

***Human
Civilization and
Earth
Environments***

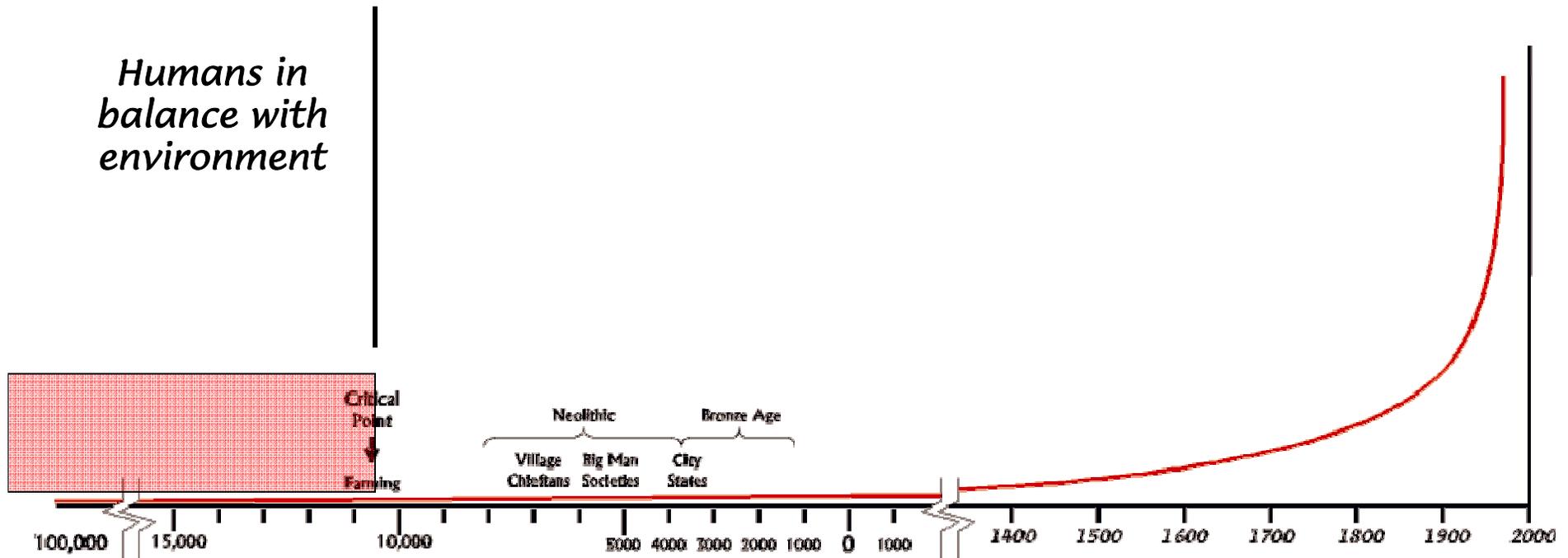
Can one little species (like ourselves) really change the Earth's environment?

And if so, when did we start?

- This past century?
- At the beginning of the Industrial Revolution?
- Before that?

Evidence is beginning to accumulate that we started changing the environment a long time ago.

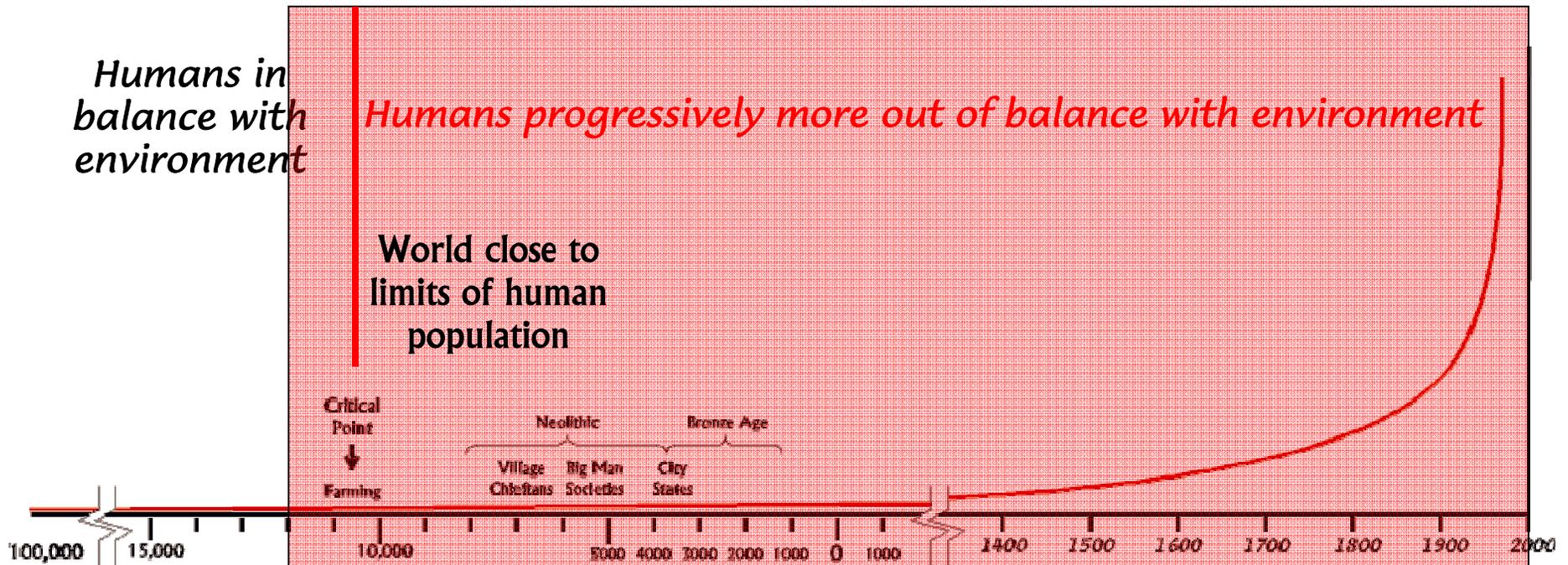
Human Population Growth Curve



Before 15,000 years ago the ability of the world's environment to support animals and people still exceeded the needs of the human population.

Stone age people lived in tiny family bands and occupied home territories extensive enough for them to be able to move around freely, even over large distances, using highly flexible survival strategies. (77)

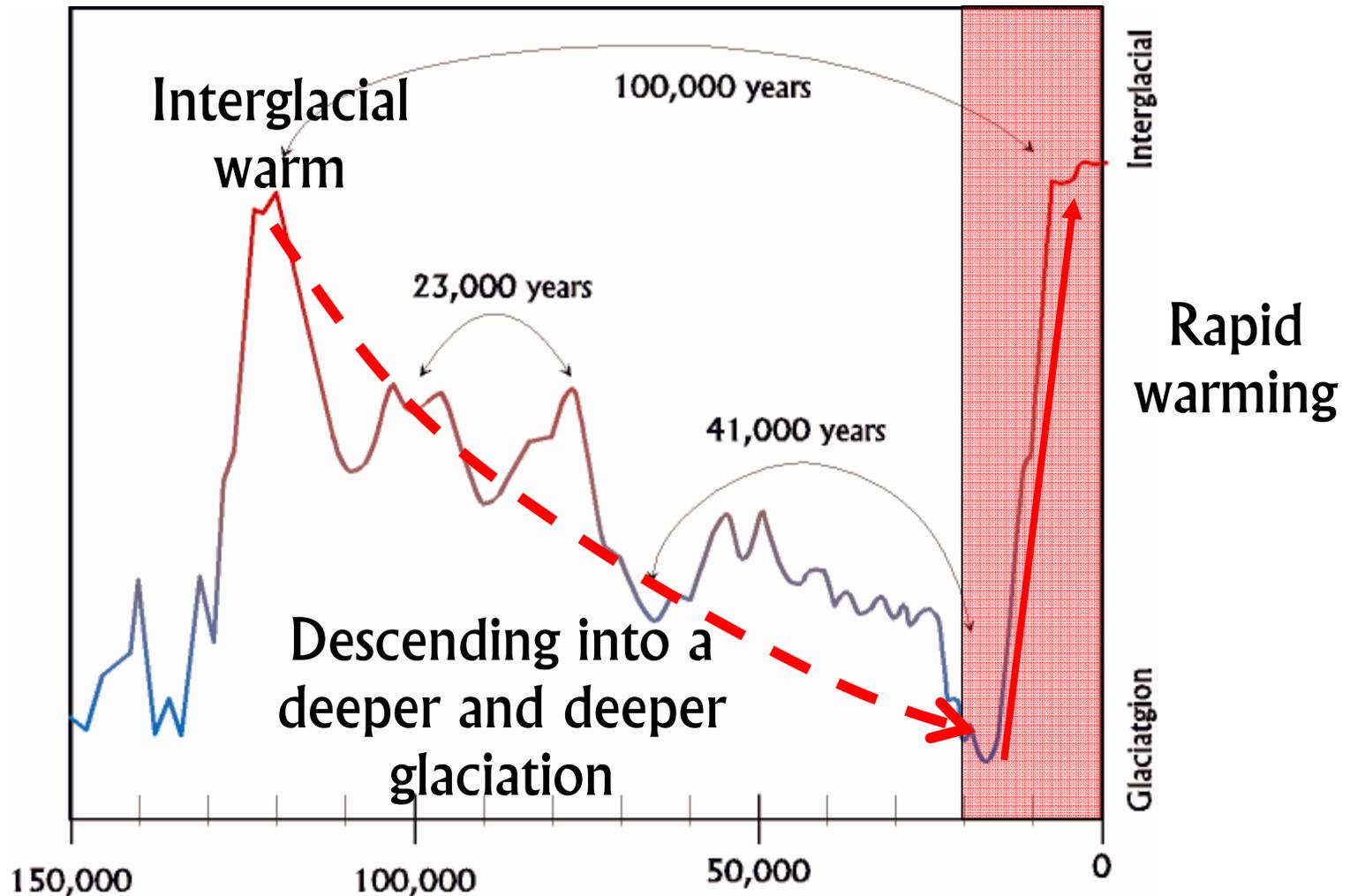
Human Population Growth Curve



Until about 11,000 years ago, when farming appeared, Earth's population had not yet reached the critical point where it exceeded the natural carrying capacity of the land.

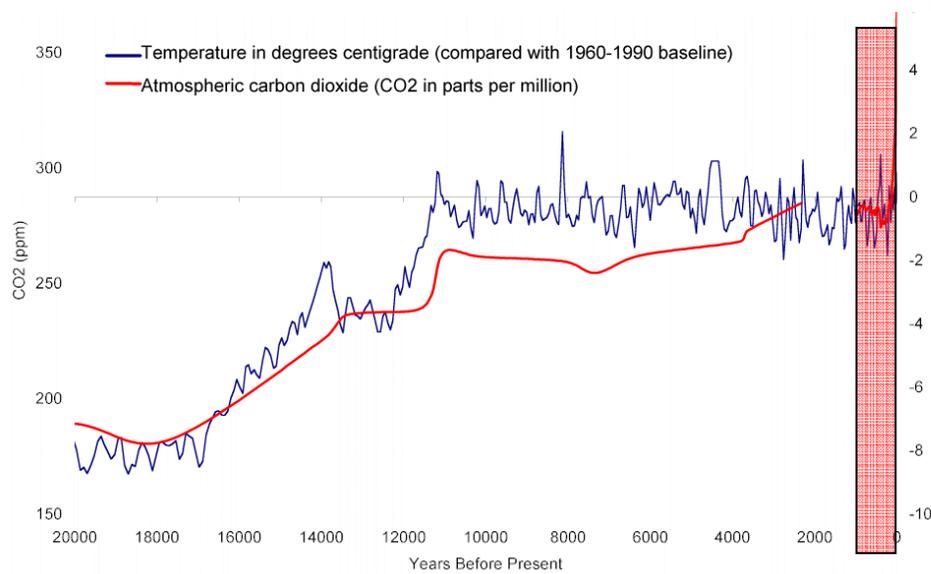
The critical point was crossed when humans learned to plant crops, rather than just gather them.

And all this was happening at a time when climate was moderating at the end of a long, deep, glacial cycle.

