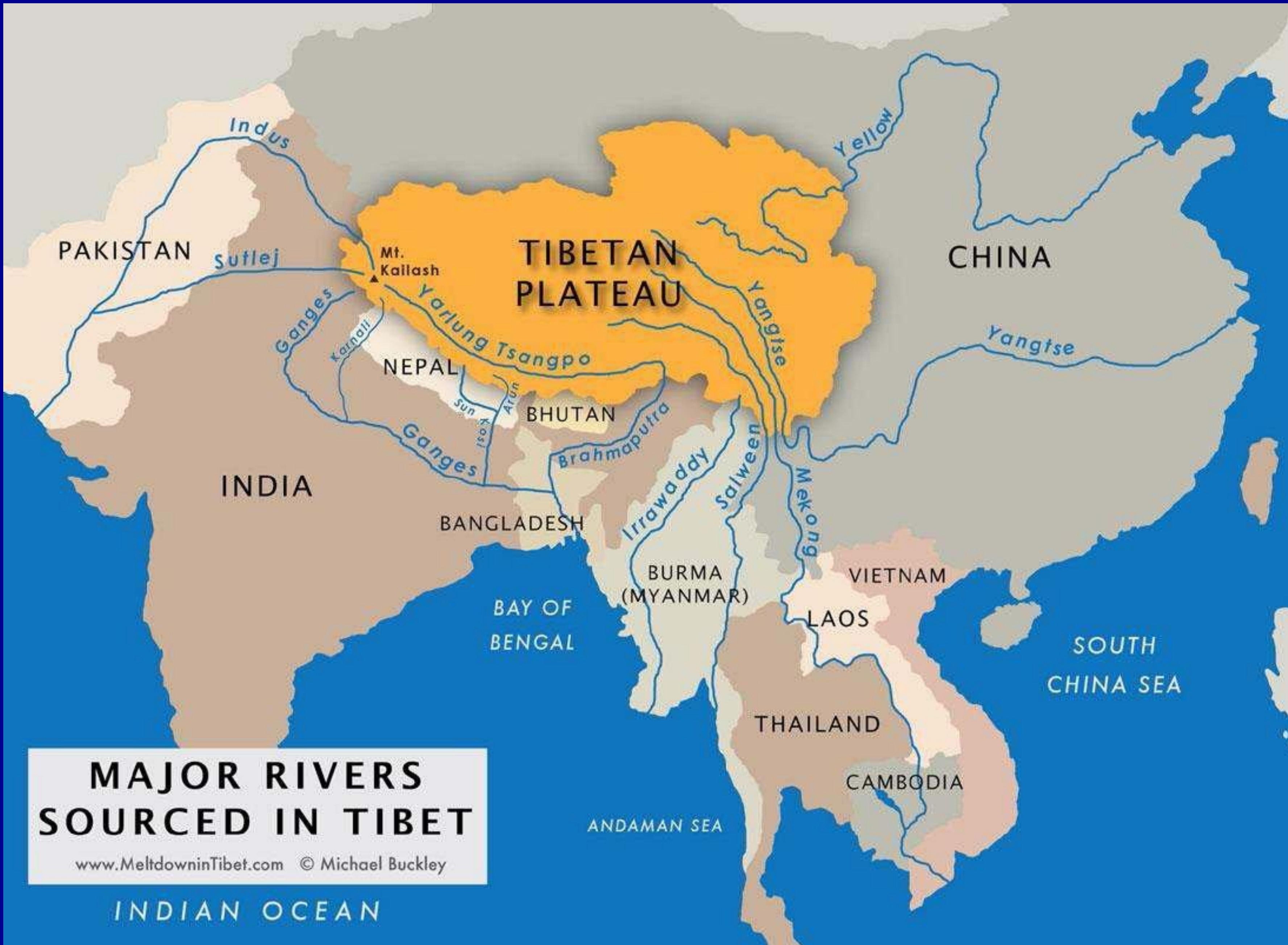
Distribution of fresh water by continent

Watersheds shared by two or more sovereign states





Turkey
Orontes
Tigris-
Euphrates
Iran
Litani
Jordan
MEDITERRANEAN
Cyprus
Syria
Iraq
Israel
Jordan
LAKE ASSAD
EUPHRATES
TIGRIS
ORONTES
YARMUK
PERSIAN GULF
Saudi Arabia
Egypt
Nile
LAKE NASSER
NILE
RED SEA
Sudan
ATBARA
SUDD
BLUE NILE
LAKE TANA
WHITE NILE
GULF of ADEN
Ethiopia
Uganda
LAKE MOBUTU
L. KIOGA
VICTORIA NILE
Kenya
LAKE EDWARD
LAKE VICTORIA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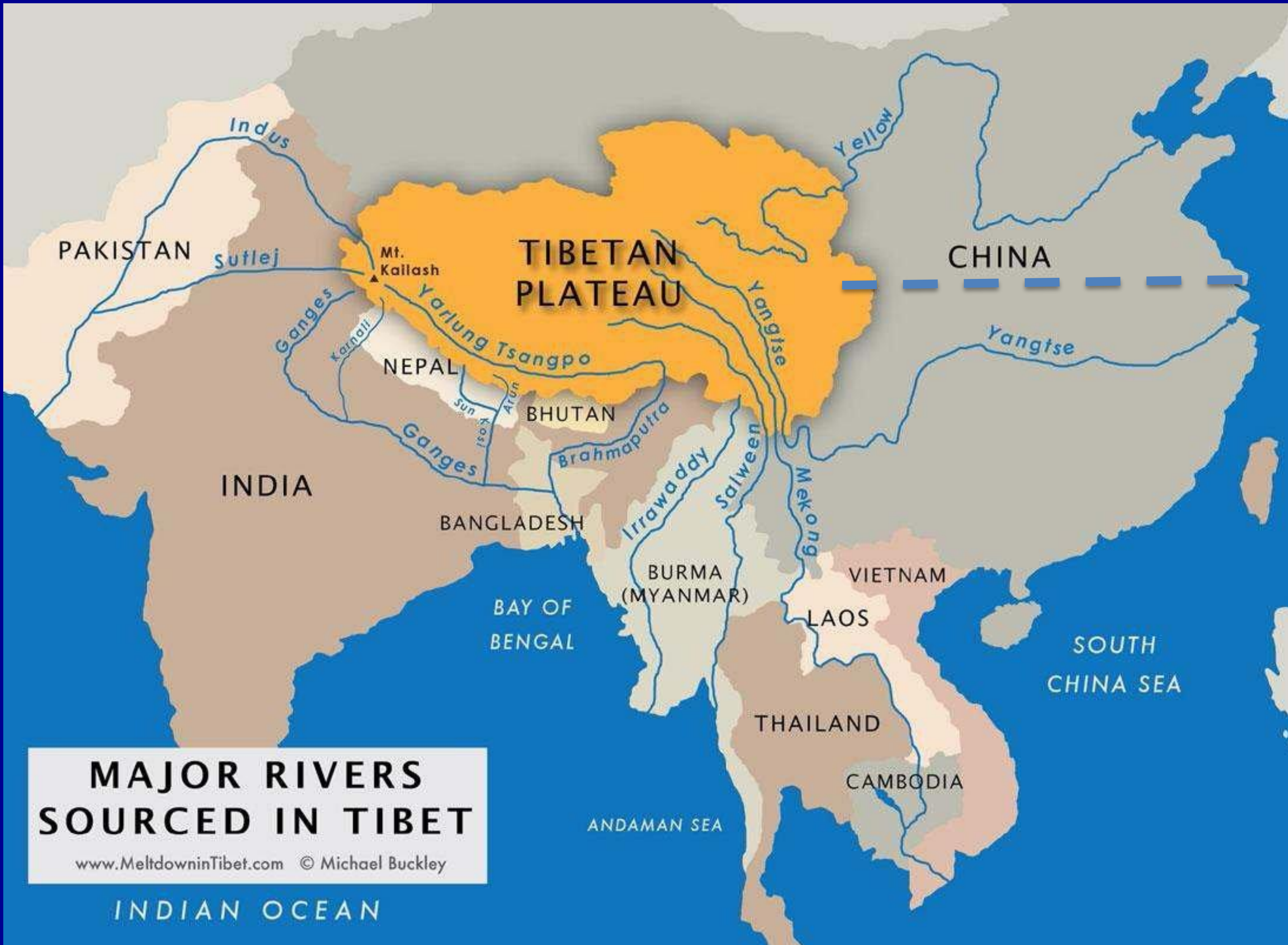
THAILAND
CAMBODIA
Mt.
Kailash
Indus
Sutlej
Ganges
Karnali
Yarlung Tsangpo
Sun
Kosi
Arun
Brahmaputra
Irrawaddy
Salween
Mekong
Yangtse
Yellow
BAY OF
BENGAL
ANDAMAN SEA
SOUTH
CHINA SEA
INDIAN OCEAN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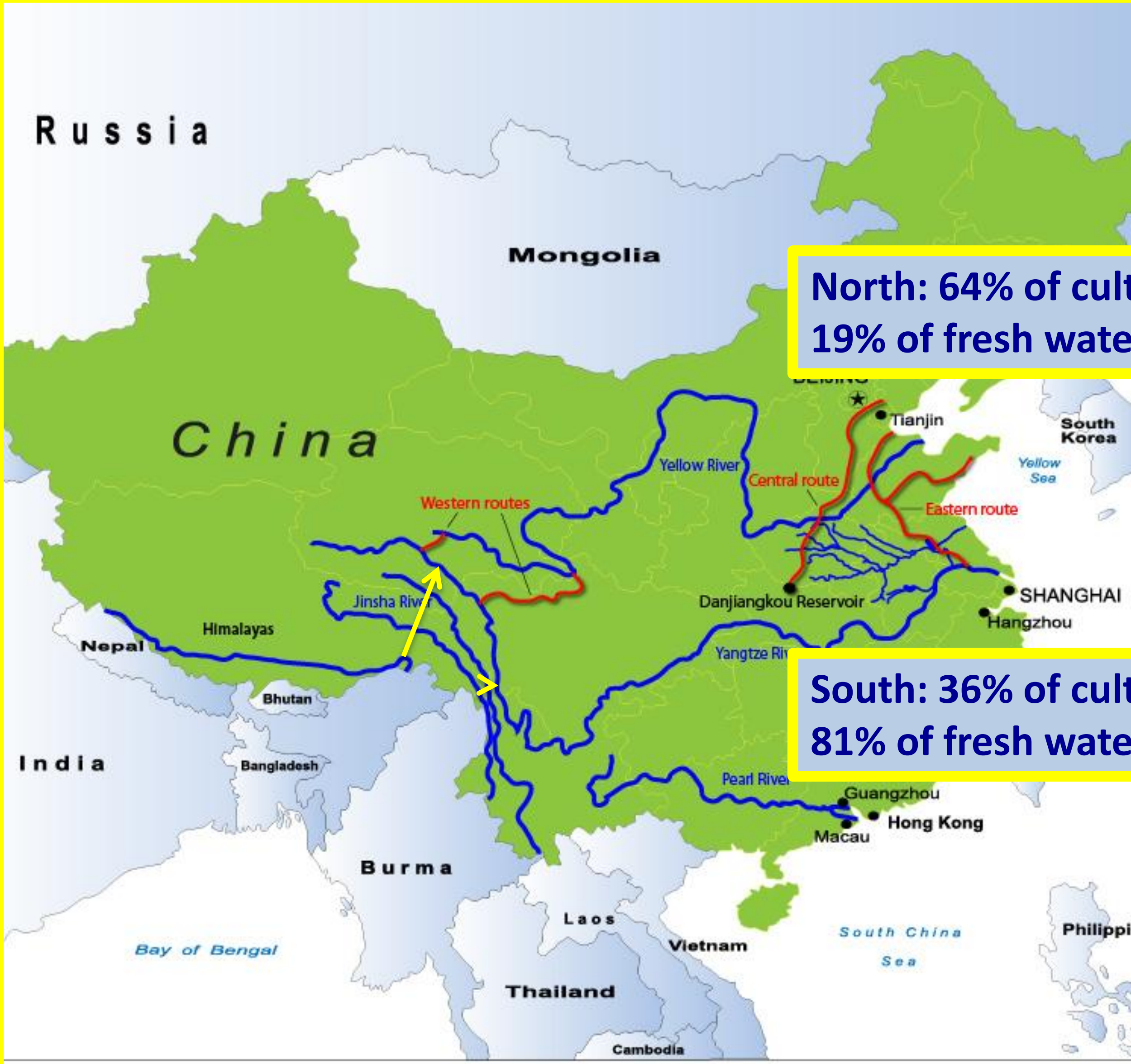
VIETNAM
THAILAND
CAMBODIA
BAY OF BENGAL
ANDAMAN SEA
SOUTH CHINA SEA
INDIAN OCEAN
Mt. Kailash
Indus
Sutlej
Ganges
Karnali
Yarlung Tsangpo
Sun Kosi
Arun
Brahmaputra
Irrawaddy
Salween
Mekong
Yangtse
Yellow



North: 64% of cultivated land
19% of fresh water resources

South: 36% of cultivated land
81% of fresh water resources

South-North Water Transfer Project, 2050 (red line)

Other planned diversions (yellow arrow)

There are conflicting messages here….

Sixteen Essential Elements

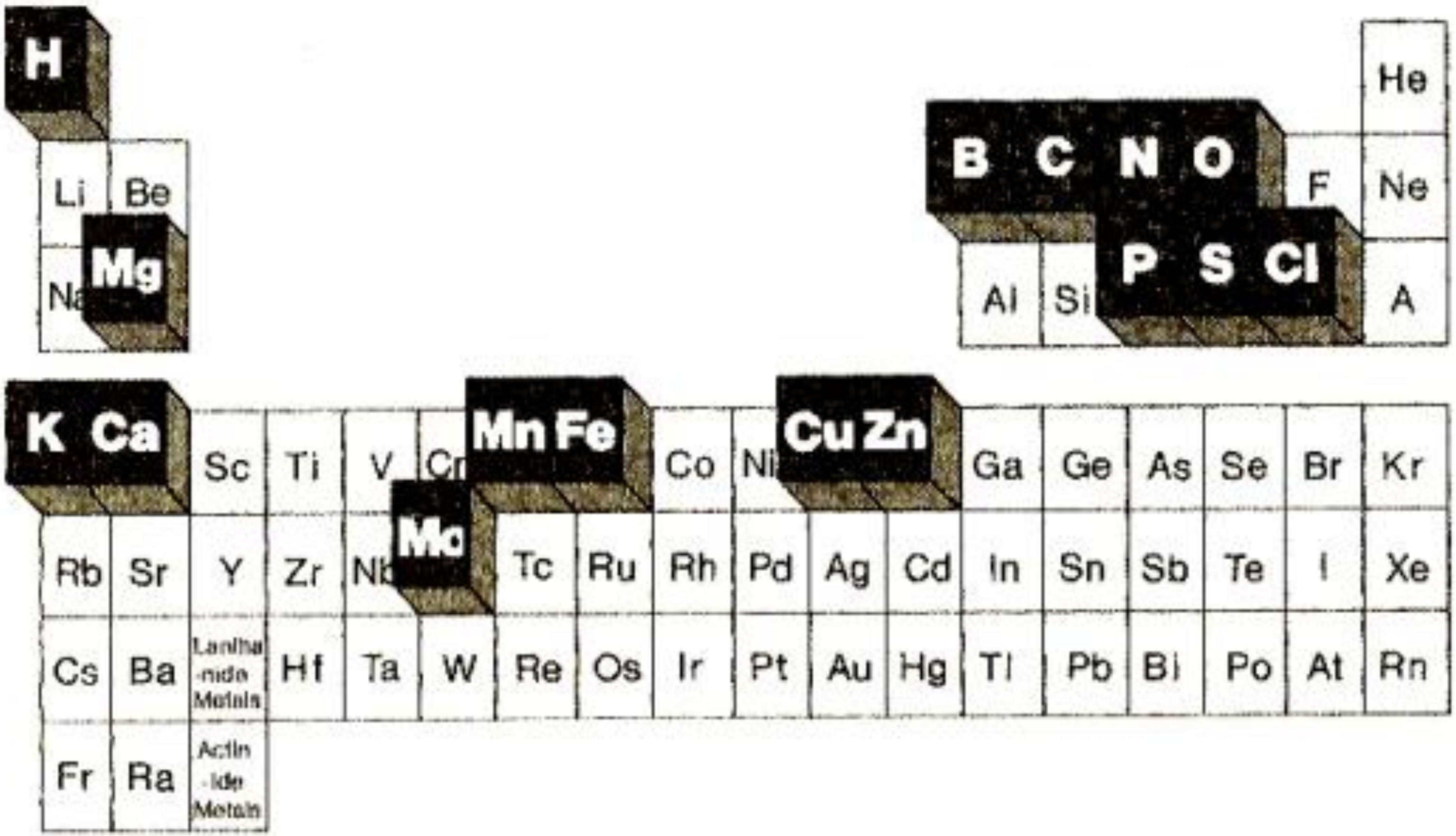


Fig. 4-1. Periodic table of elements highlighting the 16 essential plant nutrients.

Elements (nutrients) essential to plant life:

0. major non-mineral: O, H, C

1. primary: K, N, P

2. secondary: Ca, Mg, S

3. micro: Fe, Mn, Cl, Zn, Cu, B, Mo

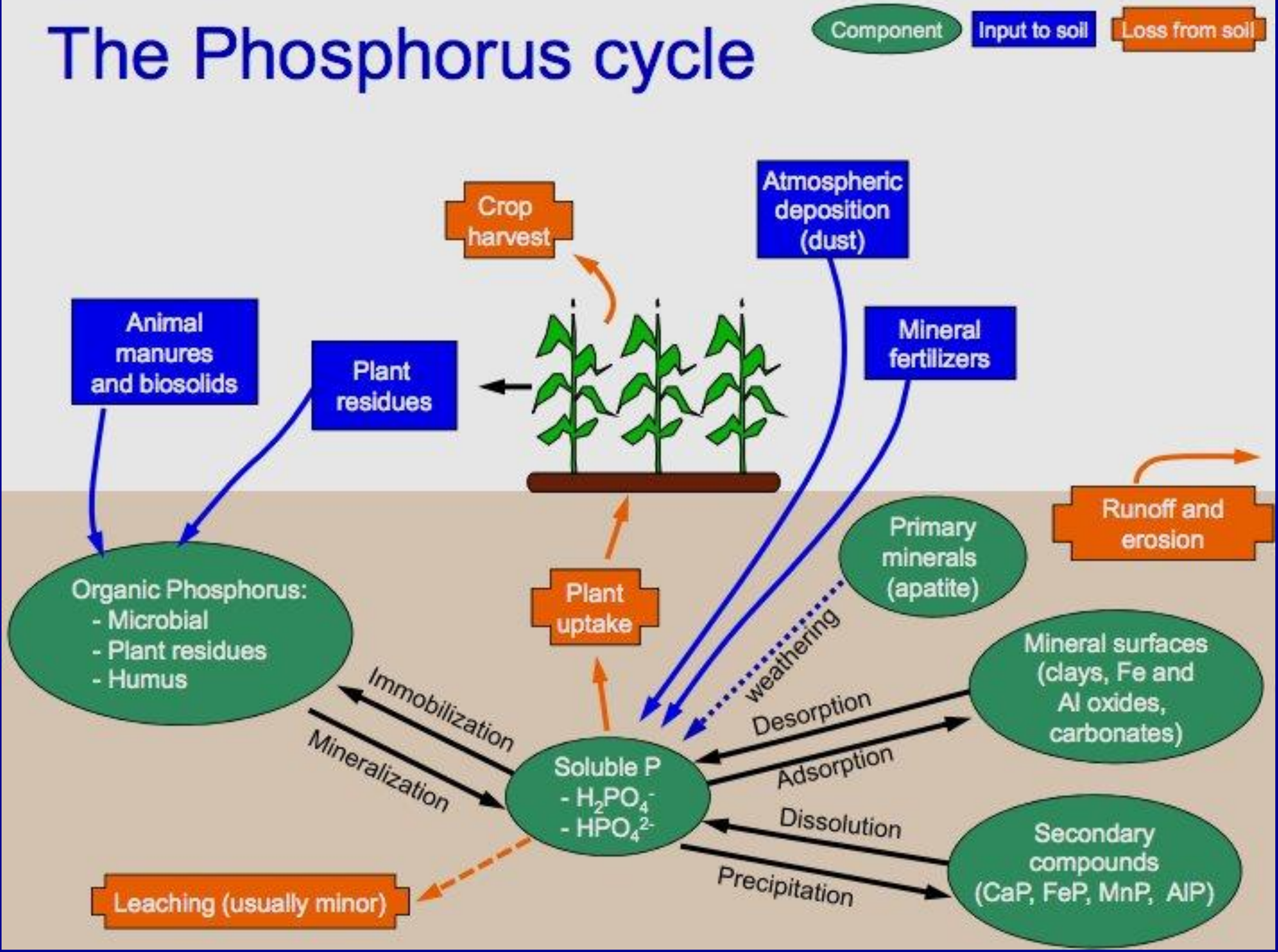
?. (maybe micro: Na, Si)

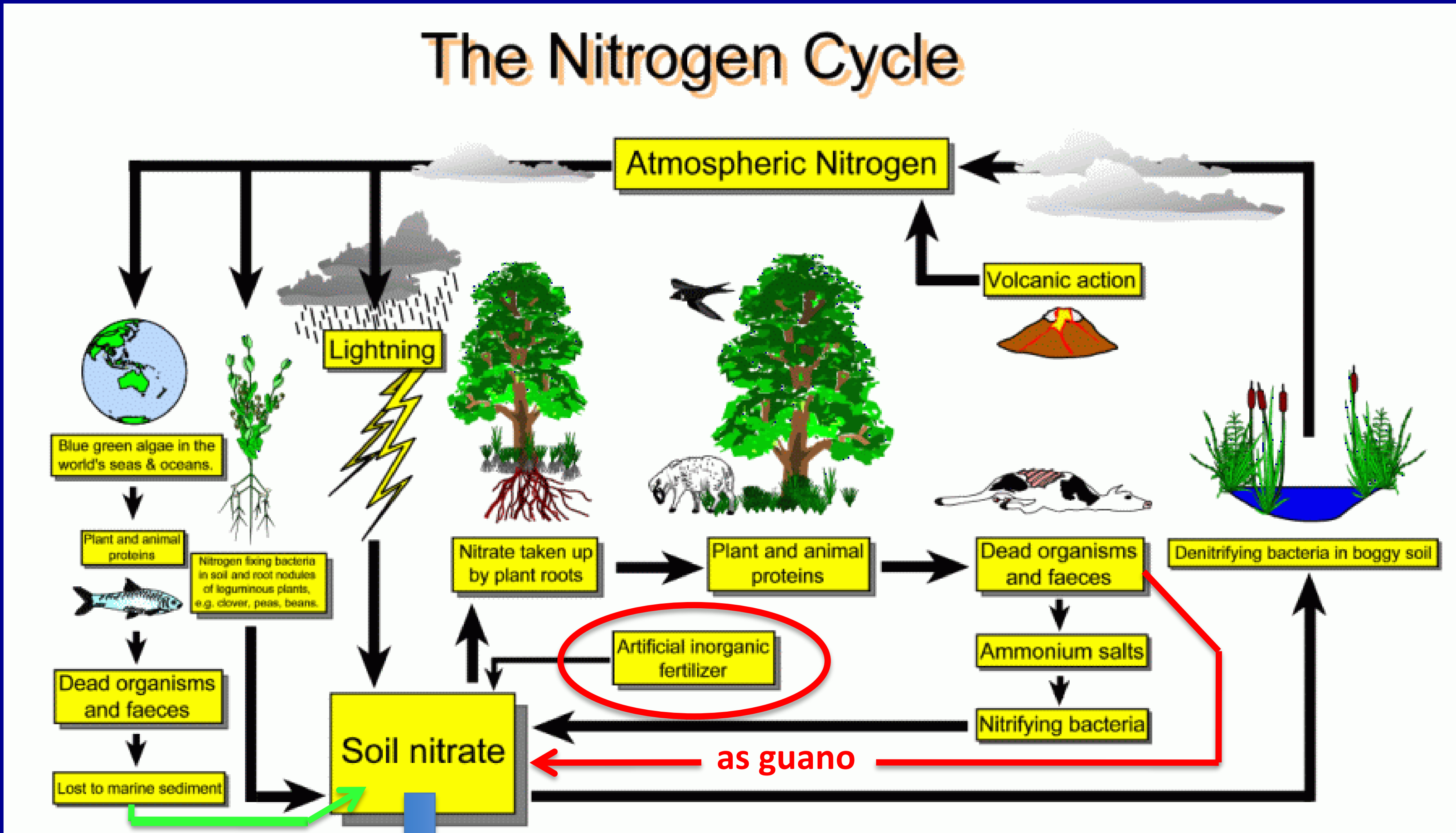
From atmosphere, hydrosphere; from rocks; from symbionts, lightning.

