Cosmology & Culture

Lecture 9

Wednesday May 20, 2009

Think Cosmically, Act Globally

UCSC Physics 80C

Summary of the modern cosmological story

• The universe is very old (about 13.7 billion years) and very big, but everything we can see is finite – from the smallest size (the Planck length, 10^{-33} cm) to the cosmic horizon (10^{29} cm). The very early universe was very hot, dense, and almost perfectly homogeneous, and has on average become steadily less so.

• The largest scale structures – galaxies, clusters, superclusters, voids – arose from the action of gravity amplifying small primordial differences in density of matter and radiation. The only idea yet proposed that can account for both the near homogeneity and also the deviations from perfect homogeneity is Cosmic Inflation, superfast accelerating expansion in the very early moments of the Big Bang.

• There was a tiny excess of matter particles over antimatter particles, about one in a billion (10^9). All ordinary matter in the universe now is the remnant of the great annihilation, which left a billion photons and neutrinos for each proton or electron. But most of the matter in the universe is invisible "cold dark matter," which is not made of atoms, but some stuff still to be discovered.

• The lightest chemical elements – hydrogen and helium – were mostly formed during the first few minutes. The remaining elements – including silicon, oxygen, carbon, nitrogen, and iron, the key elements of earth and life – were made in stars and spewed out by supernovae to form new stars and planets.

The modern cosmological story, continued

• Life arose early in the history of earth, but for 80% of its history, life consisted only of single cells. All living organisms share the same genetic code and the same basic chemistry. We are all descended from the same early living organism.

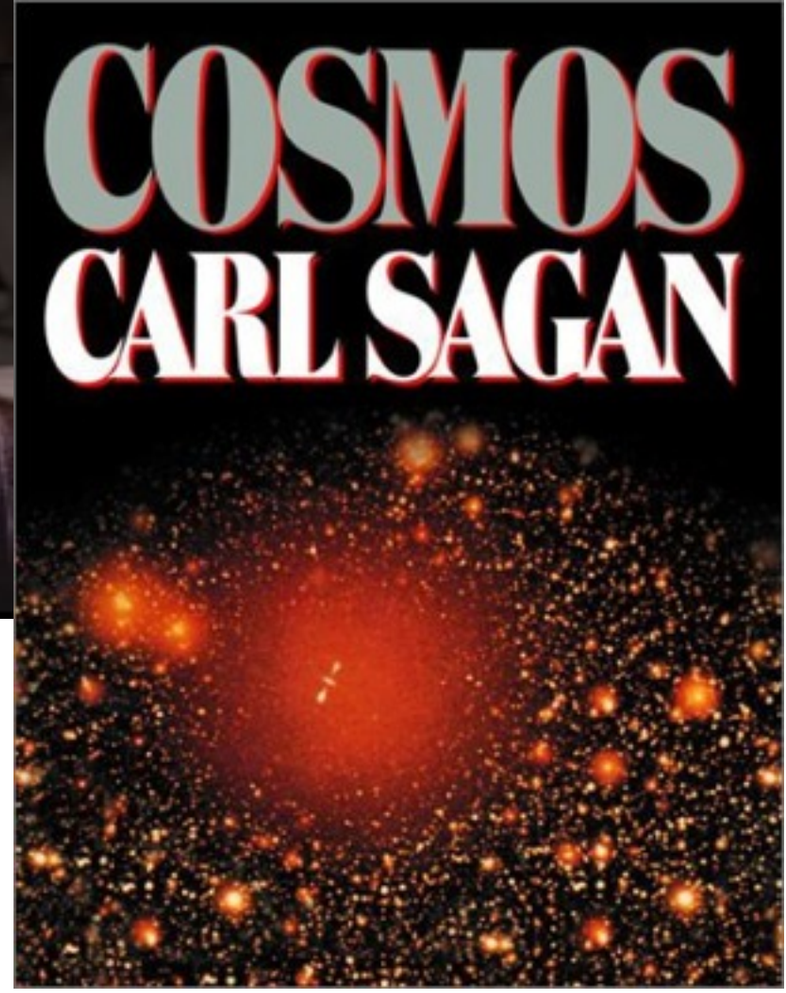
• The earth's atmosphere was largely made by living organisms, whose activities influence and perhaps control aspects of the global environment.

• Most species that ever lived are now extinct. Those alive today were generated by chance and chosen by natural selection. Evolution included both steady processes and catastrophic events such as the asteroid impact 65 million years ago that wiped out the dinosaurs and many other species then living.

• **Our species quite recently invented written language, civilization, and science. We are now changing the entire planet in ways that will have large but unknown consequences. These could be devastating unless we control our population and environmental impact. The long-term future of the world will be determined by choices made during the next decades. This is a unique opportunity for heroism!**

• The earth and sun as know them now will continue to exist for several billion years, and our galaxy will continue to make new stars and planets for many billions of years after that. But very far in the future, the universe will change in ways not yet fully understood under the control of "dark energy," which is now the main constituent of the universe.

Two excerpts from the second Cosmos program, on life in cosmic history, and evolution on earth.



I: The Shores Of the Cosmos

II: One Voice In the Cosmic Fugue

III: The Harmony Of the Worlds

IV: Heaven and Hell

V: Blues For A Red Planet

VI: Travellers' Tales

VII: The Backbone of Night

VIII: Travels In Space and Time

IX: The Lives Of the Stars

X: The Edge Of Forever

XI: The Persistence Of Memory

XII: Encyclopedia Galactica

XIII: Who Speaks For Earth?

In the last few millennia we have made the most astonishing and unexpected discoveries about the Cosmos and our place within it, explorations that are exhilarating to consider. They remind us that humans have evolved to wonder, that understanding is a joy, that knowledge is prerequisite to survival. I believe our future depends on how well we know this Cosmos in which we float like a mote of dust in the morning sky.

Carl Sagan 1934-1996

Darwin and Evolution

It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Last paragraph, *Origin of Species* (1859)

Darwin and Evolution

Key ideas of Darwin's theory (*Origin of Species*, 1859):

- There is a wide range of variation in species.
- Only competition for scarce resources prevents a geometric increase in the number of progeny.
- This competition, combined with variation, results in natural selection of the fittest individuals in each generation.

How many of YOUR direct ancestors died in childhood?

Why is this so troubling to Fundamentalists?

It conflicts with the Genesis account, in which God made all types of plants and animals, and Noah saved them from the Flood. "Although atheism might have been *logically* tenable before Darwin, Darwin made it possible to be an intellectually fulfilled atheist."

– Richard Dawkins, *The Blind Watchmaker* (1986), p. 6.

Objection: "Evolution is sheer speculation since no one was there to observe the origin of species."

Answer: A police detective would scoff at the notion that crimes can be solved only when they are witnessed directly! **Theories in the historical sciences (cosmology, geology, and evolutionary biology) are tested by their success in predicting new discoveries about the past.**

Lewis Thomas, *The Lives of a Cell* (1974)

Man thinks he is separate from and even above Nature ("stewards" according to the Bible, in charge of Nature). But man is not really even an entity. We are communities, "shared, rented, occupied" by tiny creatures:

- Mitochondria run our cells, reproducing by their own separate DNA. Every cell is an ecosystem.
- Plants are in the same situation. Their chloroplasts have separate genomes.
- Viruses' real evolutionary purpose may be to keep "new, mutant kinds of DNA in the widest circulation among us." If so, then viral diseases may just be an accident.

Earth is so complex it can't be thought of as an organism. It is most like a single cell.

"The World's Biggest Membrane"

Earth is alive, because it has created a membrane around itself to protect itself from ultraviolet, from falling into equilibrium, from entropy. The membrane is the atmosphere, the **sky**. The original anaerobic cells had to live under 10 meters of water to be protected from the sun. But when photosynthetic cells evolved and produced oxygen, gradually the accumulation of oxygen shielded out enough ultraviolet to let life come to the surface of the pools and then onto the land.

Most details in evolution are arbitrary and could have been different – the design of gills or forebrains, for example – but the evolution of the sky was essential. "It breathes for us," and protects us also from cosmic rays and millions of meteorites every day. The sky is the "grandest product of collaboration in all of nature."

Obama Acceptance Speech
Tuesday, November 4, 2008

We are at the midpoint of time in multiple ways.

This is the best time in the history of the universe for astronomical observation.

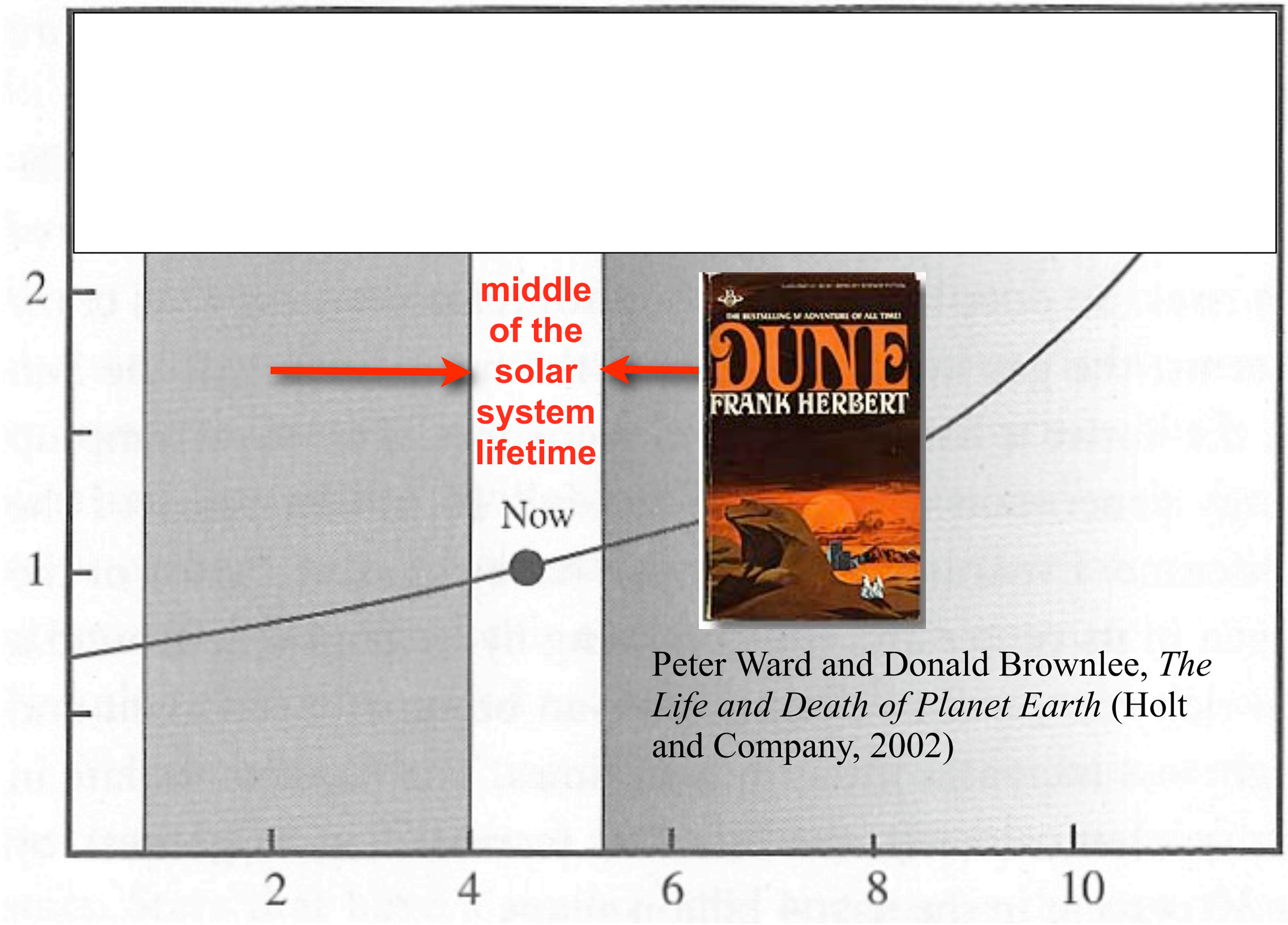
This is the middle of the lifetime of the solar system

and

This is the middle of the best period on earth for large creatures.

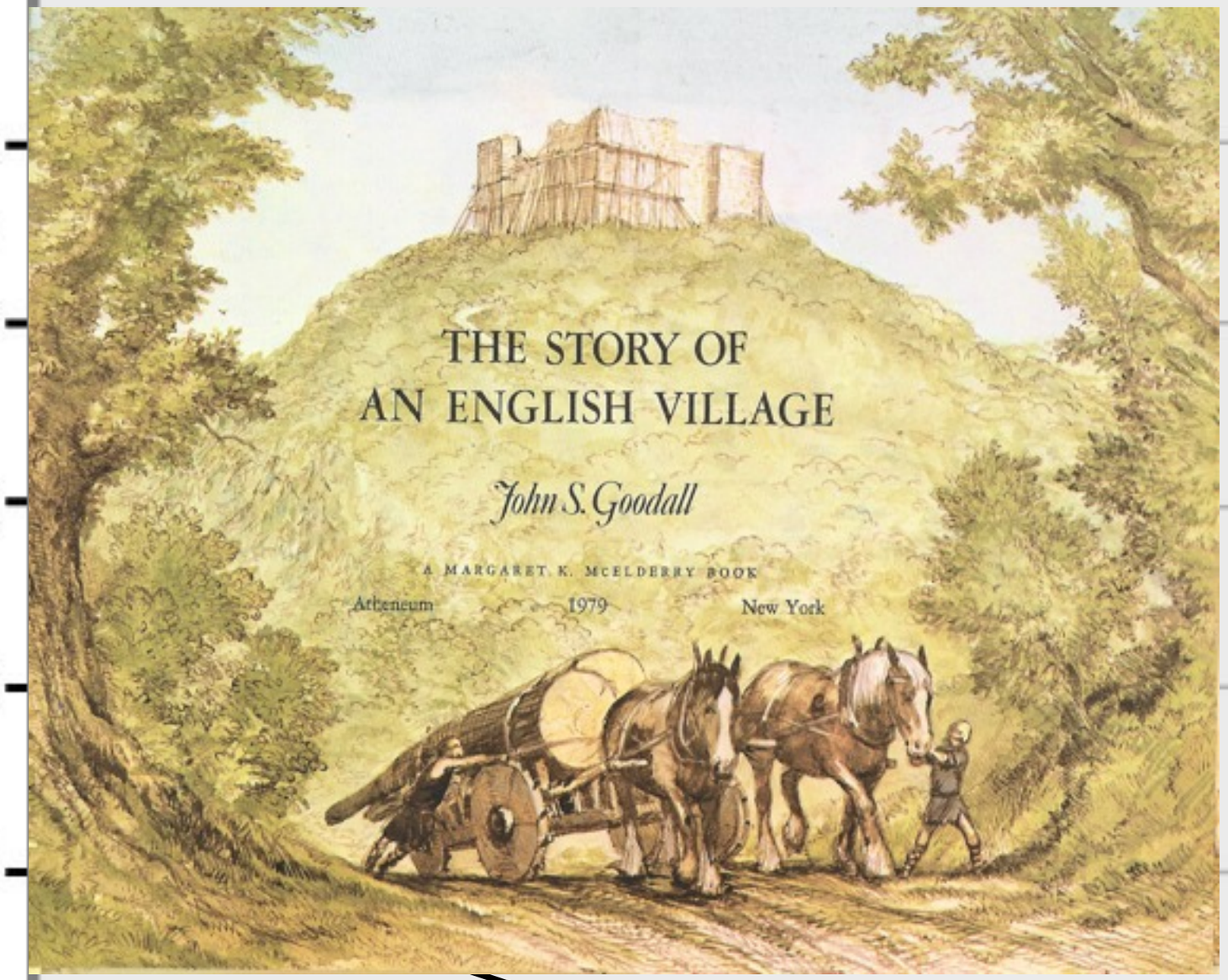
This is a turning point for the human species and our planet.