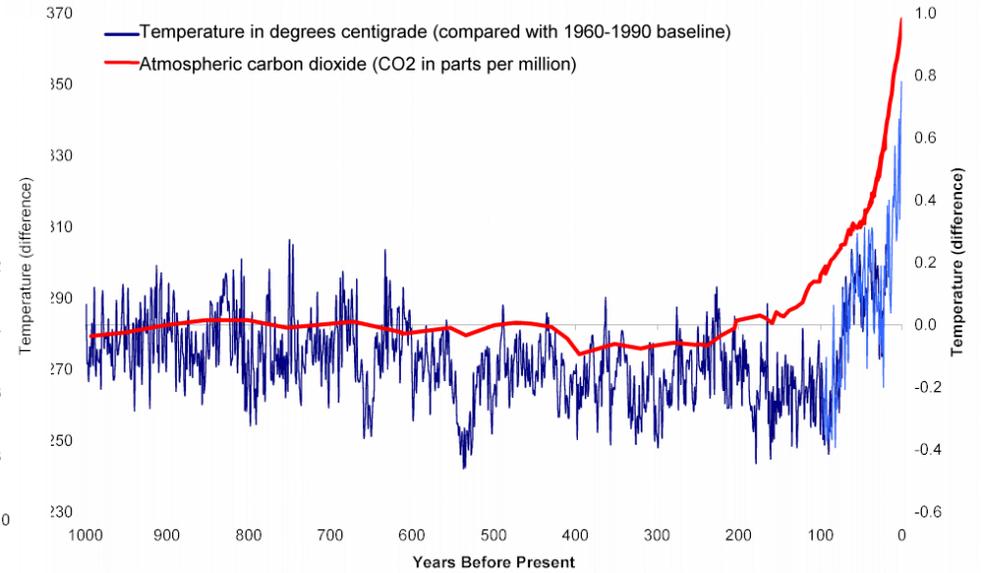


FRACTAL TEMPERATURE PATTERNS IN TIME

20,000 Year Record



1,000 Year Record



The Future in Plain Sight: The Rise of the "True Believers" and Other Clues to the Coming Instability

Eugene Linden, 2002

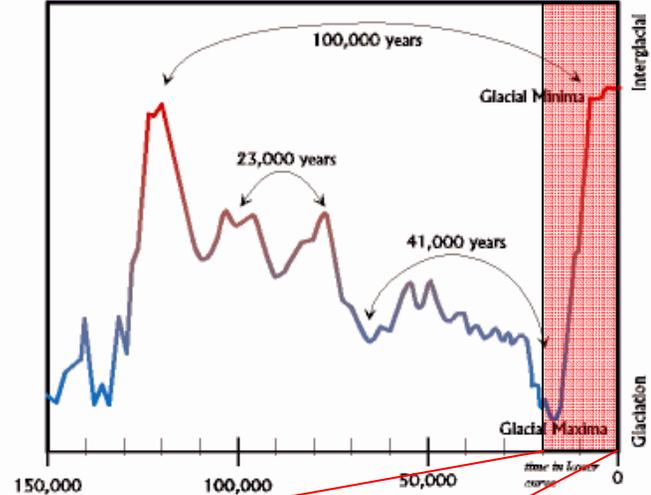


“Today’s Baby Boomers had the privilege of growing up in one of the most stable periods in the vast sweep of human history. As of this writing, more than fifty years have passed without catastrophic conflict between great powers. This fifty-year hiatus falls within a period of 150 years of extreme climate stability that has only recently begun to change. Finally, the 150-year stretch falls within an eight-thousand-year period in which climate has been relatively clement compared with the record of the past million years or so. Since our distant ancestors last saw real instability, humans have invented agriculture, writing, cities, and commerce, flown to the moon, and multiplied from some few million souls to roughly 5.6 billion.”

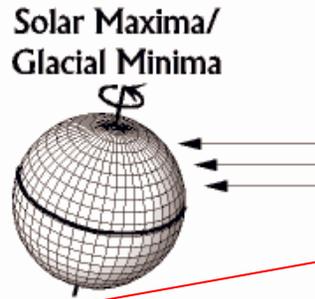
Climate Change Over the Past 20,000 Years and Its Influences

Based on Precessional Positions in Different Parts of Climate Cycle

Ice Sheet Changes Over the Past 150,000 Years Based on Oxygen Isotopes



Warming part of cycle
 CH₄ CO₂ increasing
 Melting of glaciers
 Increasing monsoons
 Forests migrate north

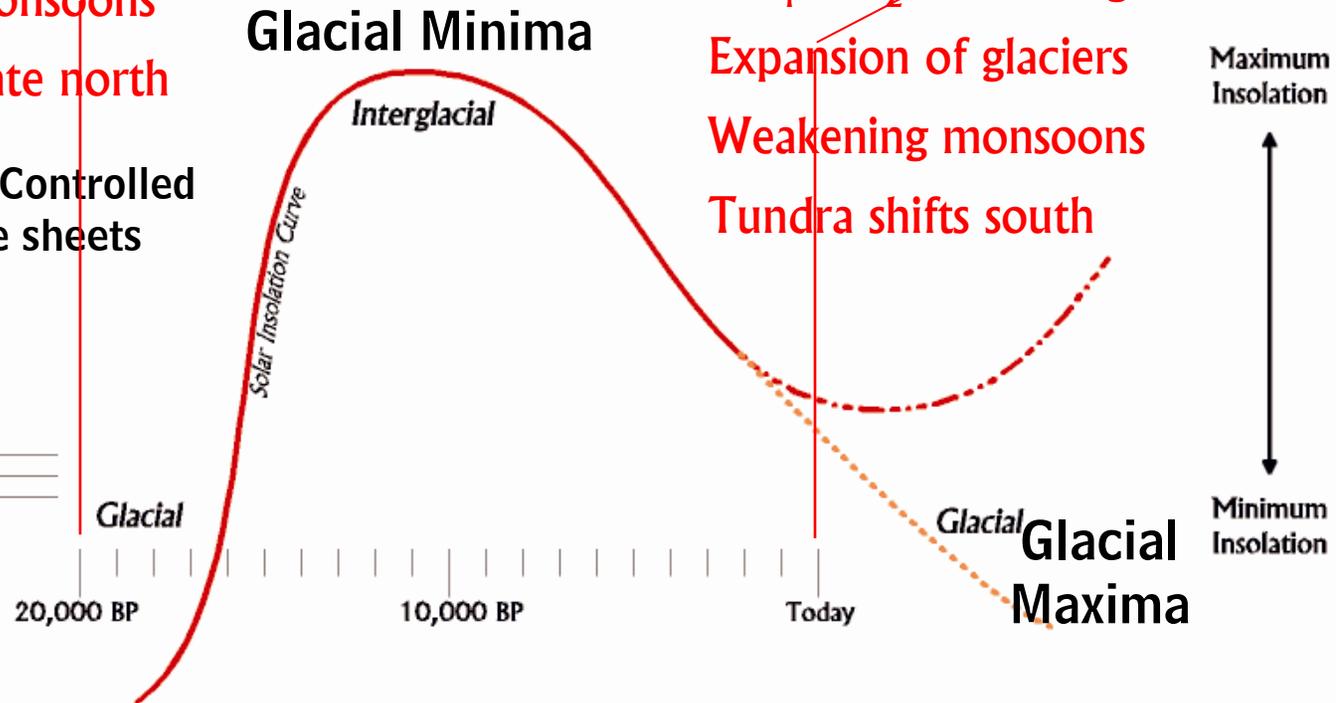


Cooling part of cycle
 CH₄ CO₂ decreasing
 Expansion of glaciers
 Weakening monsoons
 Tundra shifts south

Glacial Maxima

Climate Controlled By ice sheets

Solar Minima/
 Glacial Maxima
 (Ice controlled climate)



Glacial Minima

Interglacial

Solar Insolation Curve

20,000 BP

10,000 BP

Today

Glacial Maxima

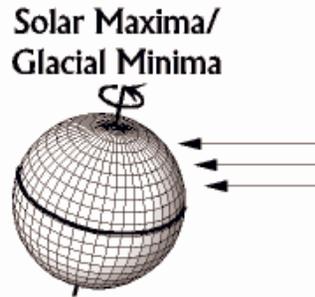
Maximum Insolation

Minimum Insolation

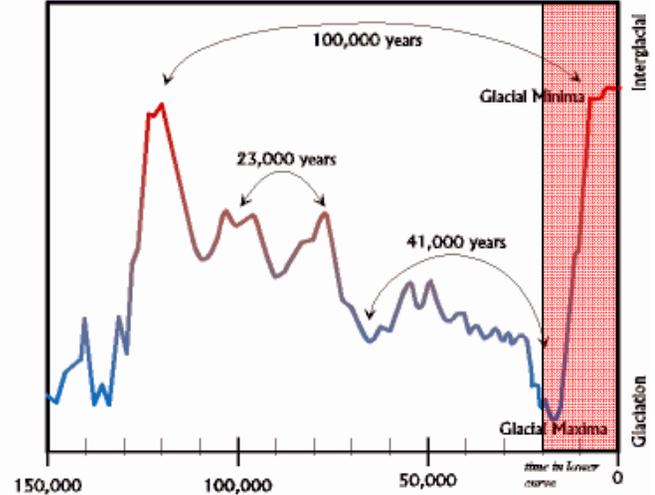
***Where Might Climate
Go in the Future
With and Without
Humans?***

Climate Change Over the Past 20,000 Years and Its Influences

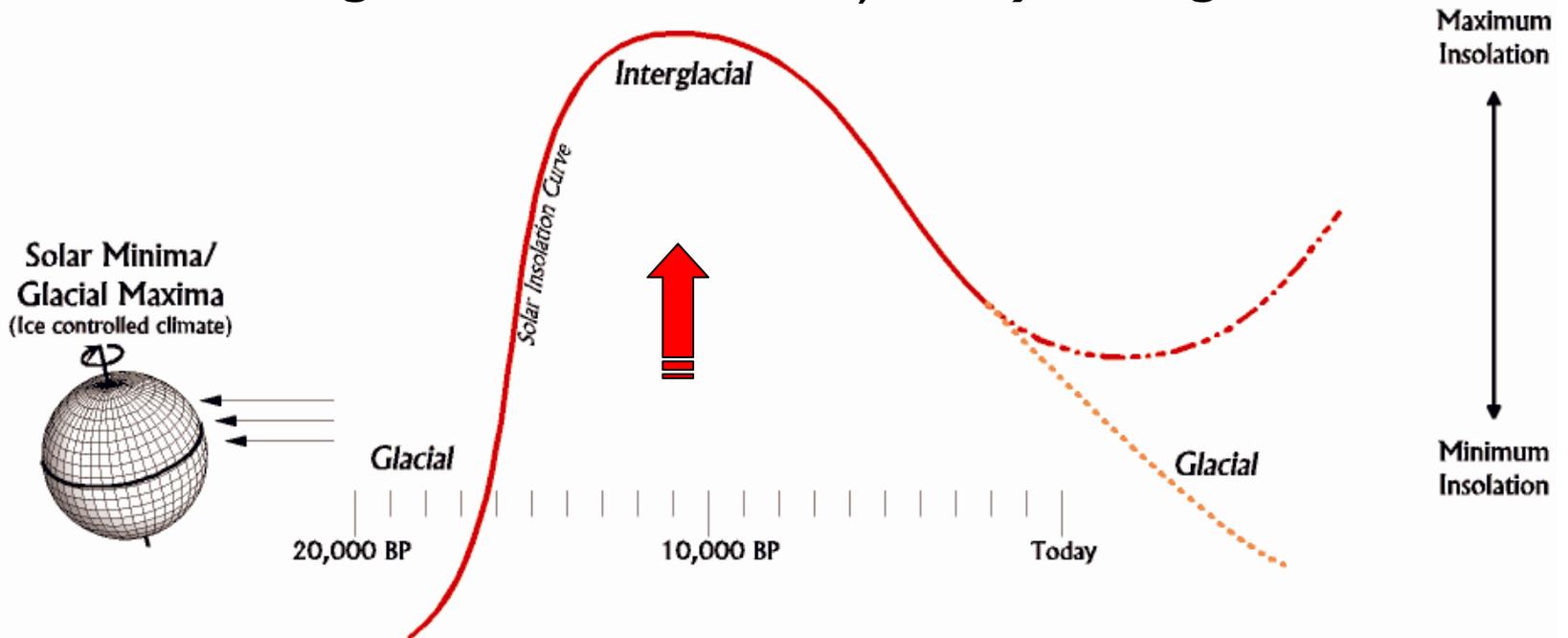
Based on Precessional Positions in Different Parts of Climate Cycle