Nutrients other than O, H, C, and N predominantly form positively charged ionic cations, which are absorbed and stored on unsatisfied negative Ionic sites on clay-mineral skeletons and organic debris in soils.

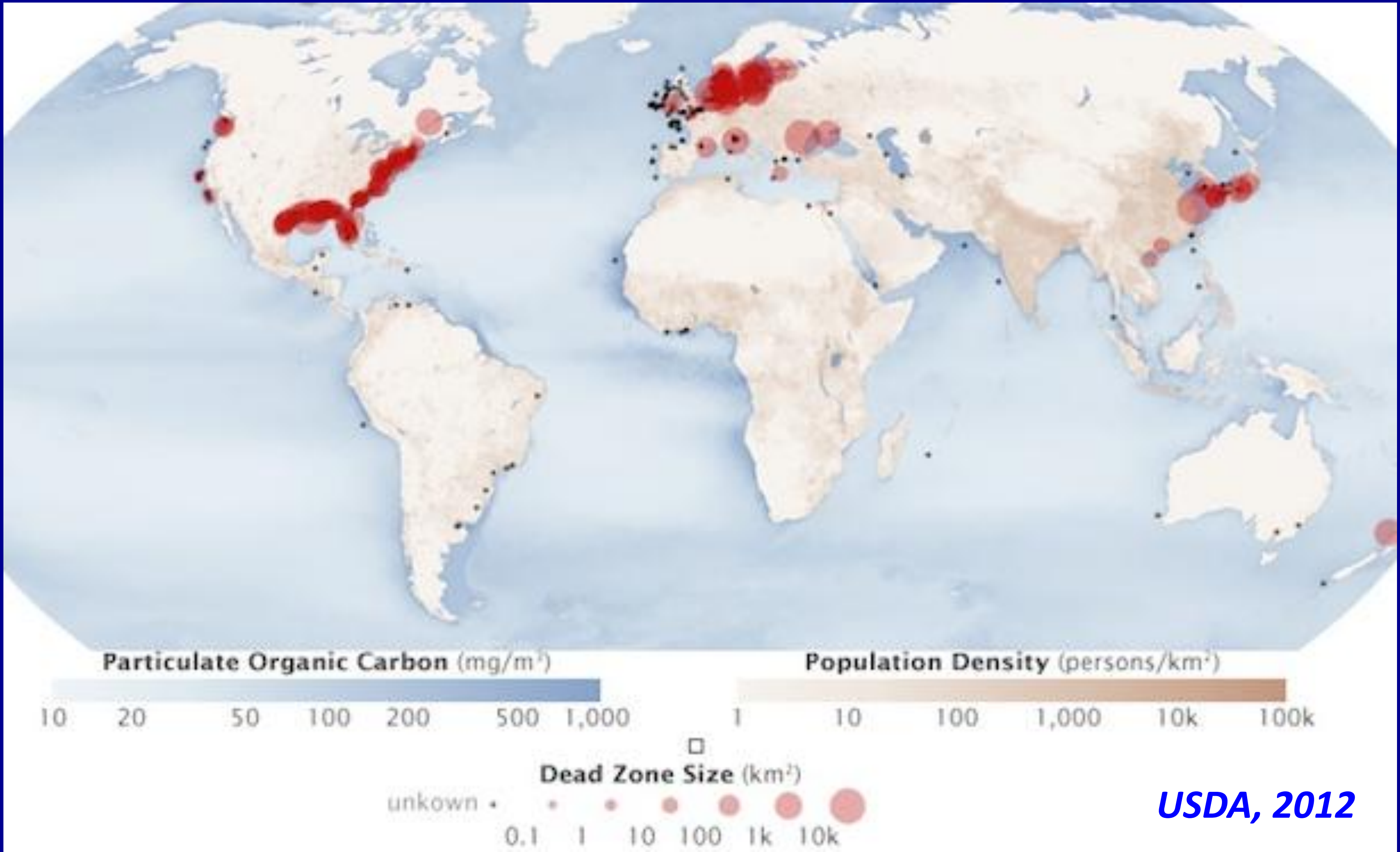
Nitrogen predominantly forms negatively charged anions, which are flushed through soils to ground and surface water and, eventually, to the global ocean.

The Phosphorus cycle





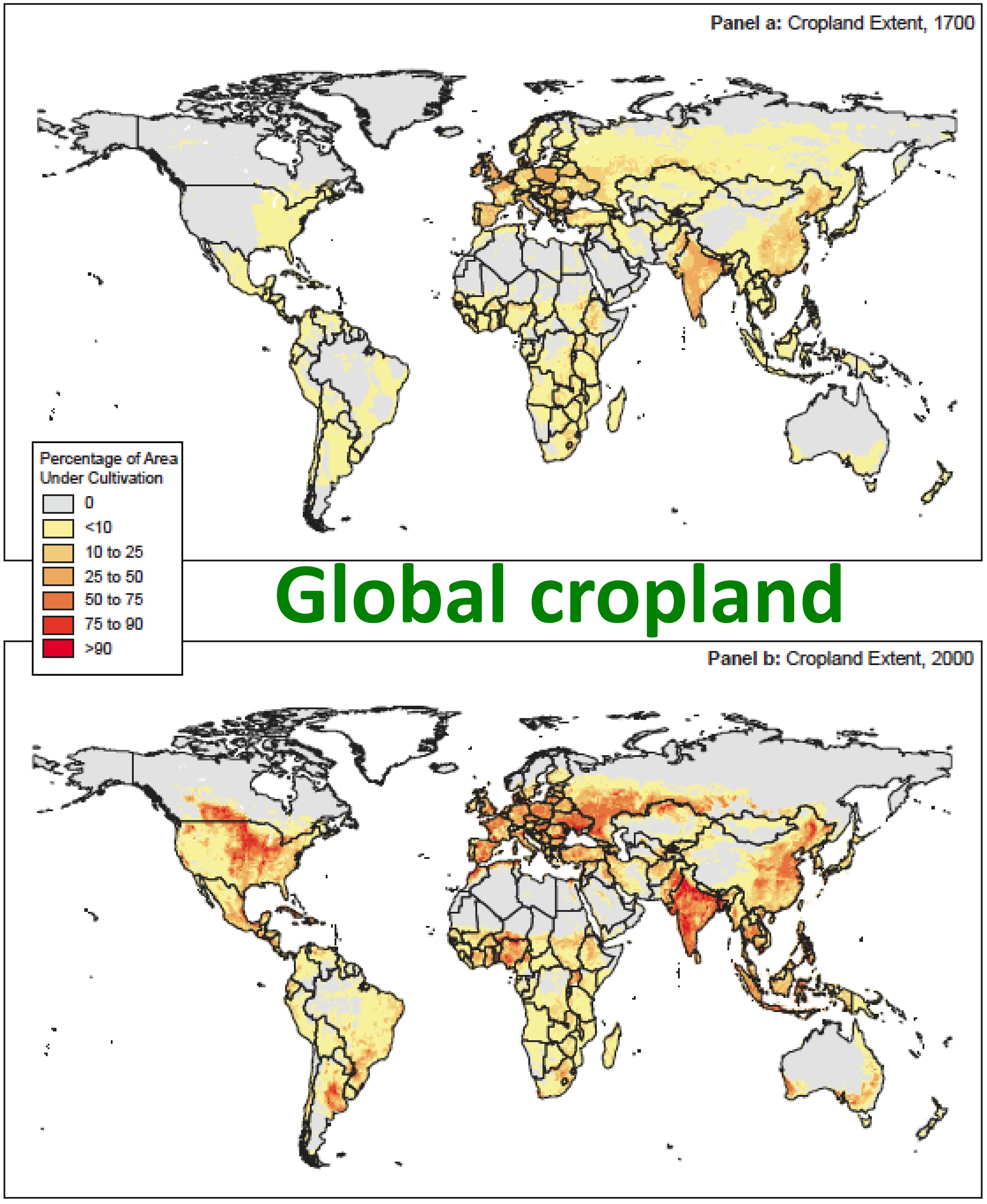
To ground and surface water
we waste 30% of applied N



Global oceanic dead zones

Everybody's favorite dead zone

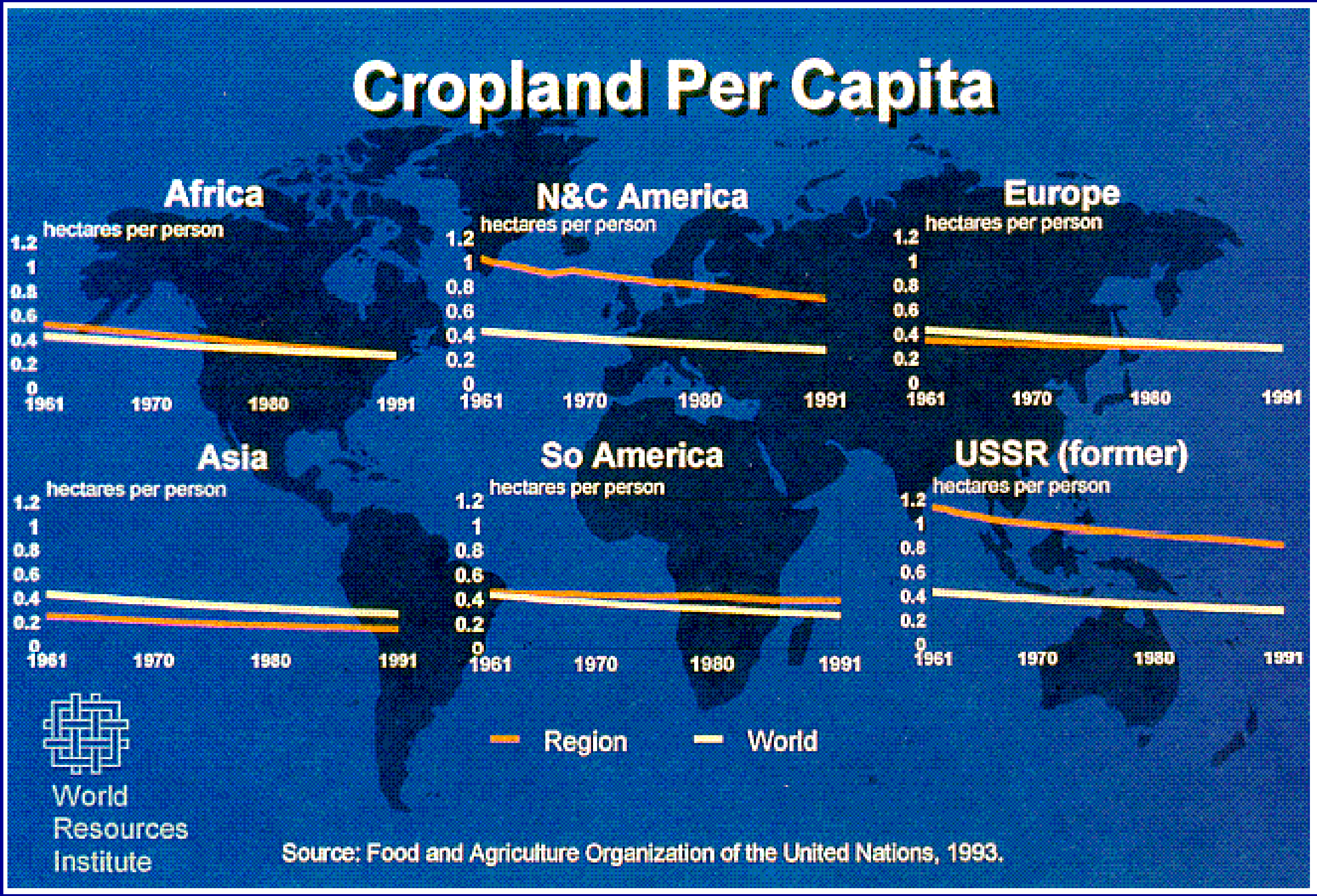
1700

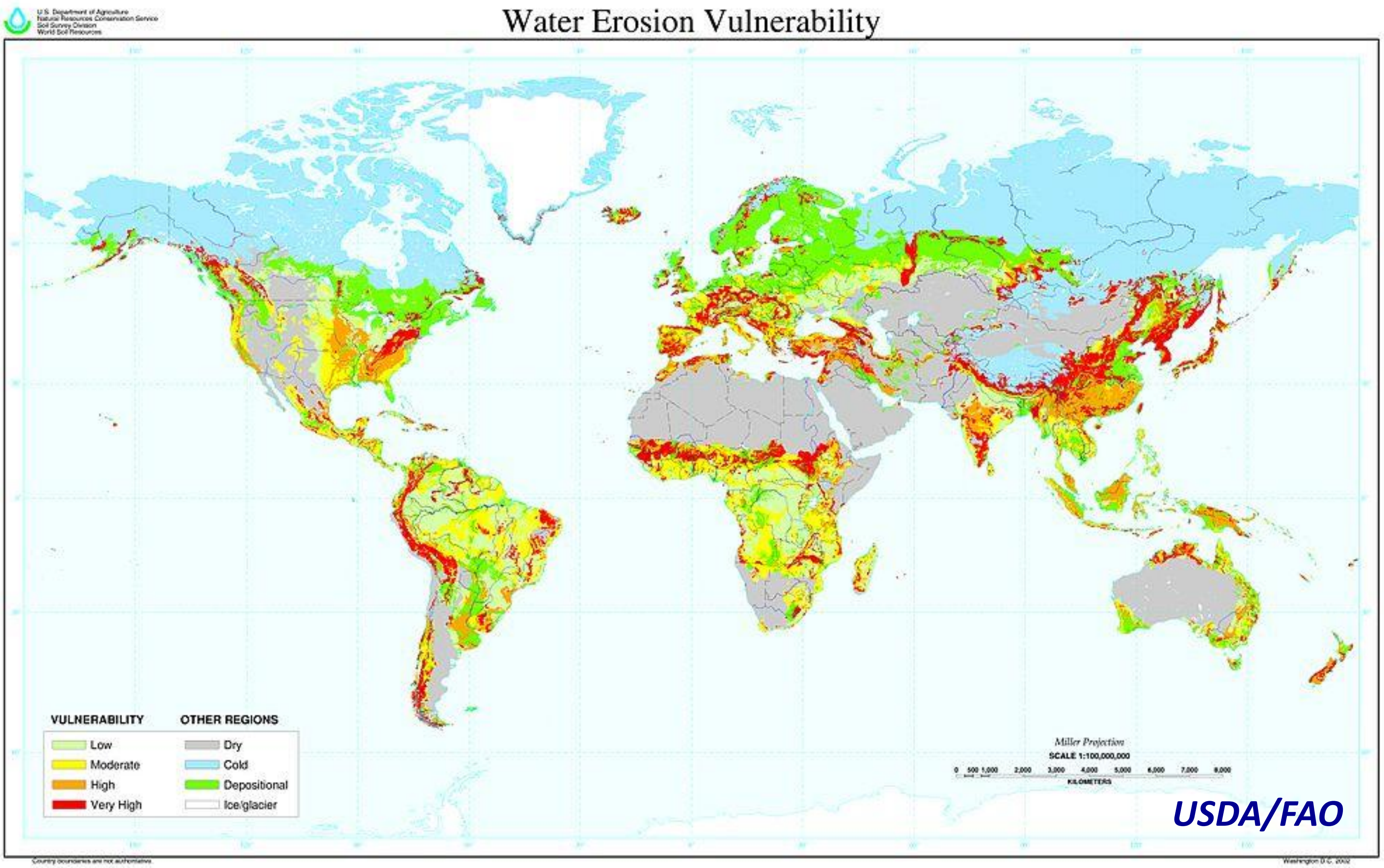


Global cropland

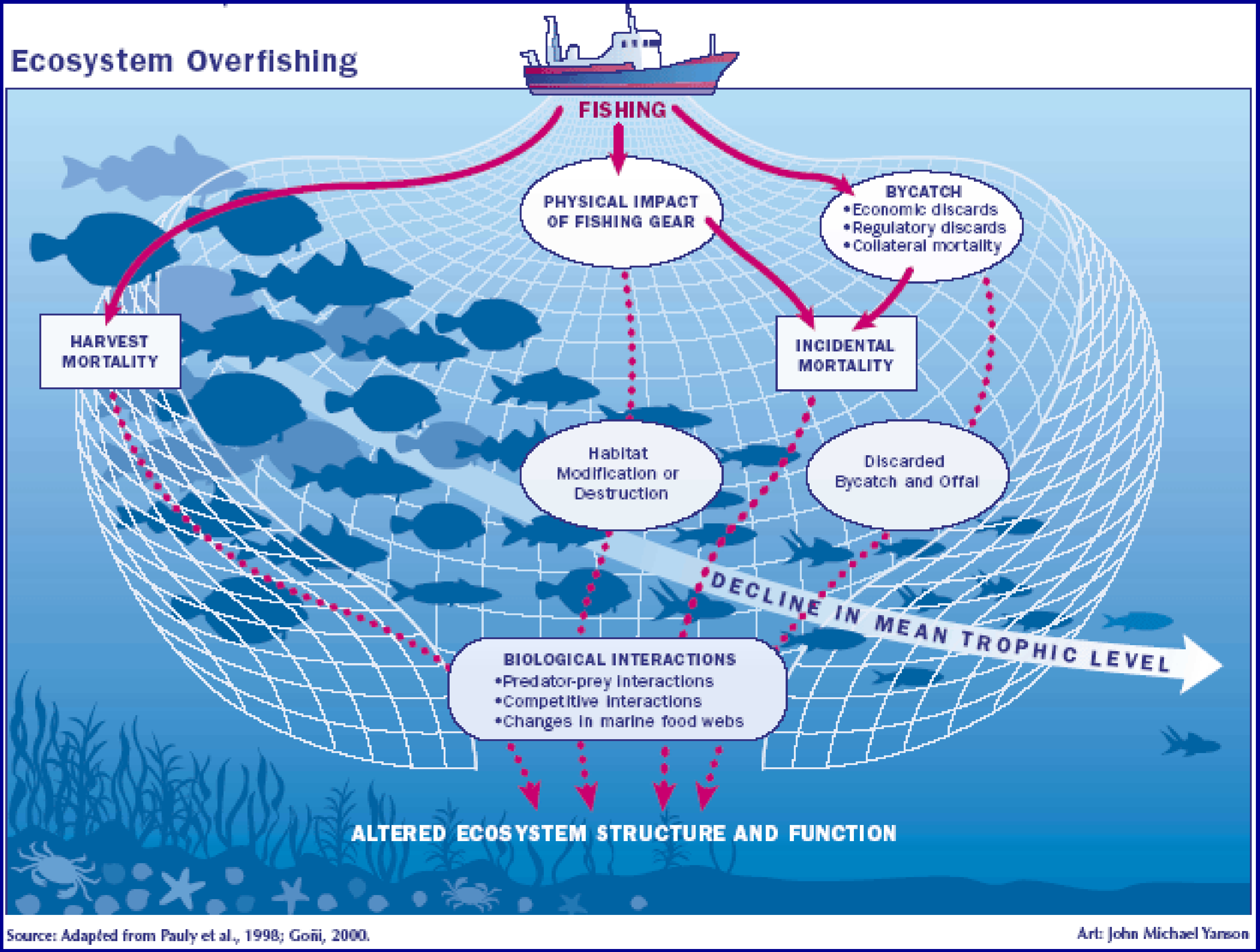
2000

Ramankutty et al. (2008)

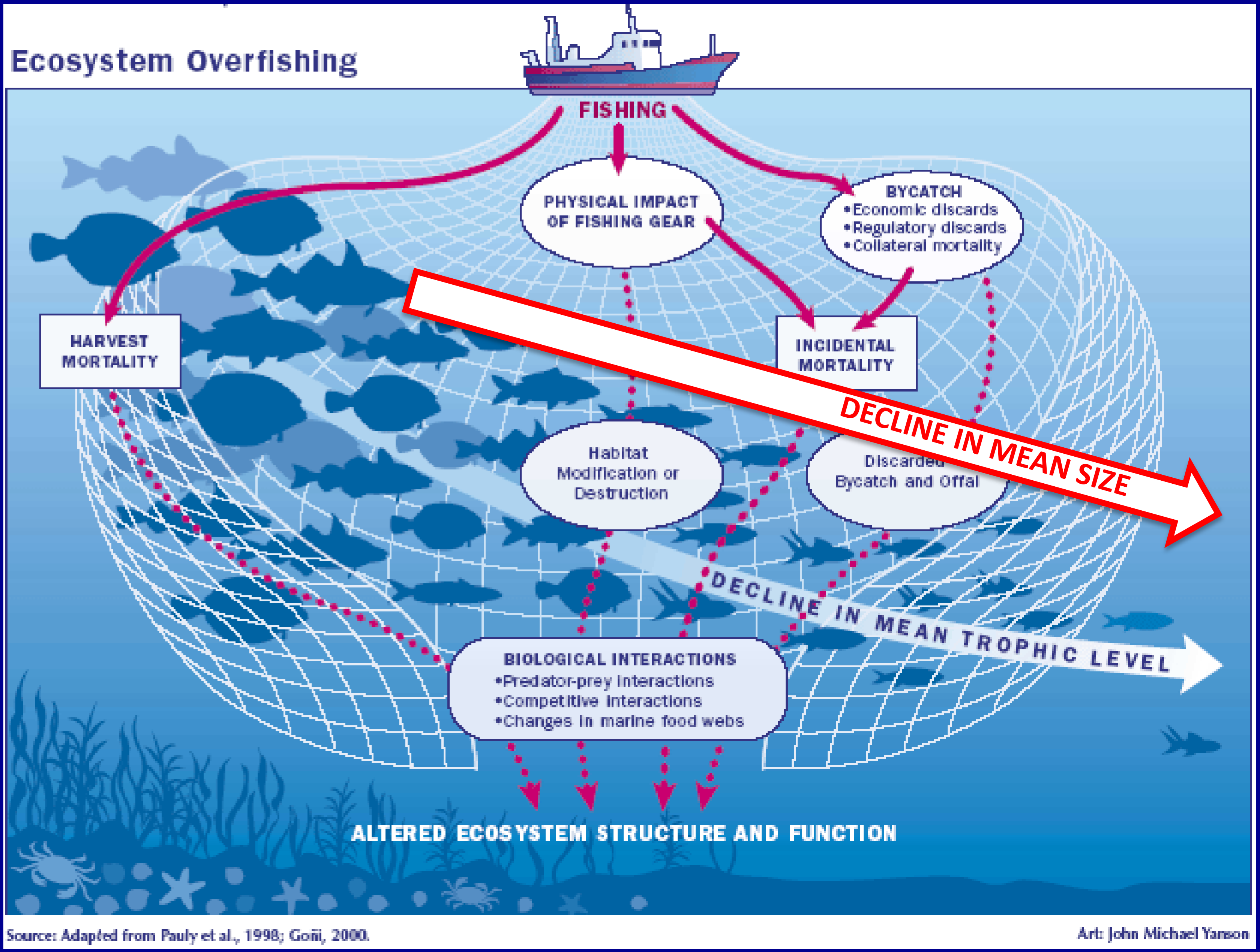

Cropland Per Capita
Africa
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
N&C America
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
Europe
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
Asia
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
So America
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
USSR (former)
hectares per person
1.2
1
0.8
0.6
0.4
0.2
0
1961
1970
1980
1991
Region
World
World Resources Institute
Source: Food and Agriculture Organization of the United Nations, 1993.