Solar Luminosity



Peter Ward and Donald Brownlee, *The Life and Death of Planet Earth* (Holt and Company, 2002)

Age of Earth (Billions of Years)



Us Today

Population (billions)

7
6
5
4
3
2
1

200 400 600 800 1000 1200 1400 1600 1800 2000

Year

THE STORY OF AN ENGLISH VILLAGE

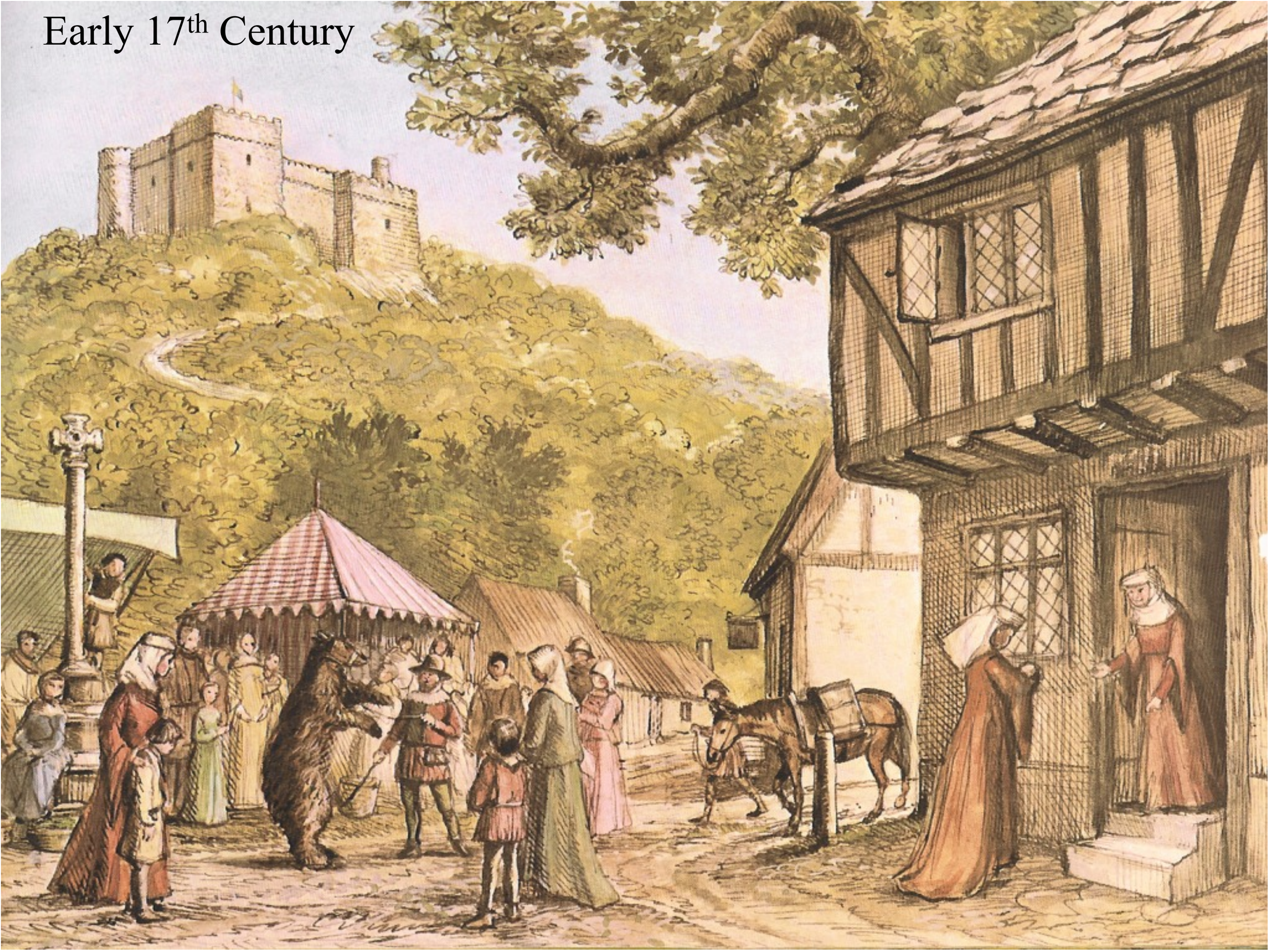
John S. Goodall

A MARGARET K. MCELDERRY BOOK

Atheneum 1979 New York

Early 15th Century

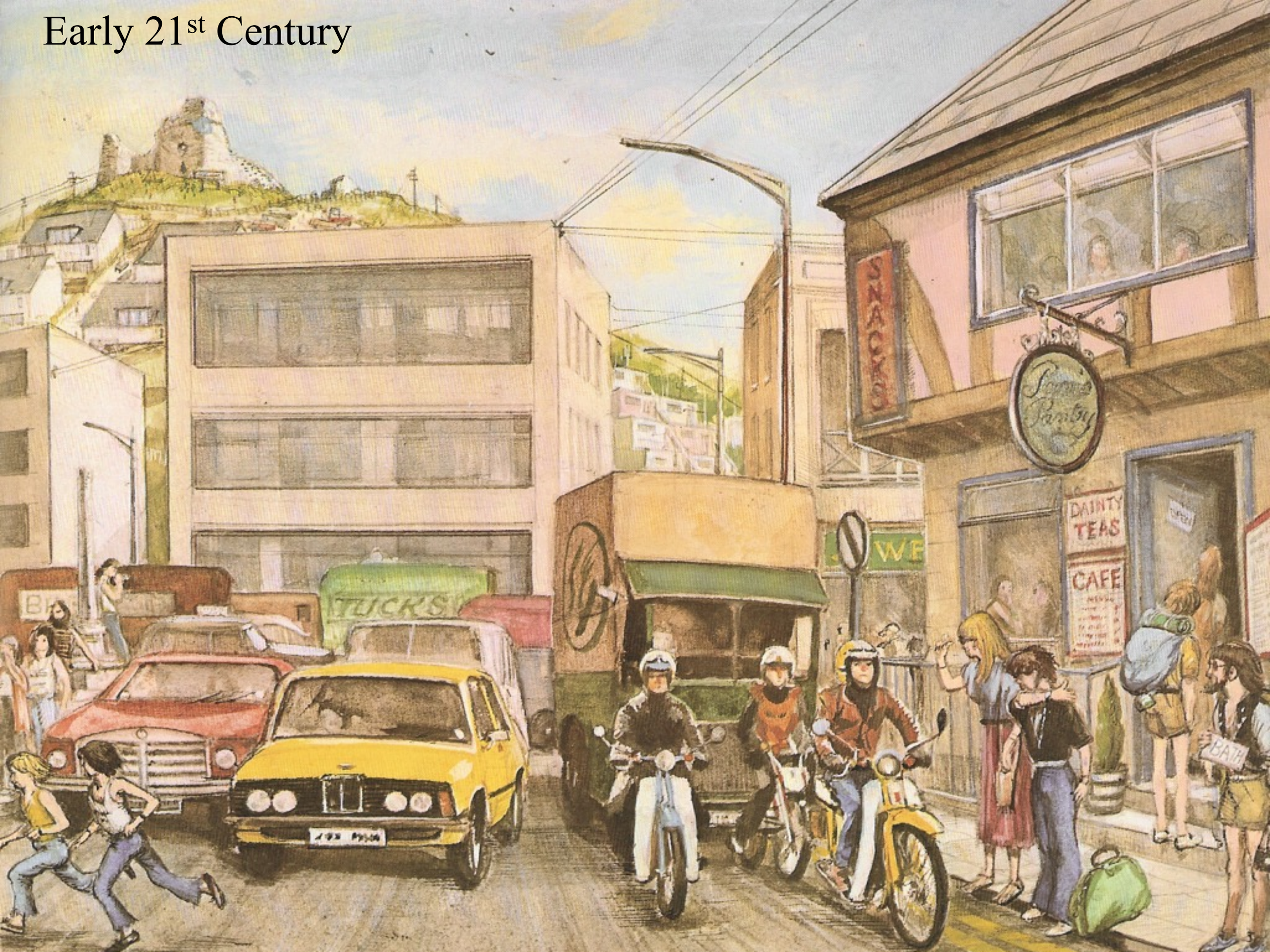
Early 17th Century

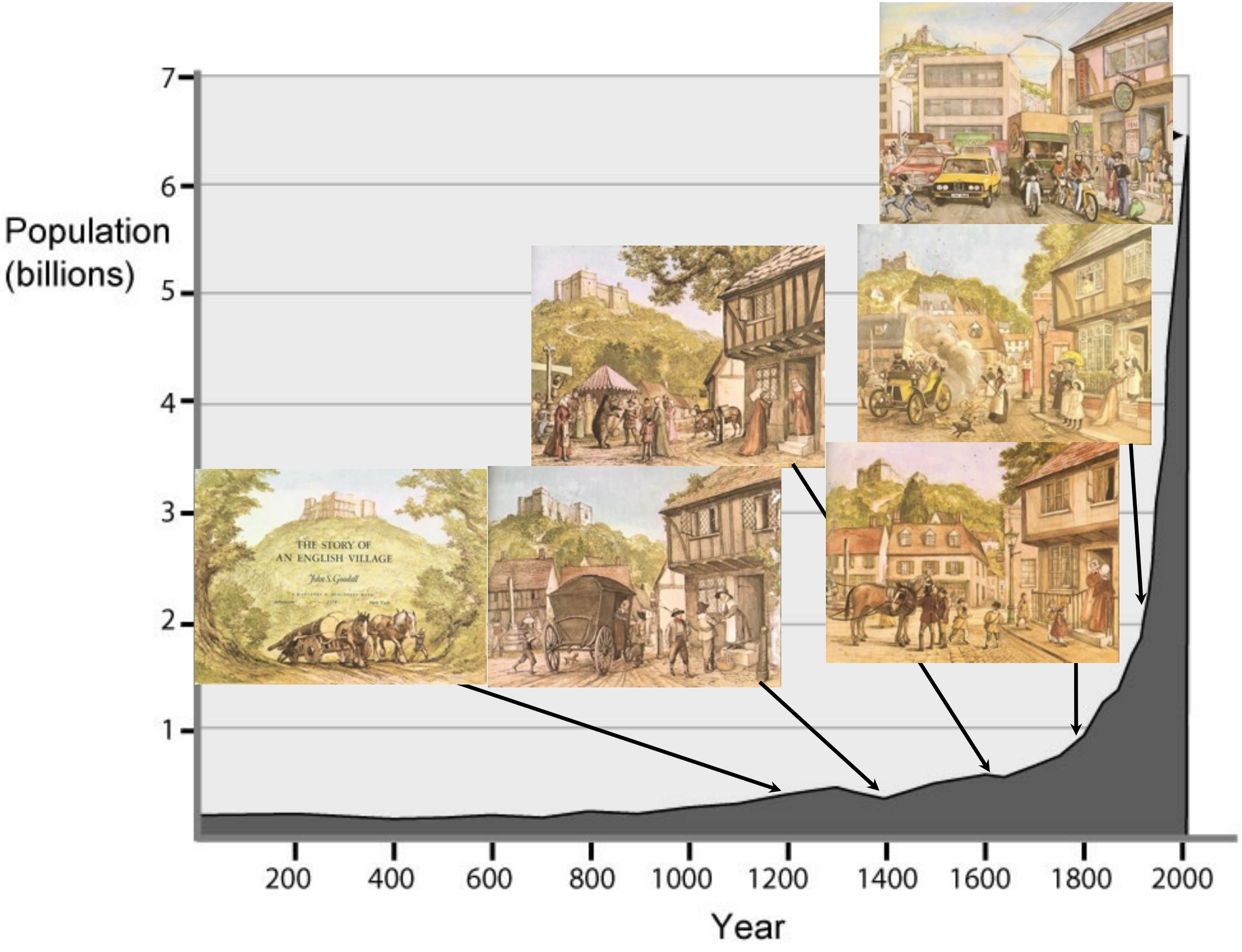


Early 19th Century

Early 20th Century

Early 21st Century

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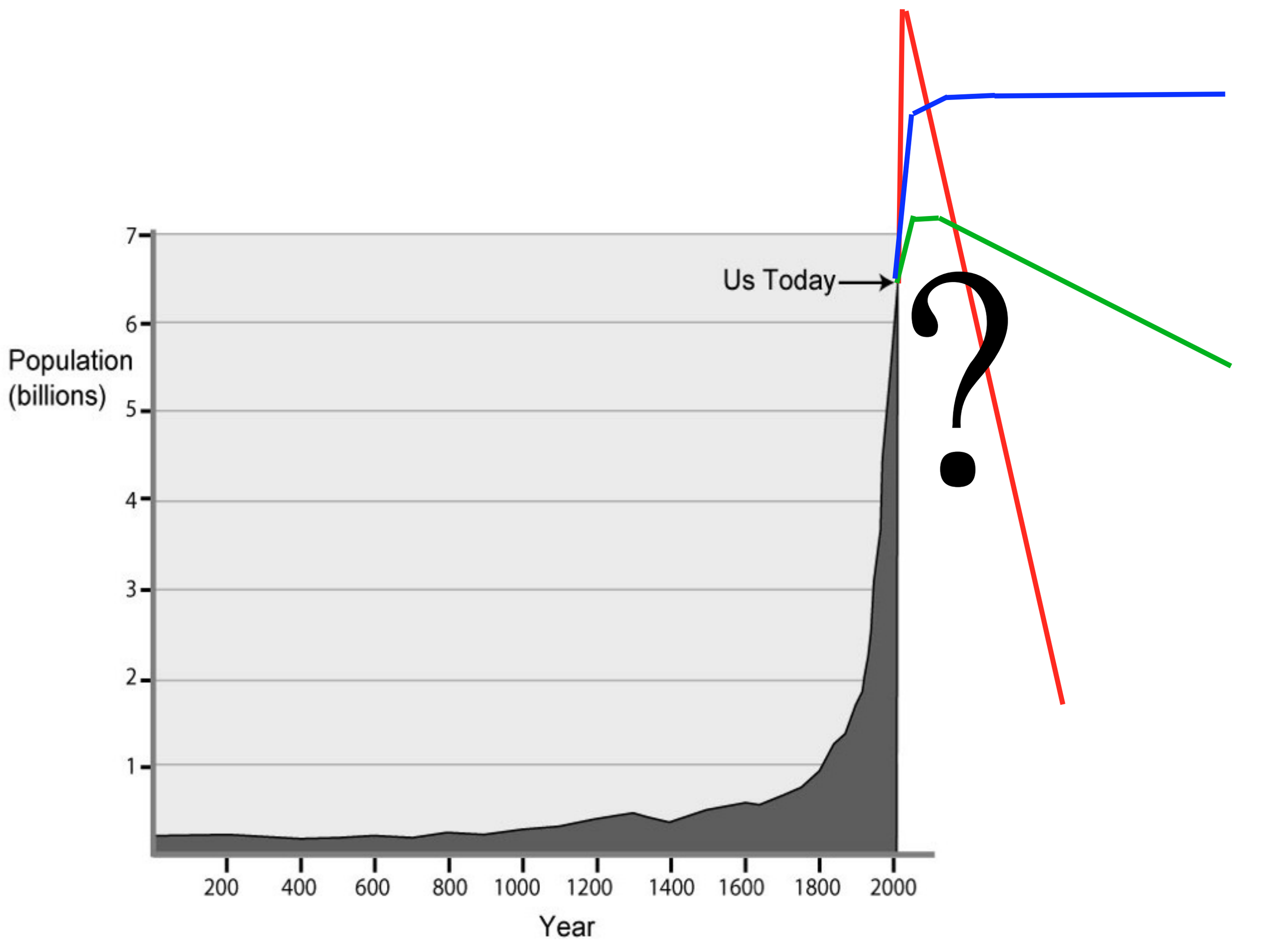
Us Today
?
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1400
1600
1800
2000
Year