Ice Sheet Changes Over the Past 150,000 Years Based on Oxygen Isotopes



The last glaciation ended 11,000 years ago



Last Glacial Retreat

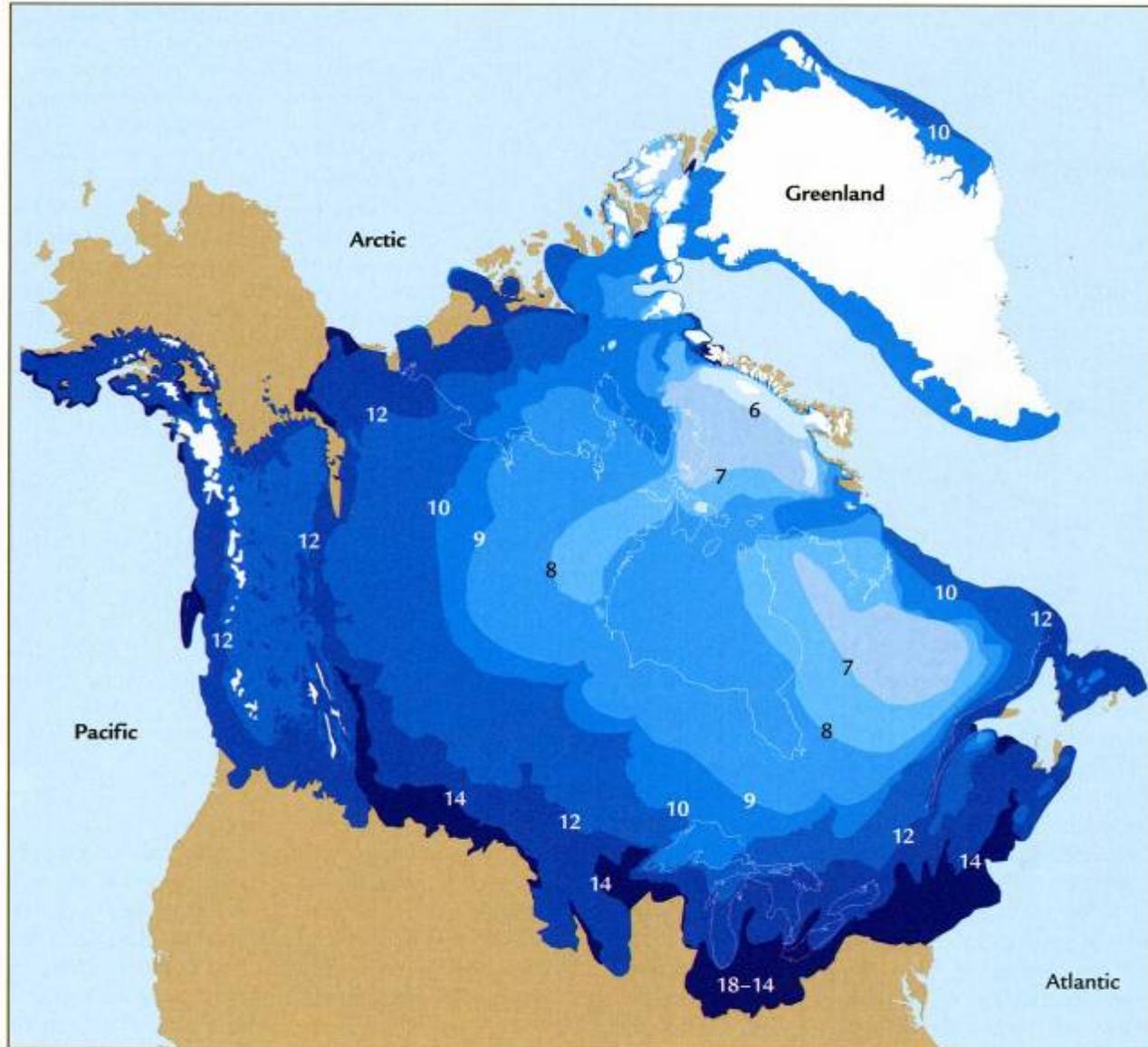
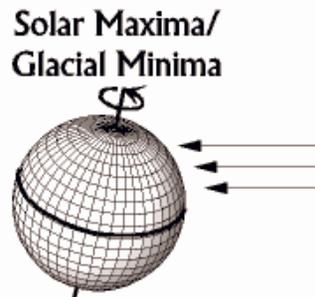


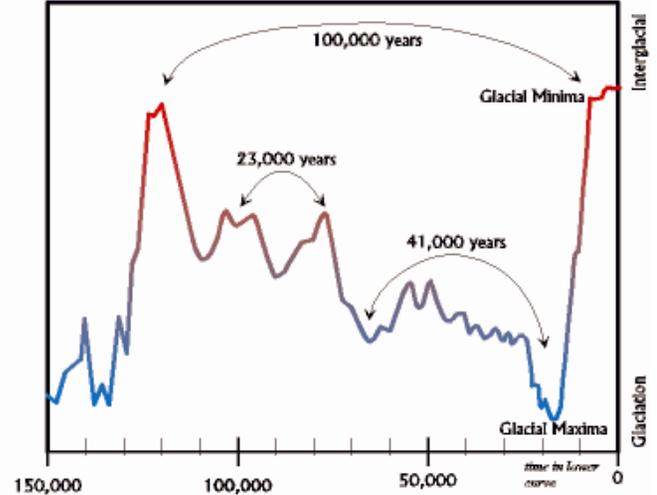
FIGURE 13-2 Retreat of the North American ice sheets Radiocarbon dating of organic remains shows that the margins of ice sheets in North America began to retreat near 14,000 ¹⁴C years ago, and the ice disappeared completely shortly after 6000 years ago. The numbers indicate ¹⁴C-dated ice limits in thousands of years. (Courtesy of Arthur Dyke, Geological Survey of Canada, Ottawa.)

Climate Change Over the Past 20,000 Years and Its Influences

Based on Precessional Positions in Different Parts of Climate Cycle



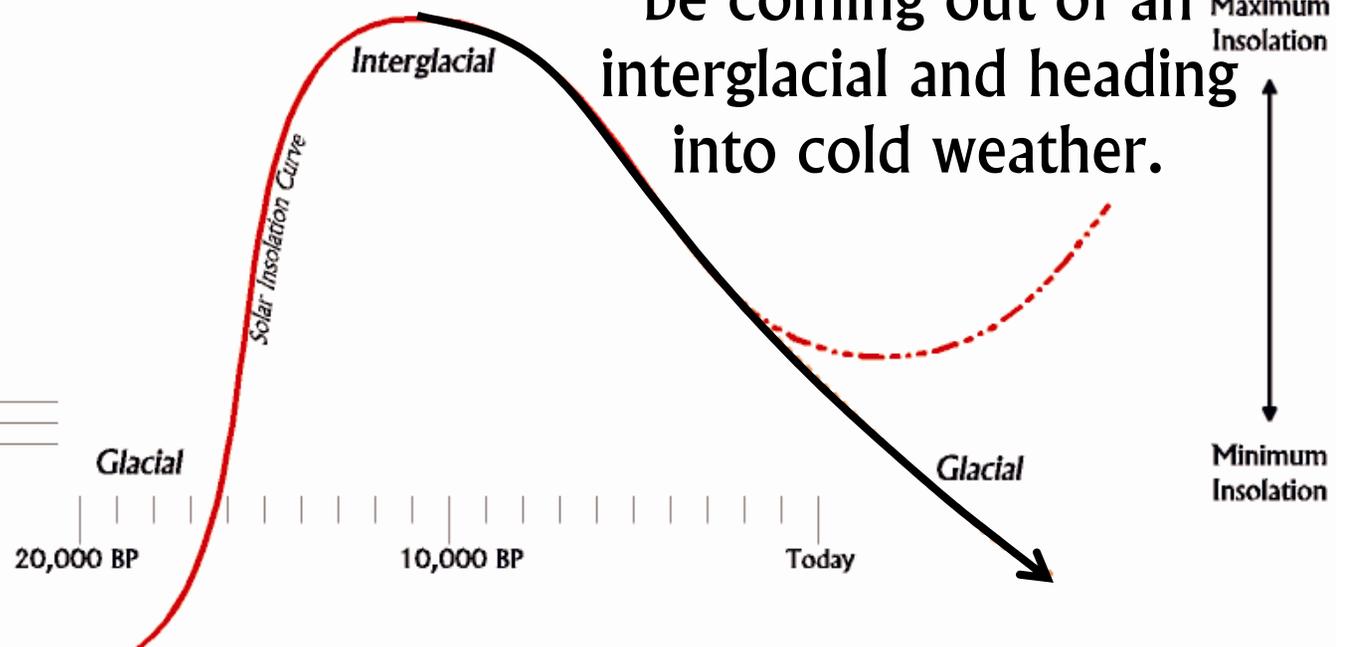
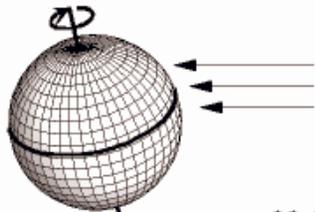
Ice Sheet Changes Over the Past 150,000 Years Based on Oxygen Isotopes



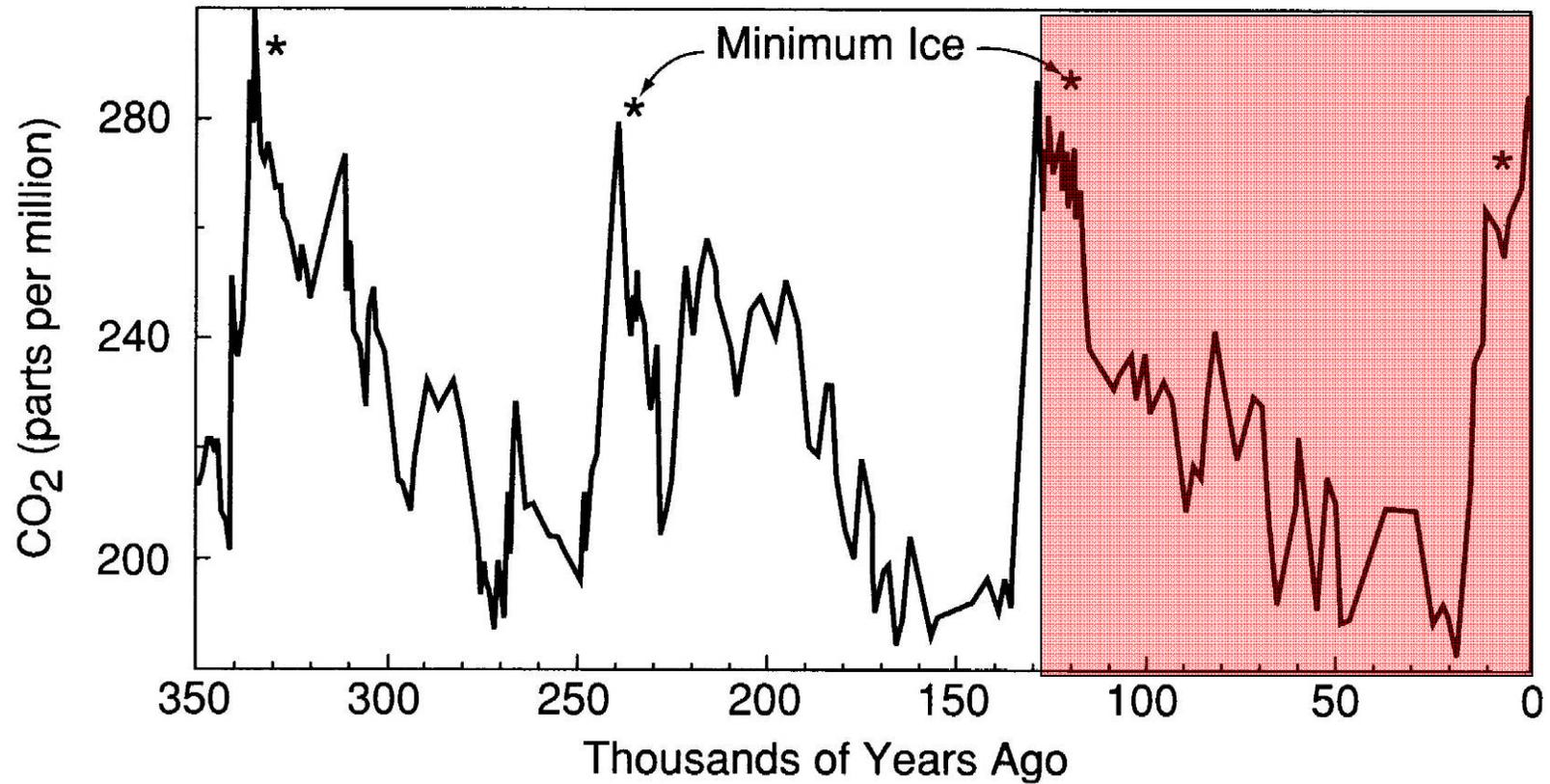
Which means we should be coming out of an interglacial and heading into cold weather.