U.S. Department of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources
Water Erosion Vulnerability
VULNERABILITY
Low
Moderate
High
Very High
OTHER REGIONS
Dry
Cold
Depositional
Ice/glacier
Miller Projection
SCALE 1:100,000,000
0 500 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000
KILOMETERS

USDA/FAO



MIT Mission 2015: Biodiversity



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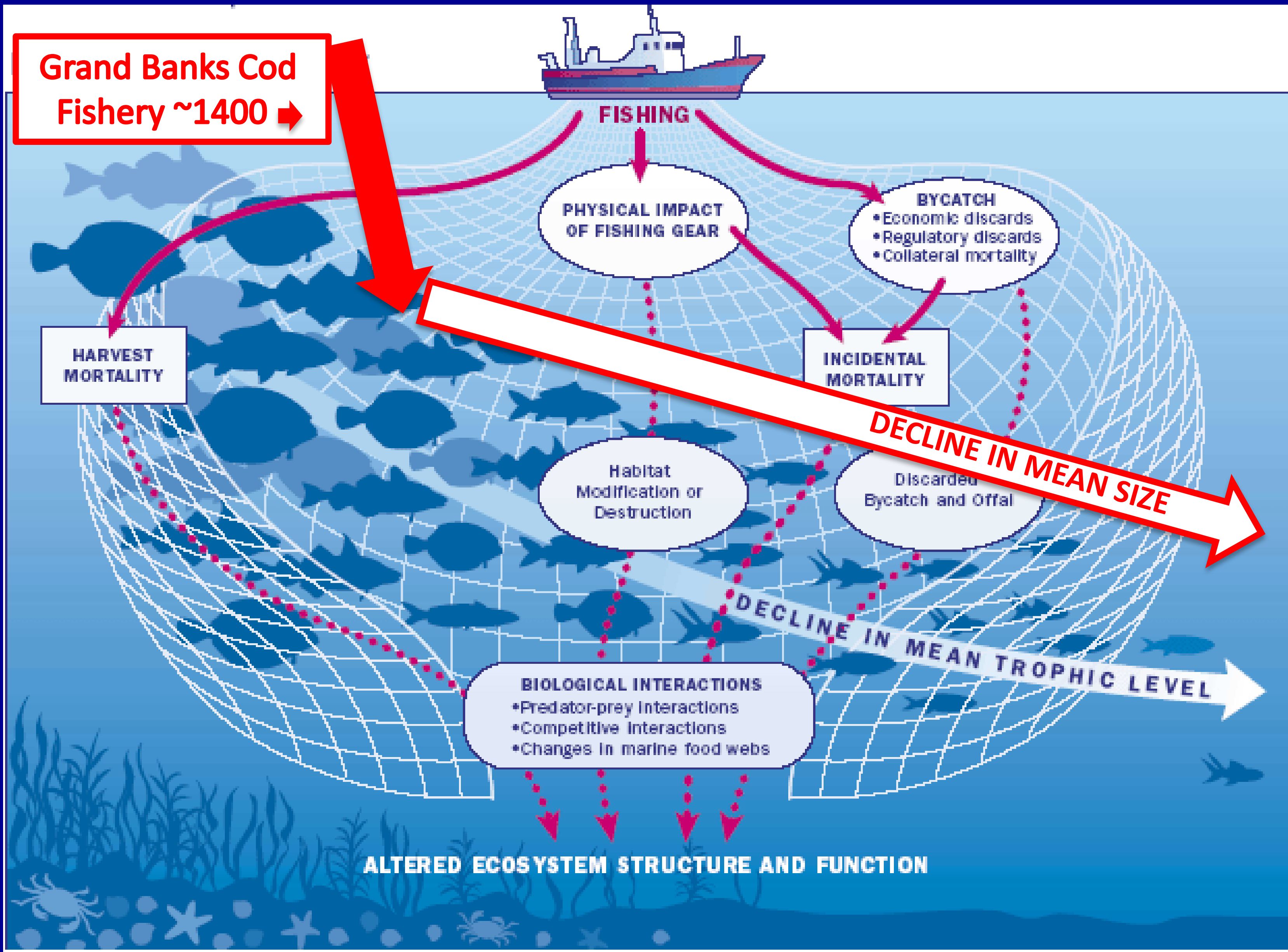
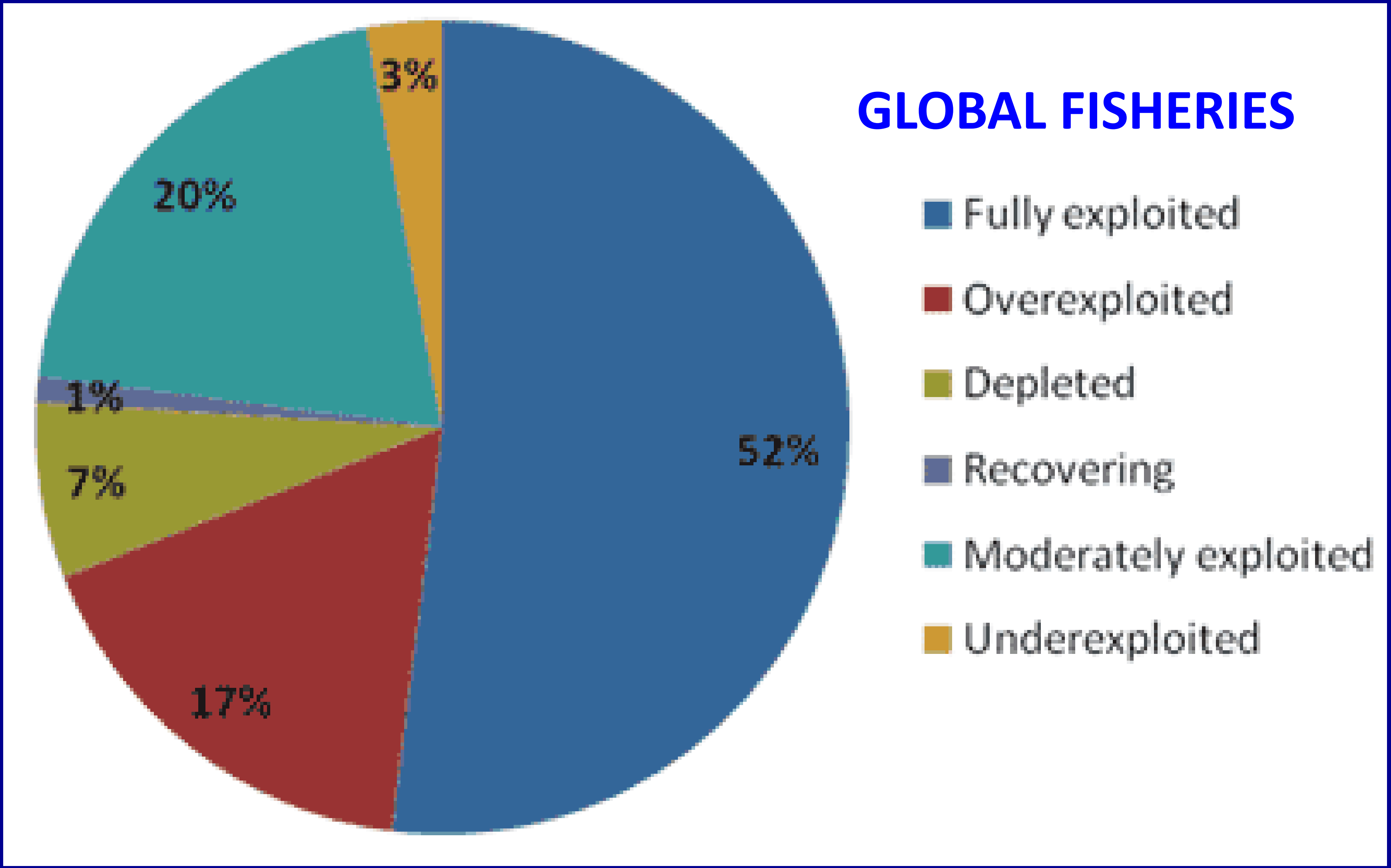


Source: Adapted from Pauly et al., 1998; Goñi, 2000.

Art: John Michael Yanson

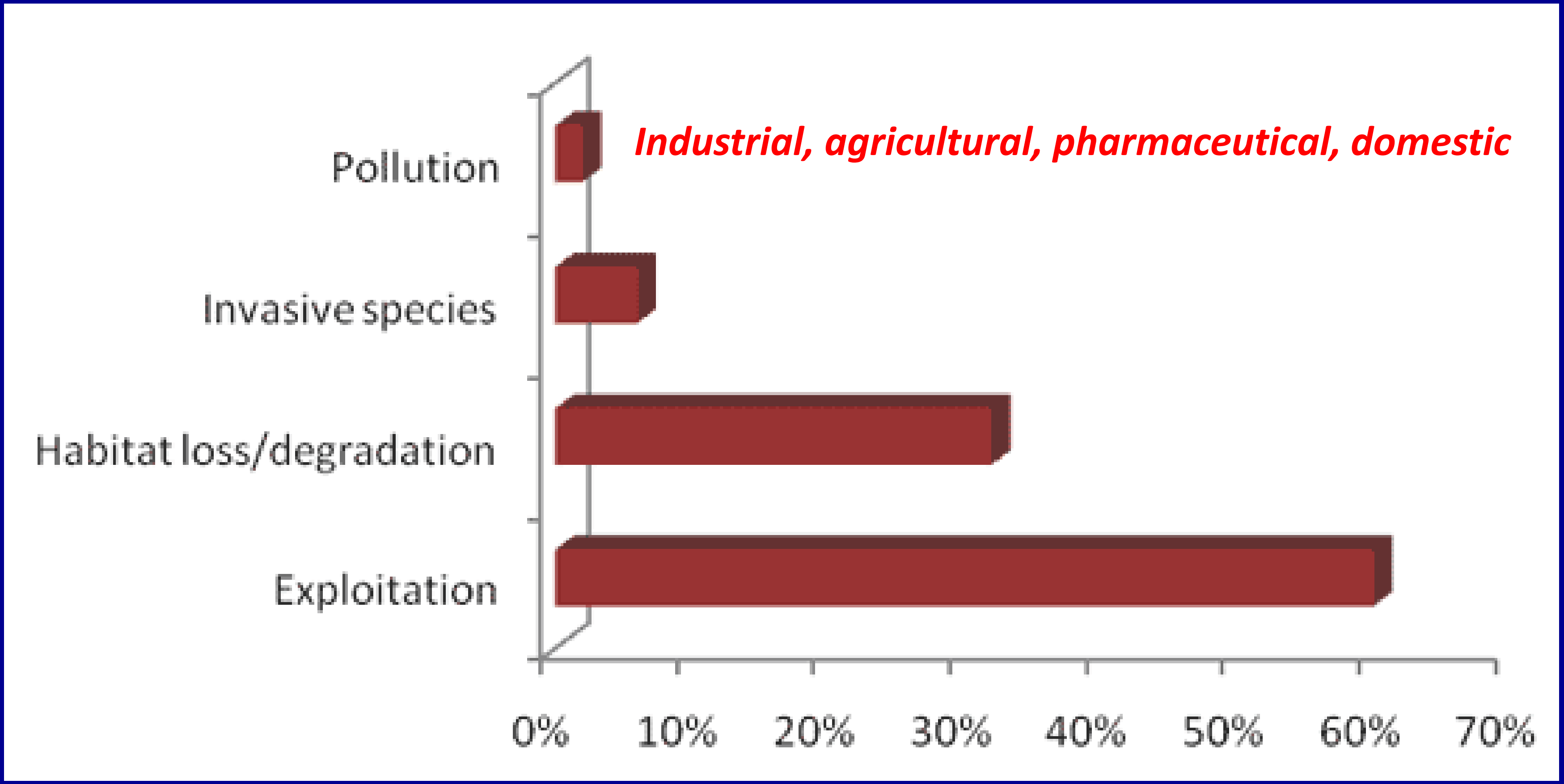
GLOBAL MARINE DISCARDS *[FAO International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP) species groups (1991)].*

	DISCARD	*LANDED*	*D/L*	*D/T*
Shrimps, prawns	**9,511,973**	**1,827,568**	**5.20**	**0.84**
Redfishes, basses, congers	3,631,057	5,739,743	0.63	0.39
Herrings, sardines, anchovies	2,789,201	23,792,608	0.12	0.10
Crabs	2,777,848	1,117,061	2.49	0.71
Jacks, mullets, sauries	2,607,748	9,349,055	0.28	0.22
Cods, hakes, haddocks	2,539,068	12,808,658	0.20	0.17
Miscellaneous marine fishes	992,356	9,923,560	0.10	0.09
Flounders, halibuts, soles	946,436	1,257,858	0.75	0.43
Tunas, bonitos, billfishes	739,580	4,177,653	0.18	0.15
Squids, cuttlefishes, octopuses	191,801	2,073,523	0.09	0.08
Lobsters, spiny-rock lobsters	113,216	205,851	0.55	0.35
Mackerels, snooks, cutlassfishes	102,377	3,722,818	0.03	0.03
Salmons, trouts, smelt	38,323	766,462	0.05	0.05
Shads	22,755	227,549	0.10	0.09
Eels	8,359	9,975	0.84	0.46
Total	27,012,099	76,999,942	0.35	0.26


3%
20%
1%
7%
17%
52%
GLOBAL FISHERIES
Fully exploited
Overexploited
Depleted
Recovering
Moderately exploited
Underexploited

FAO, 2008

Causes of fisheries depletion:



Where is climate change?

MIT, Biodiversity 2015

Farmed vs wild-caught food:

Per capita consumption of red meat and poultry: USA: 96 kg/yr
world: 42kg/yr

Per capita consumption of marine fish and shellfish: USA: 6.5 kg/yr
world: 14 kg/yr

USA per capita consumption of wild-caught game (deer, ducks, geese):
<1 kg/yr; ~1%

USA per capita consumption of wild-gathered grains and vegetables (mushrooms, blueberries, “wild” rice): <<0.1 kg/yr; <<<0.1%

In the USA, aboriginal ecosystems are preserved in parks, wildlife refuges, etc.; aboriginal ecosystems elsewhere in the USA have been replaced by farmland, grazing land, food animals

---

In the USA, we hunt/gather ~1% of our land-based food

Worldwide, 65% of fish/shellfish is still wild caught, using hunter/gatherer technology; 35% is produced via aquaculture.

Productivity and diversity of marine ecosystems have been sharply reduced, but marine biota have not been replaced by domestic biota.

Aquaculture represents the lowest-hanging fruit…

This is more like it….

Energy use in the global and US food system

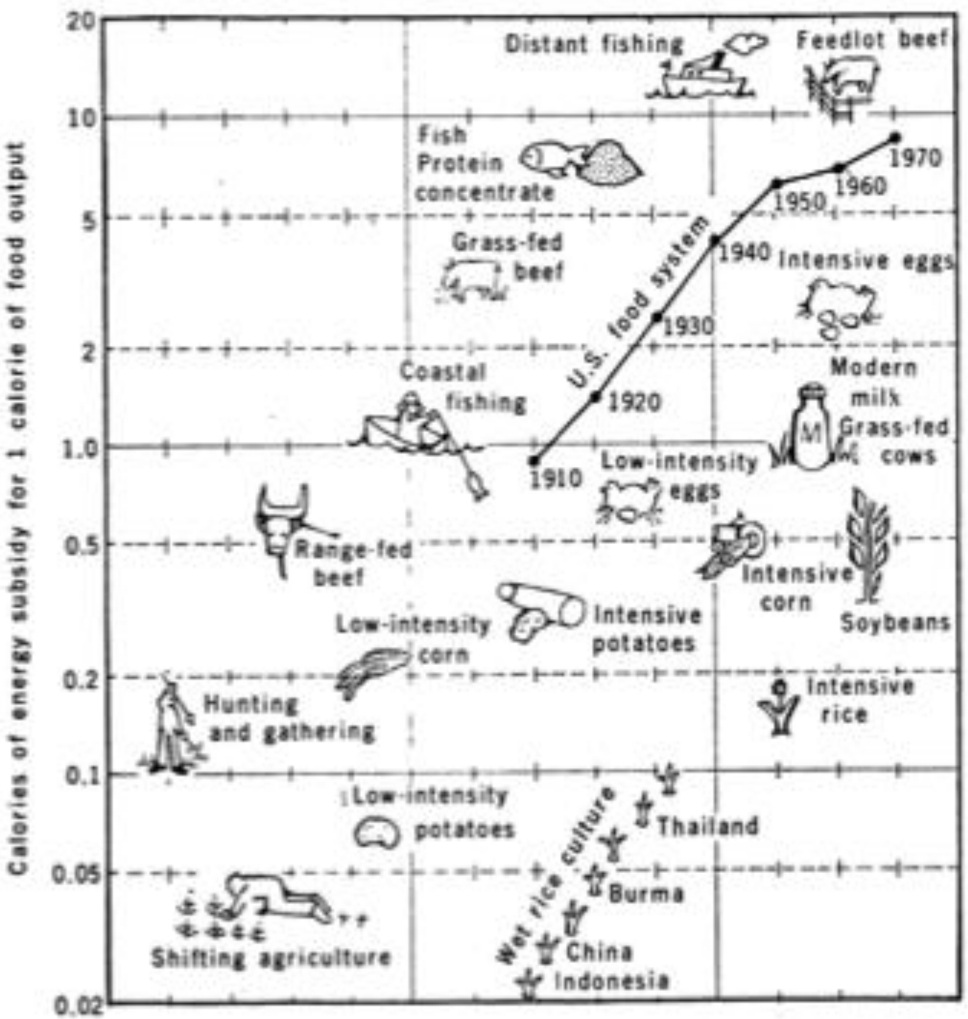


Fig. 5. Energy subsidies for various food crops. The energy history of the U.S. food system is shown for comparison. [Source of data: (31)]

Steinhart & Steinhart, 1974

Energy use in the global and US food system

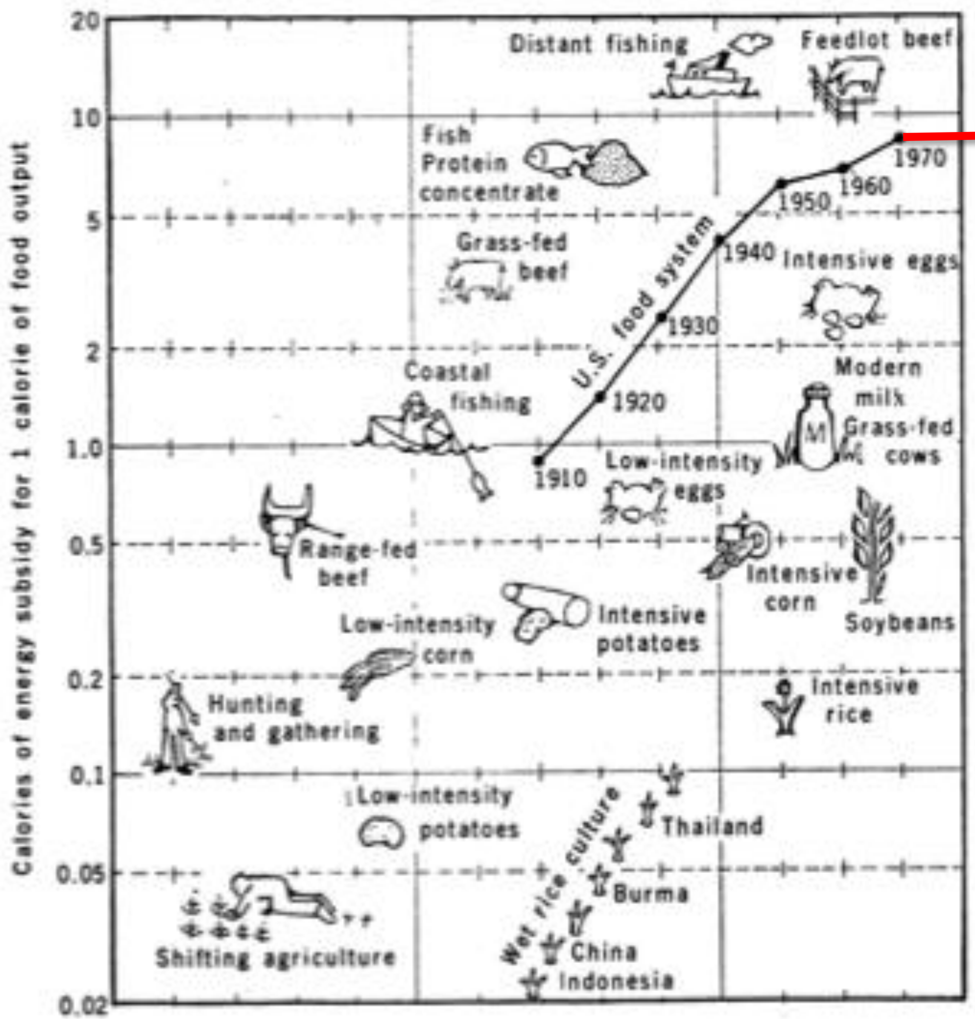


Fig. 5. Energy subsidies for various food crops. The energy history of the U.S. food system is shown for comparison. [Source of data: (31)]

No net increase since 1970

Steinhart & Steinhart, 1974

Where does bottled water plot?