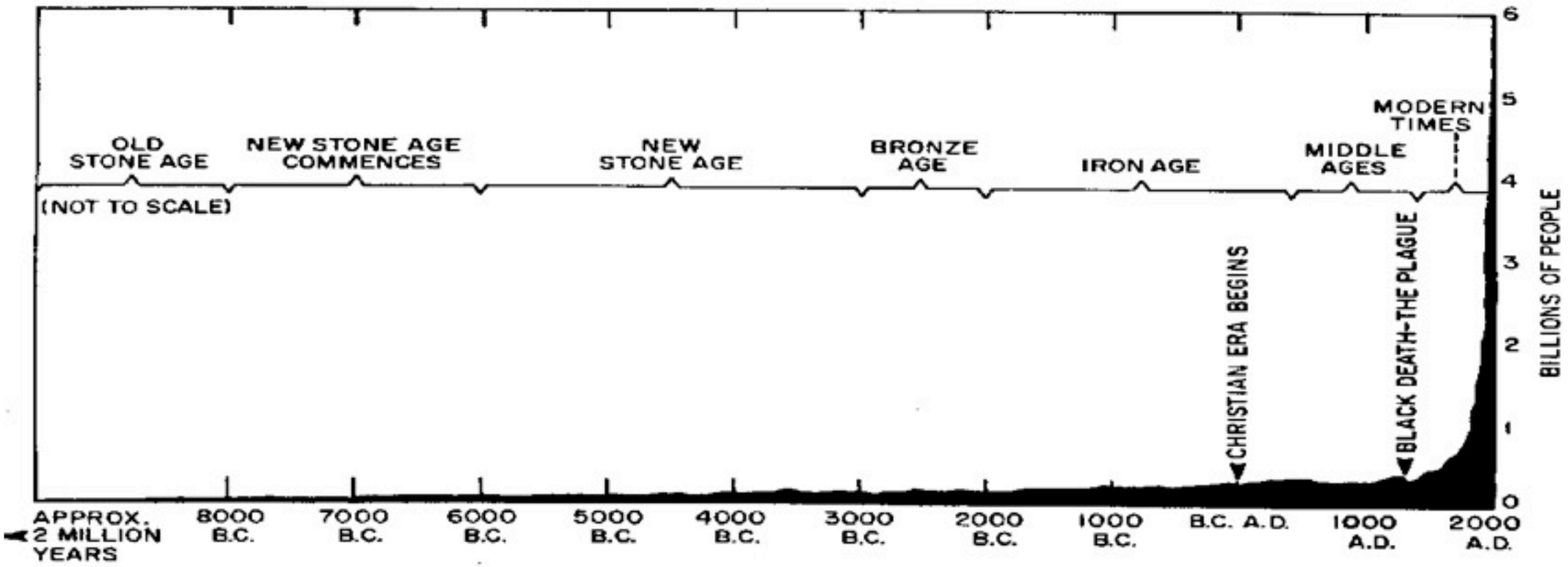
Human Inflation

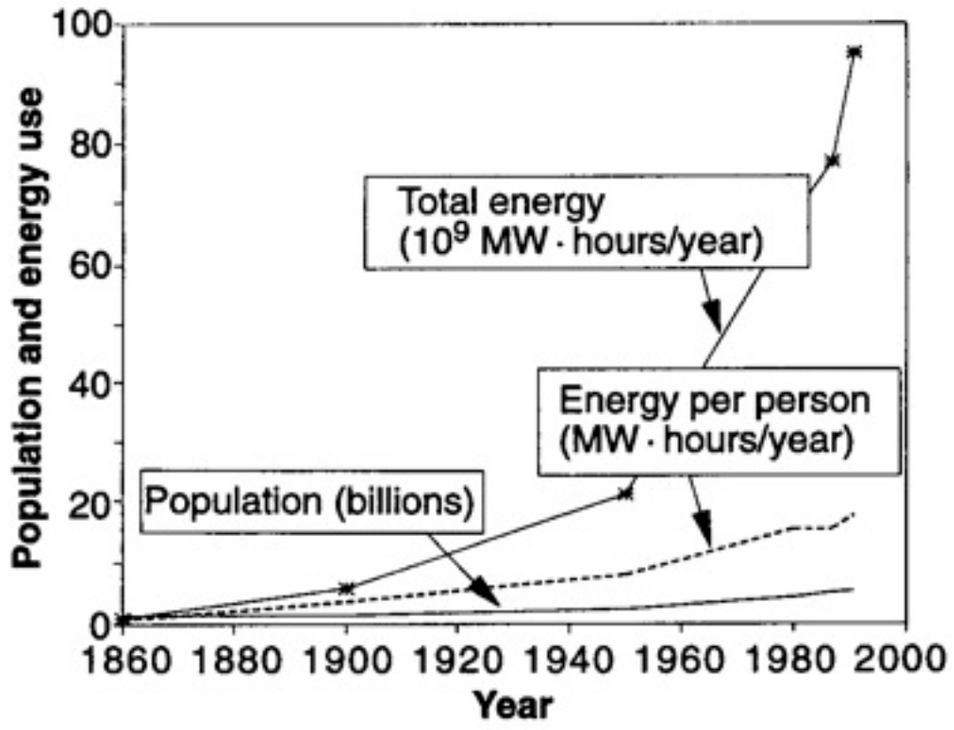
"We may know immeasurably more about the universe than our ancestors did, and yet it increasingly seems they knew something more essential about it than we do… Paradoxically, inspiration for the renewal of this lost integrity can once again be found in science…a science producing ideas that in a certain sense allow it to transcend its own limits… Transcendence is the only real alternative to extinction."

– Vaclav Havel, July 4, 1994

Exponential growth is the dominant characteristic of the world today. Not only is the human population inflating; simultaneously, so are the technological power and the resource use of each individual. Multiply these times each other: we are now processing a substantial fraction of the earth's entire crust.

Human Inflation



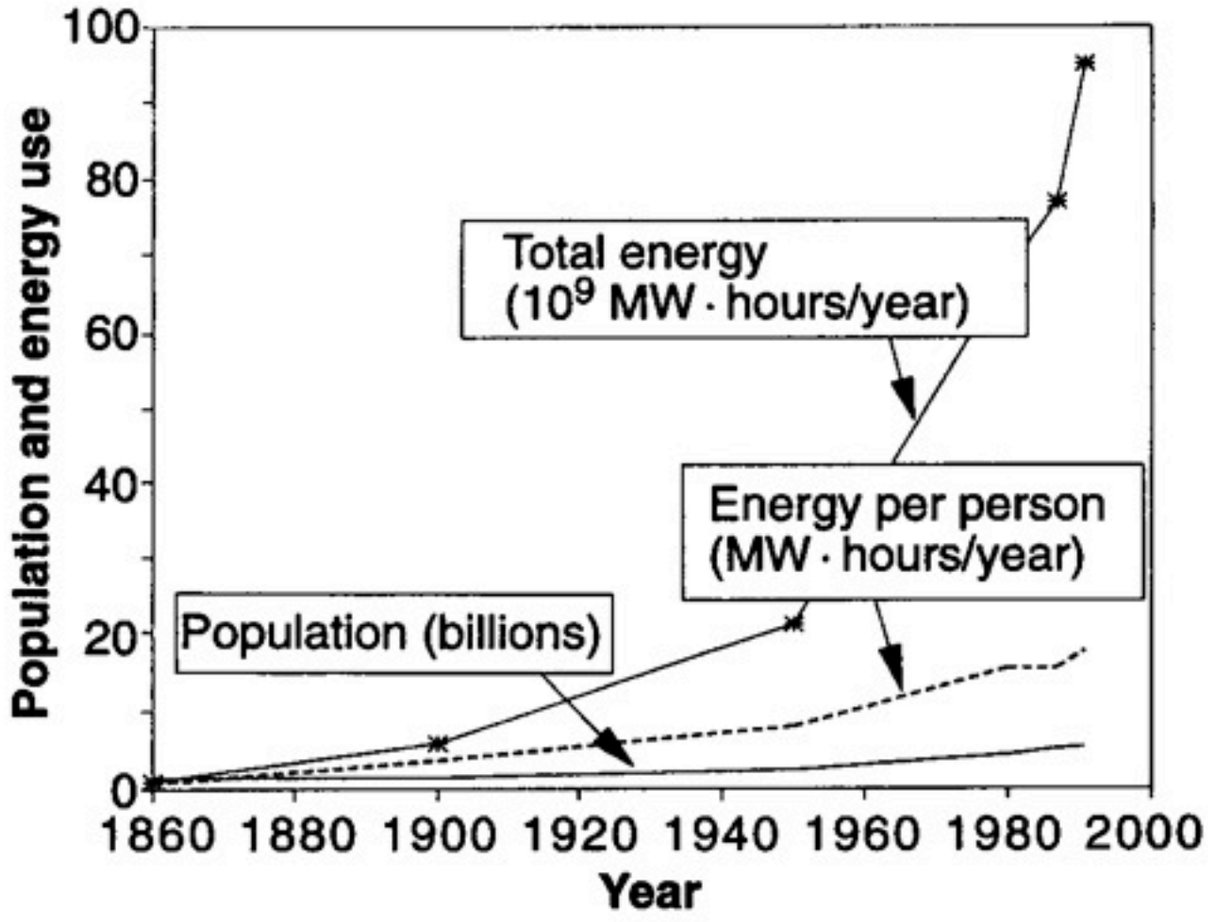


The human population increased by about a factor of four over the past century, while resource use per capita increased by about 25x. We must stop this rapid growth in global resource use and environmental impact very soon.

INFLATION AS A BRIEF TRANSITION PERIOD WITH LONG-TERM CONSEQUENCES -- example of human population and its impacts

Global human population grew faster during the period 1950-1980 than ever before. The global population growth rate peaked in 1965 at 2%, corresponding to a doubling time of only 35 years. Never before the 20th century has any human being lived through a doubling of the human population (not since Adam and Eve. anvwav). The current rate is 1.5%. doubling in 46 years.

The effect on the earth of this population growth is equal to the population multiplied by the impact per capita. For example, much of the increase in CO_2 and other greenhouse gases is caused by burning fossil fuel for energy. Although the population increased by slightly more than a factor of 4 from 1860 to 1991, the energy use per capita increased by a factor of 20 during the same period, and thus the total human energy use increased by a factor of 93 (see chart).



Inanimate energy use from all sources from 1860 to 1991: aggregate (solid line with asterisks) (54) and per person (dashed line). Global popula-tion size is indicated by the solid line.

--based on Joel E. Cohen, "Ten Myths of Population," *Discover*, April 1996, pp. 42-47; "Popula-tion Growth and Earth's Carrying Capacity," *Science*, vol. 269, pp. 341-346 (21 July 1995); and *How Many People Can the Earth Support?* (W.W. Norton & Co., 1995).

Plagues, famines, and wars, despite their continued baleful effects, have hardly slowed population growth in the 20th century. The Ebola outbreak in 1995 killed 244 people -- fewer than are born each minute. As for AIDS, a 1994 UN report on the 15 countries in central Africa where it is most prevalent estimated that in 2005 instead of 3.1%, the population growth rate will be 2.9% (the corresponding doubling times are 22 and 24 years). The World Wars killed a total of 90 million people, including civilians, and all wars since World War II killed perhaps 50 million more. The population increase of 4 billion this century (from 1.7 billion in 1900 to 5.7 billion today) is more than 20 times the number killed by wars.

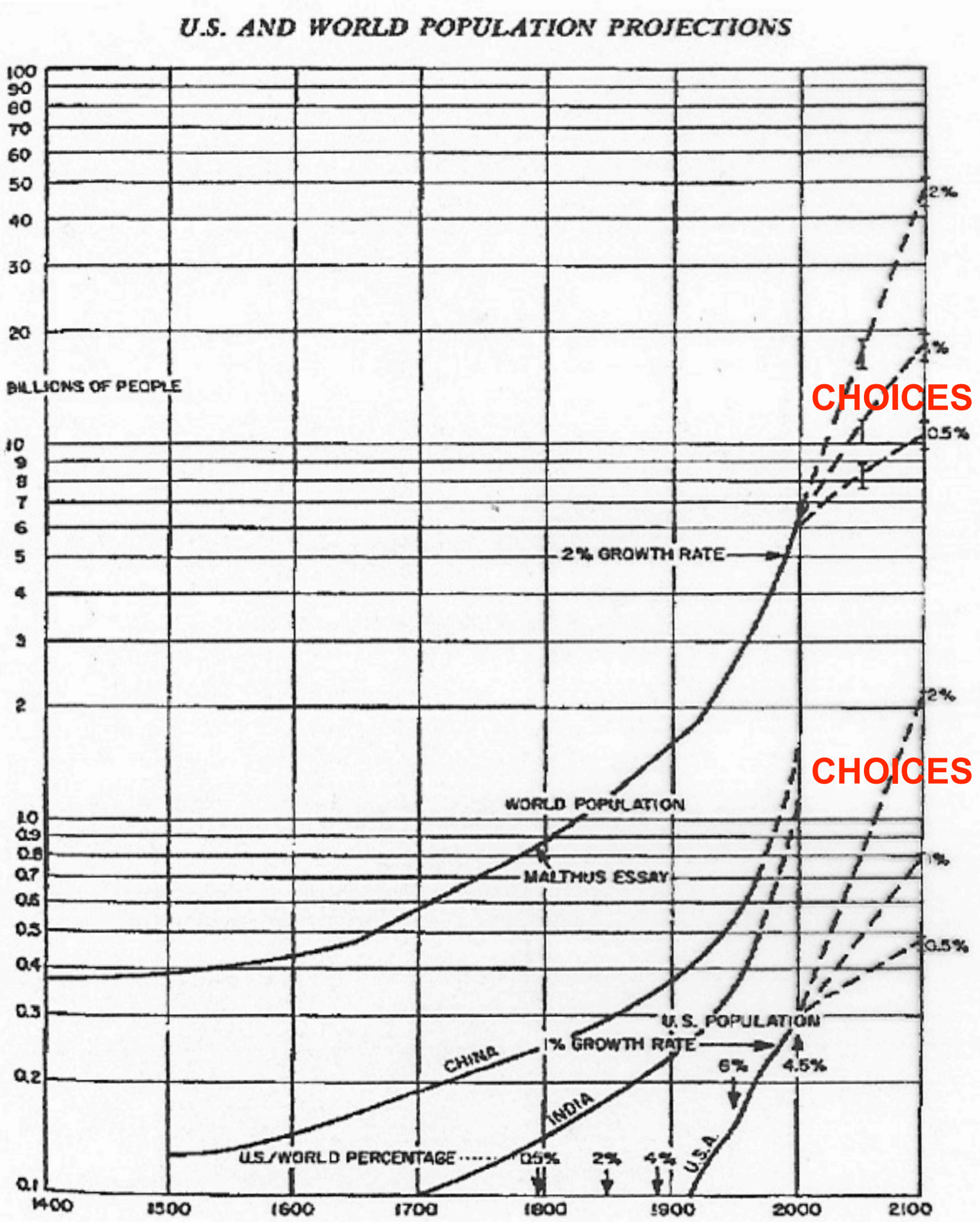
The United States has a population problem, too. In the U.S. the fraction of all births that resulted from intended pregnancies shrank from 64% in 1982 to 61% in 1988 and 55% in 1990. The current U.S. rate of population growth is about 1% per year, the same as in China, but people in the U.S. use about 5 times as much energy per capita as the world average. The myth that the U.S. is immune to population problems of developing countries ignores international labor markets, migration, infectious diseases, and the shared global commons of oceans, atmosphere, and wildlife.