Glacial Maxima

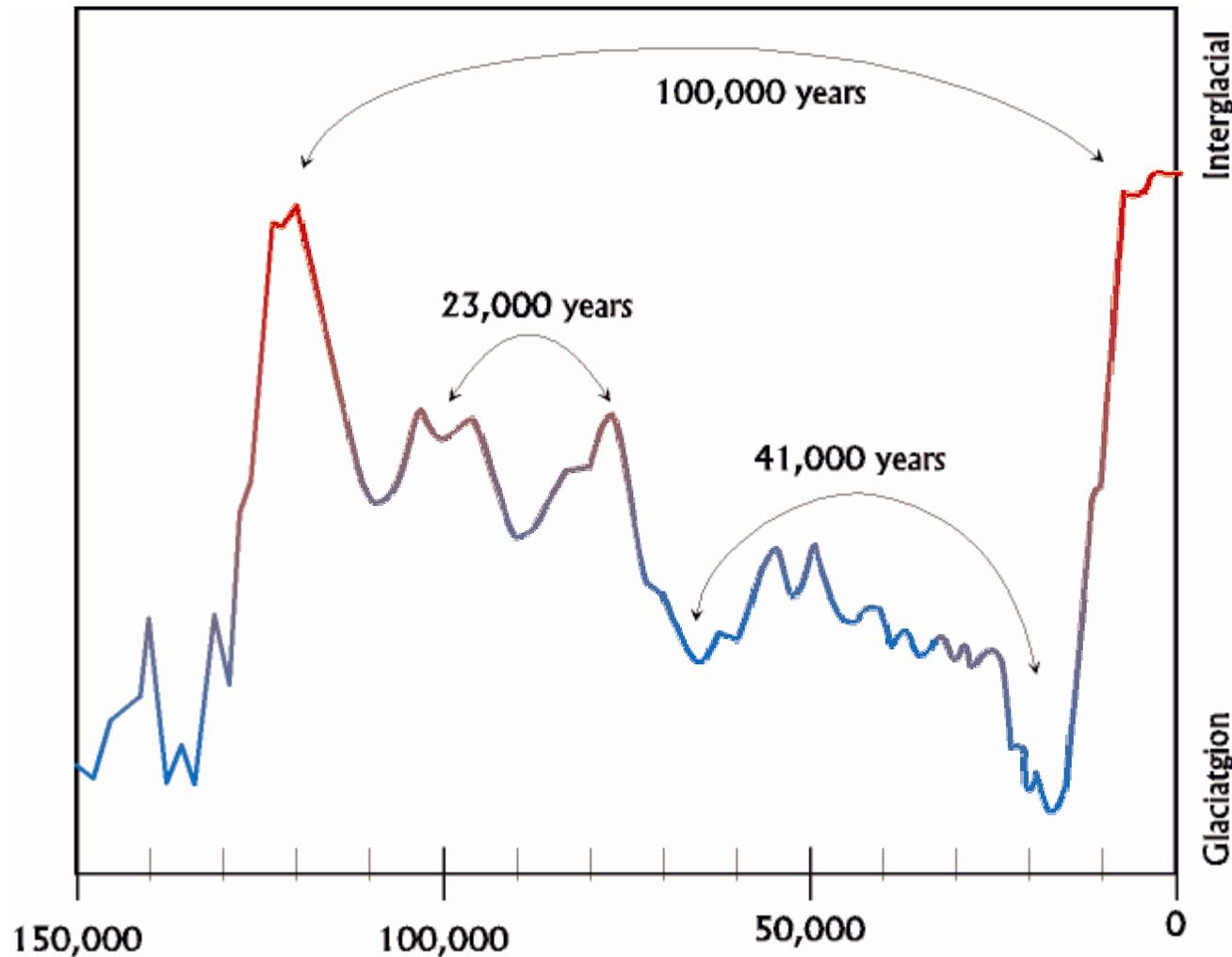
Solar Minima/
Glacial Maxima
(Ice controlled climate)



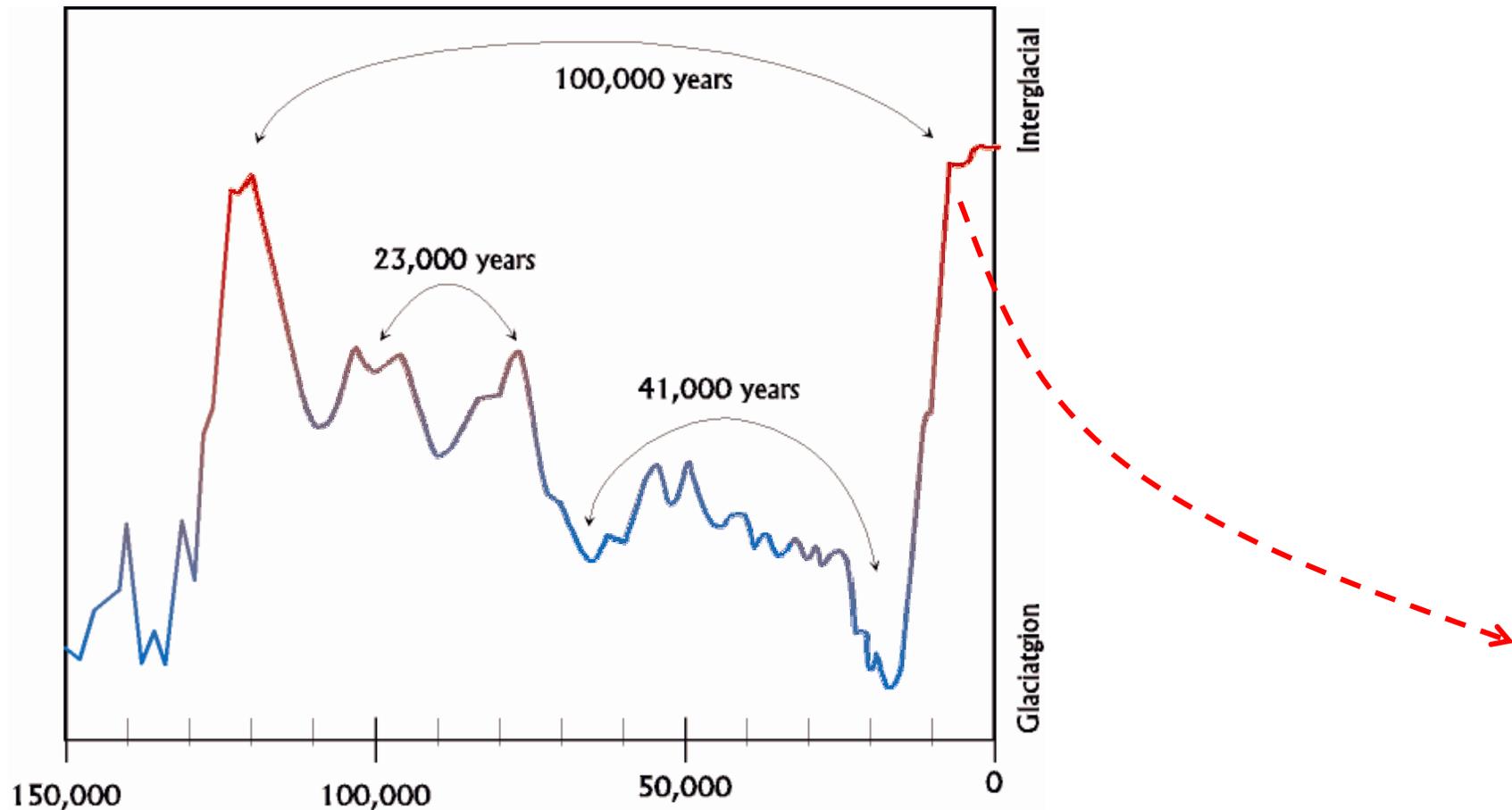
And since we are at the end of one of the 100,000 year glacial cycles that have dominated the past 400,000 years . . .



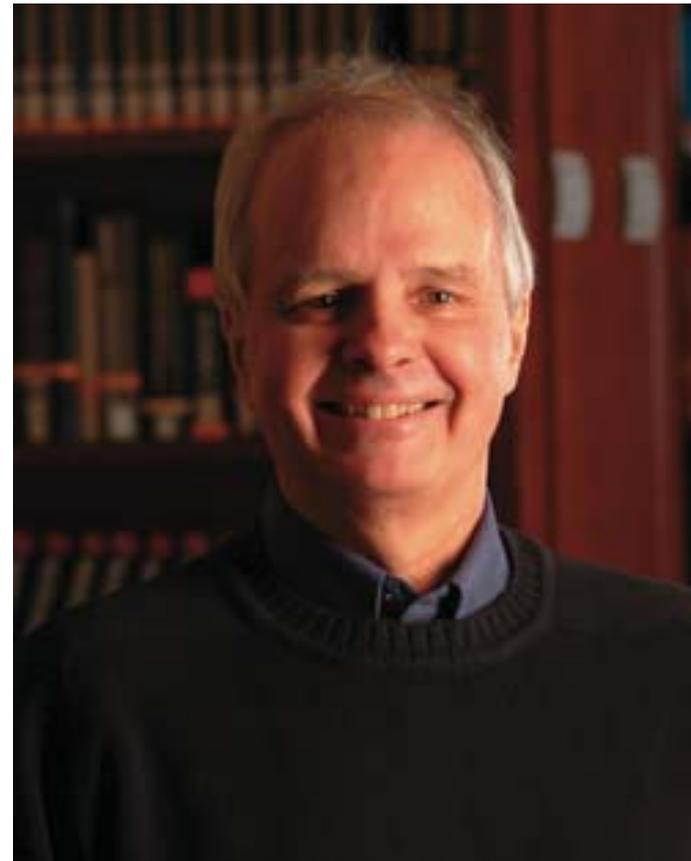
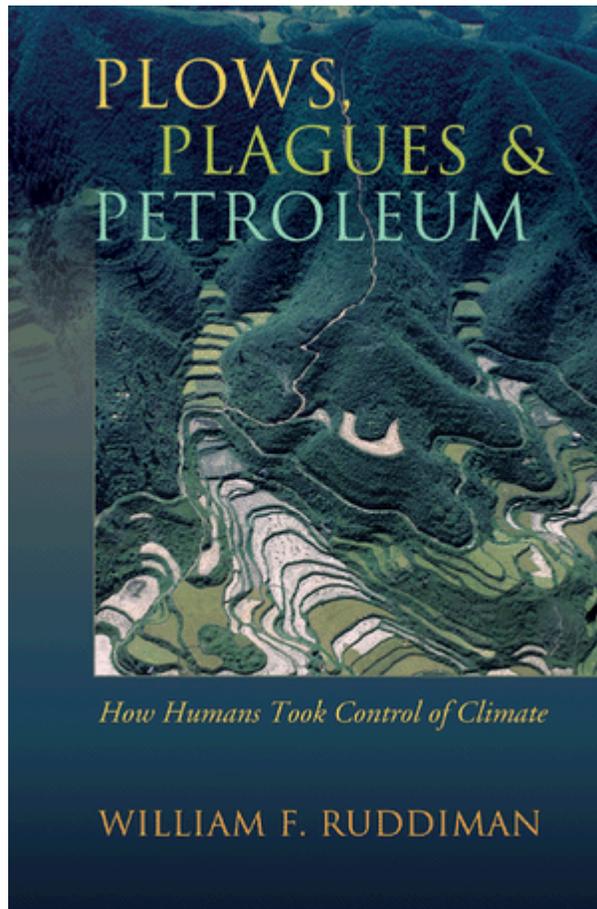
It seems reasonable that we should be just at the tipping point to descent into another major glaciation cycle.