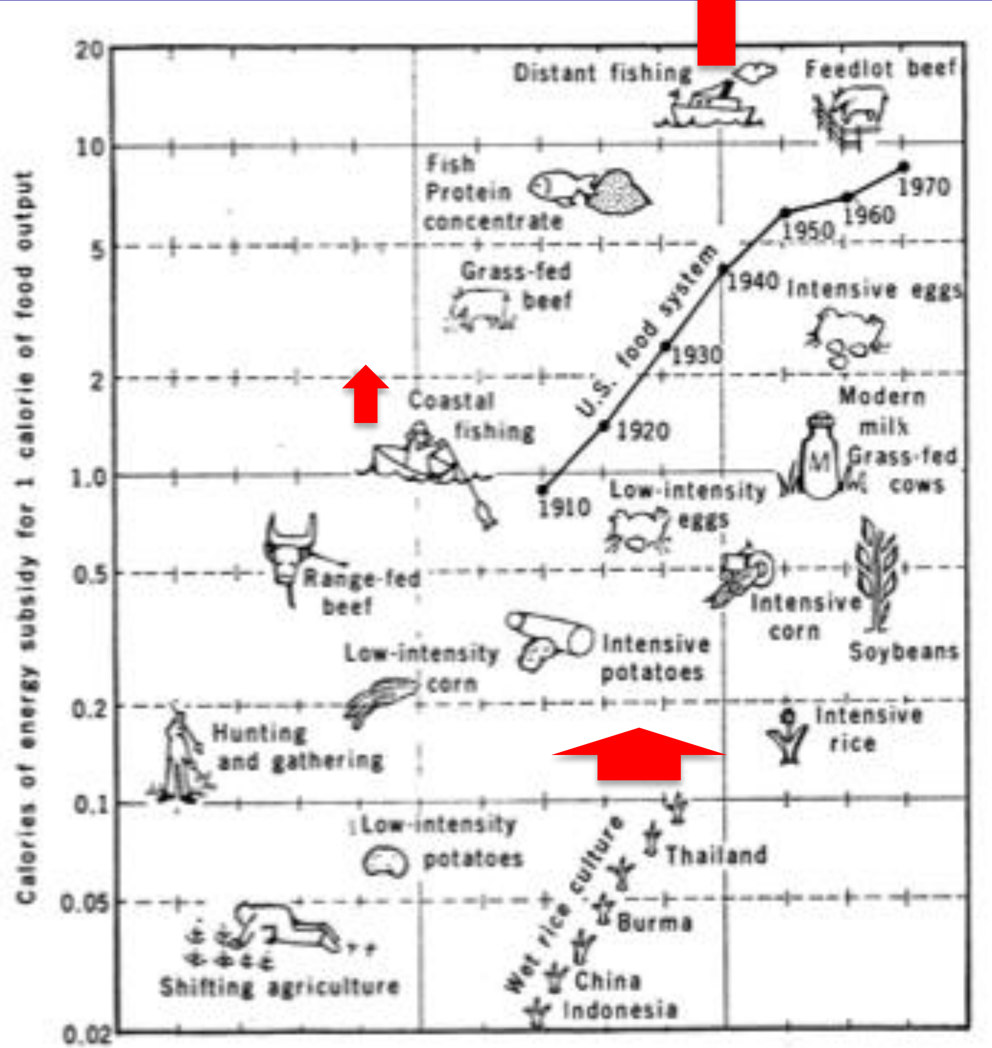


Fig. 5. Energy subsidies for various food crops. The energy history of the U.S. food system is shown for comparison. [Source of data: (31)]

Steinhart & Steinhart, 1974

WE WASTE:

Water: via careless application, contamination, over-extraction

Soils: via urban/suburban development, erosion

Nutrients: via overfertilization; loss of storage capacity

Fisheries: via overexploitation, pollution, bycatch, loss of gear, habitat destruction

ENERGY: via excessive use at every stage

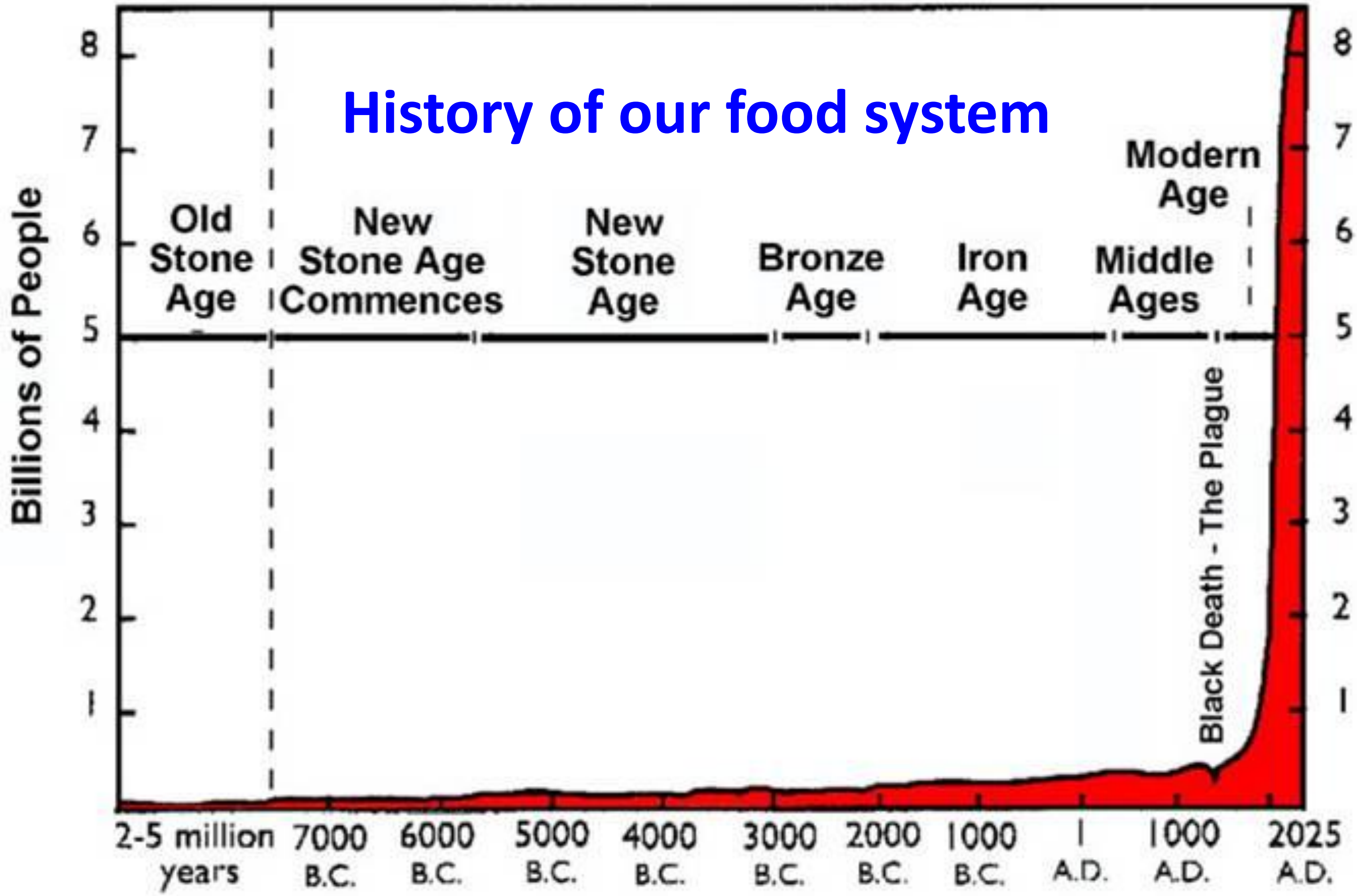
Opportunities: renewable energy sources, IT-managed applications, hydroponics, aquaculture

Finished product (food): *the theme of this conference*

THIS WASTE CANNOT BE ATTRIBUTED TO CLIMATE CHANGE

World Population Growth Through History

History of our food system



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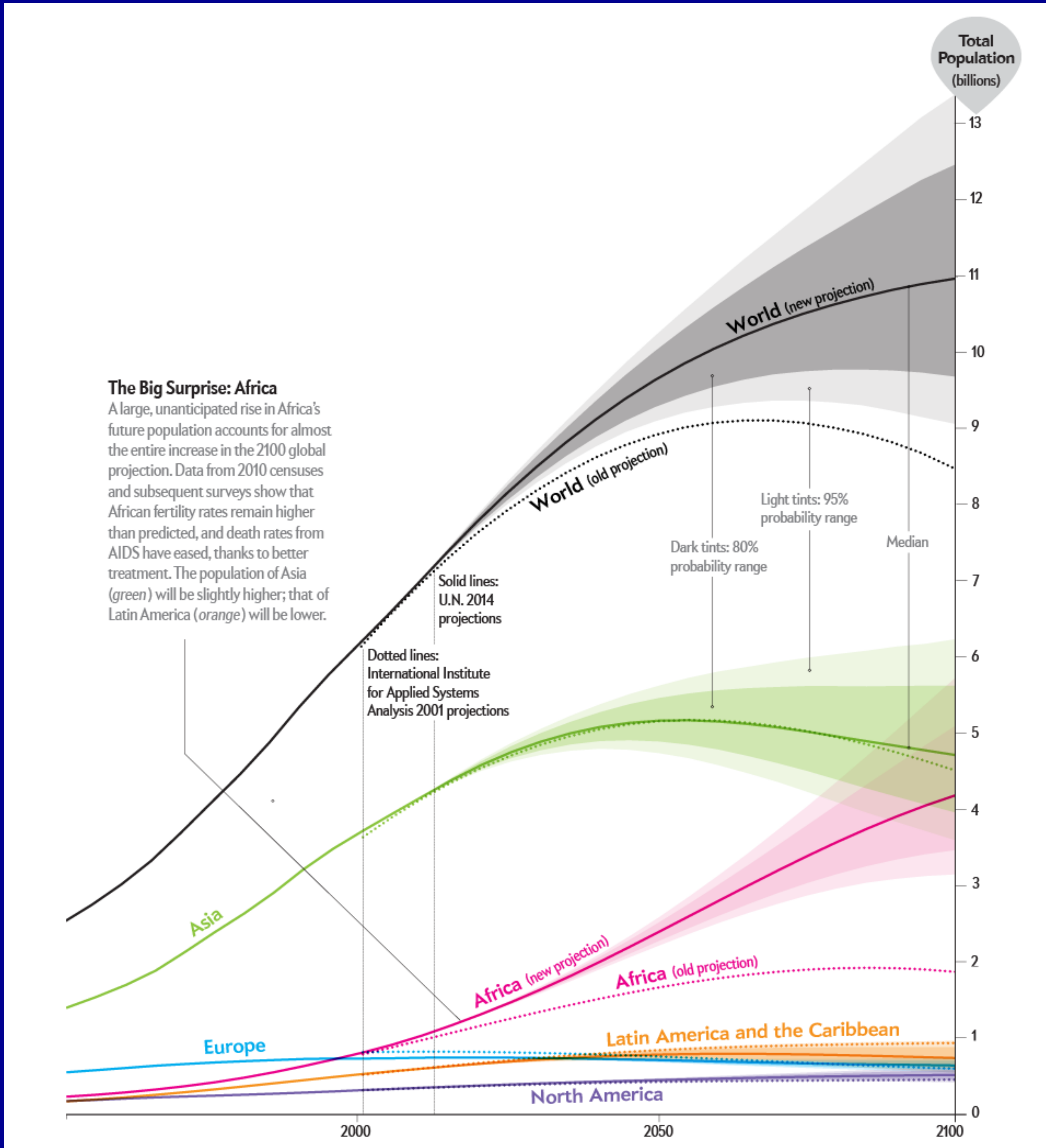
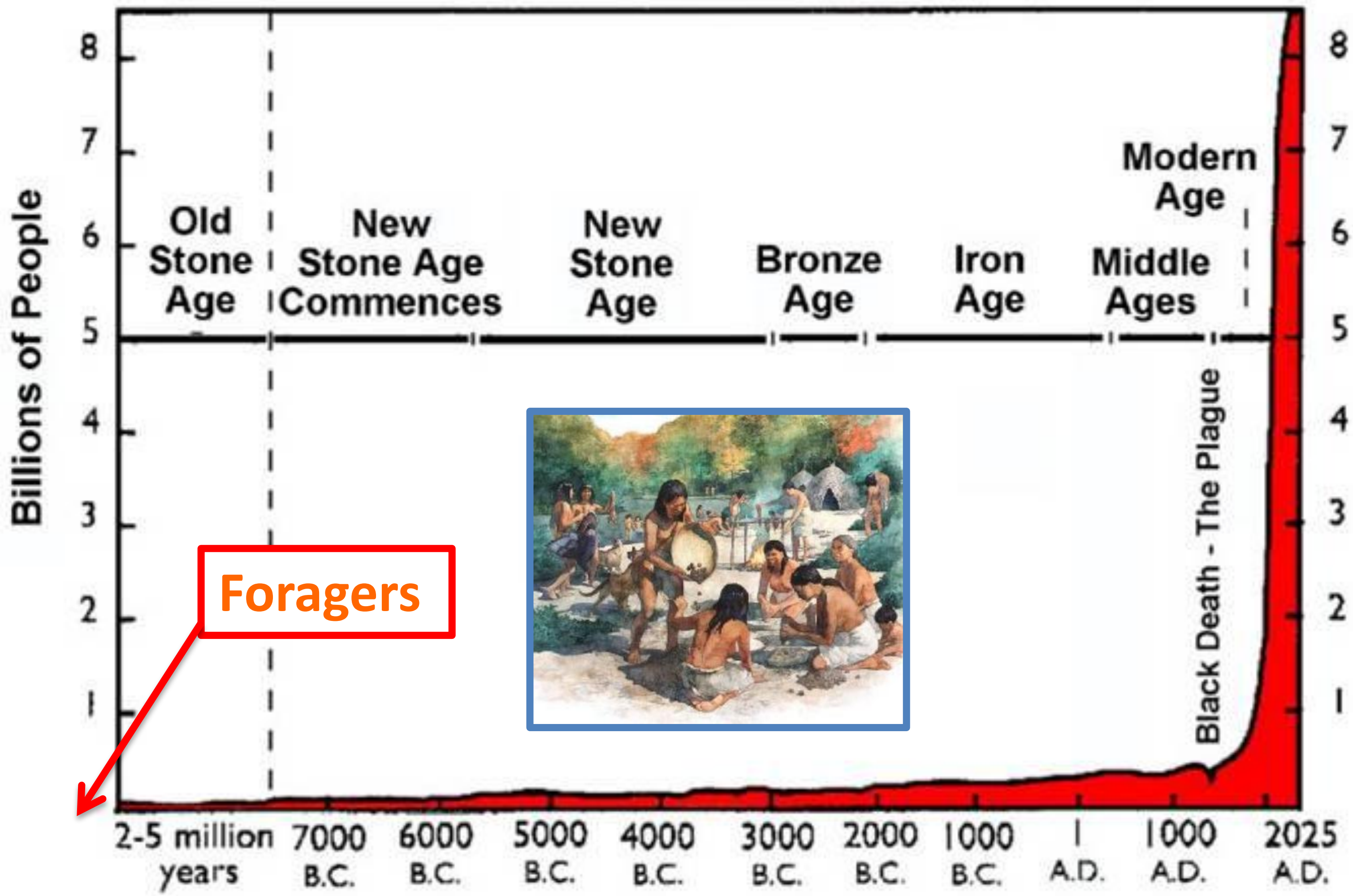


Fischetti, Mark
11/18/2014
Scientific American

World Population Growth Through History



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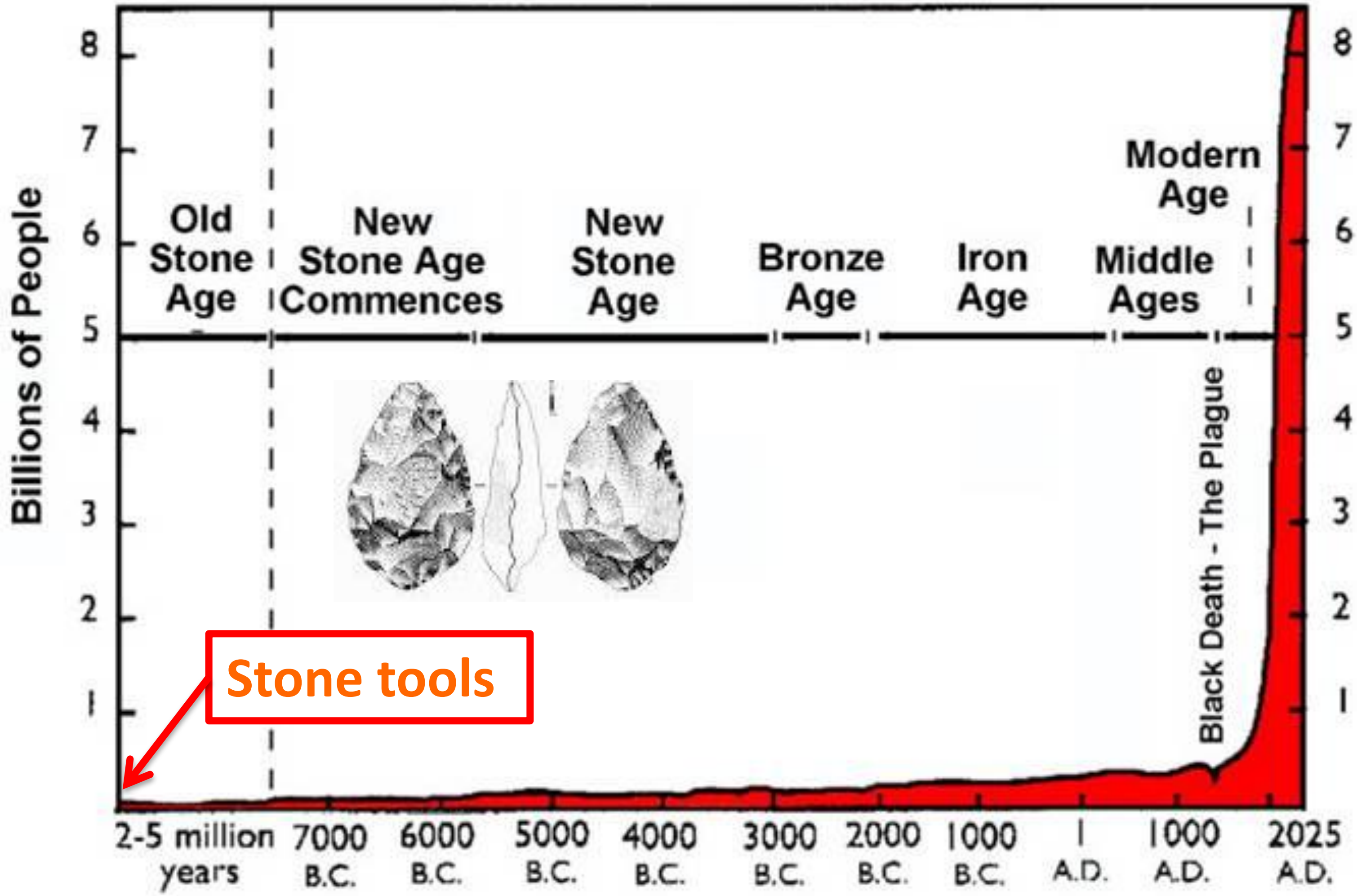
World Population Growth Through History



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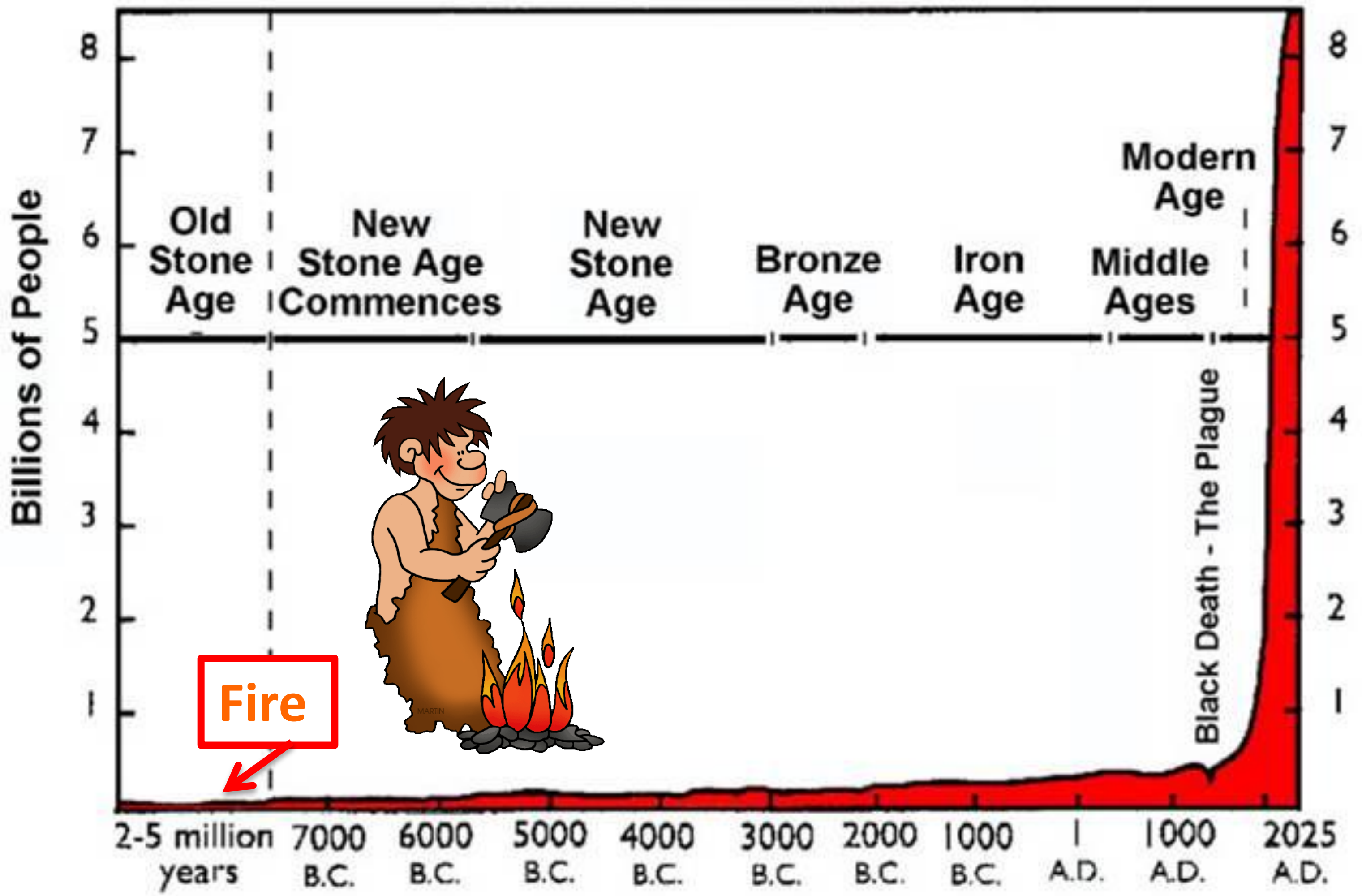
World Population Growth Through History