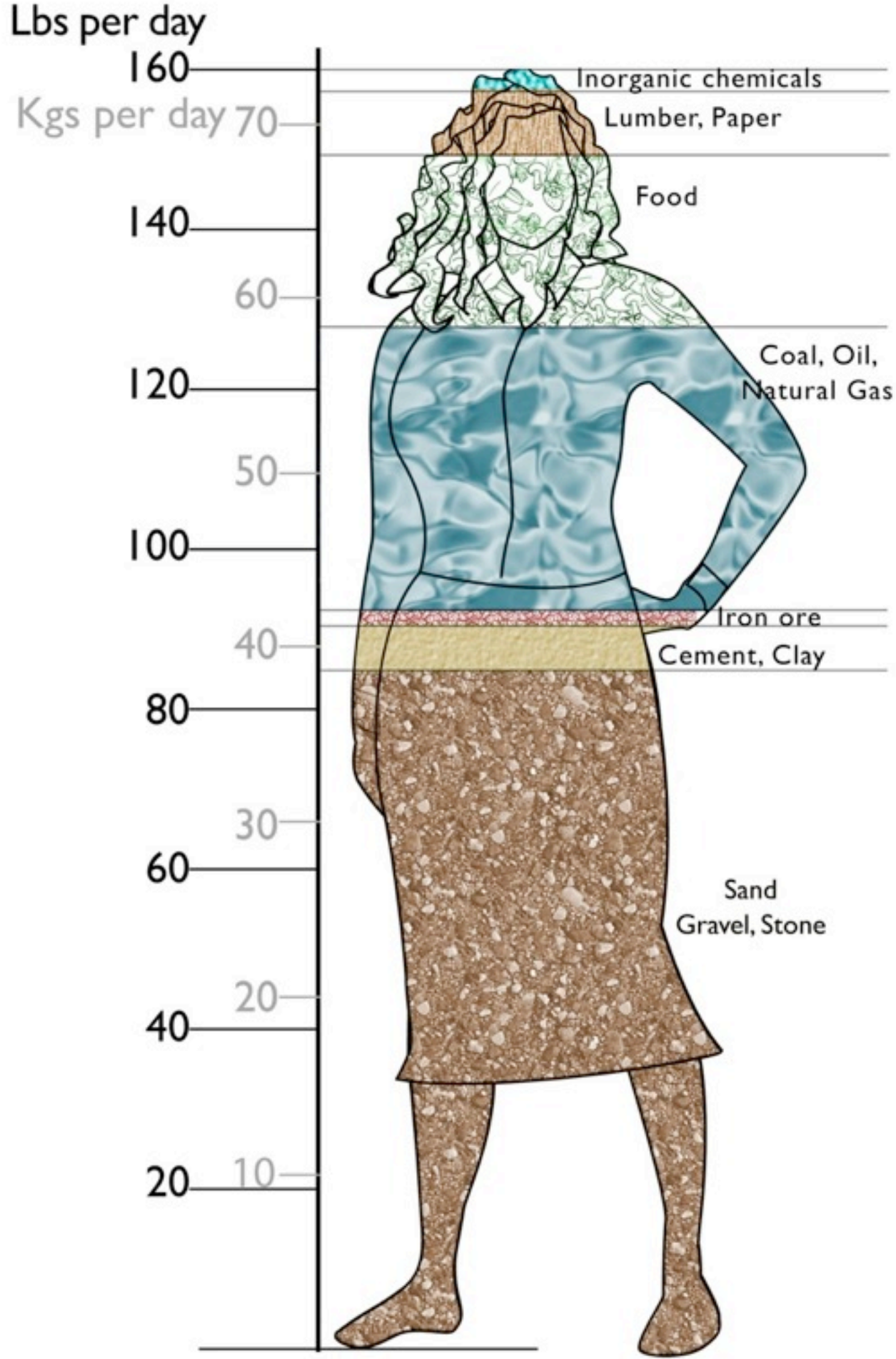
Too many children are born without the prospect of sufficient love, food, health, education, or dignity in living and dying. One way or another, exponential human population growth must ultimately end. Ending it through voluntary reductions in fertility will make it easier to improve the living standards of the 80% of the world's population whose income is less than $1000/year, which in turn will lead to reduced fertility. The alternatives are coerced reduction in fertility or the misery of rising death rates. The choice is still ours.

World Population (Billions)	Year	Years to Add Last Billion
1	1825	1,000,000
2	1930	105
3	1960	30
4	1976	16
5	1988	12
5.7	1996	
6	2000	12

World Population (Billions)	Year	Doubling Time (years)
0.25	1 AD	
0.5	1650	1650
1	1825	175
2	1930	105
4	1976	46
5.7	1996	46*

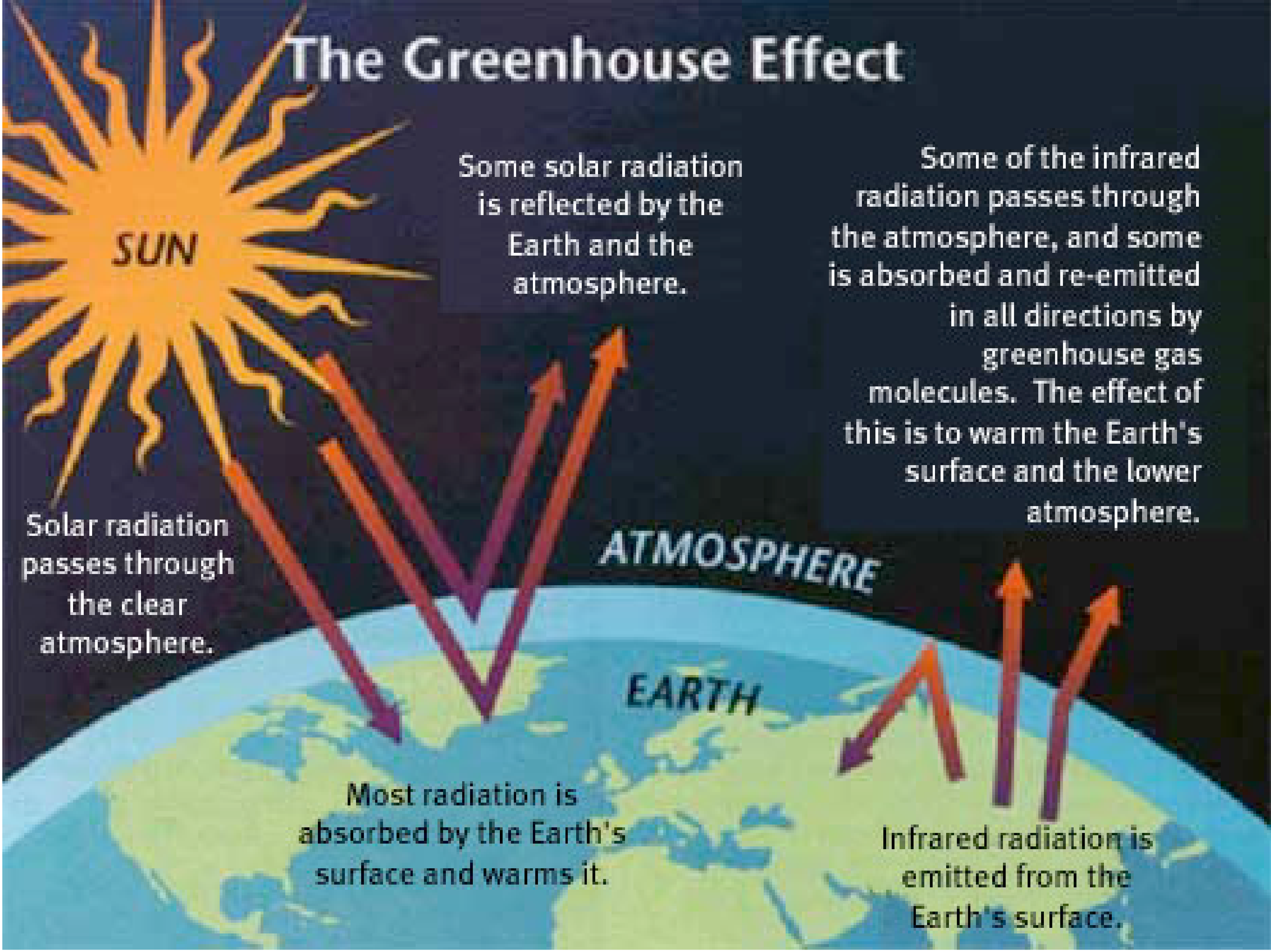
*at current rate of 1.5%/year



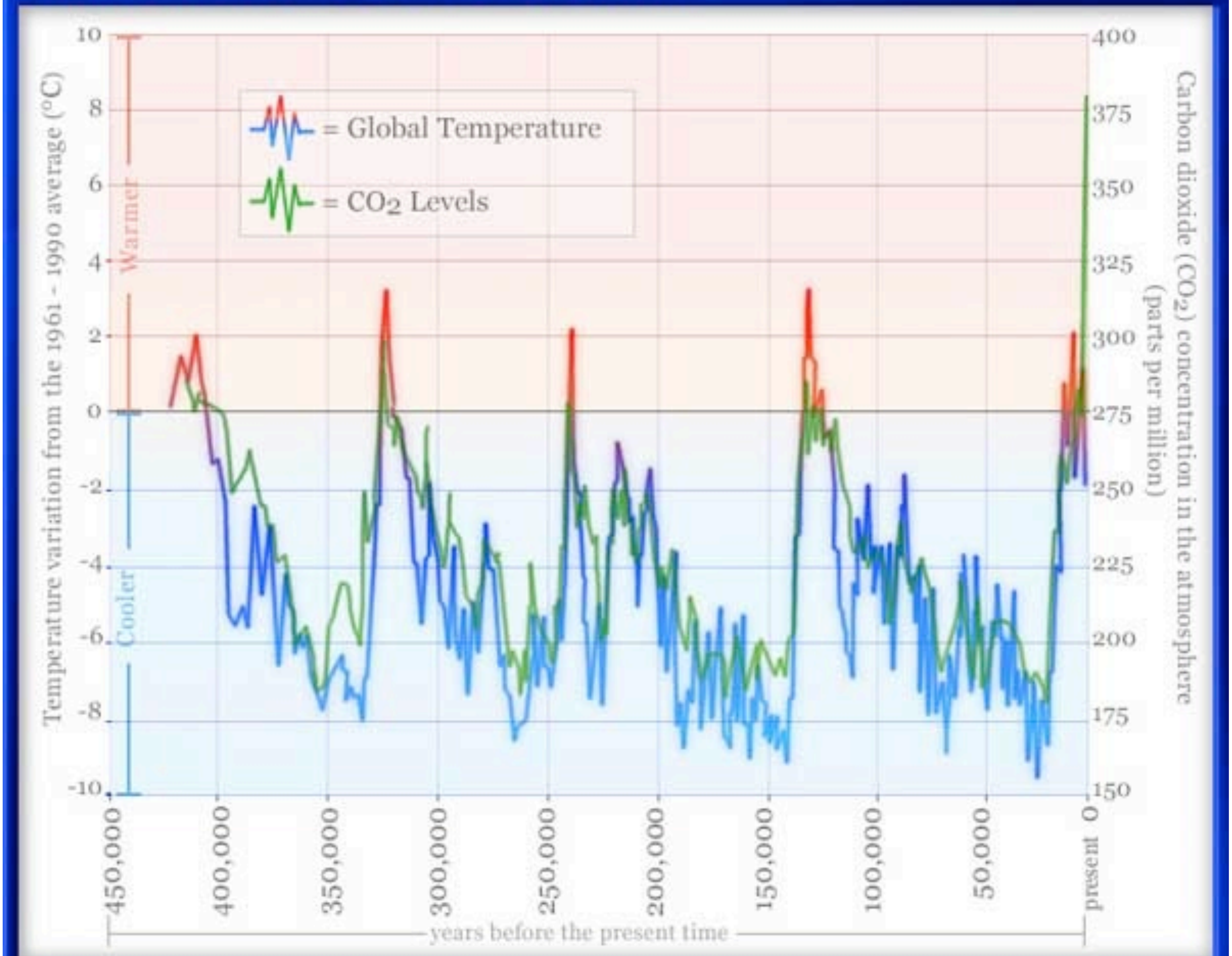


AMERICANS CONSUME THEIR WEIGHT IN RESOURCES *EVERY DAY*

The Greenhouse Effect



Carbon Dioxide Concentration



Vostok ice core

Projected (2100)

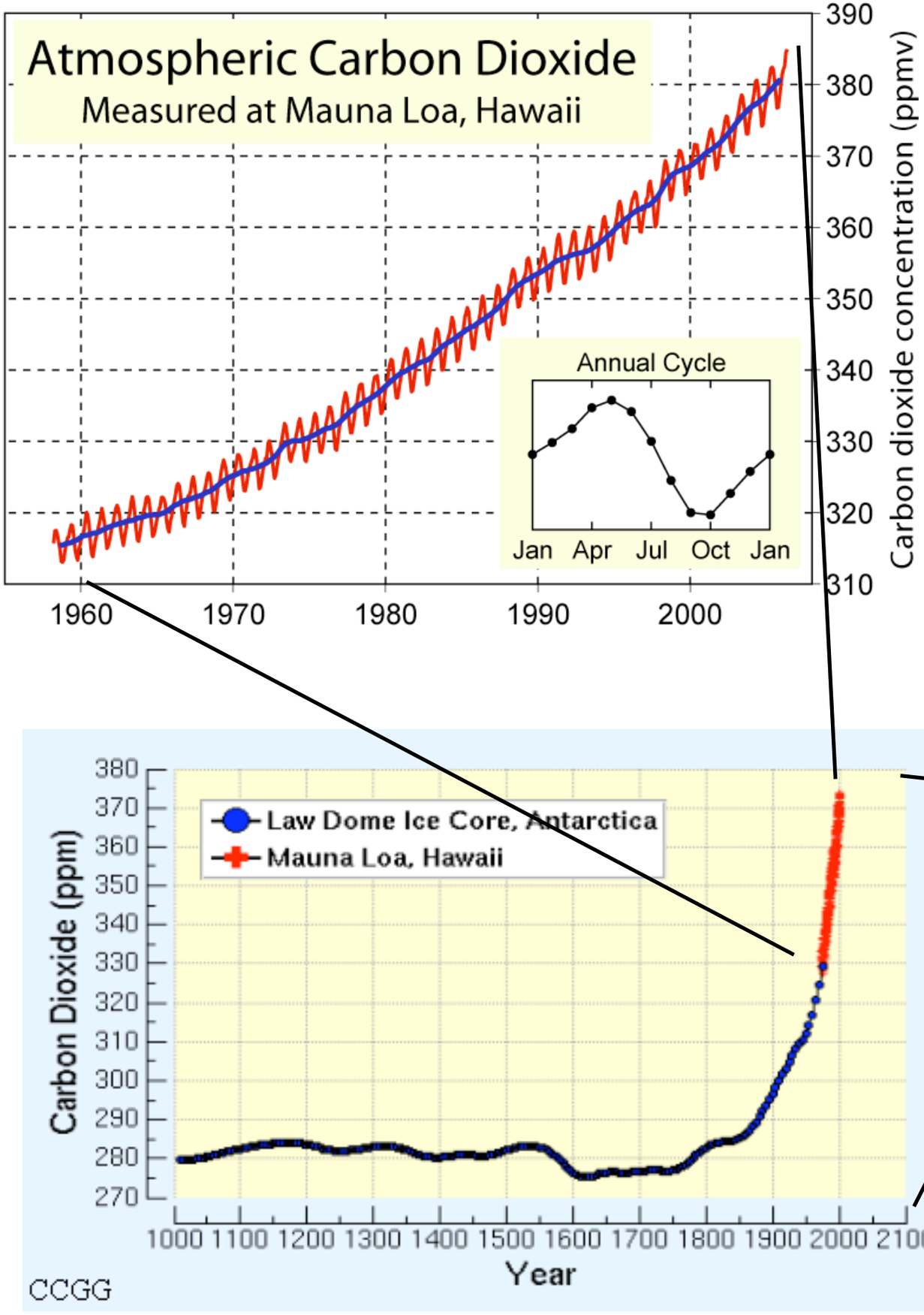
Current (2005)