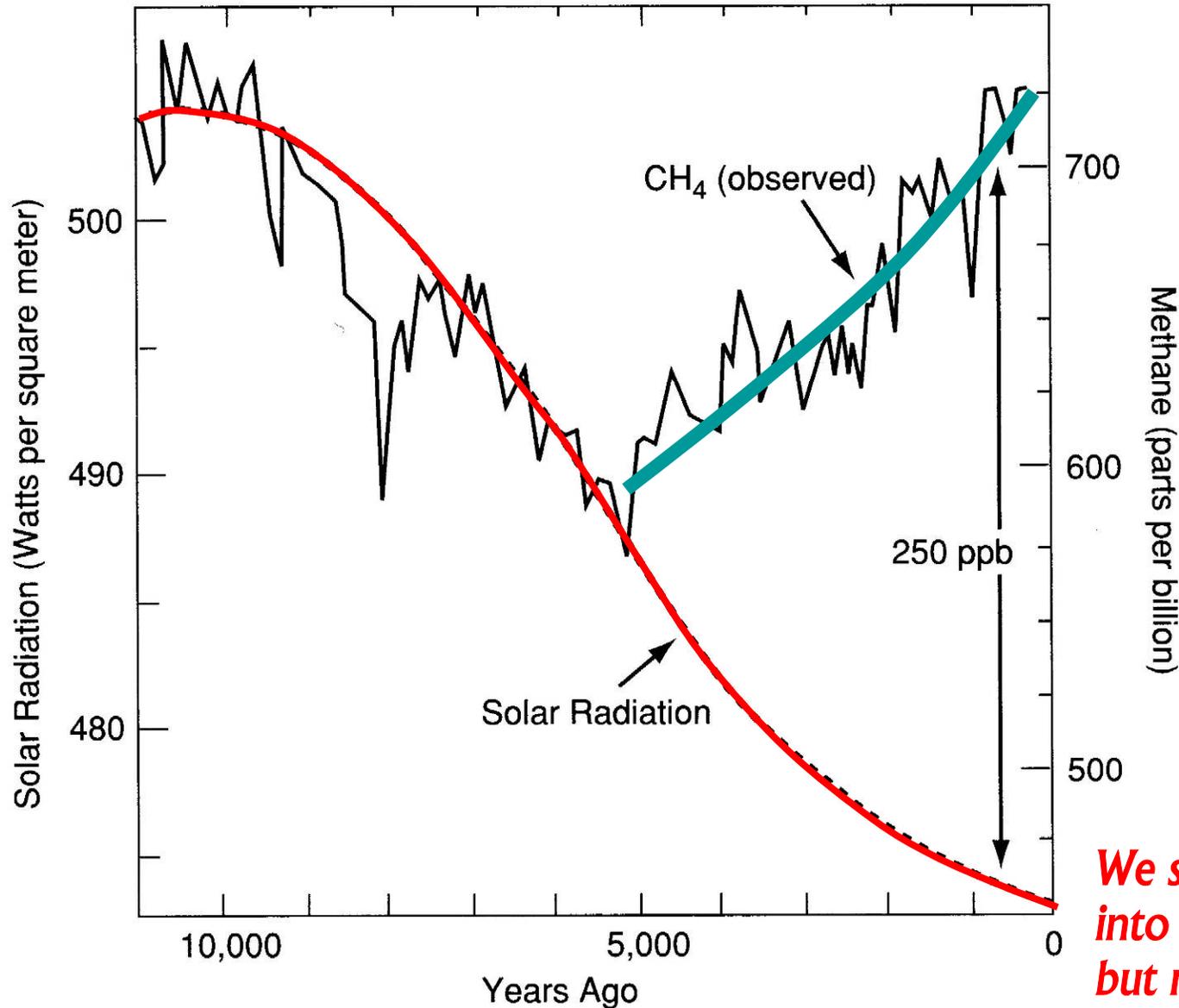


It seems reasonable that we should be just at the tipping point to descent into another major glaciation cycle.



But, Bill Ruddiman of Virginia Tech University does not think that is happening.





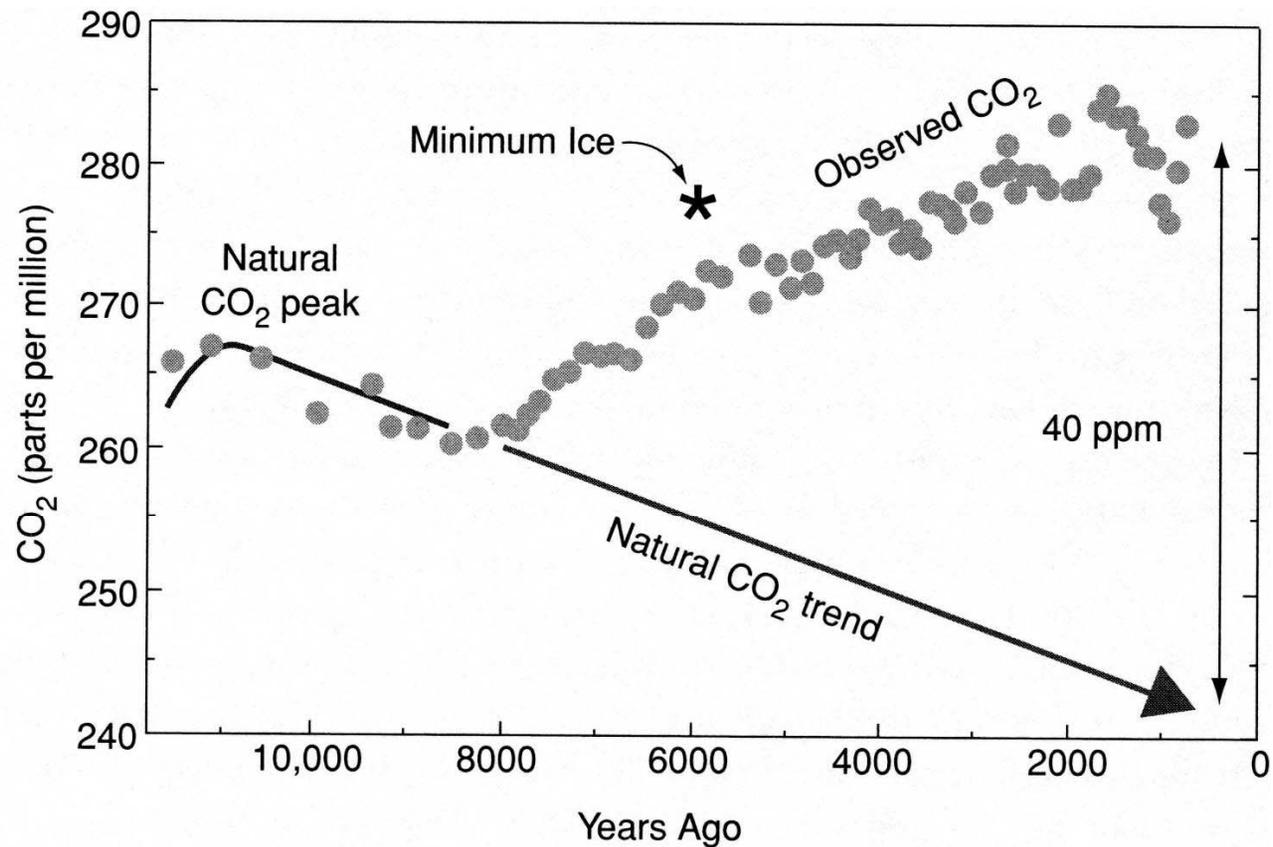
But, we are not, and the methane signature instead of dropping as it should, has begun to rise, beginning about 6000 years ago.

We should be well into the next ice age but now.

8.1. Natural (orbitally driven) changes in solar radiation caused the methane maximum 11,000 years ago and the decrease until 5,000 years ago, but humans account for the anomalous increase since that time.

The same thing turns out to be true for the carbon dioxide signature.

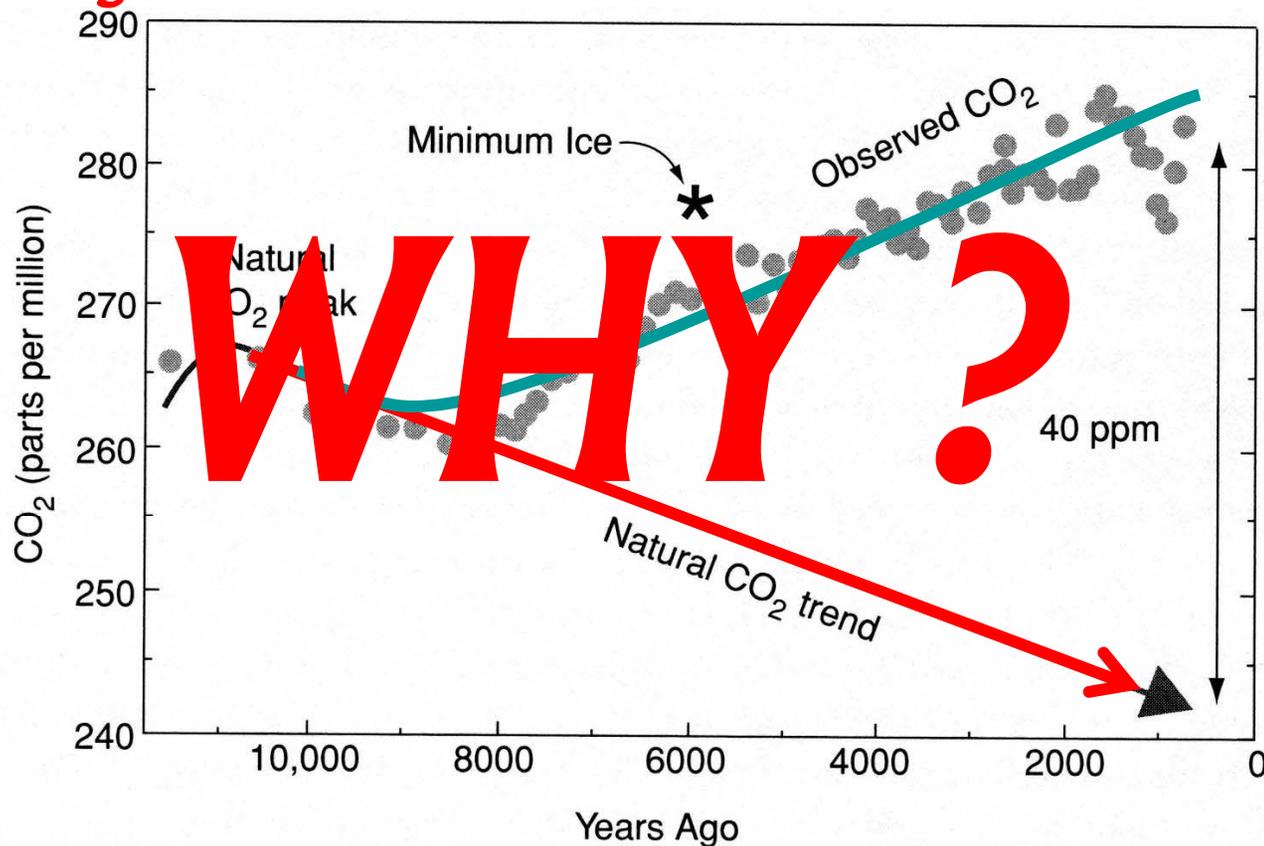
But, since we know that both methane and carbon dioxide track temperatures very well . . .



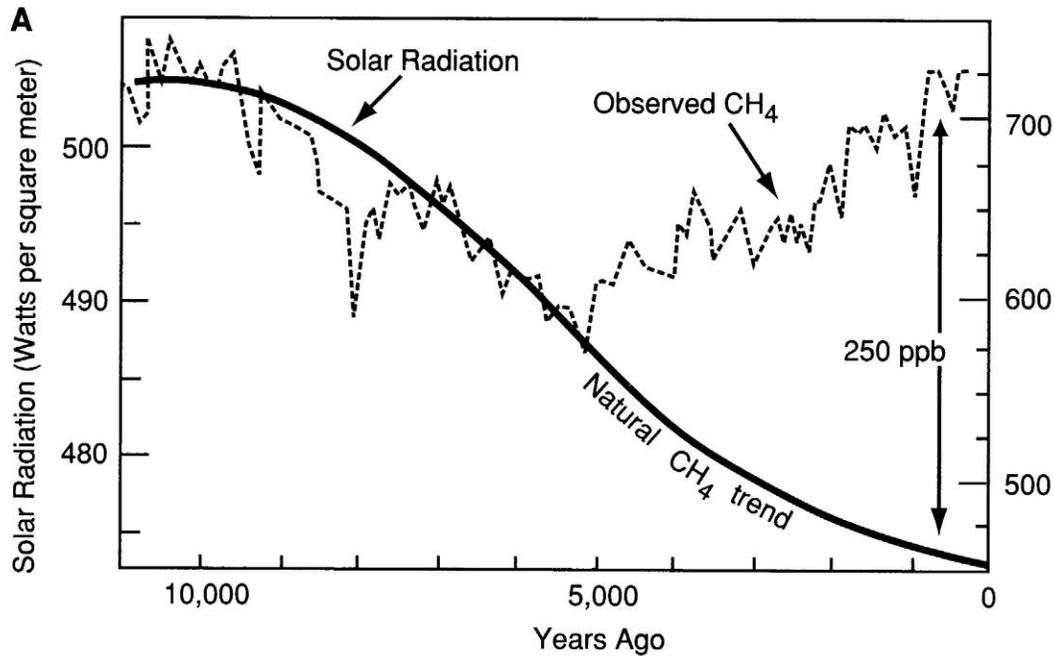
9.2. Natural processes caused the atmospheric CO₂ peak nearly 10,500 years ago and the subsequent decrease until 8,000 years ago, but humans have caused the anomalous CO₂ increase since that time.