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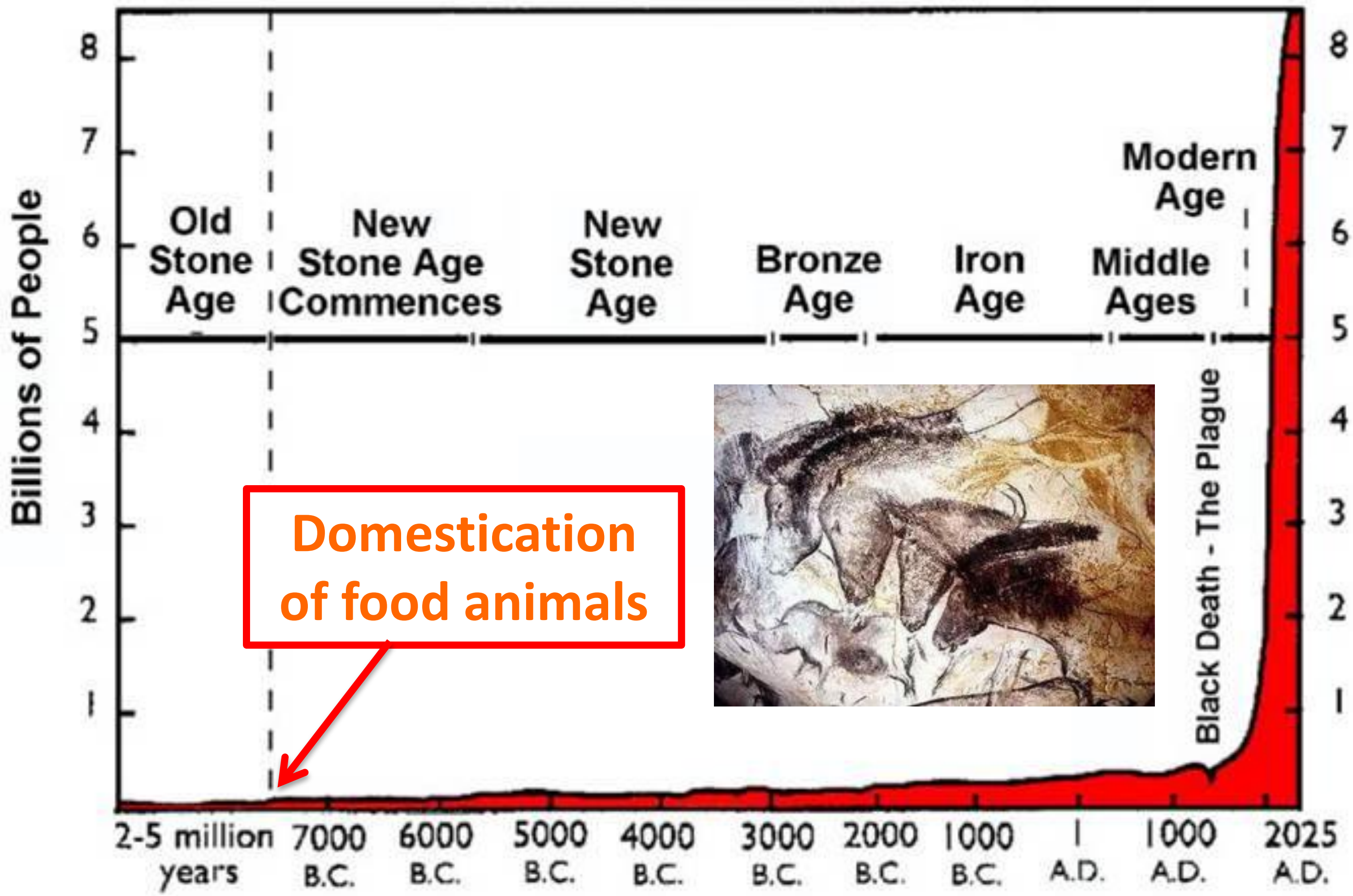
World Population Growth Through History



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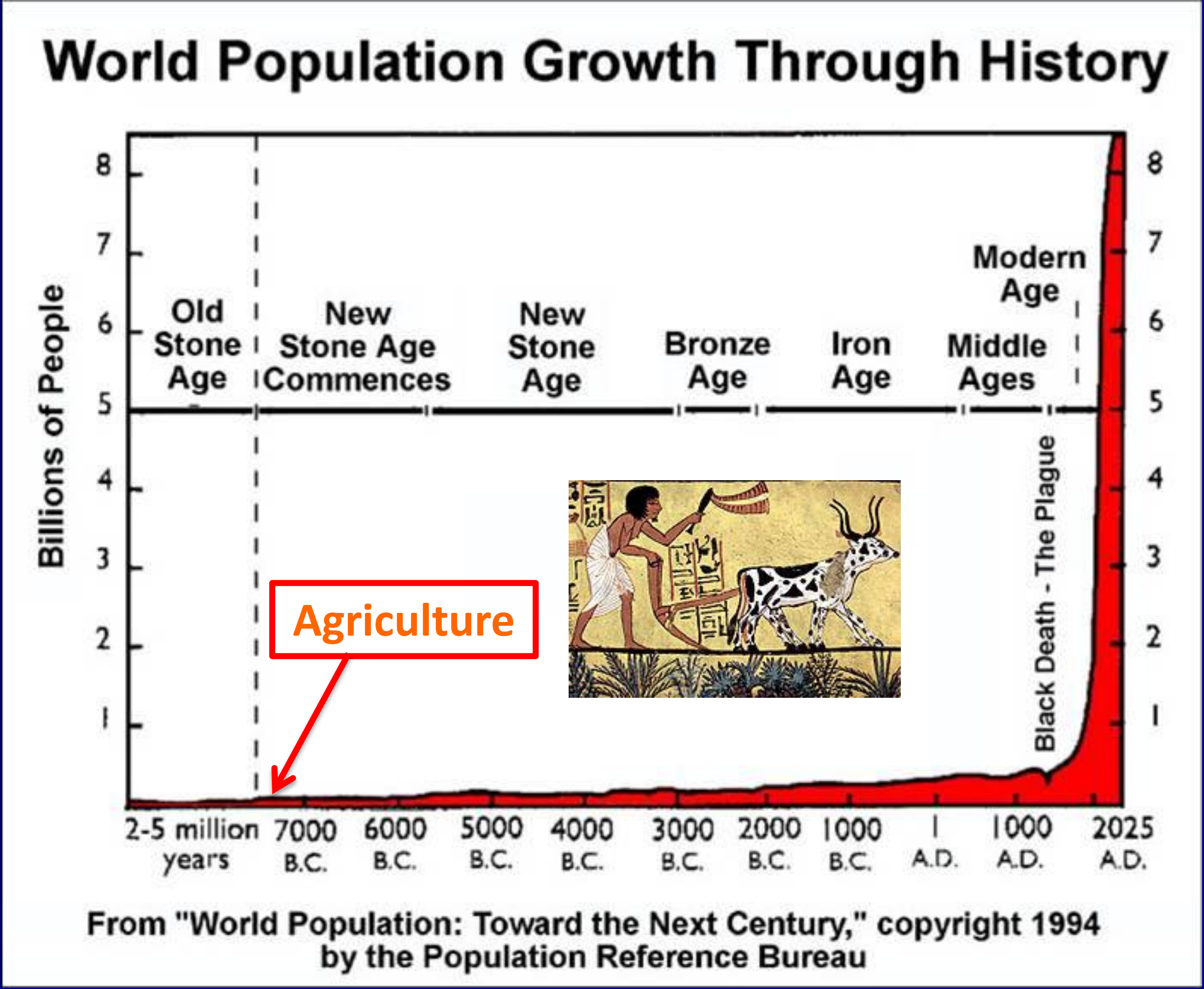
World Population Growth Through History
Billions of People
8
7
6
5
4
3
2
1
Old Stone Age
New Stone Age Commences
New Stone Age
Bronze Age
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Agriculture
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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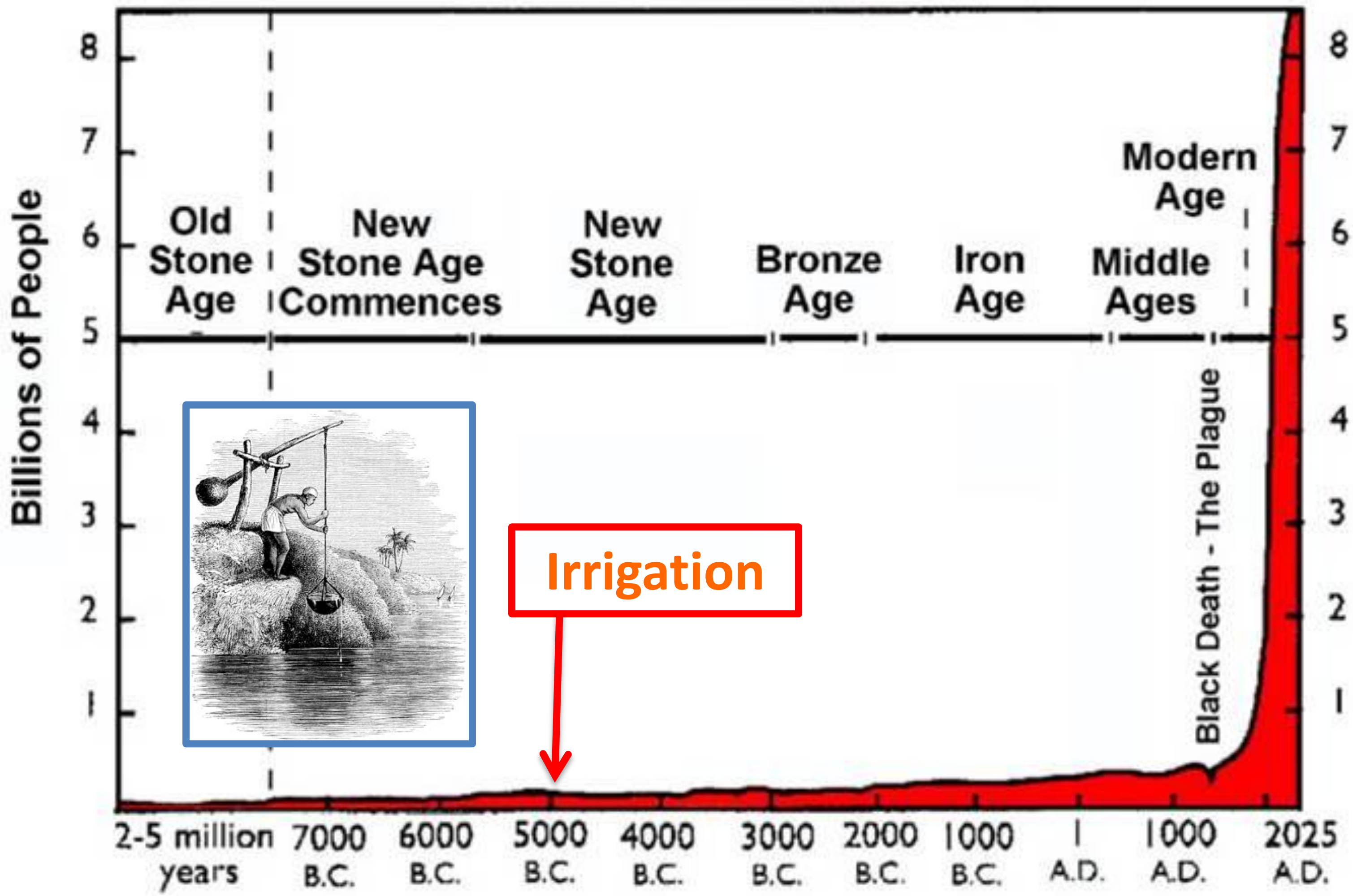
World Population Growth Through History



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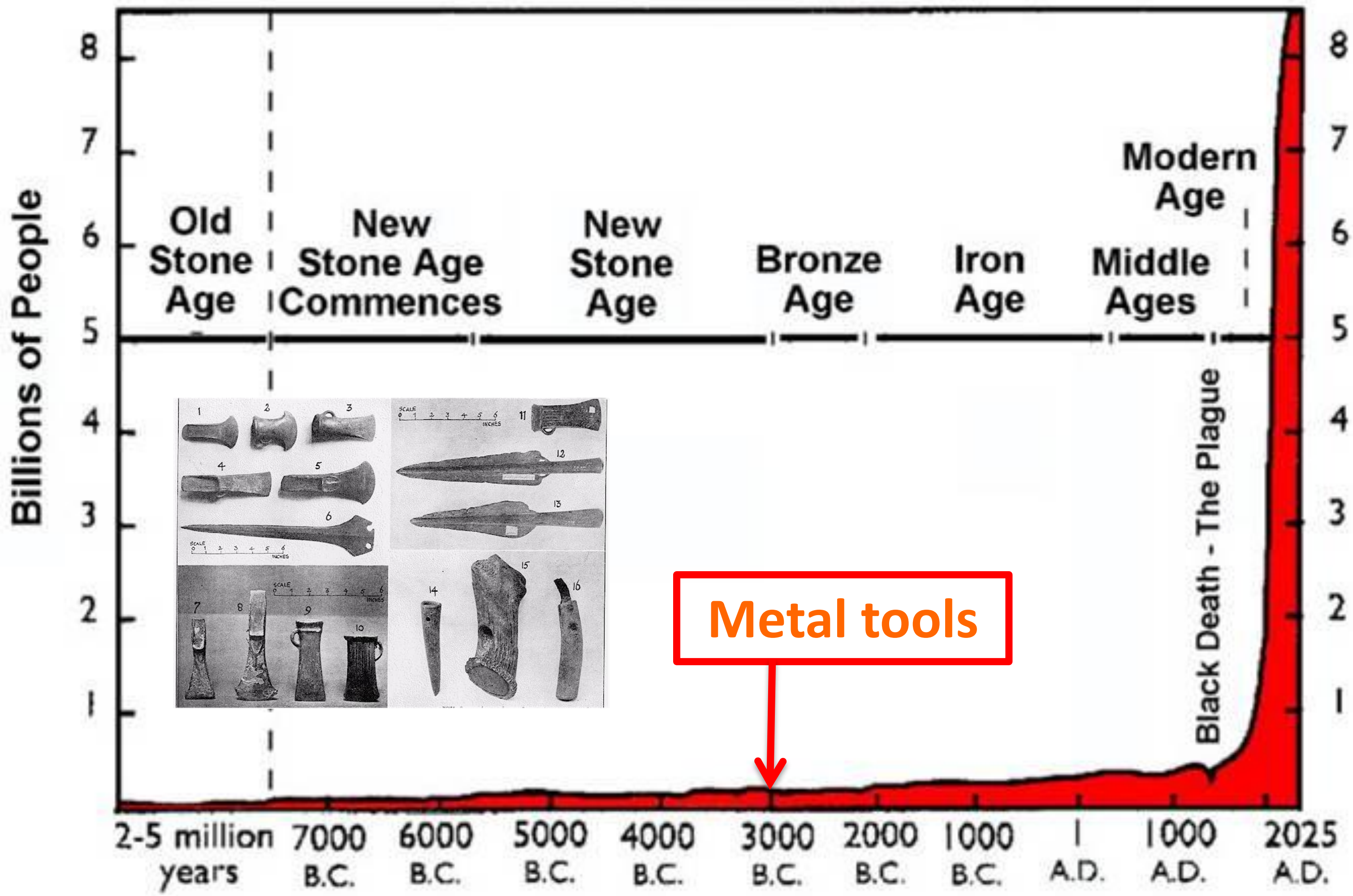
World Population Growth Through History



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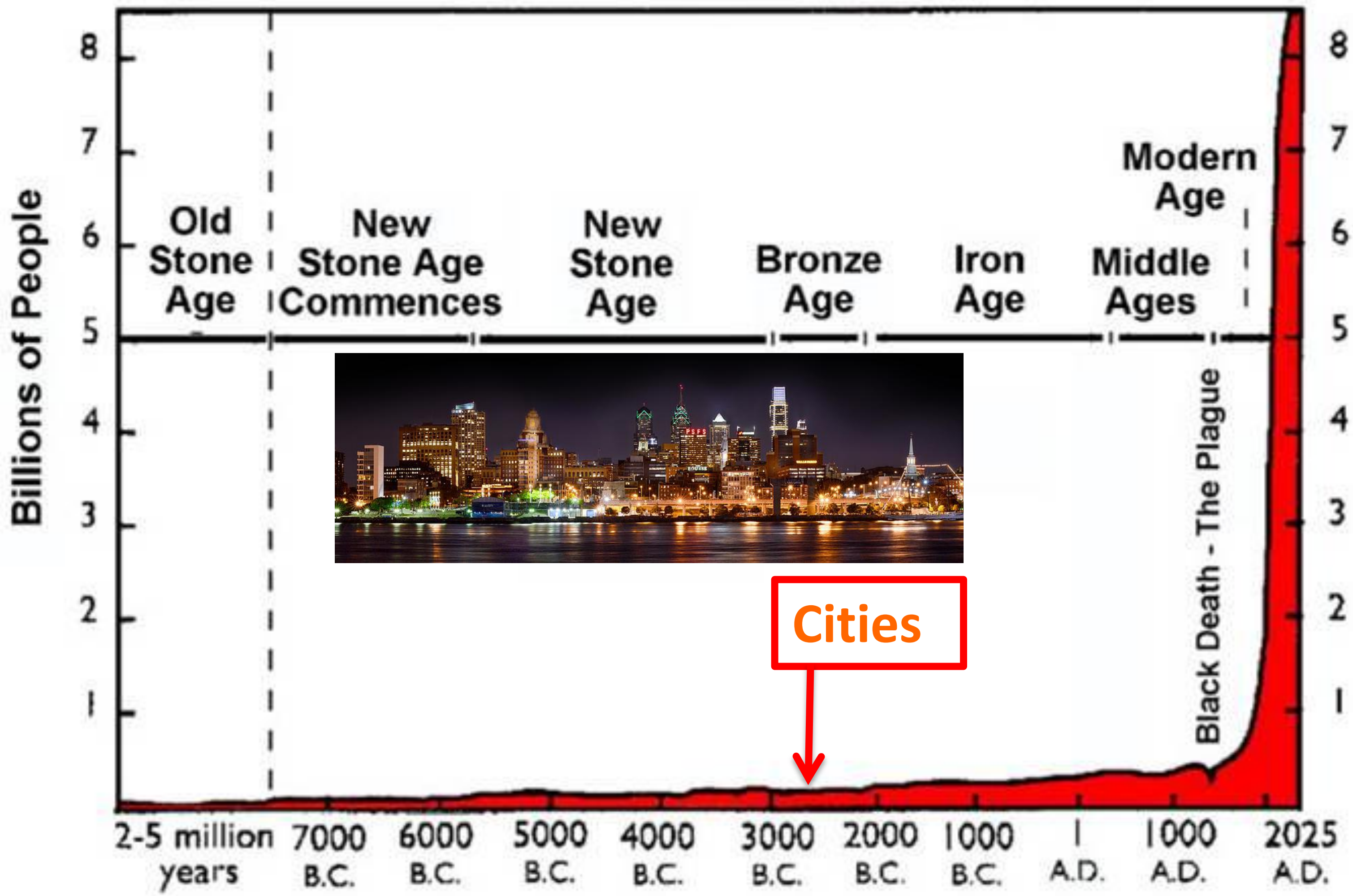
World Population Growth Through History