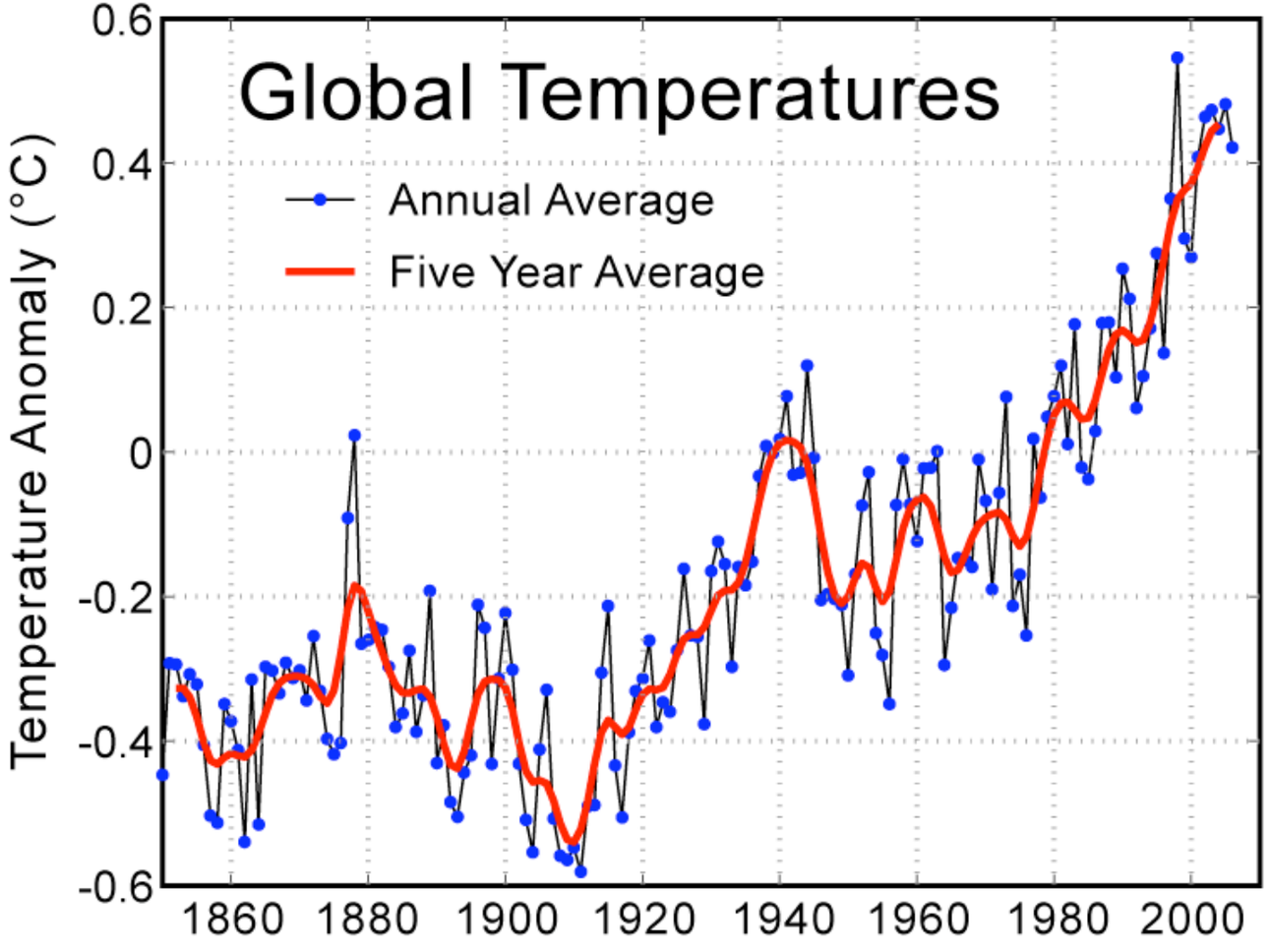
700
650
600
550
500
450
400
350
300
250
200
150

CO_2 concentration (ppmv)

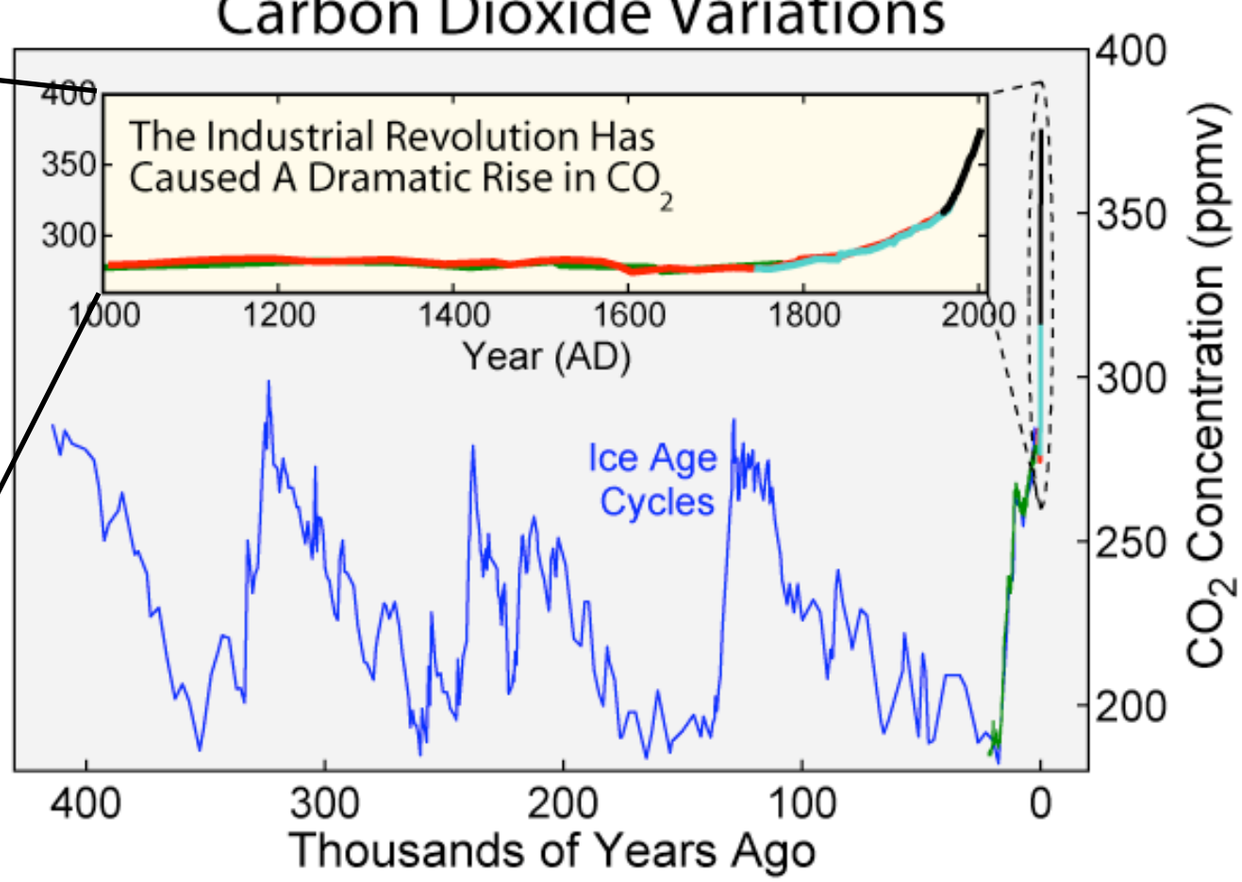
400,000
300,000
200,000
100,000
0

Years before present


Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Annual Cycle
Jan Apr Jul Oct Jan
1960 1970 1980 1990 2000
310 320 330 340 350 360 370 380 390
Carbon dioxide concentration (ppmv)


Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6 0.4 0.2 0 -0.2 -0.4 -0.6
1860 1880 1900 1920 1940 1960 1980 2000

Law Dome Ice Core, Antarctica
Mauna Loa, Hawaii
Carbon Dioxide (ppm)
380 370 360 350 340 330 320 310 300 290 280 270
1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100
Year
CCGG


Carbon Dioxide Variations
The Industrial Revolution Has
Caused A Dramatic Rise in CO2
400 350 300
1000 1200 1400 1600 1800 2000
Year (AD)
Ice Age
Cycles
400 300 200 100 0
Thousands of Years Ago
400 350 300 250 200
CO2 Concentration (ppmv)

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP http://www.ipcc.ch/

Climate Change 2007: The Physical Science Basis of Climate Change

Assesses the current scientific knowledge of the natural and human drivers of climate change, observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change.

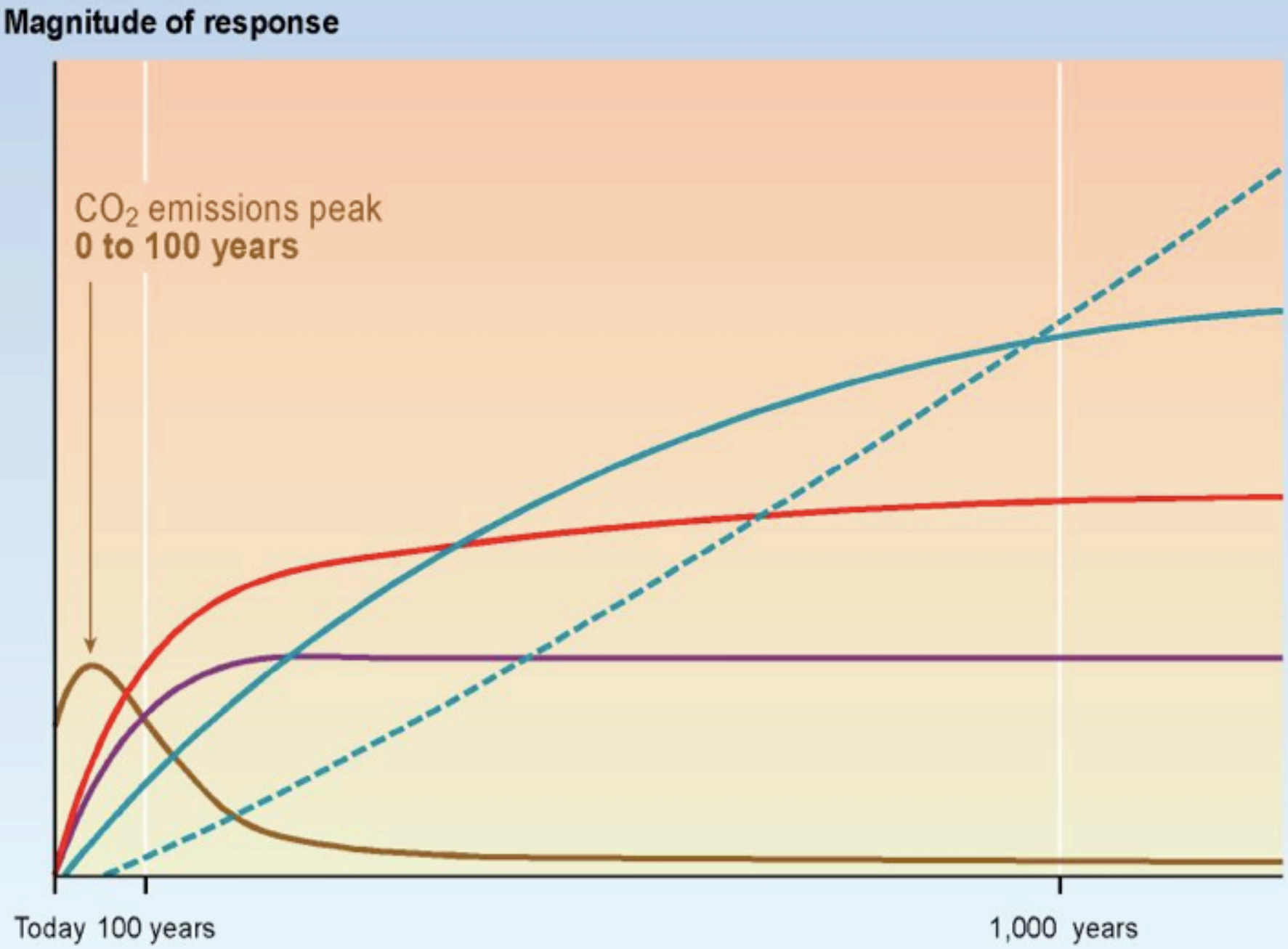
- Observing climate change – warming has now been observed across the Earth system. The atmosphere, land observations and even data from below the surface of the oceans have all shown this warming trend. In the past, there has been some apparent inconsistencies between measurements from different parts of the system. Now, in this report, there is far greater certainty that the planet is undergoing warming.

- Causes of planetary warming – this report provides new evidence that humans have played a major part in the observed warming trend.

- The future – as the climate changes, the challenges are likely to be profound. Understanding what aspects of the weather and climate will change most rapidly is important. With research showing that the climate is changing faster and in a more dramatic fashion than has previously been reported, what will the climate look like in the years to come? what will our day-to-day weather be like and, a question for society in general, how is this going to affect our behaviour in the future?

Long Term Consequences of CO_2 Releases

CO_2 concentration, temperature, and sea level continue to rise long after emissions are reduced



Time taken to reach equilibrium

Sea-level rise due to ice melting:
several millennia

Sea-level rise due to thermal expansion:
centuries to millennia

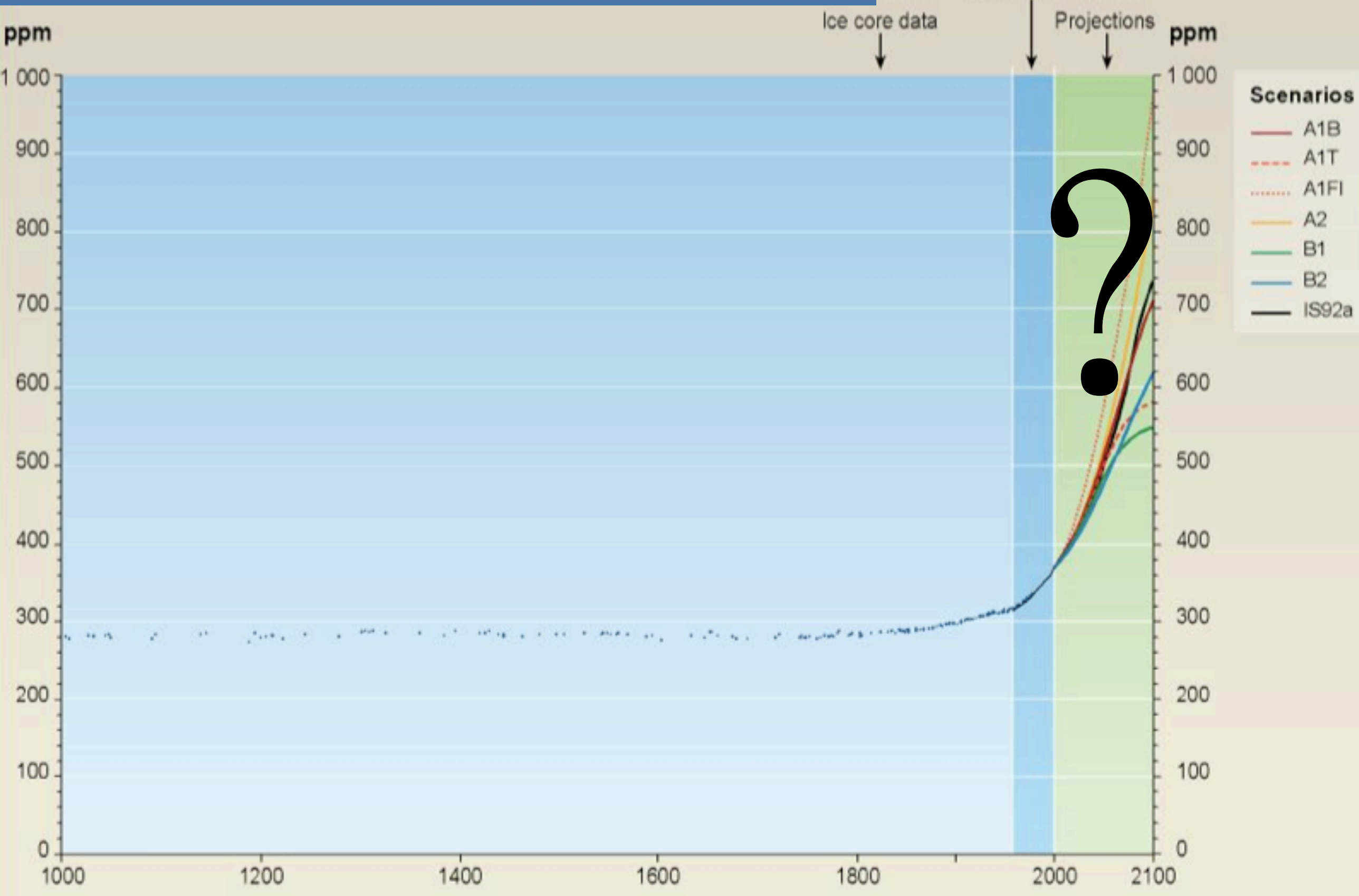
Temperature stabilization:
a few centuries