. . . we are surprised that the observed methane and carbon dioxide curves are not tracking what the temperature should be doing, . . .

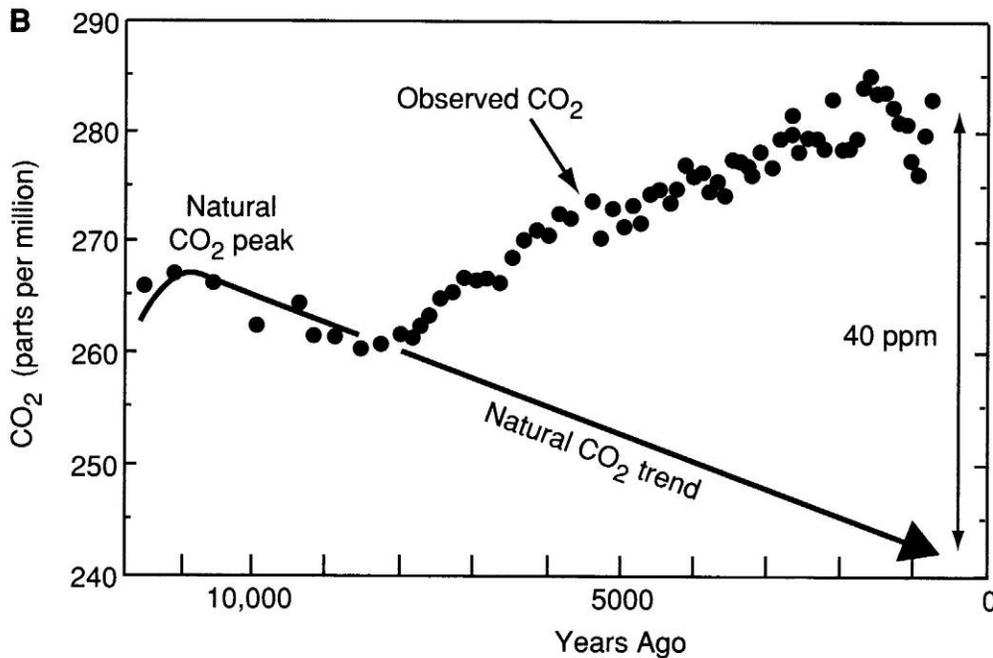
And, the temperature is also not tracking what it is supposed to be doing.



9.2. Natural processes caused the atmospheric CO₂ peak nearly 10,500 years ago and the subsequent decrease until 8,000 years ago, but humans have caused the anomalous CO₂ increase since that time.



Ruddiman argues it is because humans began to affect the climate not recently, like with the beginning of the Industrial Revolution as has been argued, but between 5 and 8,000 years ago, shortly after intensive agriculture began.



11.1. Concentrations of methane (A) and CO₂ (B) should have fallen during the last several thousand years but instead rose because of human activity.

The Spread of Agriculture

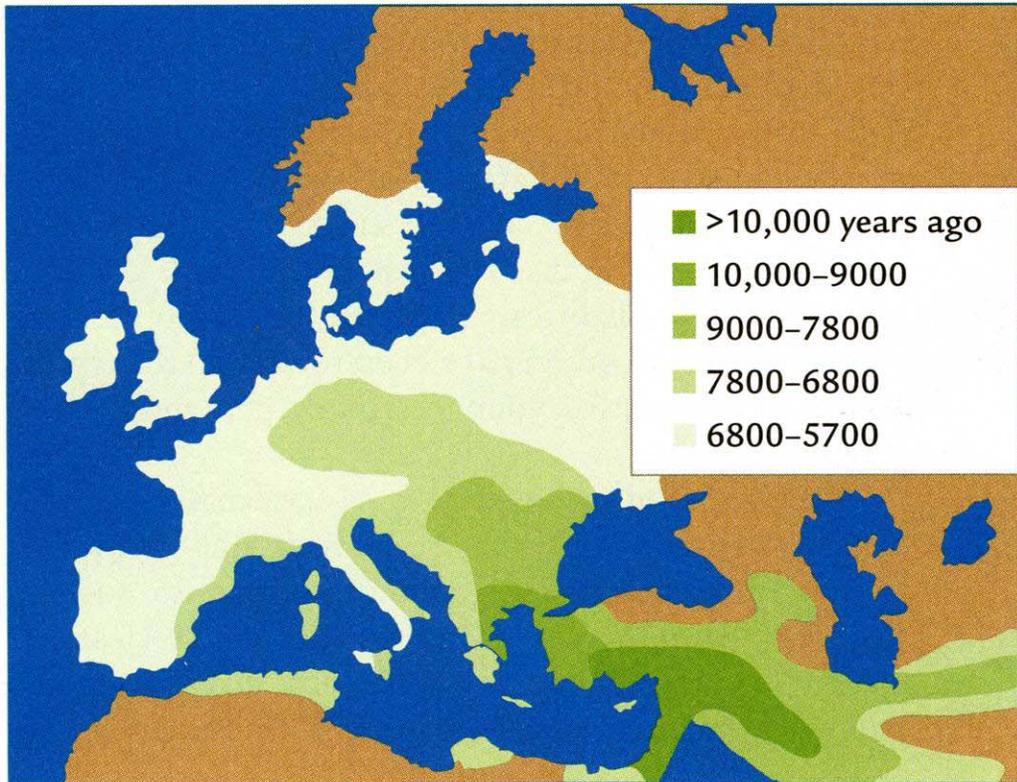
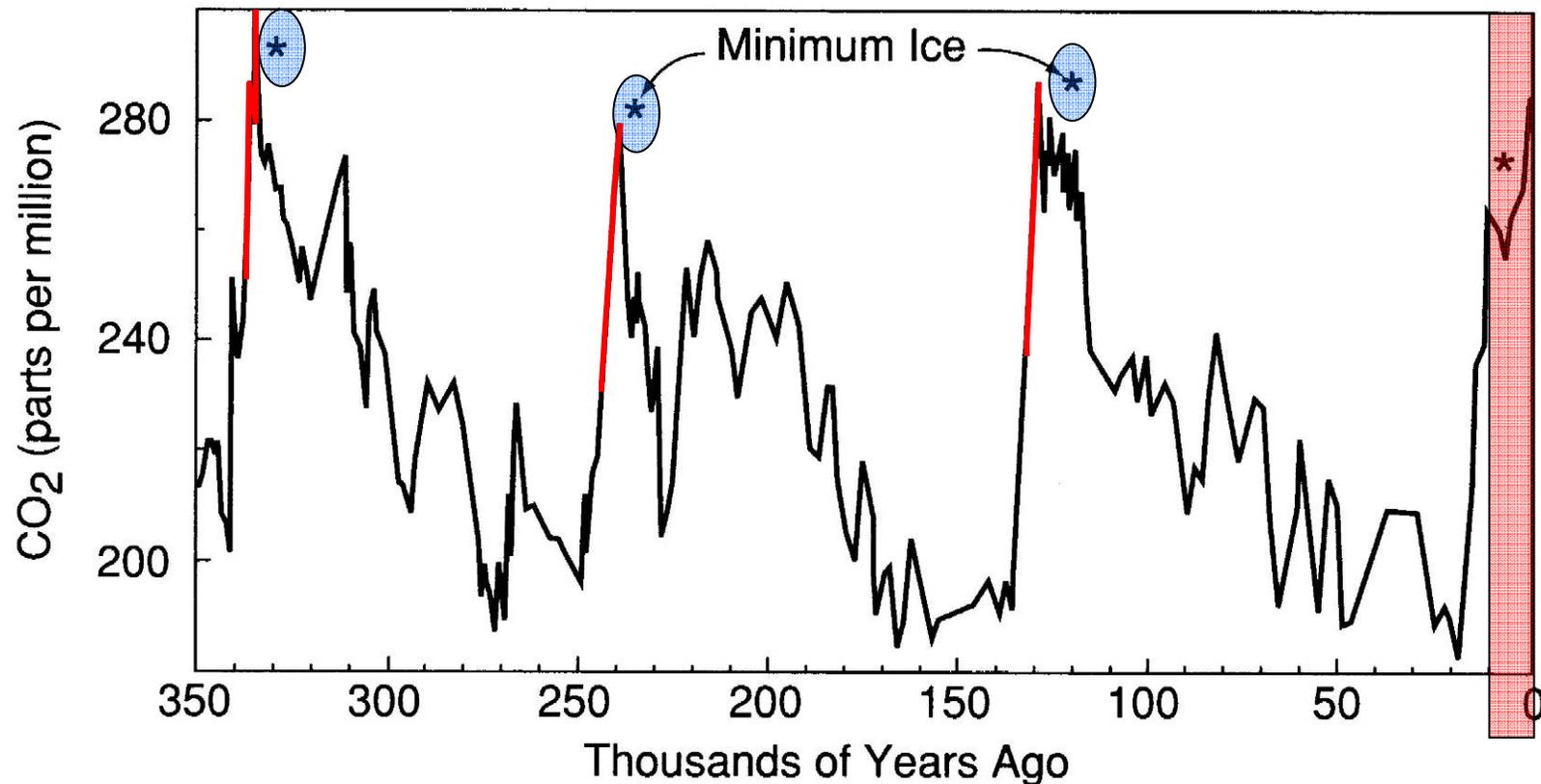


FIGURE 15-15 The spread of agriculture The practice of agriculture originated in the region north and east of the Mediterranean and gradually spread into Europe, North Africa, and other parts of Asia. (Adapted from N. Roberts, *The Holocene*, 2nd ed. [Oxford: Blackwell, 1998].)

Plus, he noticed another anomalous situation. In past orbital cycles temperature always peaked and began to fall just before the ice minimum was reached.

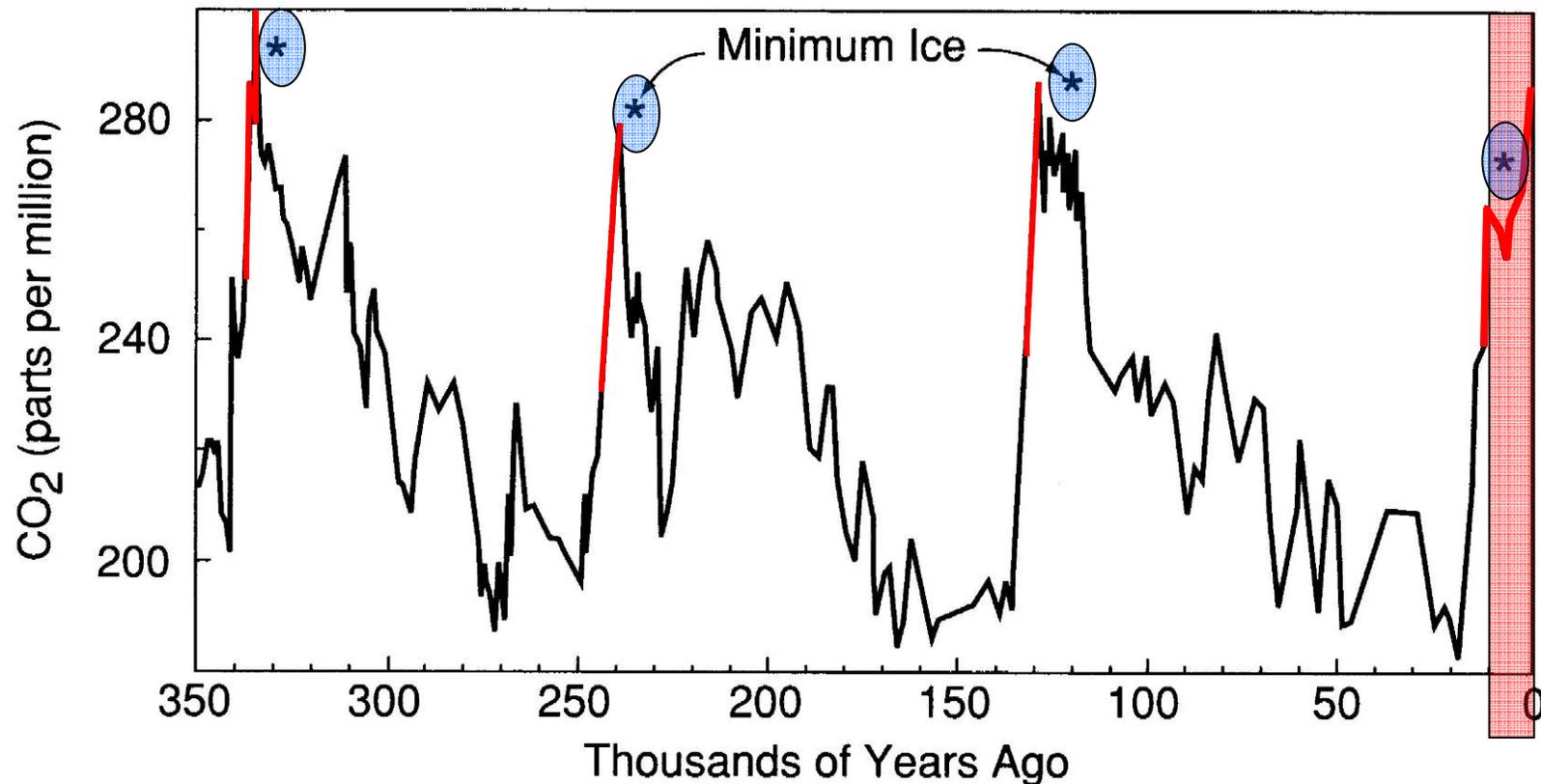
That is, the melting of the ice lagged behind the end of warming (a hysteresis effect). . .