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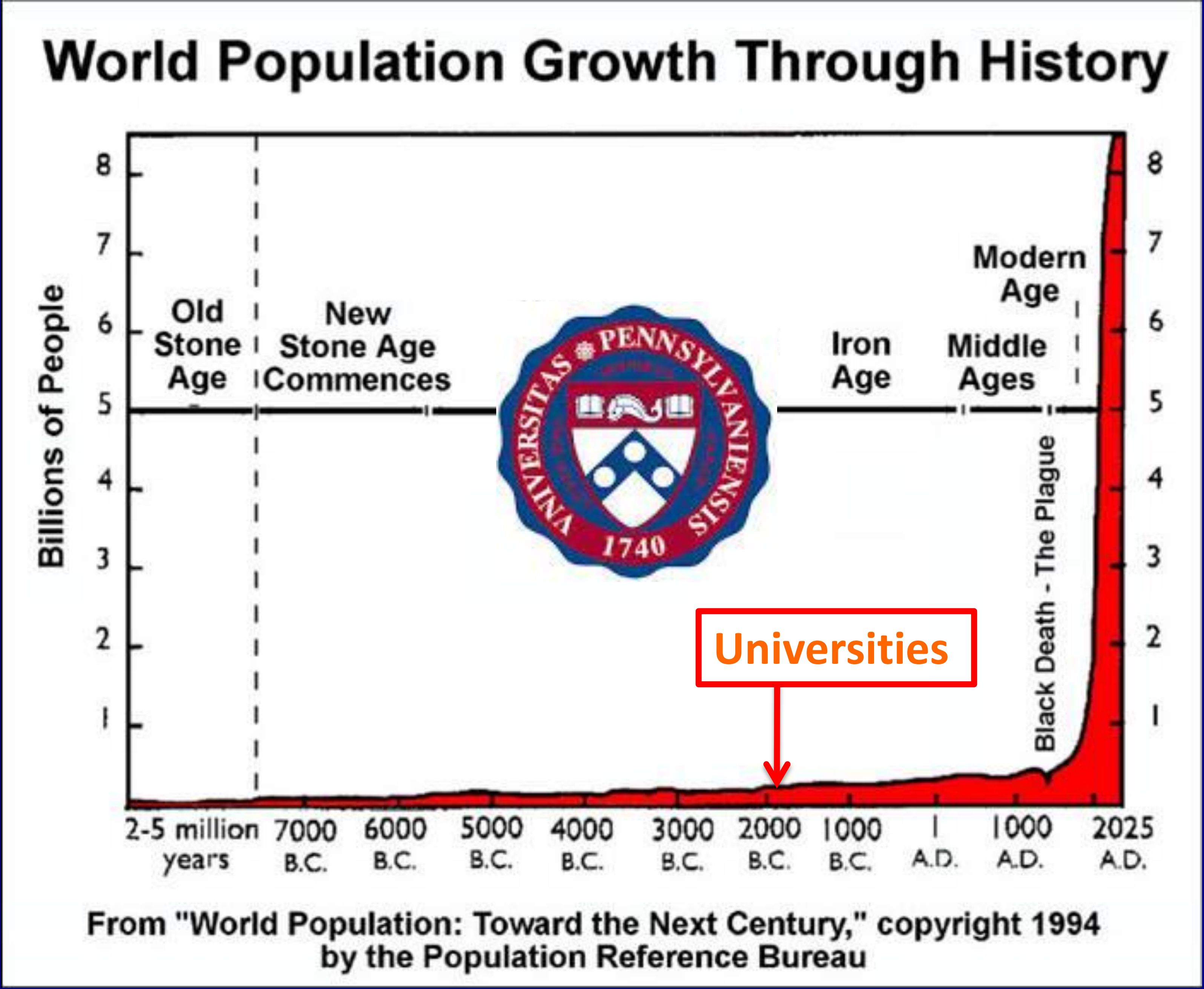
World Population Growth Through History
Billions of People
8
7
6
5
4
3
2
1
Old Stone Age
New Stone Age Commences
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Universities
PENNSYLVANIENSIS
VNIVERSITAS
1740
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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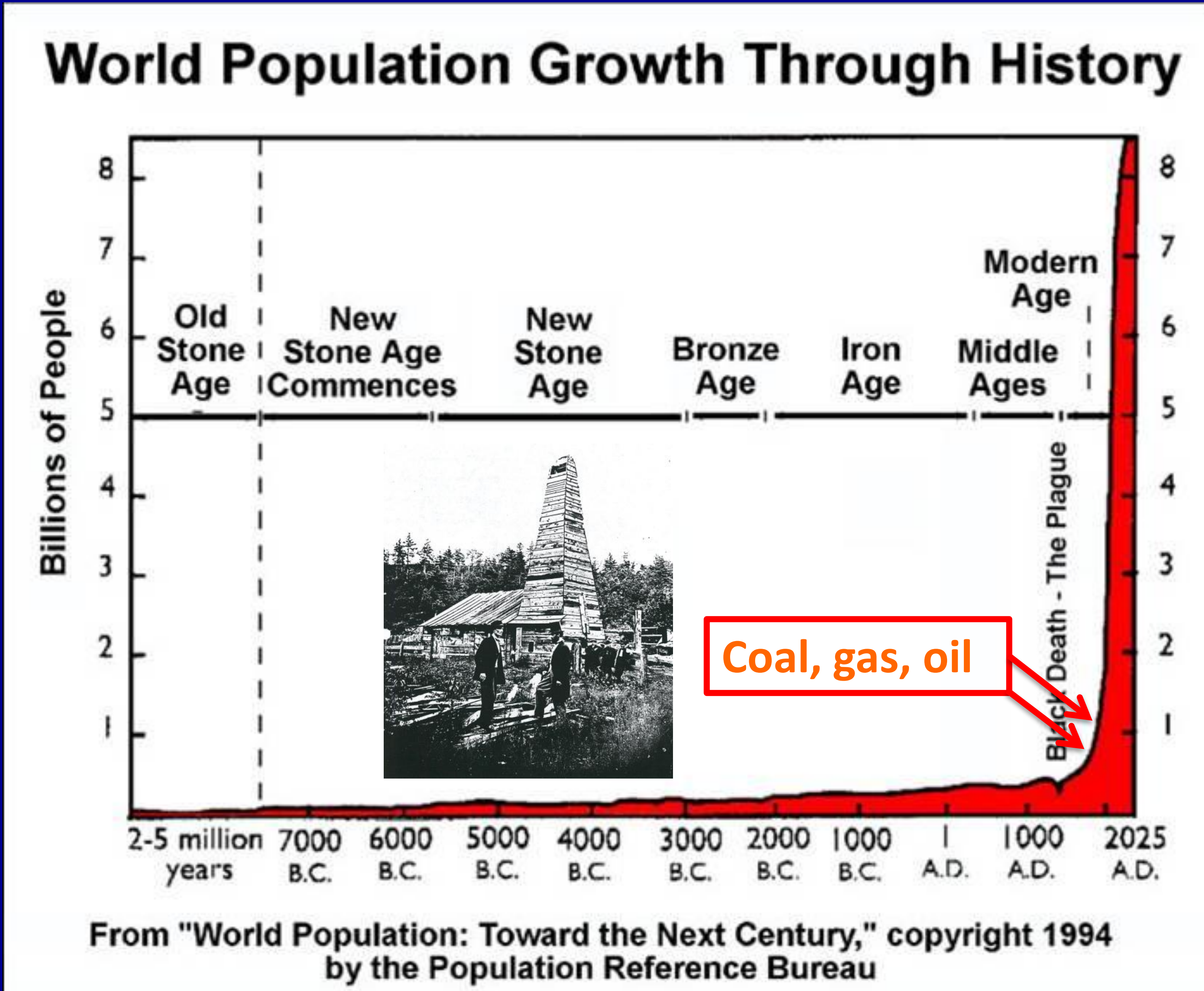
World Population Growth Through History
Billions of People
1
2
3
4
5
6
7
8
Old Stone Age
New Stone Age Commences
New Stone Age
Bronze Age
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Coal, gas, oil
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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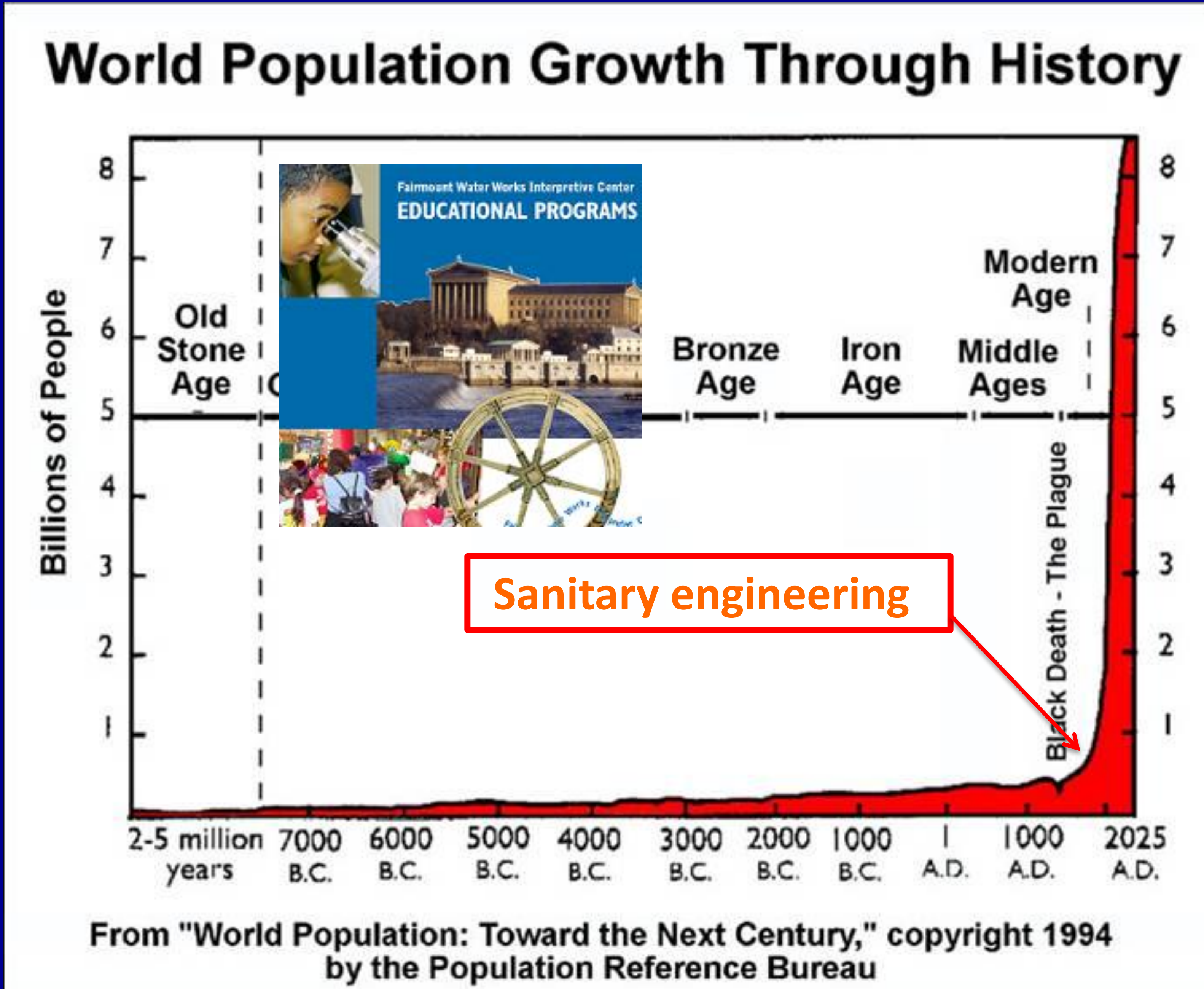
World Population Growth Through History
Fairmount Water Works Interpretive Center
EDUCATIONAL PROGRAMS
Billions of People
8
7
6
5
4
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2
1
Old Stone Age
Bronze Age
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Sanitary engineering
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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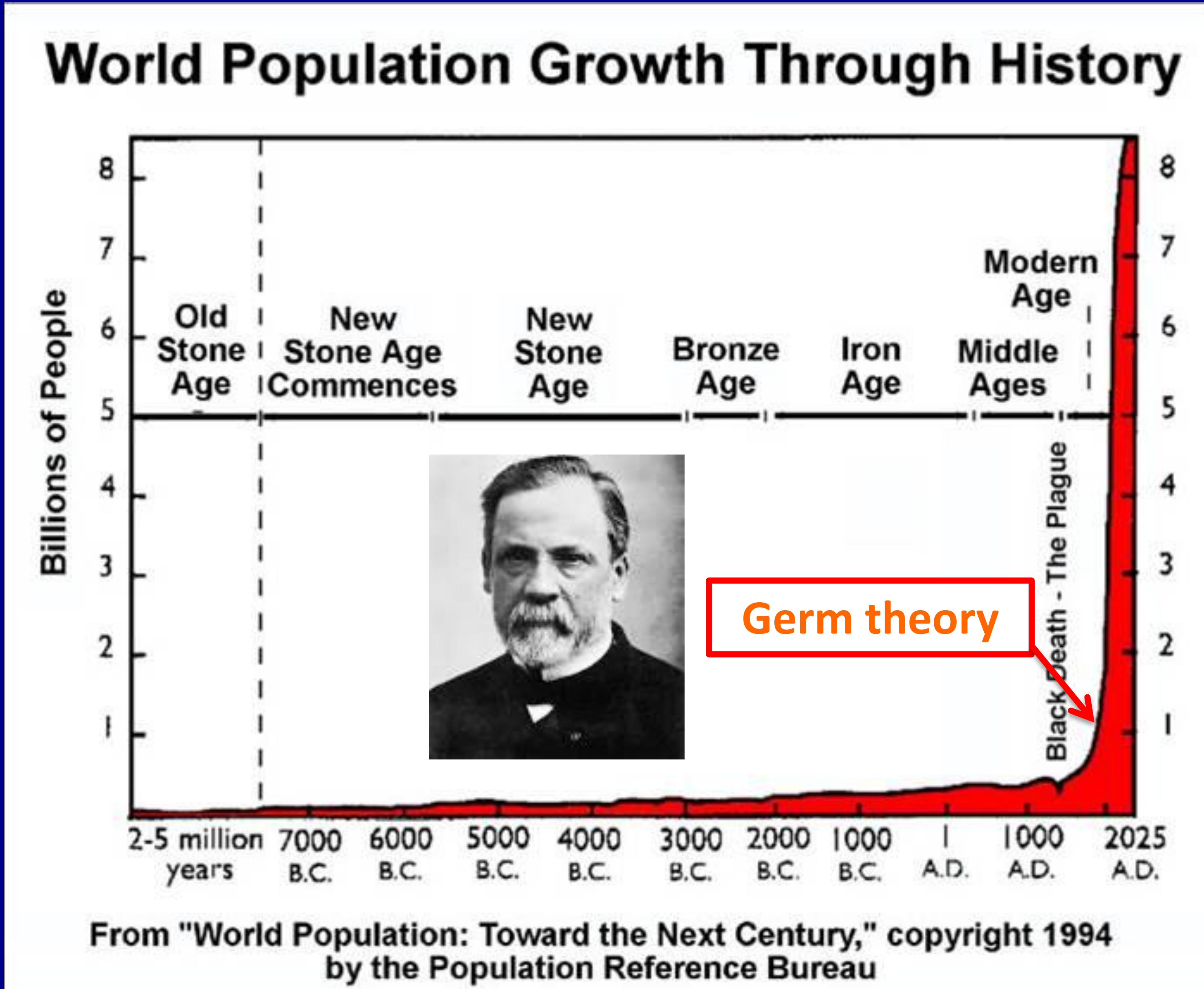
World Population Growth Through History
Billions of People
8
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4
3
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Old Stone Age
New Stone Age Commences
New Stone Age
Bronze Age
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Germ theory
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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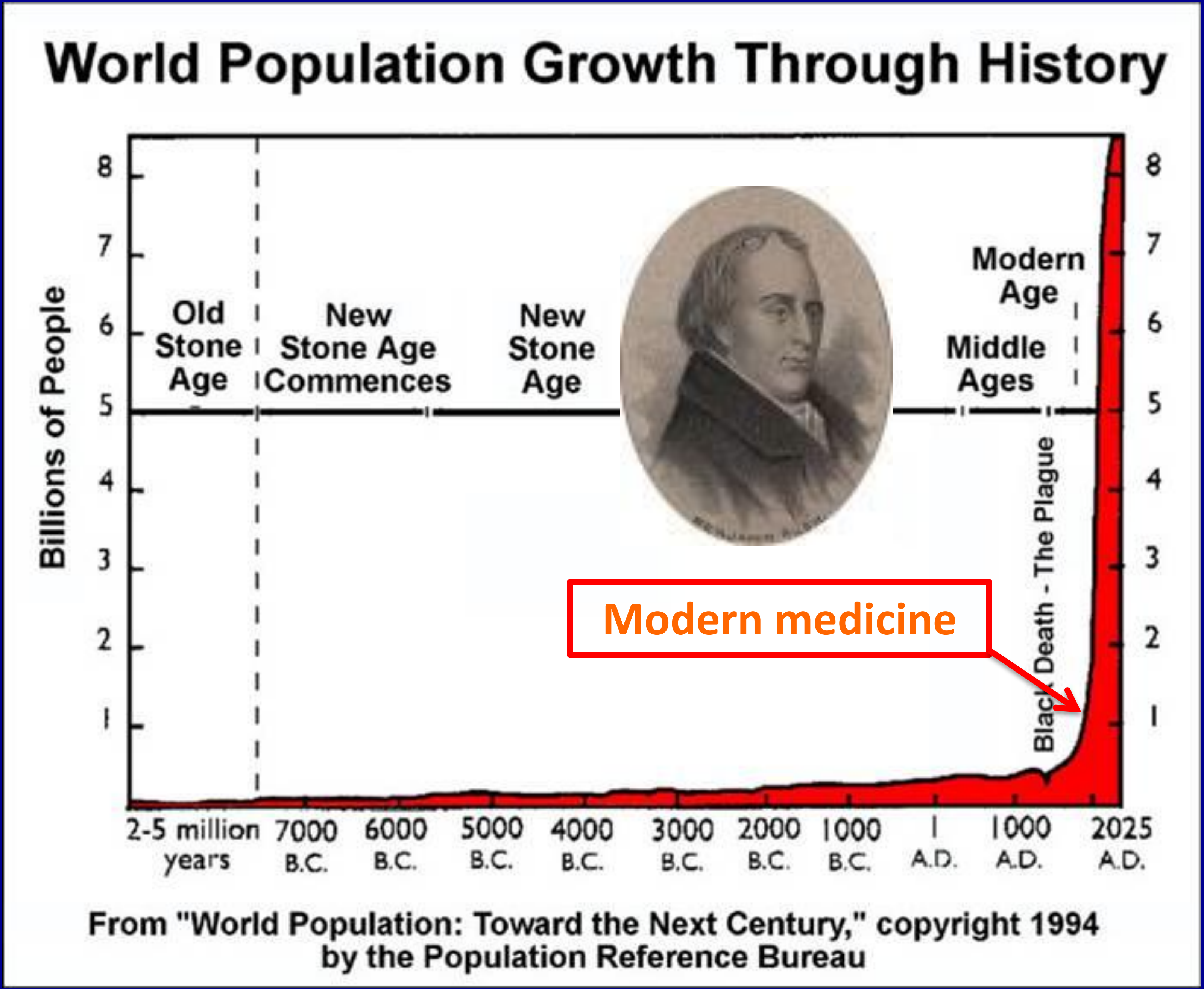
World Population Growth Through History
Billions of People
1
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3
4
5
6
7
8
Old Stone Age
New Stone Age Commences
New Stone Age
Middle Ages
Modern Age
Black Death - The Plague
Modern medicine
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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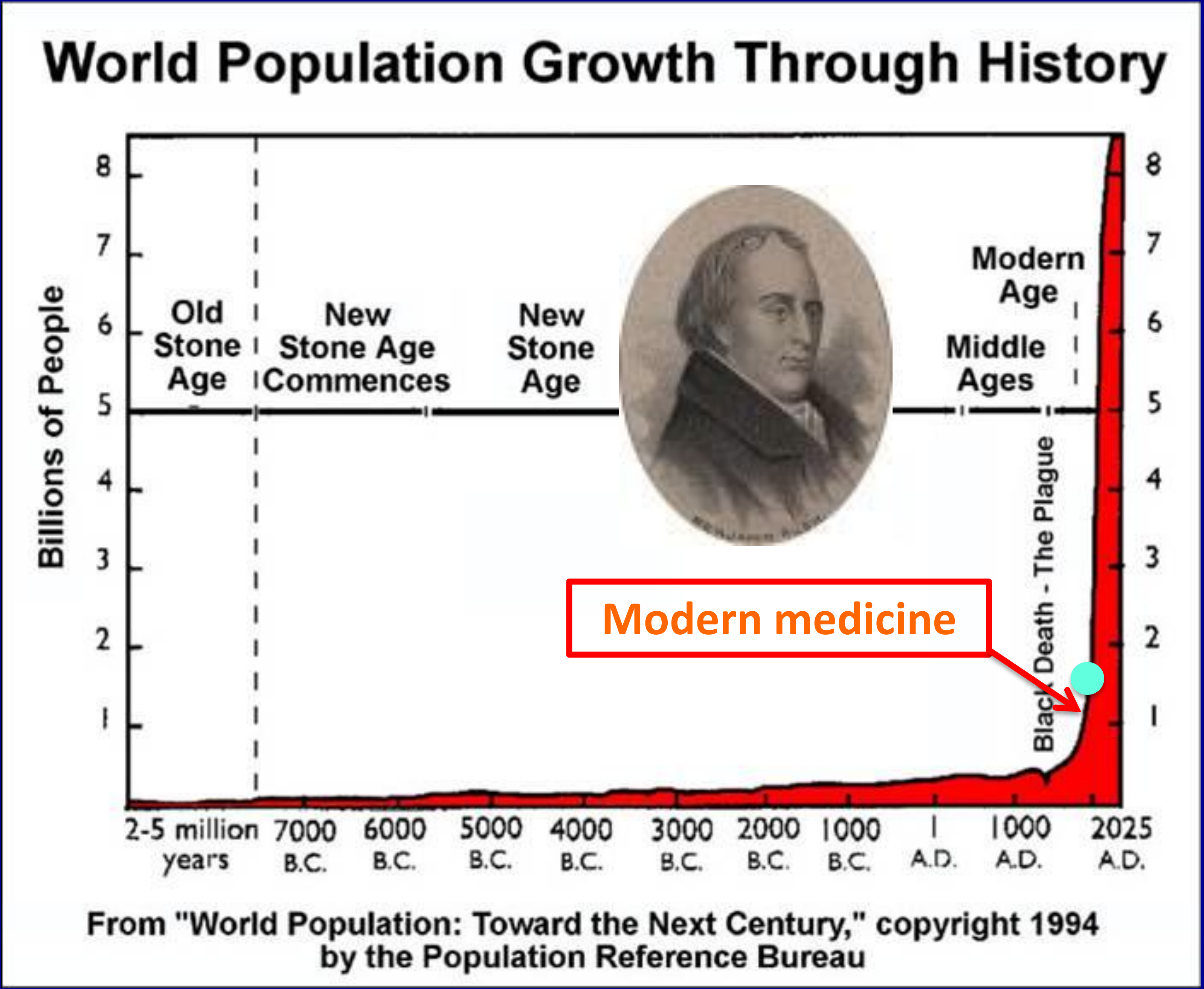

World Population Growth Through History
Billions of People
8
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4
3
2
1
Old Stone Age
New Stone Age Commences
New Stone Age
Middle Ages
Modern Age
Black Death - The Plague
Modern medicine
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
2025 A.D.
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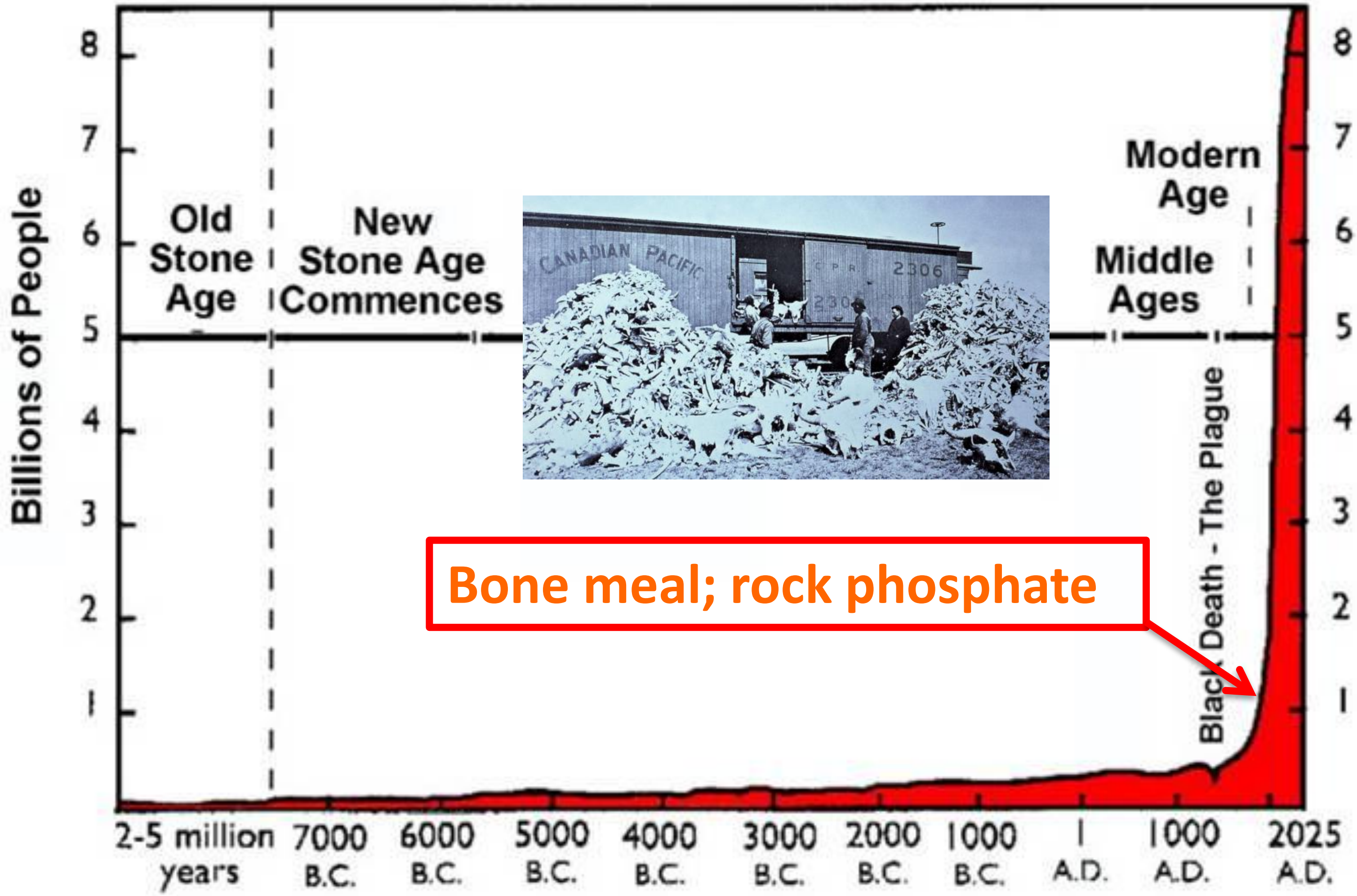
World Population Growth Through History