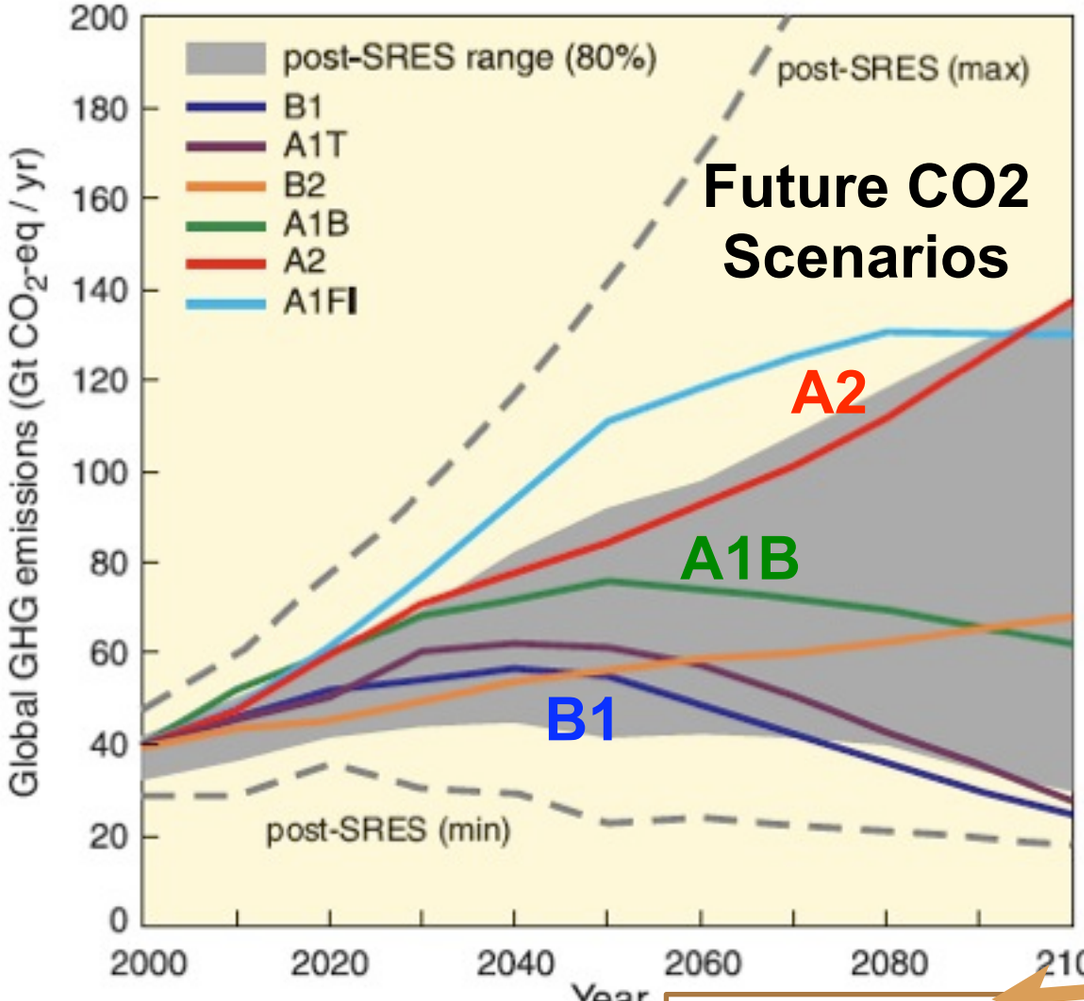
CO_2 stabilization:
100 to 300 years

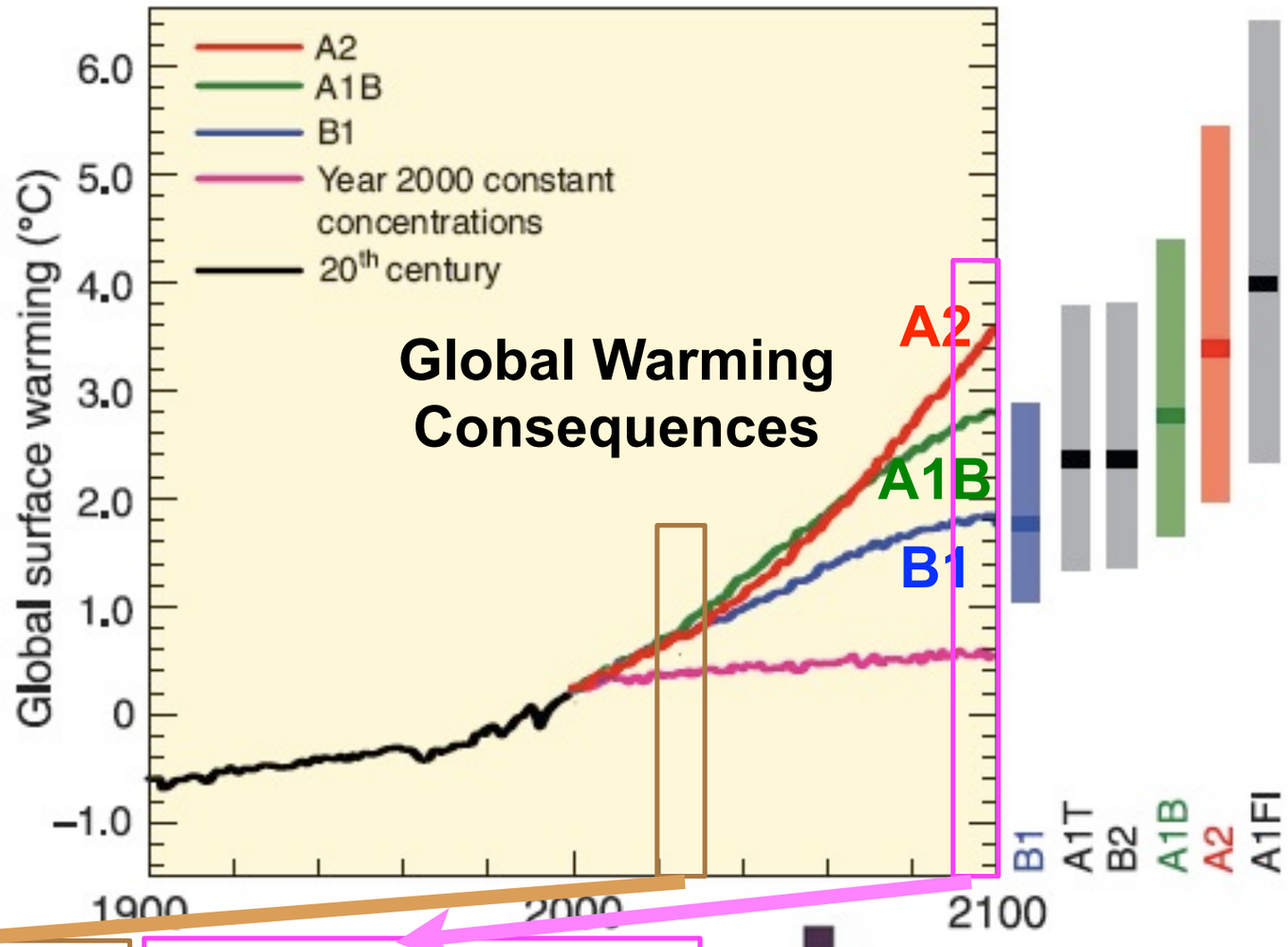
CO_2 emissions

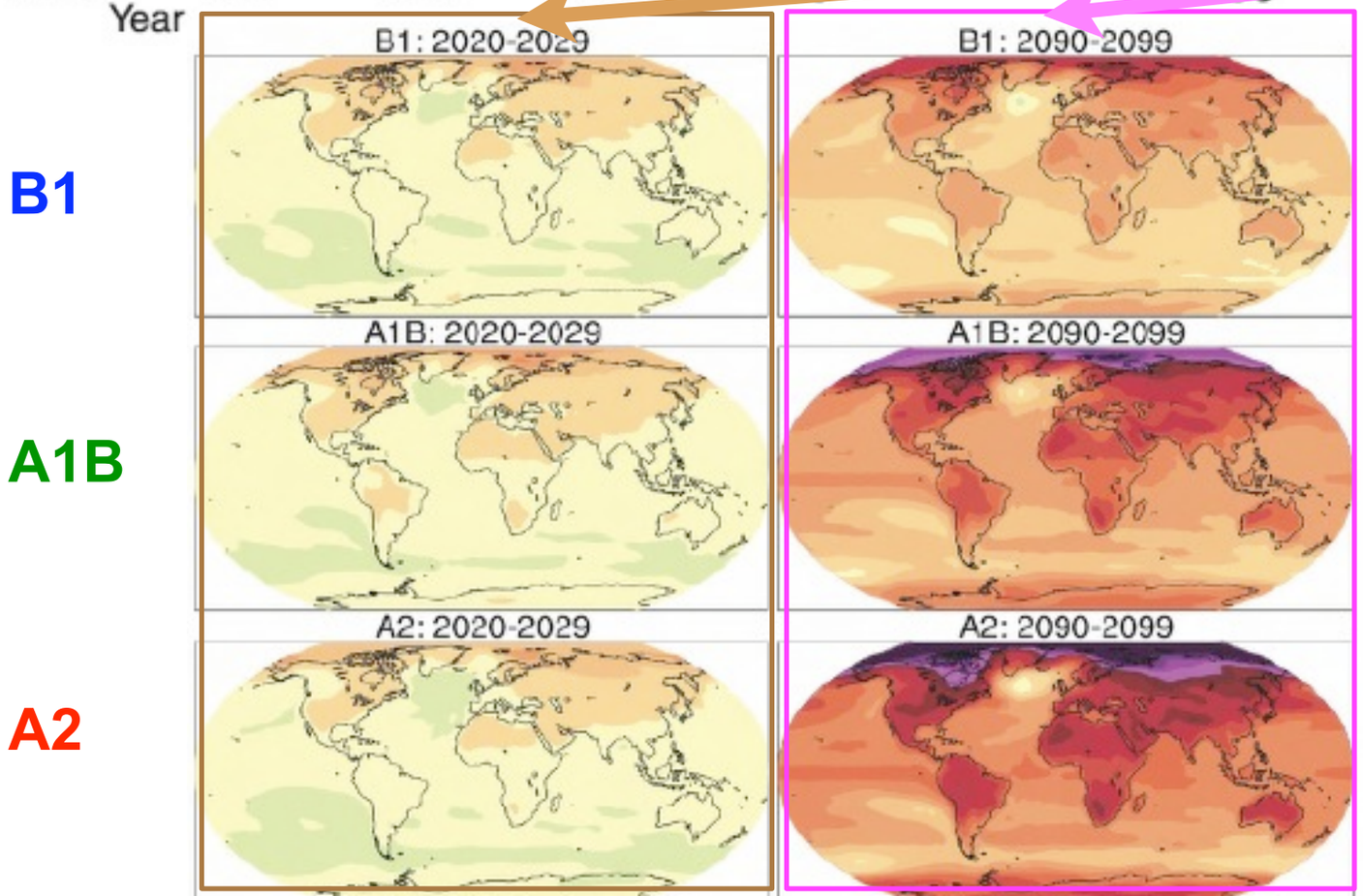
Past and future CO_2 atmospheric concentrations

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE





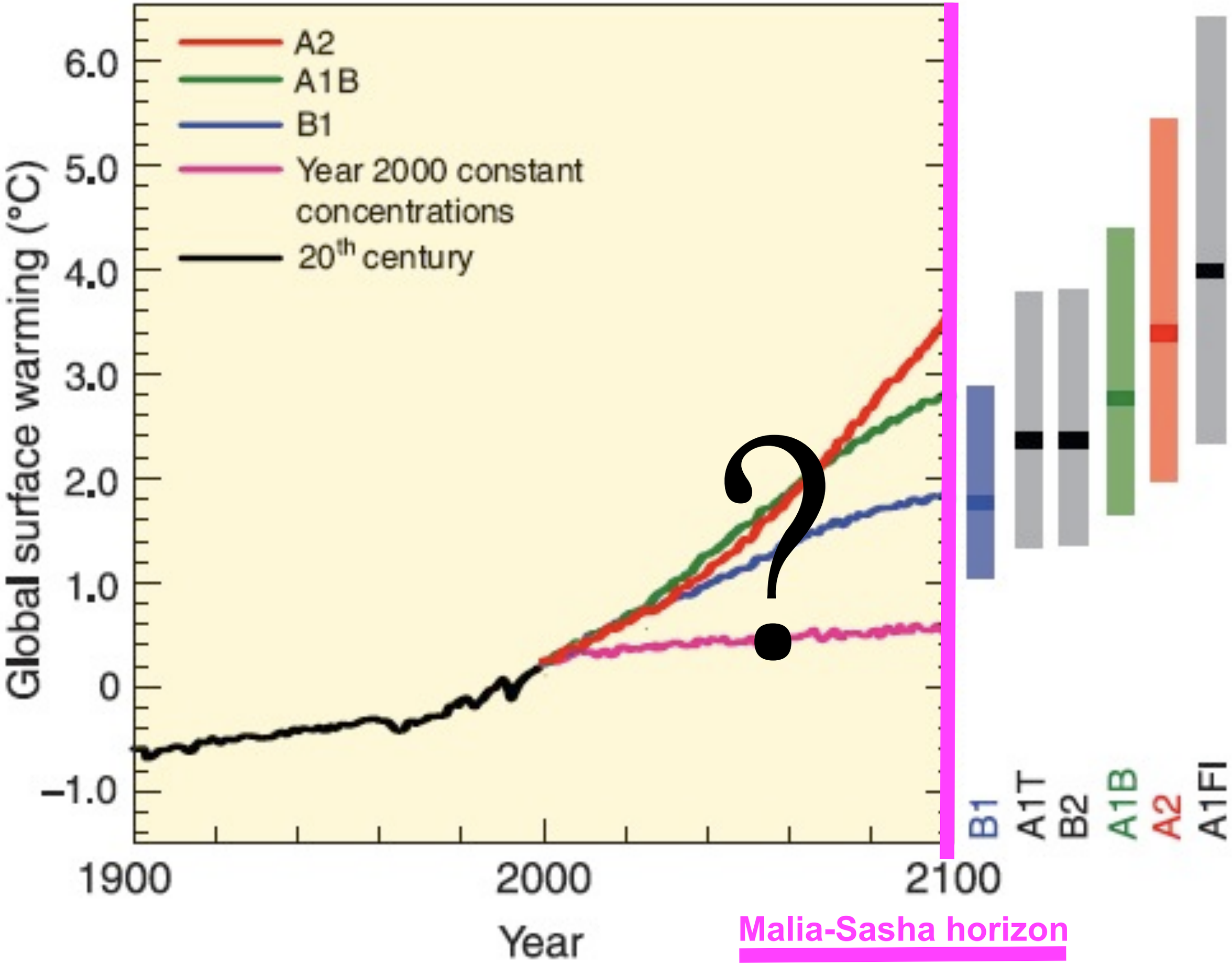




Malia-Sasha horizon

ΔT °C

IPCC 2007


A2
A1B
B1
Year 2000 constant concentrations
20th century
Global surface warming (°C)
6.0
5.0
4.0
3.0
2.0
1.0
0
–1.0
1900
2000
2100
Year
?
B1
A1T
B2
A1B
A2
A1FI
Malia-Sasha horizon

1990

GLOBAL WARMING DOESN'T EXIST!

1995

OKAY, IT EXISTS, BUT IT ISN'T MAN-MADE!

OK, SO IT'S MAN-MADE, BUT ITS EFFECTS AREN'T ALL BAD.