Except for the last warming peak where T has continued to rise after last of ice melted.



After the ice minimum was reached, the temperature dropped for a short while, but then reversed and went back on climbing

Ruddiman argues this correlates with the beginning of rice farming on a wide scale.



The Spread of Agriculture



Unlike other farming, rice farming requires ponded water, and ponded water (like during times of monsoons) allows the expansion of methanogenic populations.

Normally, as the orbital cycling declined toward a minimum, monsoons weakened and lakes began to dry up. This leads to a decline in methane.

But, rice farming created artificial, irrigated wet lands that countered the effects of the declining monsoons.

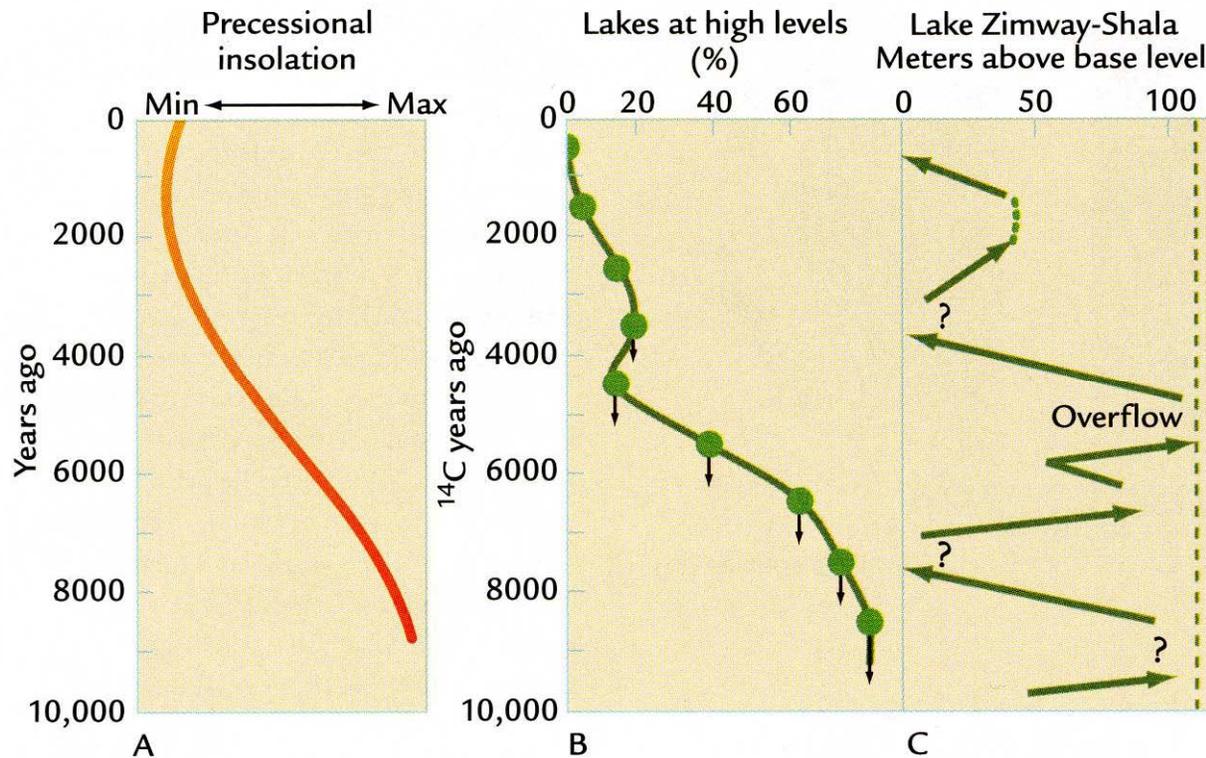


FIGURE 13-16 Weakening monsoons (A) Low-latitude summer insolation has slowly decreased since reaching a maximum value 10,000 years ago. (B, C) The decrease in summer insolation has weakened the summer monsoons and caused lake levels in North Africa to fall. (B: Adapted from J. E. Kutzbach and F. A. Street-Perrott, "Milankovitch Forcing of Fluctuations in the Level of Tropical Lakes," *Nature* 317 [1985]: 130-34. C: Adapted from R. Gillespie et al., "Post-glacial Arid Episodes in Ethiopia Have Implications for Climate Prediction," *Nature* 306 [1983]: 680-83.)

The Spread of Rice Agriculture



© Miguel Cruz. <http://travel.u.nu>

The Spread of Rice Agriculture

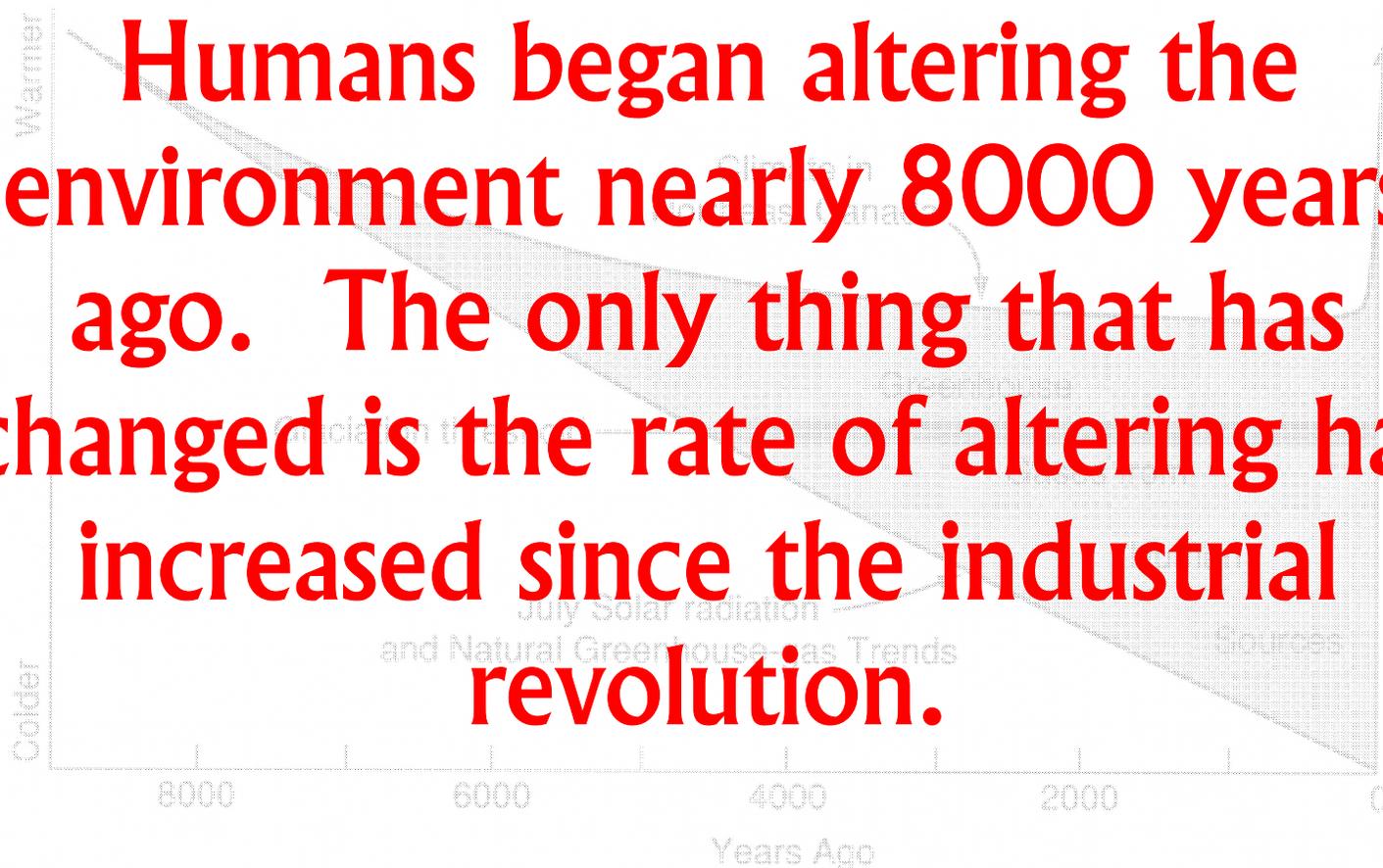


The Spread of Rice Agriculture



We are lead to the conclusion that Earth has not entered another ice age because the generation of greenhouse gasses by humans have overridden the normal orbital cooling trends.

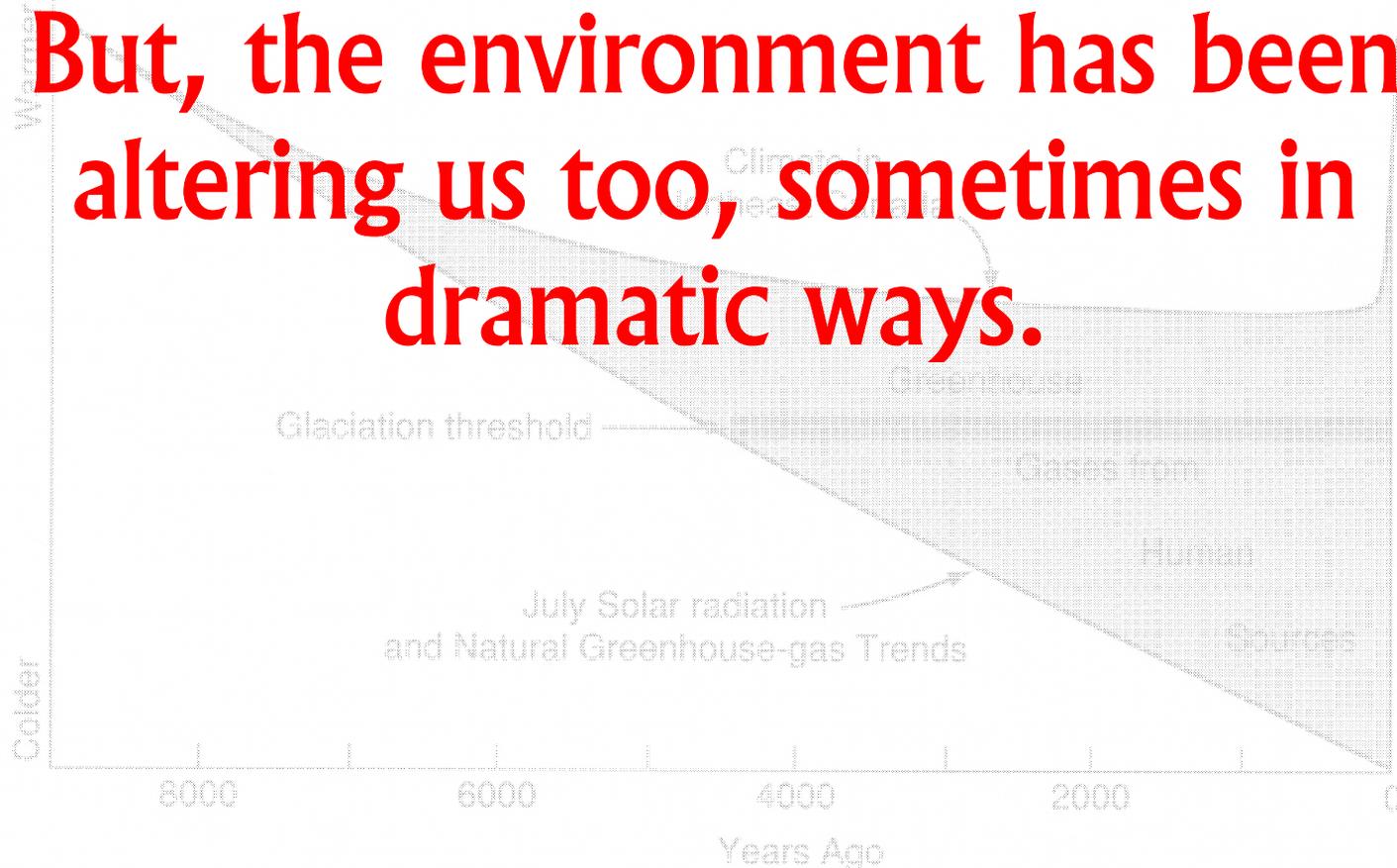
Humans began altering the environment nearly 8000 years ago. The only thing that has changed is the rate of altering has increased since the industrial revolution.