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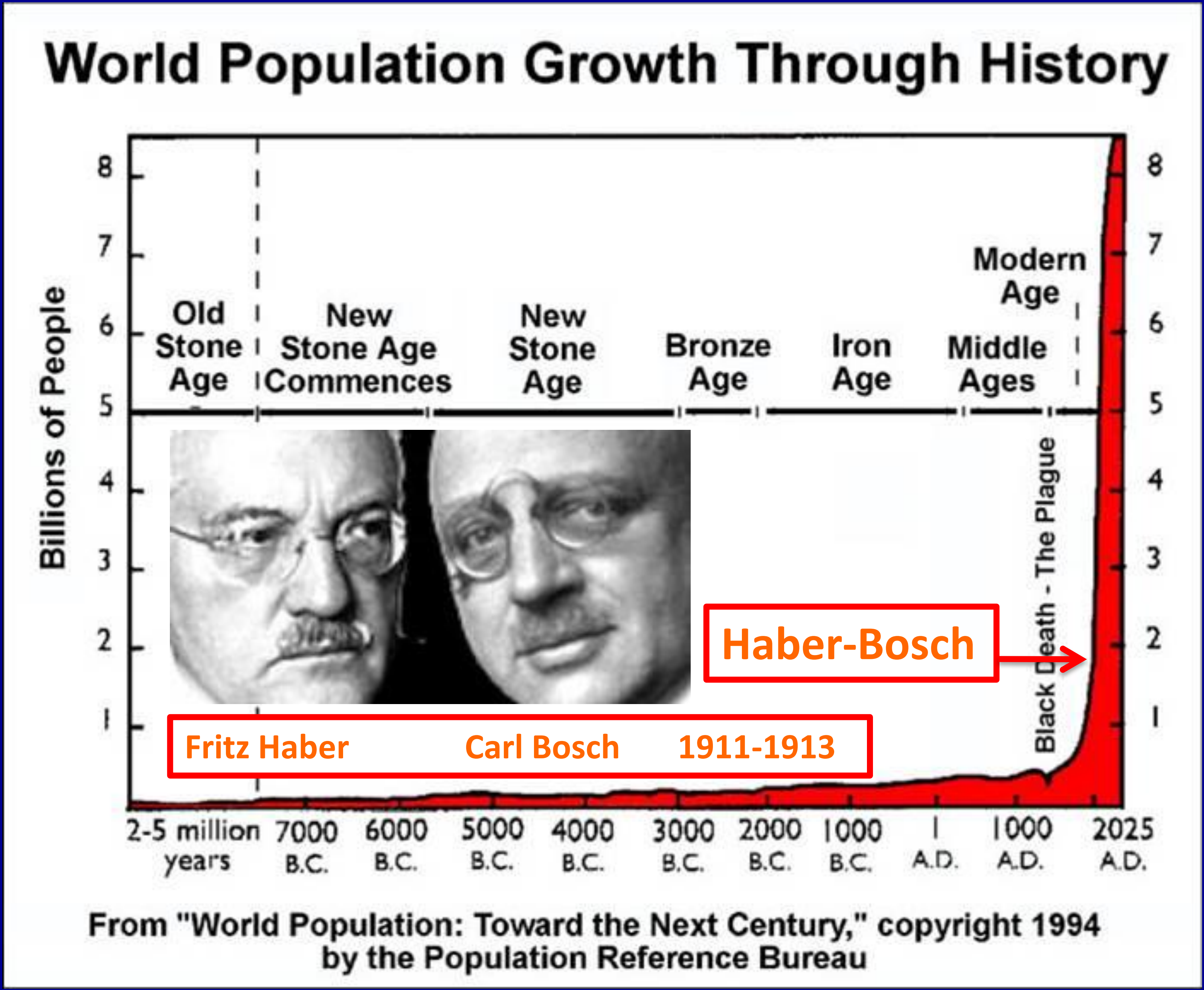
World Population Growth Through History
Billions of People
8
7
6
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3
2
1
Old Stone Age
New Stone Age Commences
New Stone Age
Bronze Age
Iron Age
Middle Ages
Modern Age
Black Death - The Plague
Haber-Bosch
Fritz Haber
Carl Bosch
1911-1913
2-5 million years
7000 B.C.
6000 B.C.
5000 B.C.
4000 B.C.
3000 B.C.
2000 B.C.
1000 B.C.
1 A.D.
1000 A.D.
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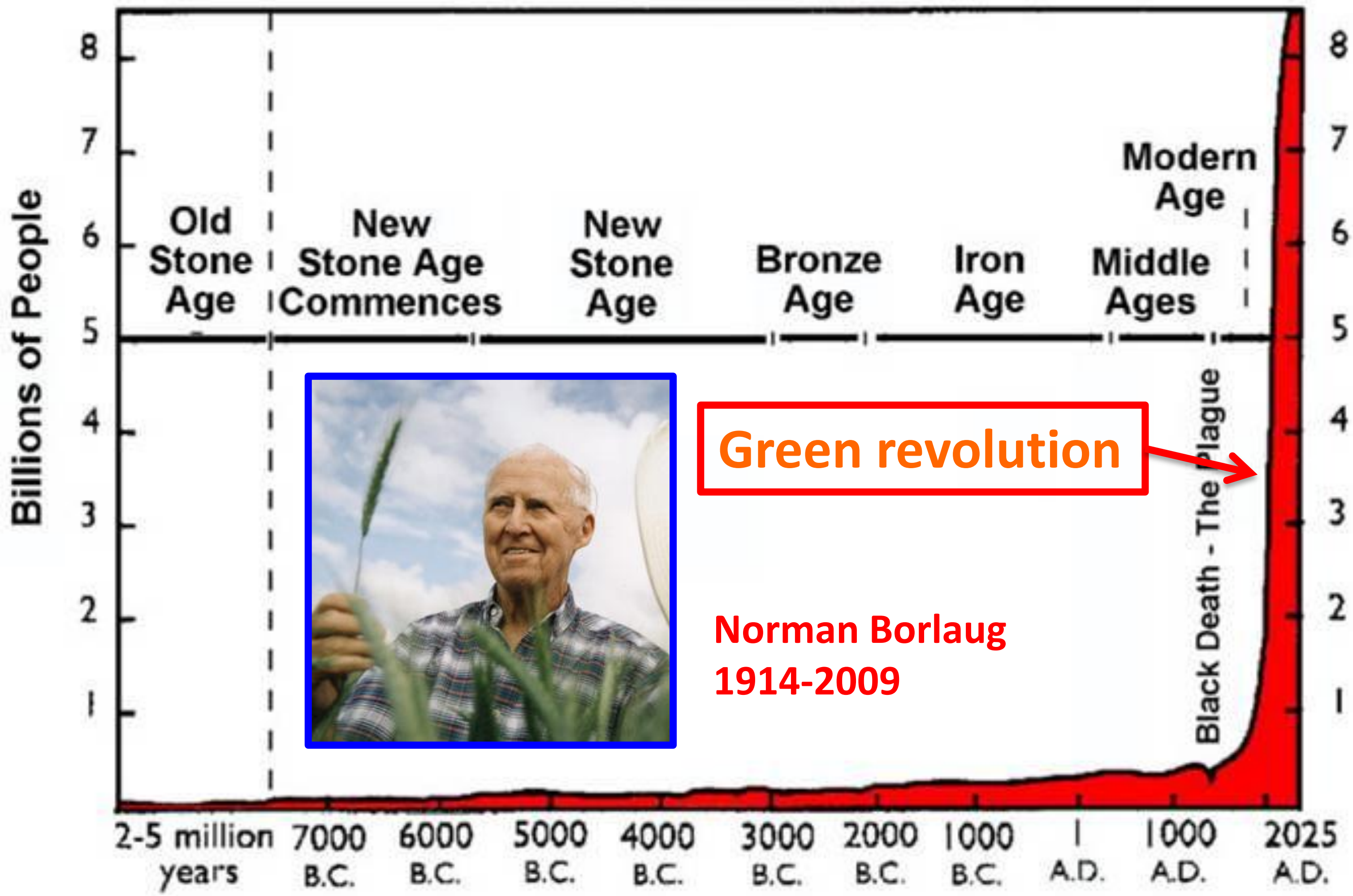
World Population Growth Through History



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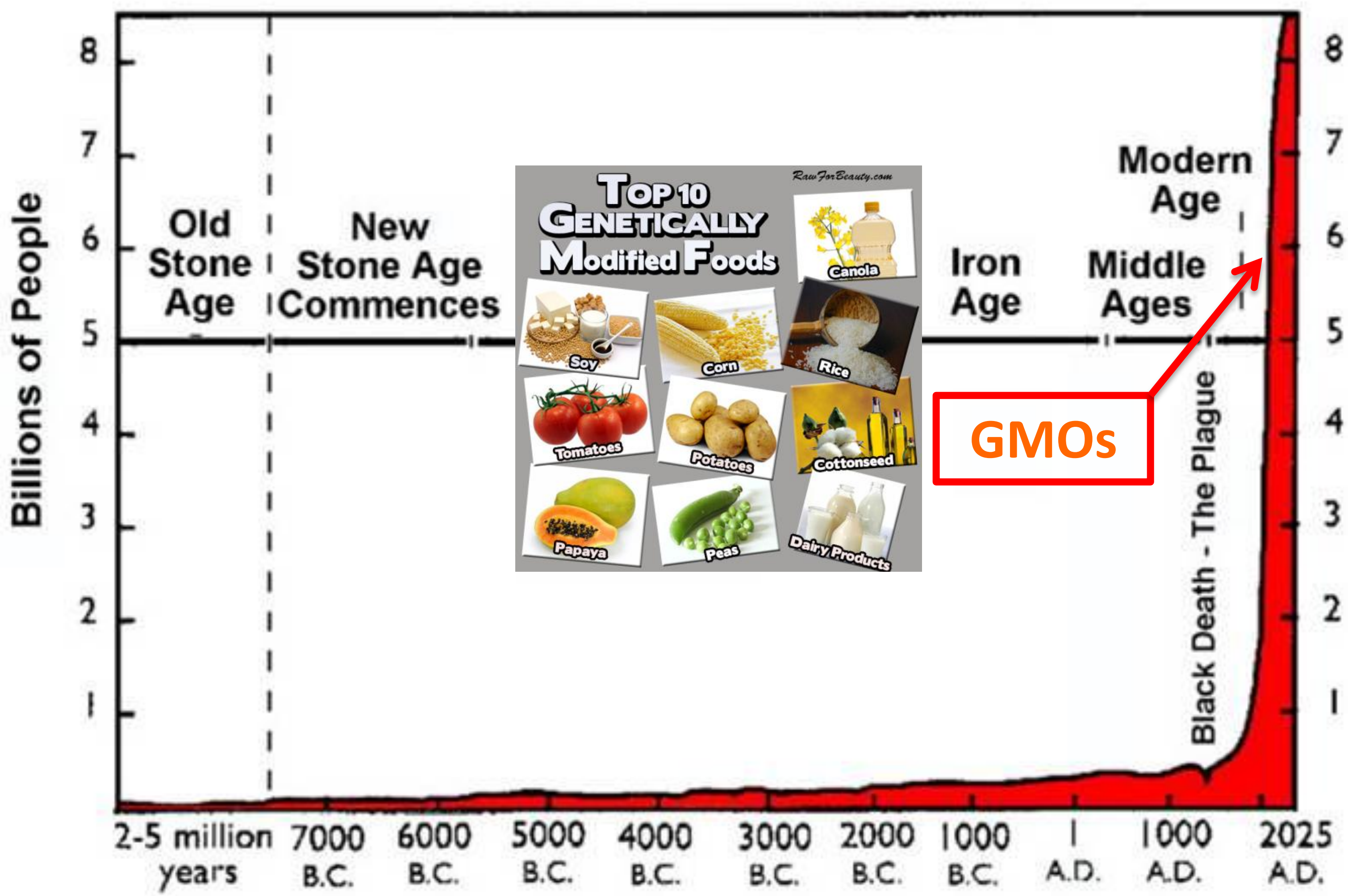
World Population Growth Through History



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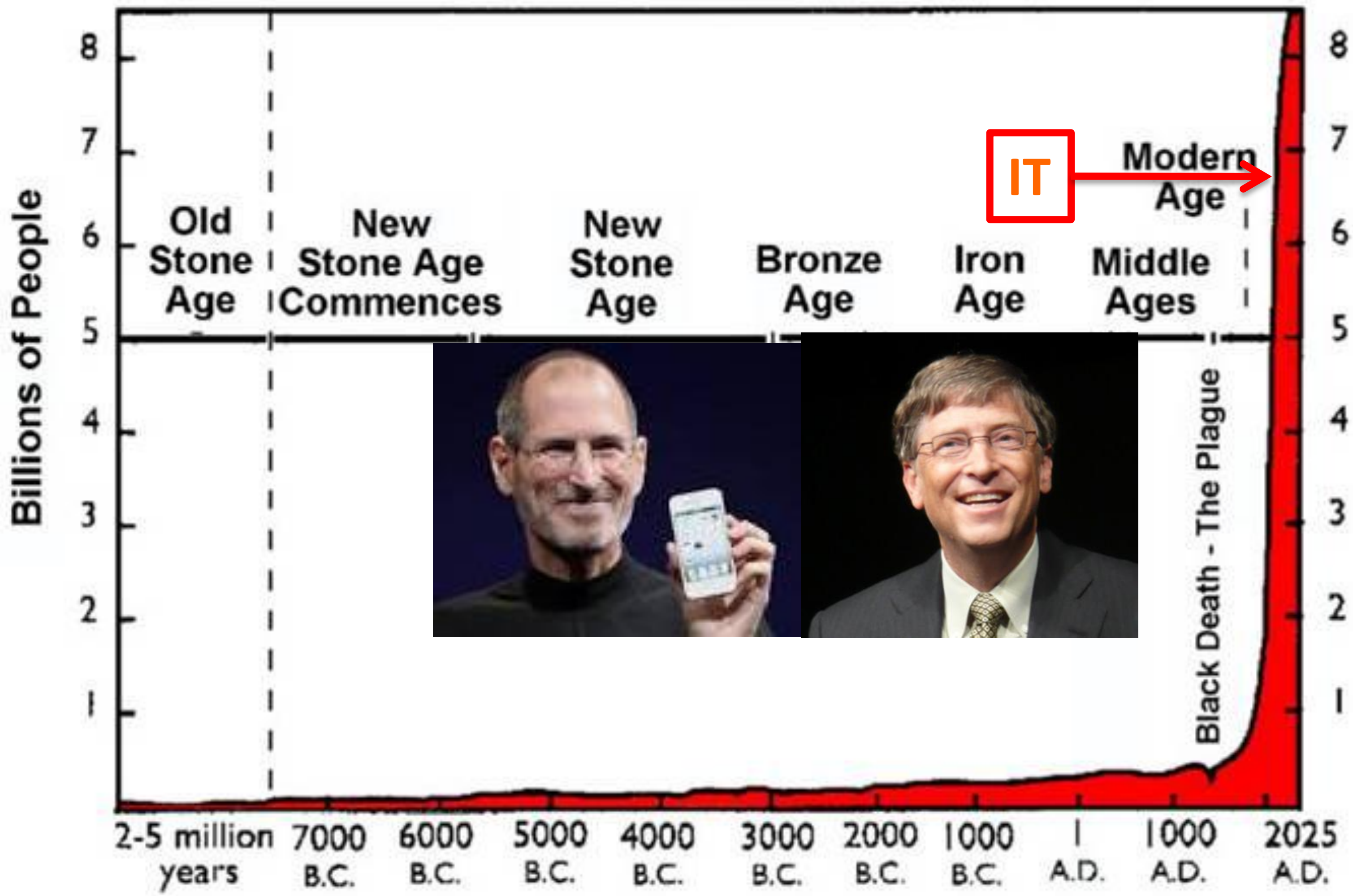

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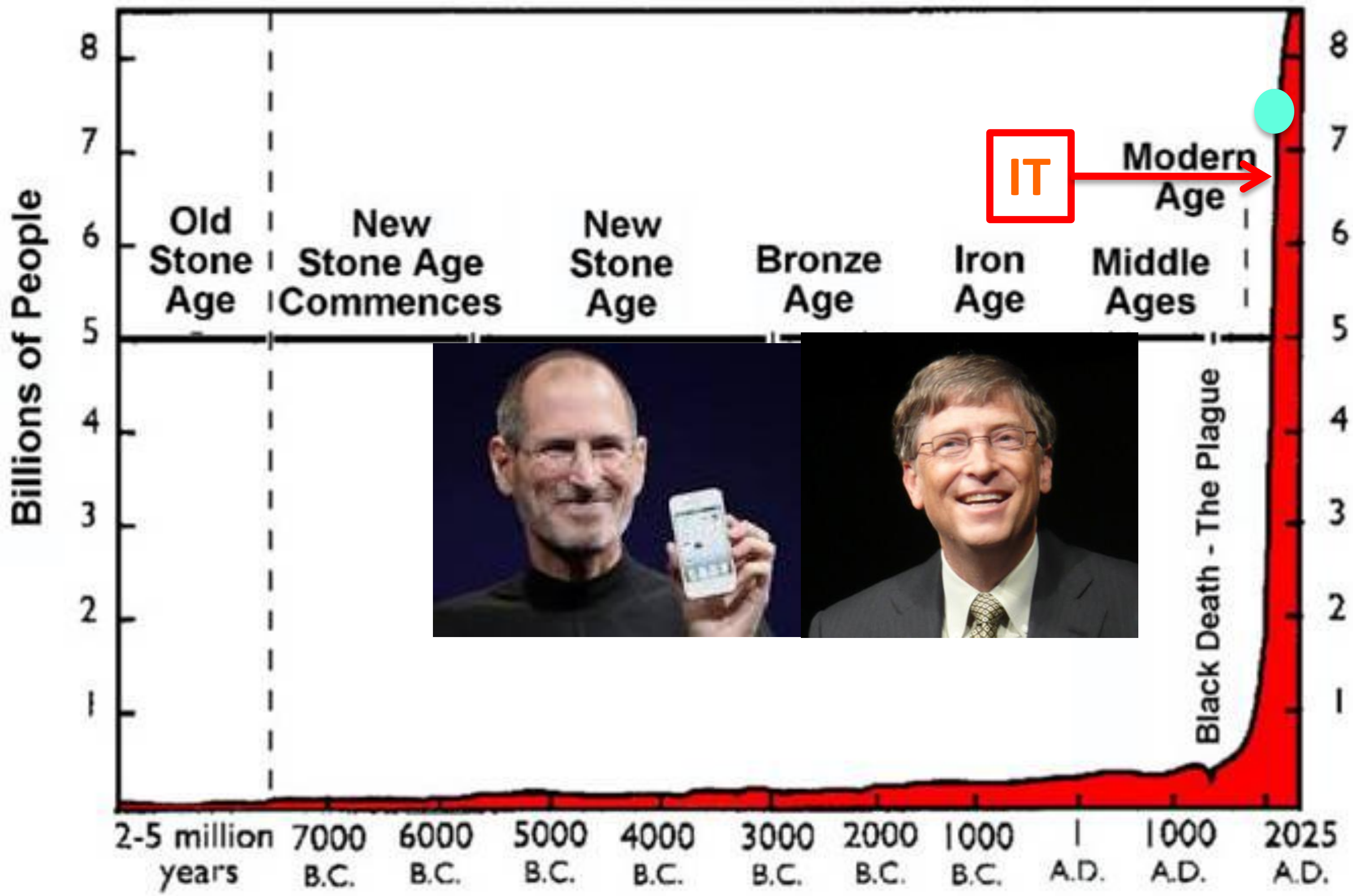
World Population Growth Through History



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We can't go back:

To return to traditional agriculture will require that <u>></u>3 billion people starve

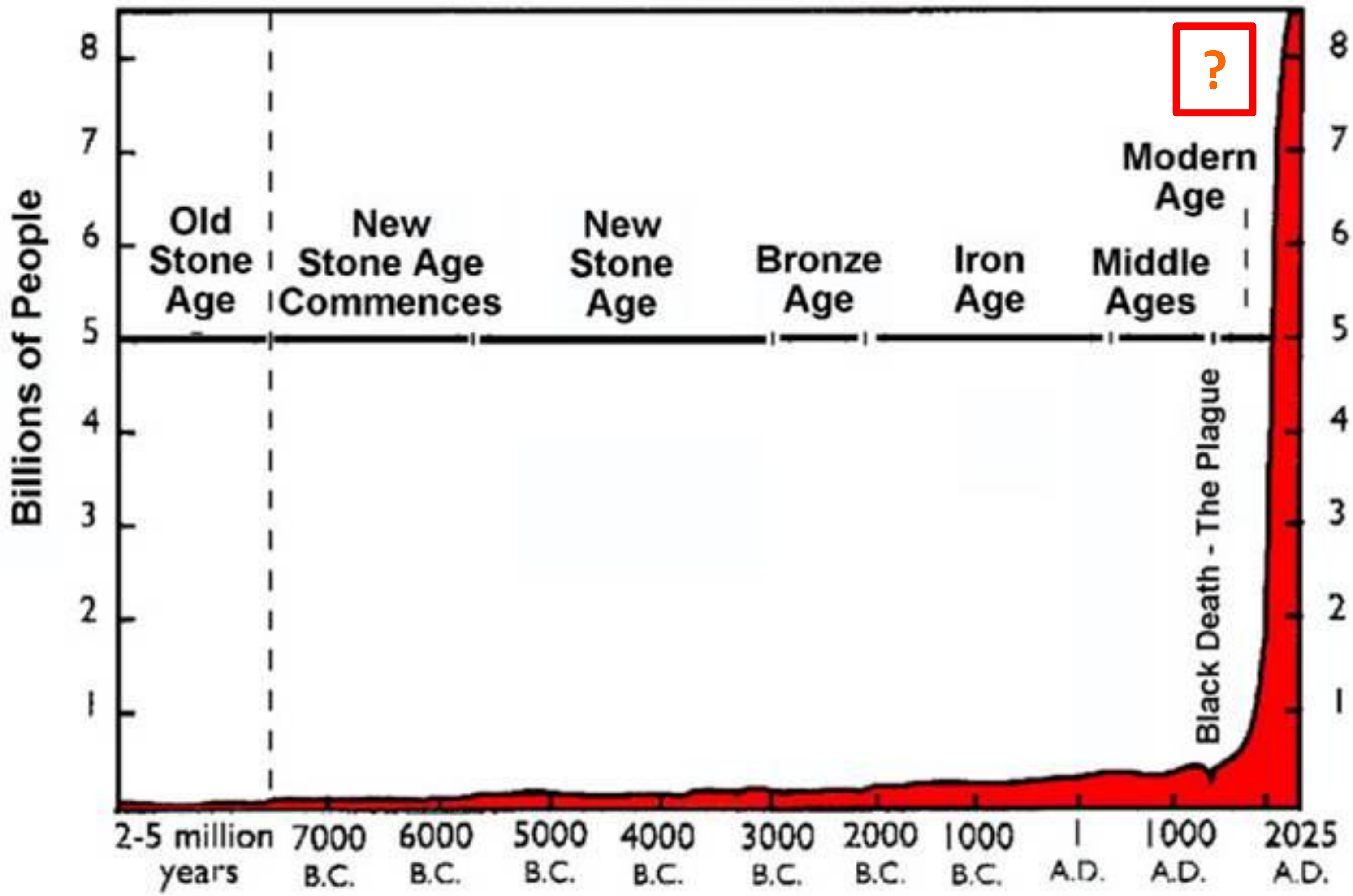
And 60% of those who survive must return to manual tillage of the soil

In contemporary subsistence-agriculture societies, neonatal mortality is ~50% and life expectancy is ~40 years

No Smartphones, no internet, no NFL, no oranges in NYC in January, no Upenn, no Novocaine….