2000

2005

ITS EFFECTS WILL BE REALLY BAD, BUT NOT UNTIL AFTER I'M DEAD.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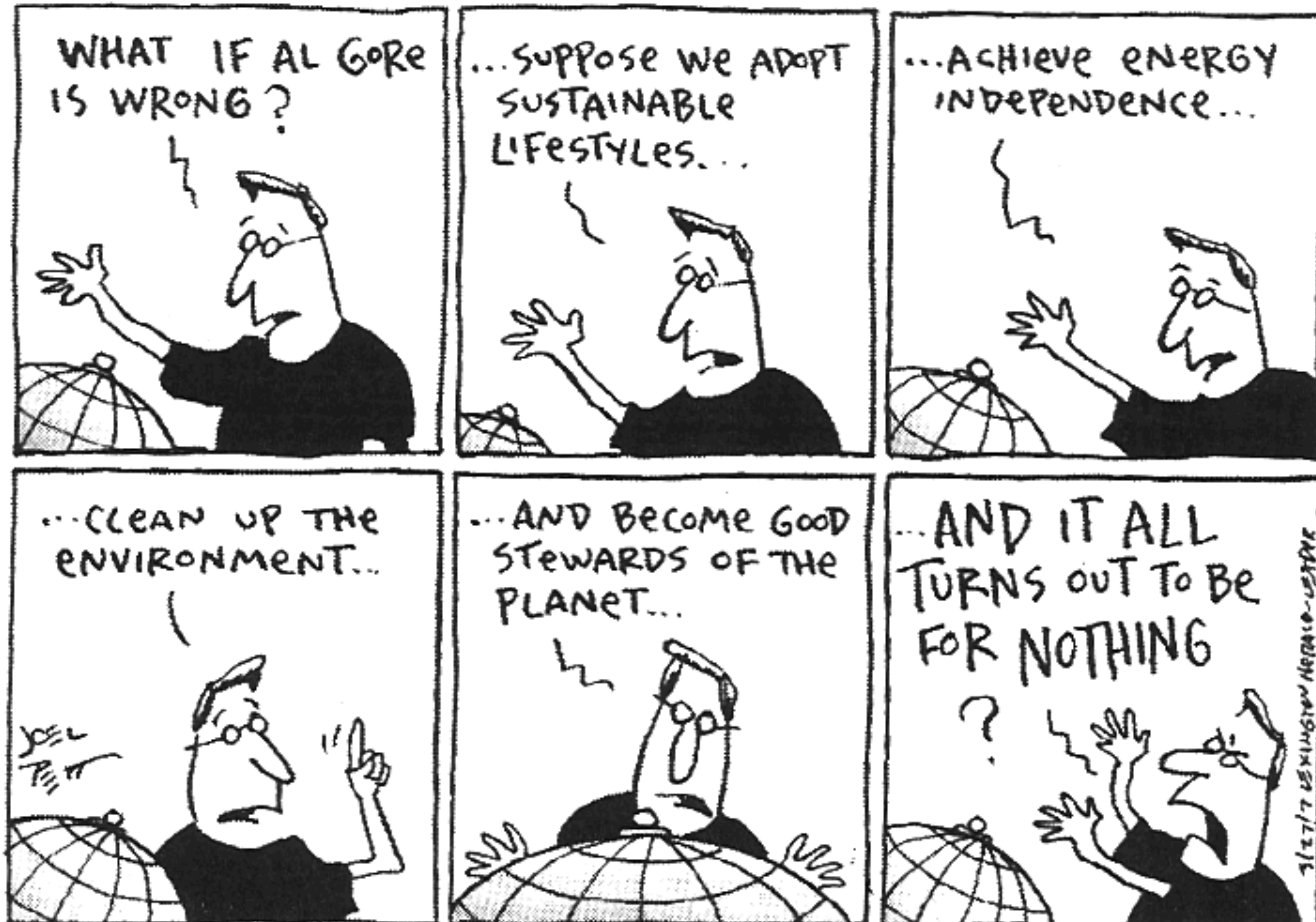
PIONEER PRESS
KIRK 2009

2010

?


WHAT IF AL GORE IS WRONG?
...SUPPOSE WE ADOPT SUSTAINABLE LIFESTYLES...
...ACHIEVE ENERGY INDEPENDENCE...
...CLEAN UP THE ENVIRONMENT...
...AND BECOME GOOD STEWARDS OF THE PLANET...
...AND IT ALL TURNS OUT TO BE FOR NOTHING?
JOEL PETT
3/27/7 LEXINGTON HERALD-LEADER

METAPHORS

***The Correspondence theory of truth*:**
"Statements are true or false objectively, depending on how they map directly onto the world – independent of any human understanding of either the statement or the world."

***Lakoff and Johnson's theory (Philosophy in the Flesh)*:**
The classical correspondence theory of truth is false. Truth depends on the bodily experience and conceptual equipment of the being seeking that truth. ***This does not mean that truth is purely subjective or that there is no stable truth. It means our common embodiment allows for common, stable truths.***

"An embodied concept is a *neural structure* that is actually part of, or makes use of, the sensorimotor system of our brains." Neurons that fire together, wire together.

Meaning is a matter of what is meaningful *to thinking, functioning beings*.

Our sense of what is "real" depends on our bodies, especially our apparatus for perceiving, moving, and manipulating, which have been shaped by evolution and experience.

Hundreds of **conceptual metaphors** become hard-wired during childhood as we move around in a human body on a planet with sunlight, plants, gravity, and other people. What is considered good or bad may differ between cultures, but "up is good" and "down is bad" are fundamental conceptual metaphors everywhere. In English this can be seen in phrases like "the economy is picking up," "she is rising in the ranks," "he really dropped the ball," and "she is feeling down." The use of conceptual metaphors is unconscious; they structure our thinking and can determine what we are able – and unable – to see. They don't act like figures of speech; they don't provide the spark, charm, or insight that makes us appreciate a genuine literary metaphor. They are instead the unnoticeable medium of thought itself. The fact that many conceptual metaphors are bound into the wiring in our brains is amazing news, because to the extent that meaning is grounded in our bodies, it is as "real" as we are.

“Time is money”

Conceptual metaphors are not all biological in origin. Cultural ones also influence our unconscious thinking. For example, “time is money” governs how we envision and talk about time – we “spend” time or “save” time, we “invest it wisely,” we “squander it,” we “budget” it, we “run out” of it and “never have enough” of it. Yet “time is money” is not hard-wired like “affection is warmth.” “Time is money” did not exist before the introduction of the mechanical clock in the late Middle Ages made it possible to measure hours and minutes fairly accurately. The metaphor didn’t really take over our brains and our language until the Industrial Revolution reorganized all of life around time-keeping by starting to pay people not for what they produced but for their time. “Time is money” is merely a few centuries old, a heartbeat in human evolution, yet in this surprisingly brief time it has transformed the world. This illustrates the potential power of a cultural metaphor – the category into which new cosmological metaphors will also fall.

COGNITIVE UNCONSCIOUS

We have no conscious access to most of what goes on in our minds, but this shapes and structures all conscious thought. “It creates the entities that inhabit the cognitive unconscious – abstract entities like friendships, bargains, failures, and lies – that we use in ordinary unconscious reasoning. It thus shapes how we automatically and unconsciously comprehend what we experience. It constitutes our unreflective common sense.”

COGNITIVE UNCONSCIOUS
TIAMAT
“THE DEEP”

The Universe as Inspiration

Tzimtzum – the withdrawal of God – in the Kabbalistic creation myth, was interpreted by Kabbalists as the model for the Jews' exile from Israel, Spain, and other former homelands. Jews were exhorted to recover the sparks of goodness in the original creation in order to repair the universe: ***tikkun olam***.

The great question for our time is how to end human inflation gently on earth, so that creative restoration can overtake it. As the notion of God in exile gave cosmic meaning to the lives of a people in exile, understanding Cosmic Inflation may give new inspiration to people today. Inflation is a taste of what it is like to be God. In a finite environment, it cannot continue. That does not mean that growth must stop. The great transition model for the future of the earth may be the universe. Inflation transformed to expansion can go on for a very long time.

The Ultimate Scrooge Principle?

Although gravity is the ultimate Scrooge principle, it is not inexorable. For everything in the universe except black holes, gravity is counterbalanced – by circular motion for planetary systems and disk galaxies like our own, by random motion for elliptical galaxies and for the dark matter that holds together all galaxies and larger structures.

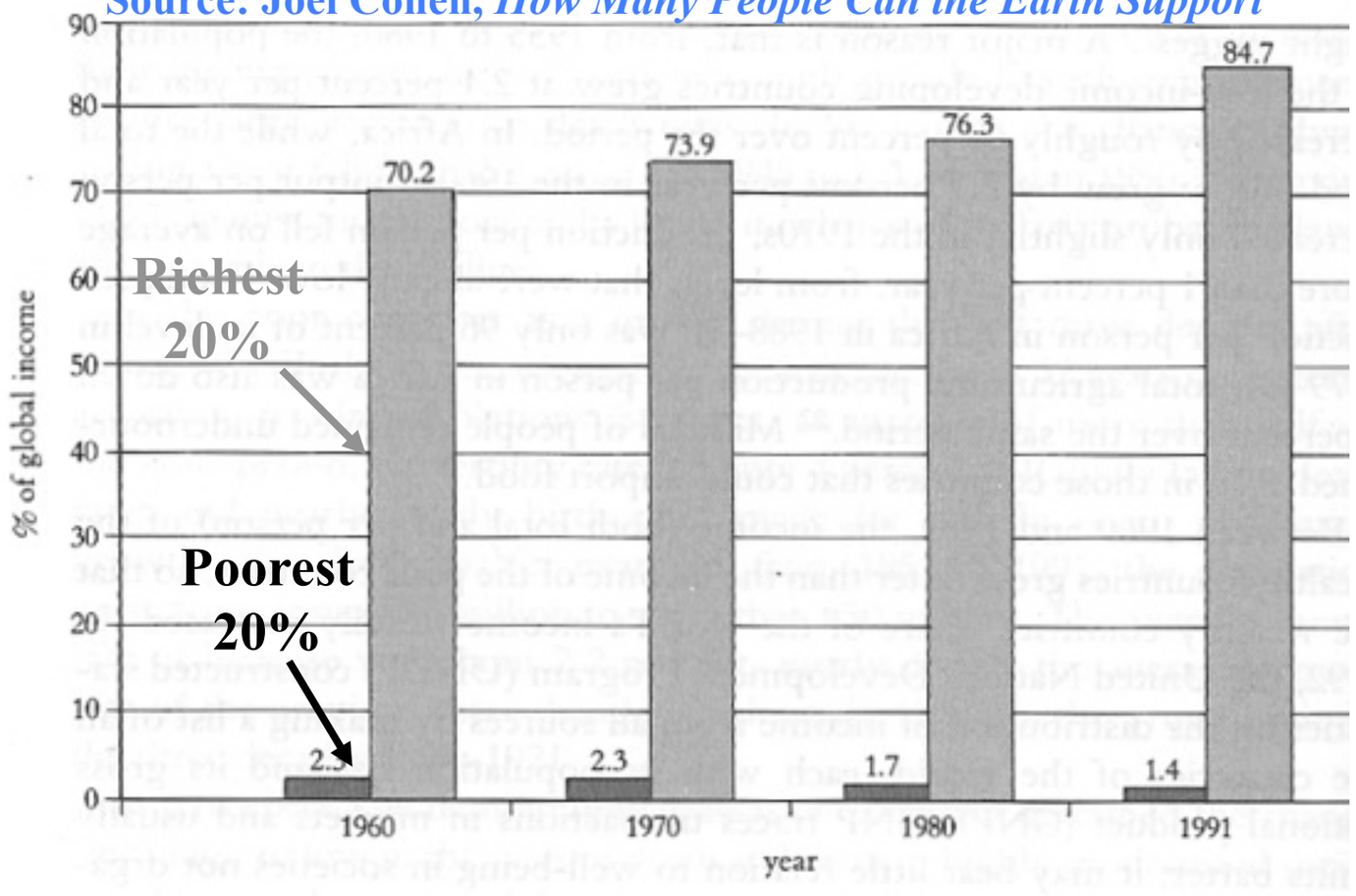
Both in the United States and worldwide, disparities of income and wealth are increasing. Building international regimes to protect the global commons will have a greater chance of success if, at least on average, the rich stop growing richer and the poor poorer. Something must play the role of motion opposing gravity to keep wealth and power from accumulating without limit and dragging us all into an economic and political black hole. The fact that the cosmos accomplished this may be an inspiration for us all.

The Ultimate Scrooge Principle?

Gravity magnifies differences – that is, if one region is ever so slightly denser than average, it will expand slightly more slowly and grow relatively denser than its surroundings, while regions with less than average density will become increasingly emptier. When any region reaches about twice the density of typical regions its size, gravity wins out over expansion. The region reaches a maximum radius, stops expanding, and starts falling together. Through "violent relaxation" the collapsing dark matter quickly reaches a stable configuration. It might appear that gravity is inexorable and can never be stopped. But the opposite is actually the case, except in black holes. At a certain point gravity is always counterbalanced by motion – random motion for the dark matter in galaxies, circular motion for disks of galaxies and for planetary systems. Only when such stable configurations have formed can life and ultimately intelligence evolve.

How could this be a model for earth? As fluctuations evolved into structures as the universe expanded, gravity amplified inhomogeneities. Unless there are counterbalancing forces, wealth follows the same principle – the rich get richer and the poor get poorer. This is happening between the rich and poor countries, and also in the United States.

Source: Joel Cohen, *How Many People Can the Earth Support*



The Ultimate Scrooge Principle?

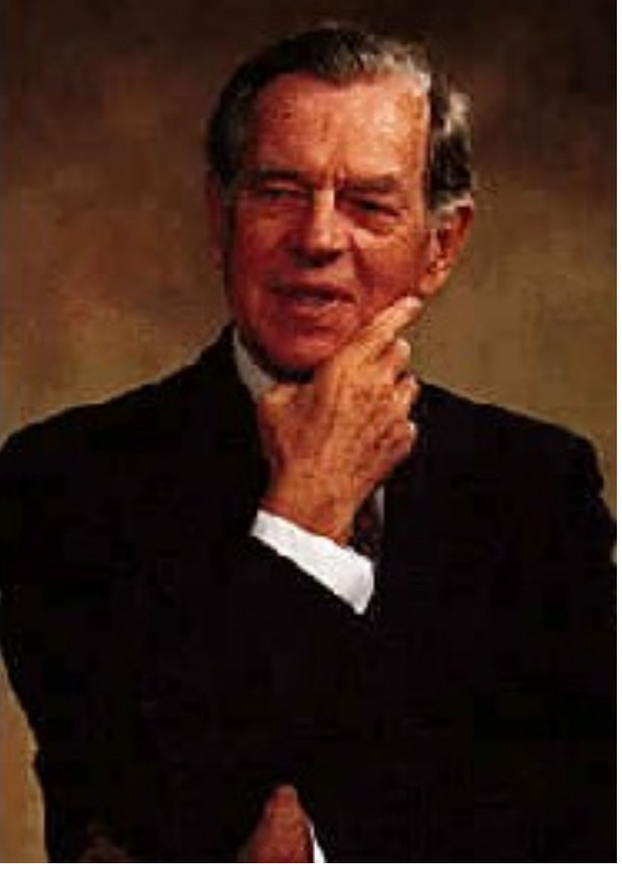
Within the United States, the wealthiest ten percent now own more than 75% of all stock and the top one percent own 42%, according to the U. S. Census Bureau. Income disparities have increased as salaries of top executives skyrocketed during the past decade, while the average inflation-adjusted hourly wage was about the same in 1998 as in 1973. From 1986 through 1997, the average after-tax income of the top 1% of Americans increased 89%, from $273,562 to $517,713 (in 1997 dollars), while the average income of the lower 90% increased a scant 1.6%, to $23,815. Almost all the benefits of the past decade's economic growth have gone to the upper 5% of families. Although the United States has the highest average income of any large country, it also has the worst income inequality and the largest fraction of its population in poverty.

The ideal in democratic societies is to give basic rights and some material security to all, and this requires a counterbalance to the gravity of wealth. A fundamental purpose of government must be redistribution. Unless the tendency of wealth and power to concentrate is opposed, this can ultimately undermine the long-term development of human society – and our ability and willingness to take action to develop a sustainable relationship with the Earth. Something must play the role of motion opposing gravity to keep capital from accumulating and dragging us all into an economic black hole.

Probably more than knowledge or material goods, our society needs inspiration. This may be the only thing capable of drastically changing enough minds so that the human species does not, in Einstein's remark about nuclear weapons, “drift toward unparalleled catastrophe.” Modern cosmology can perhaps help. Cosmology is not only an intellectual passion, but can perhaps also make a social contribution in the expansion of the human imagination.

The Existential View

- Human centrality is a laughable notion.
- There is no higher organization in the universe.
- There is no system of thought that can give us lasting truths.
- We create whatever meaning works for us.

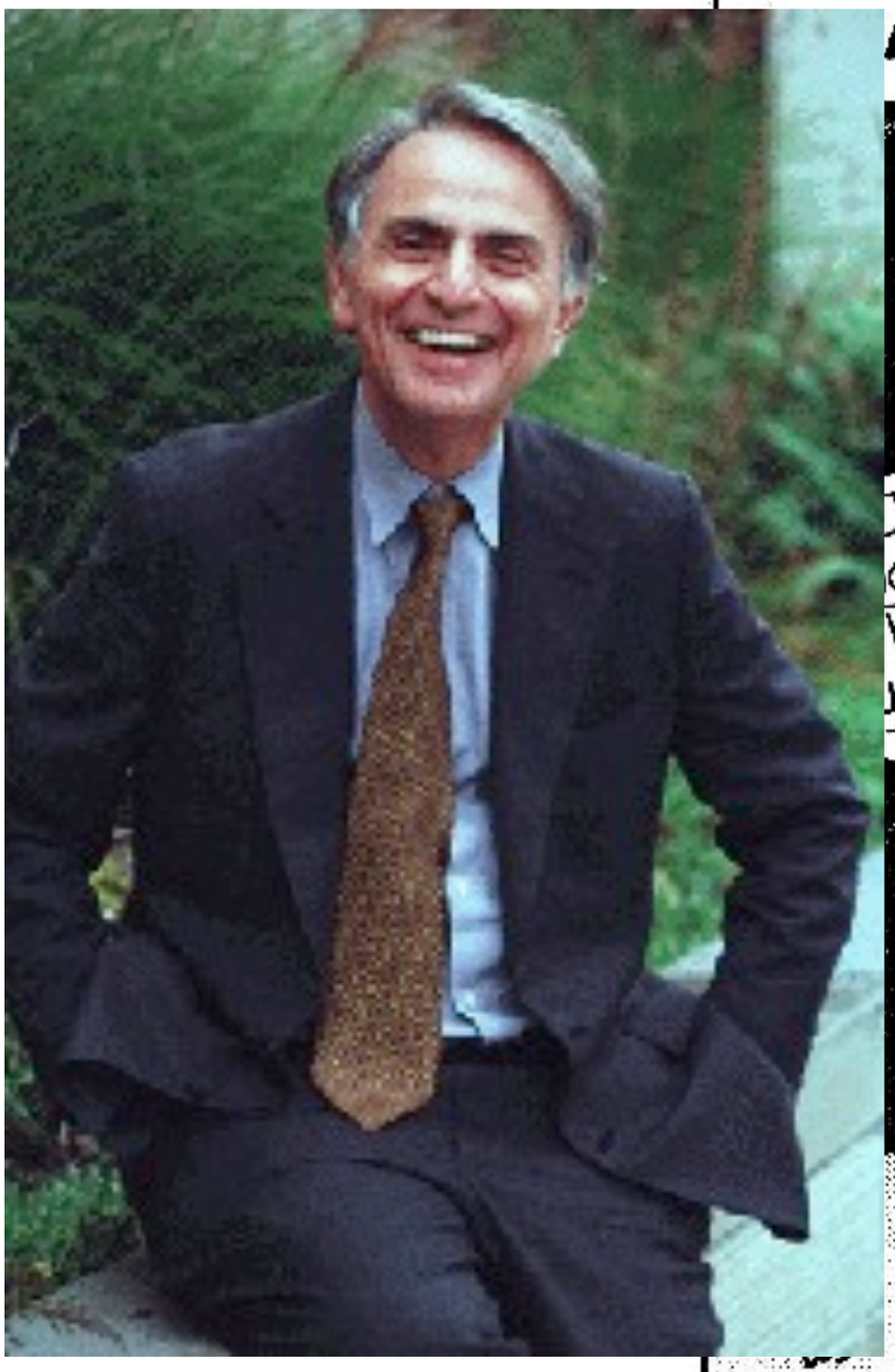


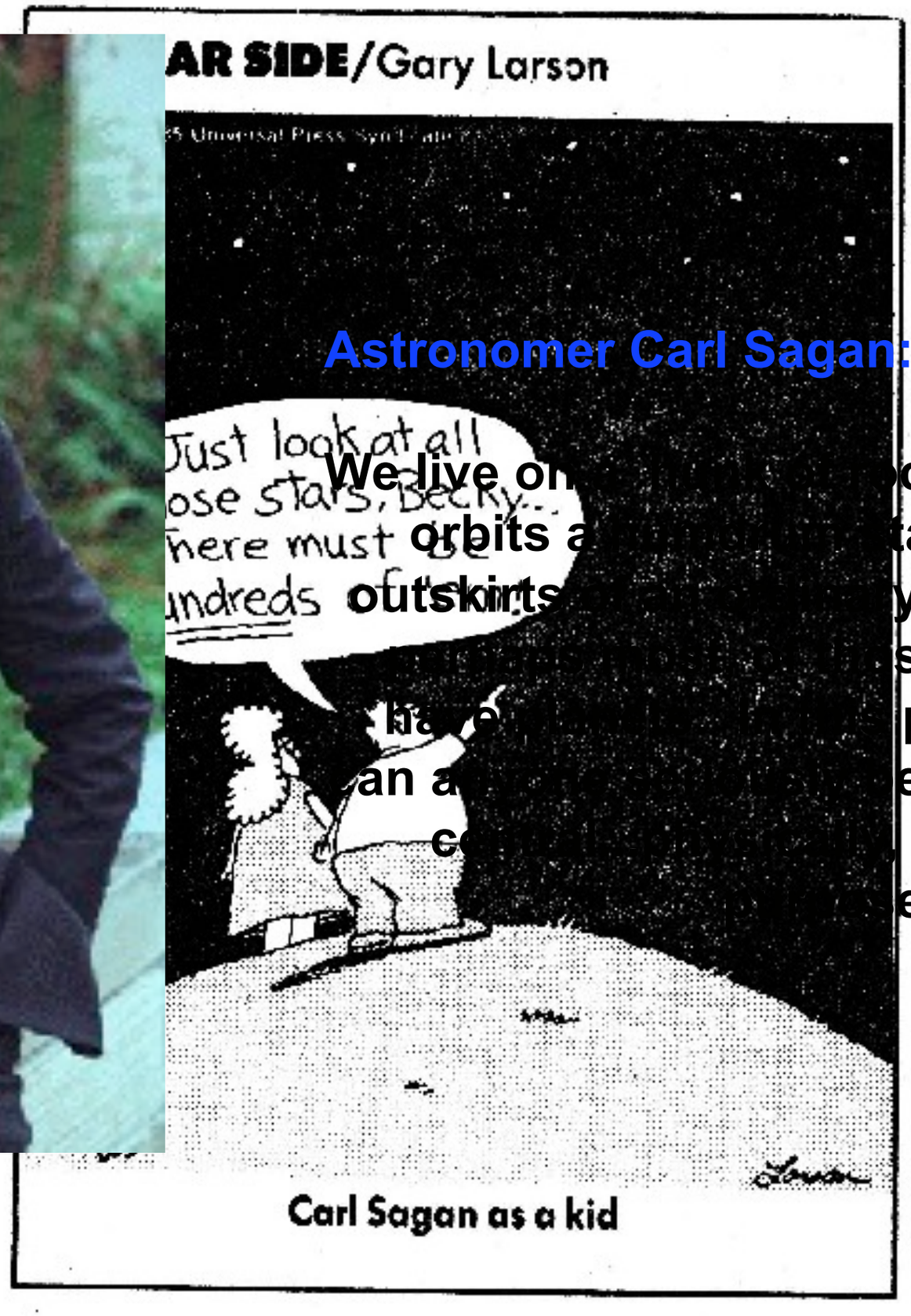
Mythologist Joseph Campbell:

humanity is a “scurf on the epidermis”
of a small planet of an average star

Biologist Stephen Jay Gould:

humans are merely
“a fortuitous cosmic afterthought”





Astronomer Carl Sagan:

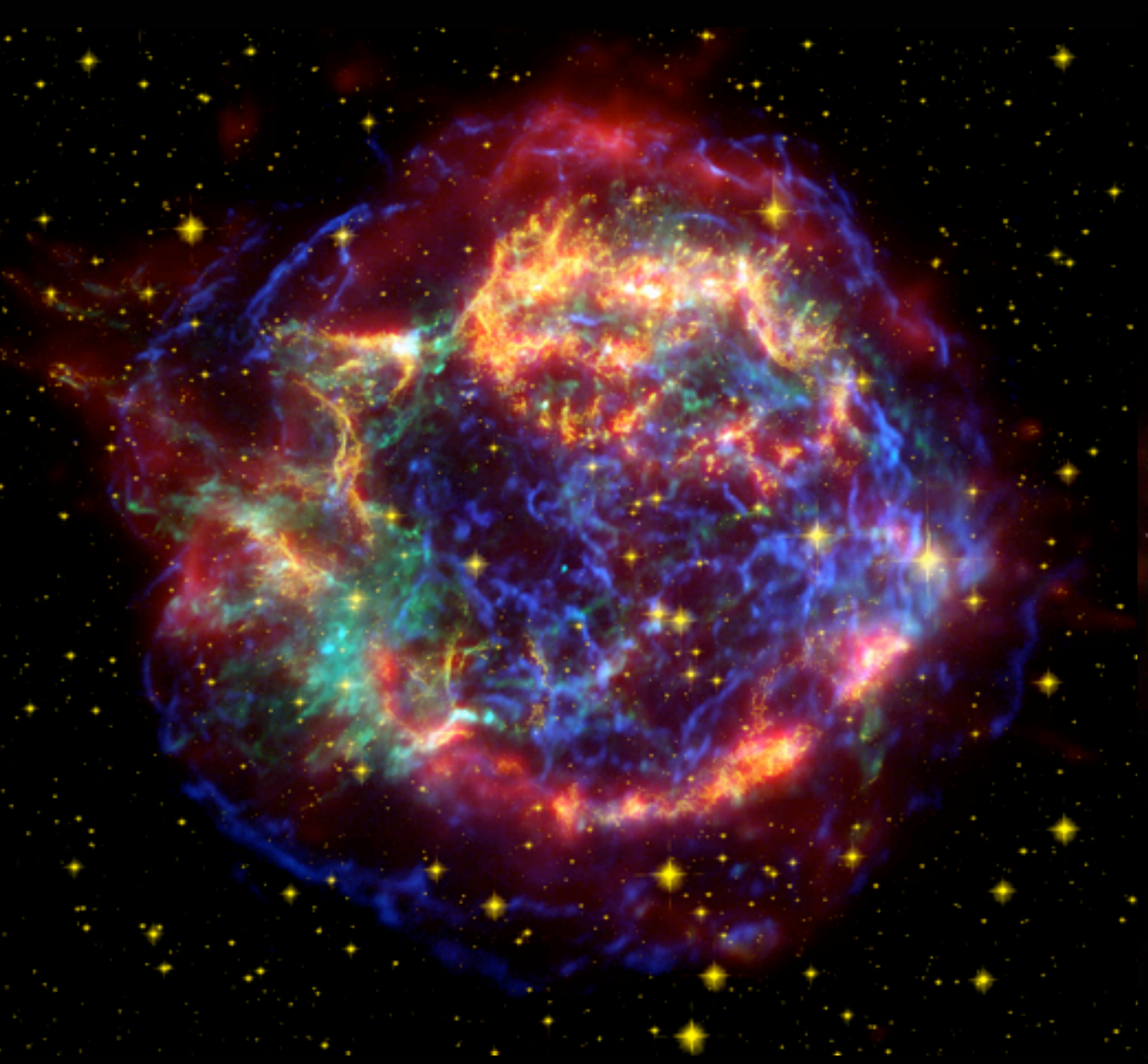
We live on ck and metal that orbits a tar in the obscure outskirts y galaxy.... Many, se stars probably have perspective, how an a elieve that we are ce much less to the e of the universe.

From Lecture 4...

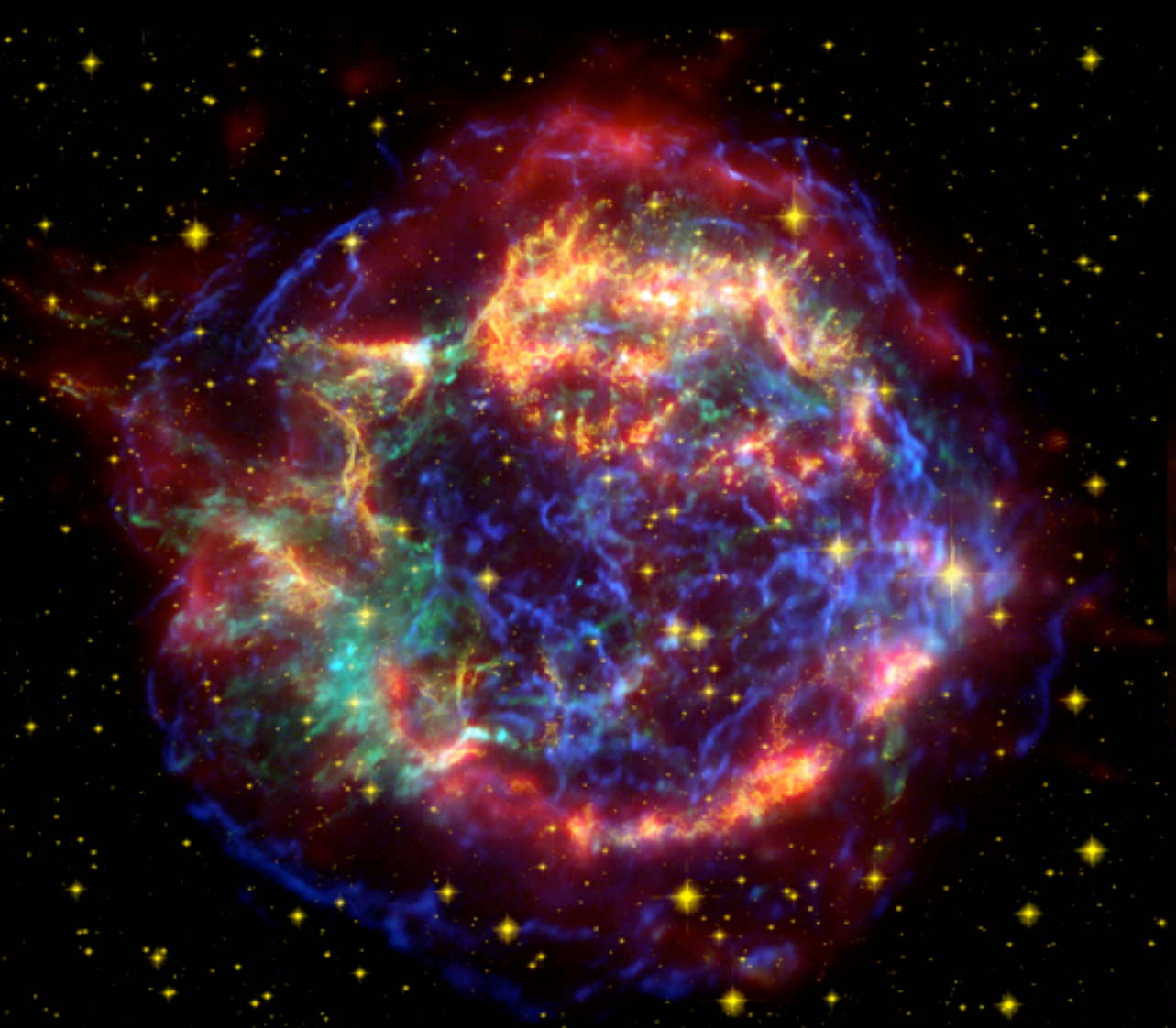
Joel Primack (1984):

If the bulk of the matter in the universe is not made of atoms, "that is yet another blow to anthropocentricity. Not only is man not the center of the universe physically (Copernicus) or biologically (Darwin), it now appears that we and all that we see are not even made of the predominant variety of matter in the universe."

Romantics
Cynics



Romantics are made of stardust, but cynics are made of the nuclear waste of dead stars



Cassiopeia A Supernova Remnant

Helix Planetary Nebula