Ain't gonna happen…..

World Population Growth Through History



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Just in the last 100 years, humankind has committed to an industrialized, energy-intensive, technology-facilitated food system. That has been made possible by low-cost fossil-fuel energy.

In that century, the human population has grown from 1.6 to 7.2 billion, and is now predicted to reach 11 billion before declining birth rates lead to a stable, or even shrinking, human population.

We require unsustainable practices to feed the people now on Earth.

We can realize very substantial reduction in resource use (and mis-use) by improving efficiencies of current systems.

We can feed 11 billion people

We will still be far from "sustainability".

Global strategies to feed 11 billion people:

1. Achieve universal gender-neutral education
2. PRICE ENERGY REALISTICALLY *(gradually…)*
3. Eat lower in the food chain *(for some cultures, eat less)*
4. Use only agricultural waste for biofuel
5. Mandate energy efficiency in construction and renovation; achieve transition to renewable energy sources; cover all buildings built after 2015 with PV cells
6. Grow food where the water is – *reform irrigation technology*
7. Apply fertilizer only as utilized by crops; recycle nutrients; apply pesticides, herbicides only as needed
8. Protect soils from erosion
9. Recycle sewage as drinking water
10. Close most of global ocean to fishing; replace by aquaculture *recycle nutrients between hydroponics and aquaculture*
11. Use gene manipulation to further increase agricultural yields, reduce loss to pests, *enhance photosynthetic efficiency*
12. Eat insects
13. Reduce waste late in the food-production process

Bon appétit

Bon appétit

 

WATER ON EARTH: $4 \pi r^2 \times 0.7 \times 4$ km

$4\pi \times (6{,}000)^2 \times 0.7 \times 4 \times 10^9 \times 10^3 \times 55 \times (6 \times 10^{23}) = 5 \times 10^{49}$ molecules of water on Earth

(except for deep ground water and Glacier ice, the world's water mixes in 2,000 years)

Water that has passed through any one human being = 4 liters/day x 365 days x 50 years x 55 moles x (6×10^{23}) = 2.4×10^{29} molecules

Proportion of water on Earth that has passed through Moses: $2.4 \times 10^{29} / 5 \times 10^{49} = 5 \times 10^{-19}$

A 250-ml glass of water contains 13 moles, or 10^{25} molecules

Number of molecules in a 250 ml glass of water that have passed through Moses:

10^{25} X $5 \times 10^{-19} = 2 \times 10^{5}$

200,000 molecules of water in the glass of water have passed through Moses

CONCLUSIONS:

1. **Avogadro's number is a *BIG* number**
2. **The wisdom of the ages resides in each glass of water**
3. ***All water is recycled***

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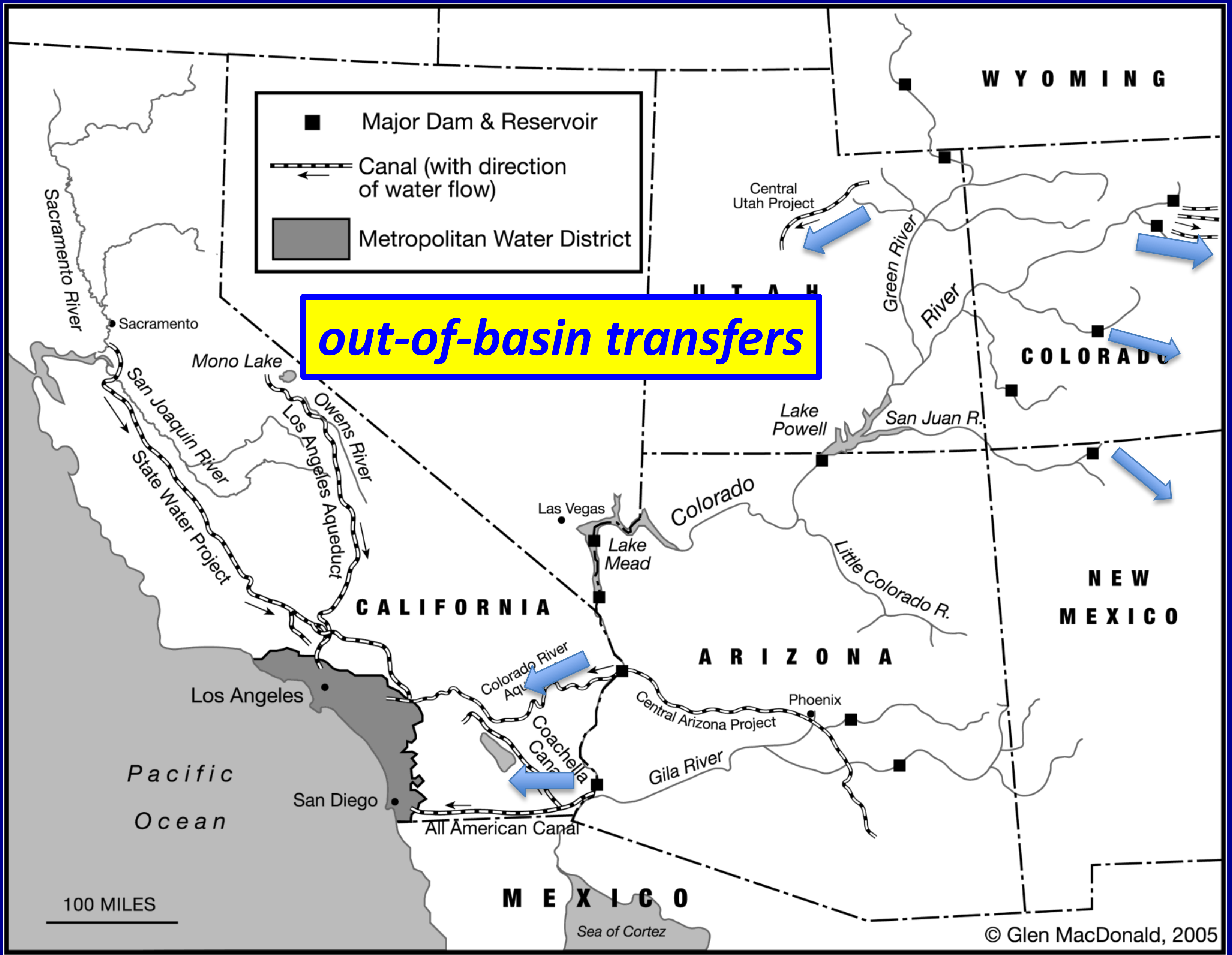
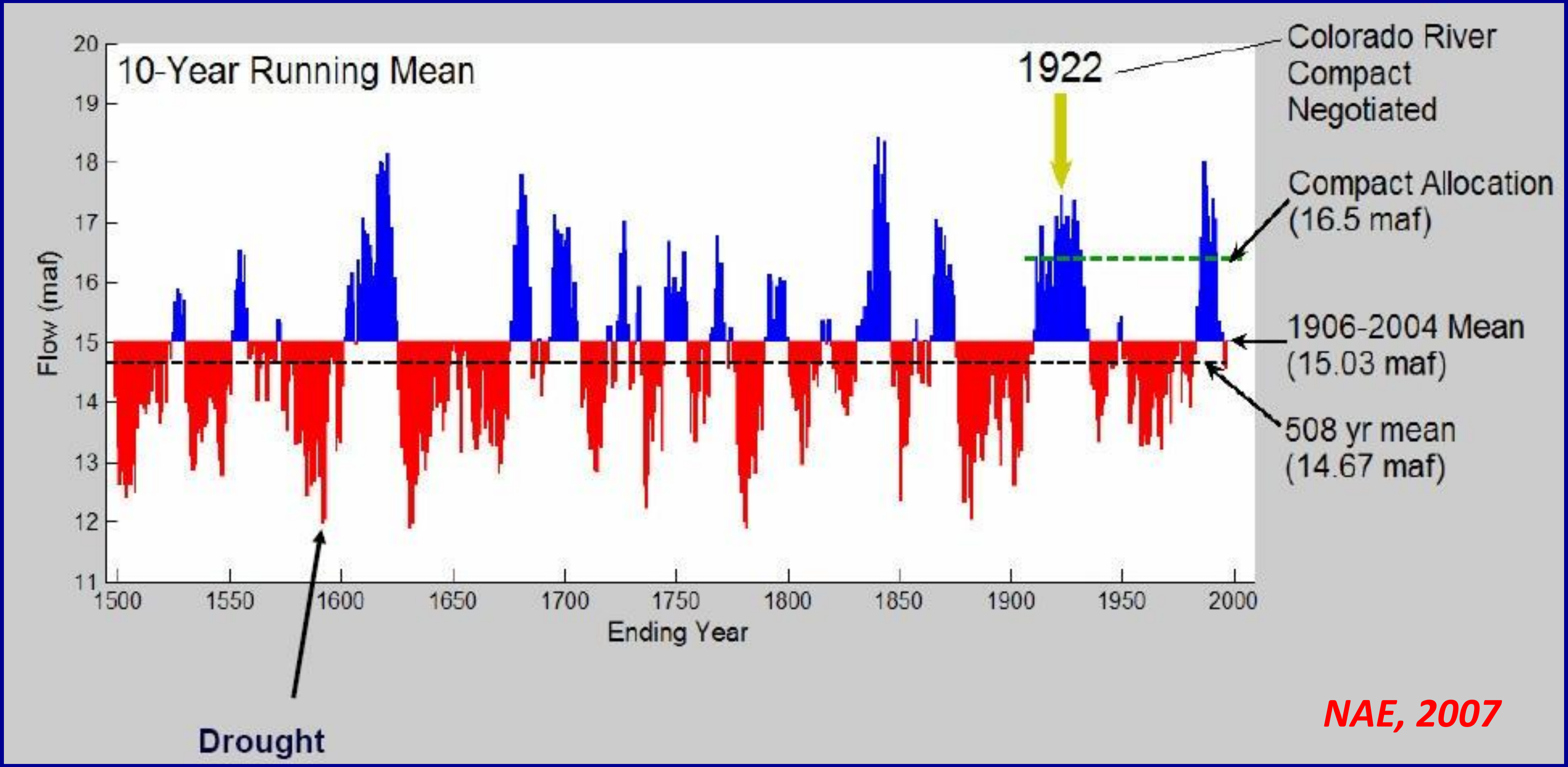


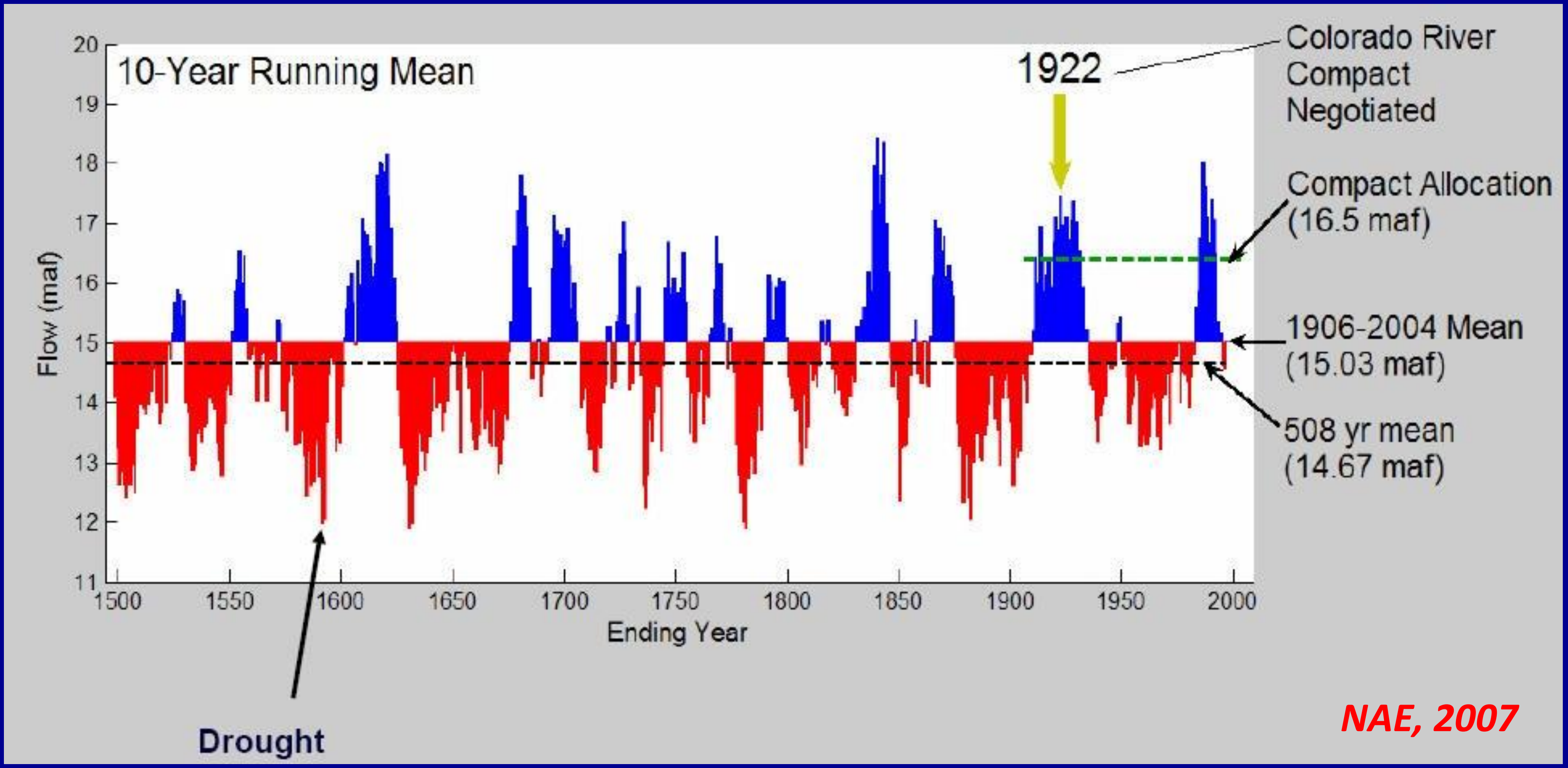
Not a drop of water makes it to the Sea of Cortez

McDonald, NAE, 2007

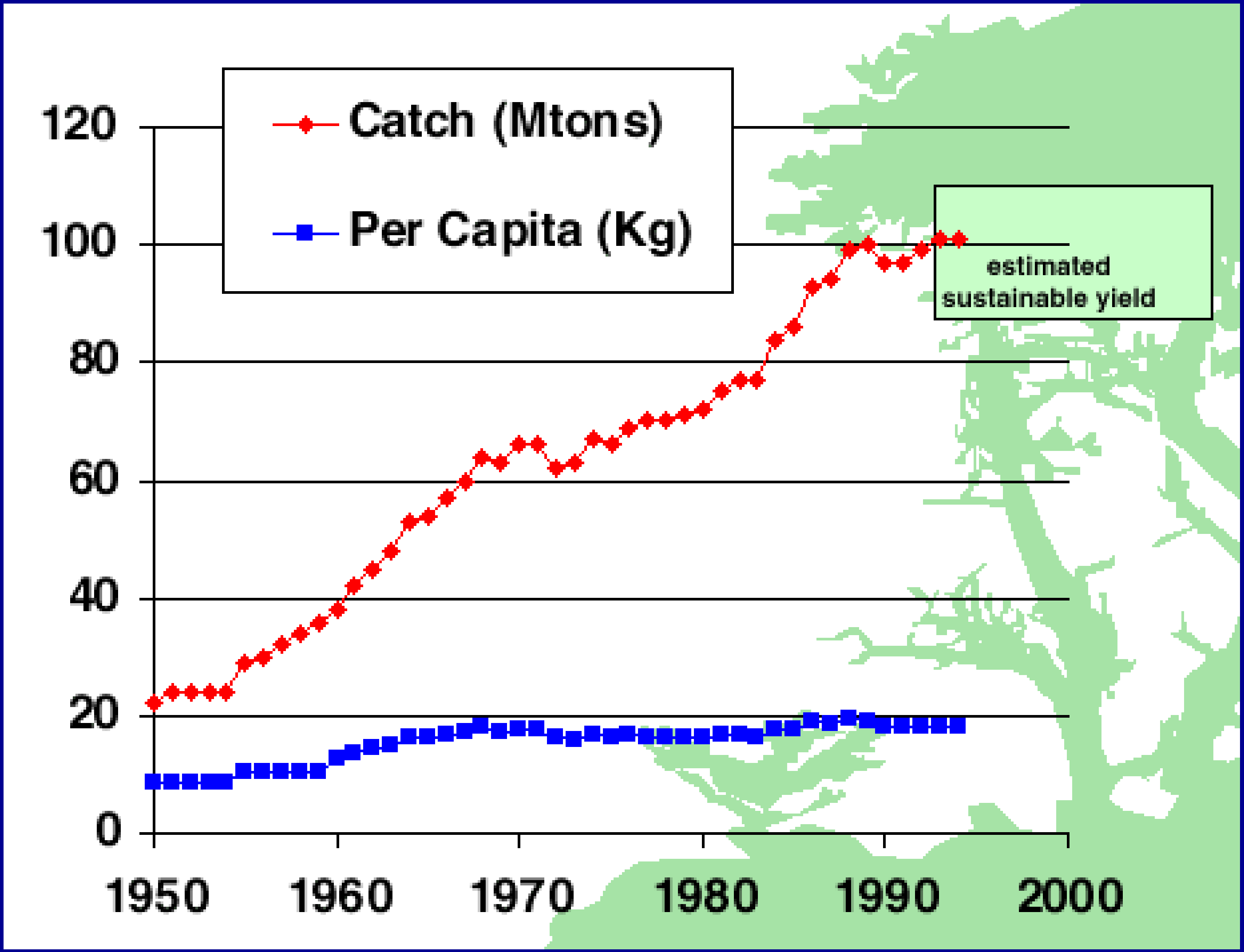
Flow of the Colorado River at Lees Ferry in the Grand Canyon



Data from the Lees Ferry Gauging Station: 1904-2012, and reconstructed from tree rings 1500-1904 AD



Water allocation 1922: **Upper Basin 7.5 maf/yr**
Lower Basin 7.5 maf/yr
Mexico 1.4 maf/yr *(caveat)*



Global fish harvest, salt- and fresh-water, 1950-2000

Univ. of Michigan, Global Change

Very little of this combined impact on our food system can be attributed to anthropogenic climate change. The primary effect of excess CO_2 on food production is fertilization.

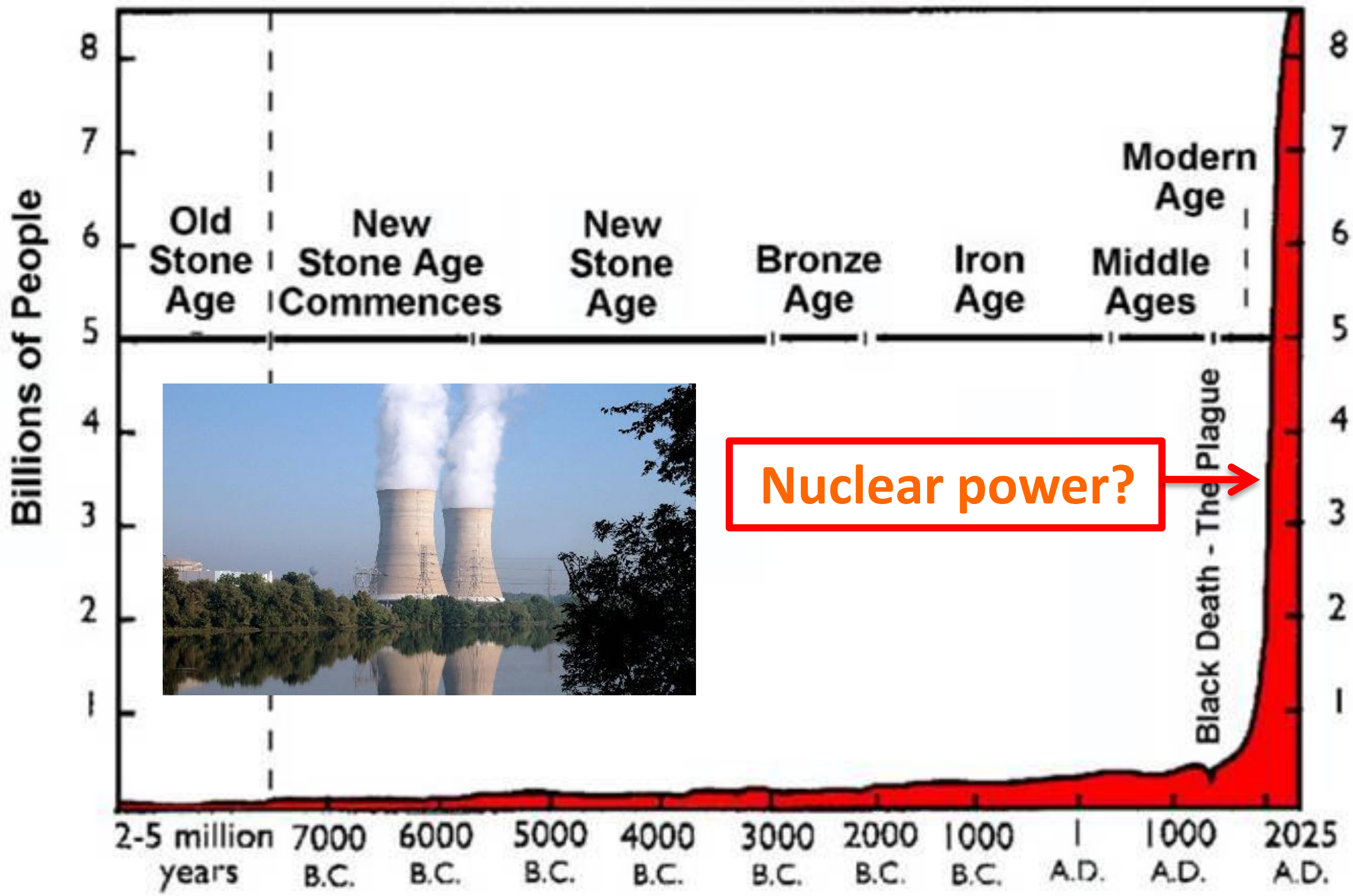
Sea level is rising, and reducing total arable land. This effect is slow, and trivial compared to the record of human manipulation of natural resources. Deliberate destruction of agricultural land reduces global cropland more than sea-level rise.

Humans have always struggled to produce enough food – in warming times, in cooling times……….humans have fared better in warming times than in cooling.

Today, all bets are off – there are many people, we are depleting resources at an unprecedented rate, and we are contaminating remaining resources. Lessons of the past may be less valuable…….

Among our affronts to the systems that sustain us, the impact of the food industry on ocean biota, direct and indirect, represents simple abuse – it does not rise to the level of mismanagement.

World Population Growth Through History



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