10.3. A natural cooling trend in the Northern Hemisphere should have passed the threshold for initiating a new glaciation several thousand years ago, but greenhouse gases added by humans kept climate warm enough to avoid the start of a new ice age.

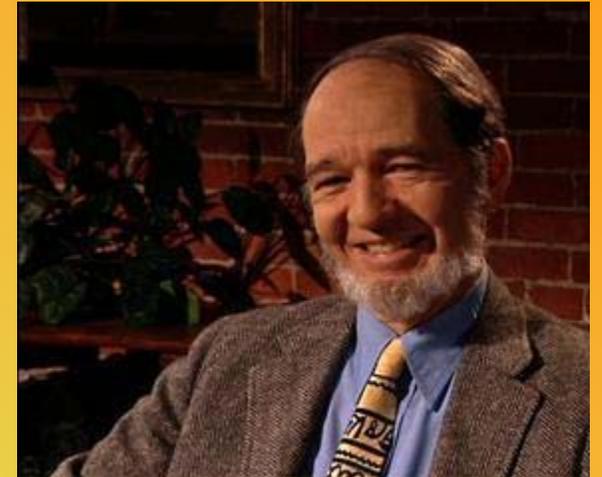
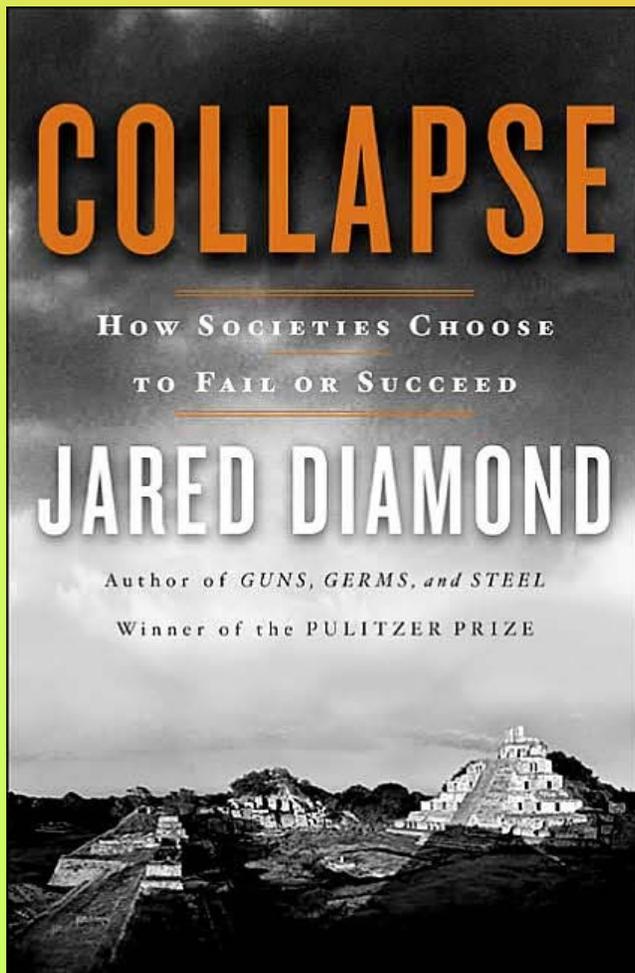
We are lead to the conclusion that Earth has not entered another ice age because the generation of greenhouse gasses by humans have overridden the normal orbital cooling trends.

But, the environment has been altering us too, sometimes in dramatic ways.



10.3. A natural cooling trend in the Northern Hemisphere should have passed the threshold for initiating a new glaciation several thousand years ago, but greenhouse gases added by humans kept climate warm enough to avoid the start of a new ice age.

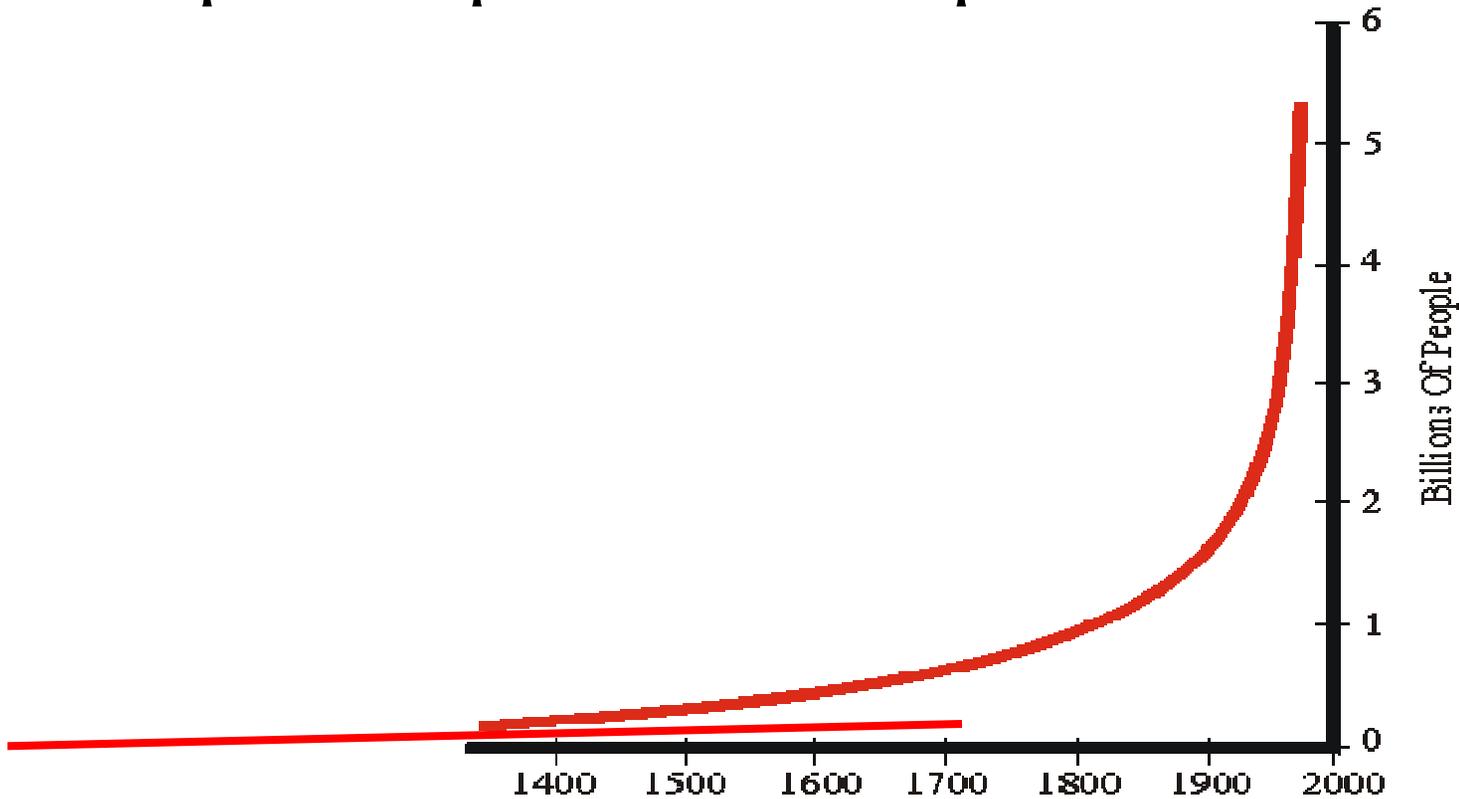
Can one little special really change the environment?



*“How Societies **Choose** to Fail or Succeed”*

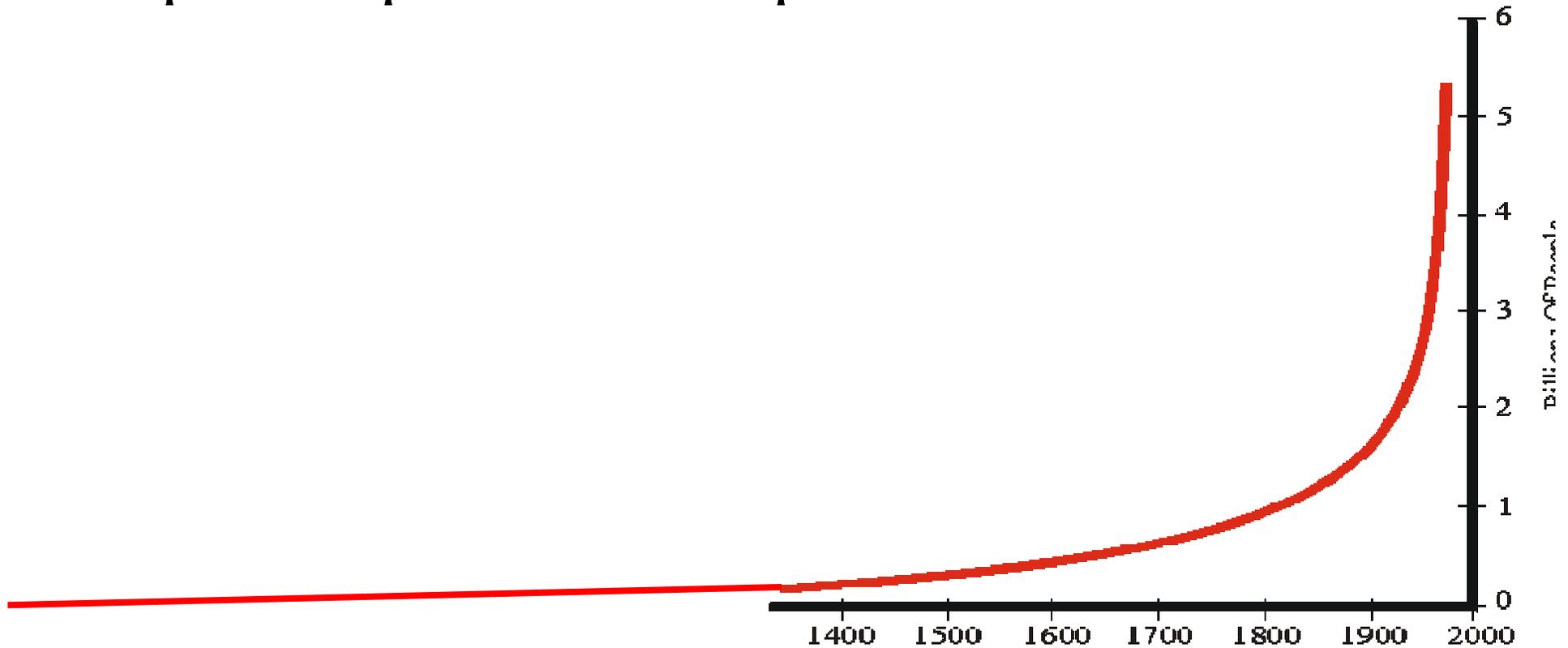
The Growth of the Human Species

Human population growth is currently in a runaway exponential positive feedback process.



And, sometime in the distant past a couple of million years ago the population was near zero.

Human population growth is currently in a runaway exponential positive feedback process.



What Theory Explains Population Patterns ?

Is it normal, or inevitable that populations grow this way ?

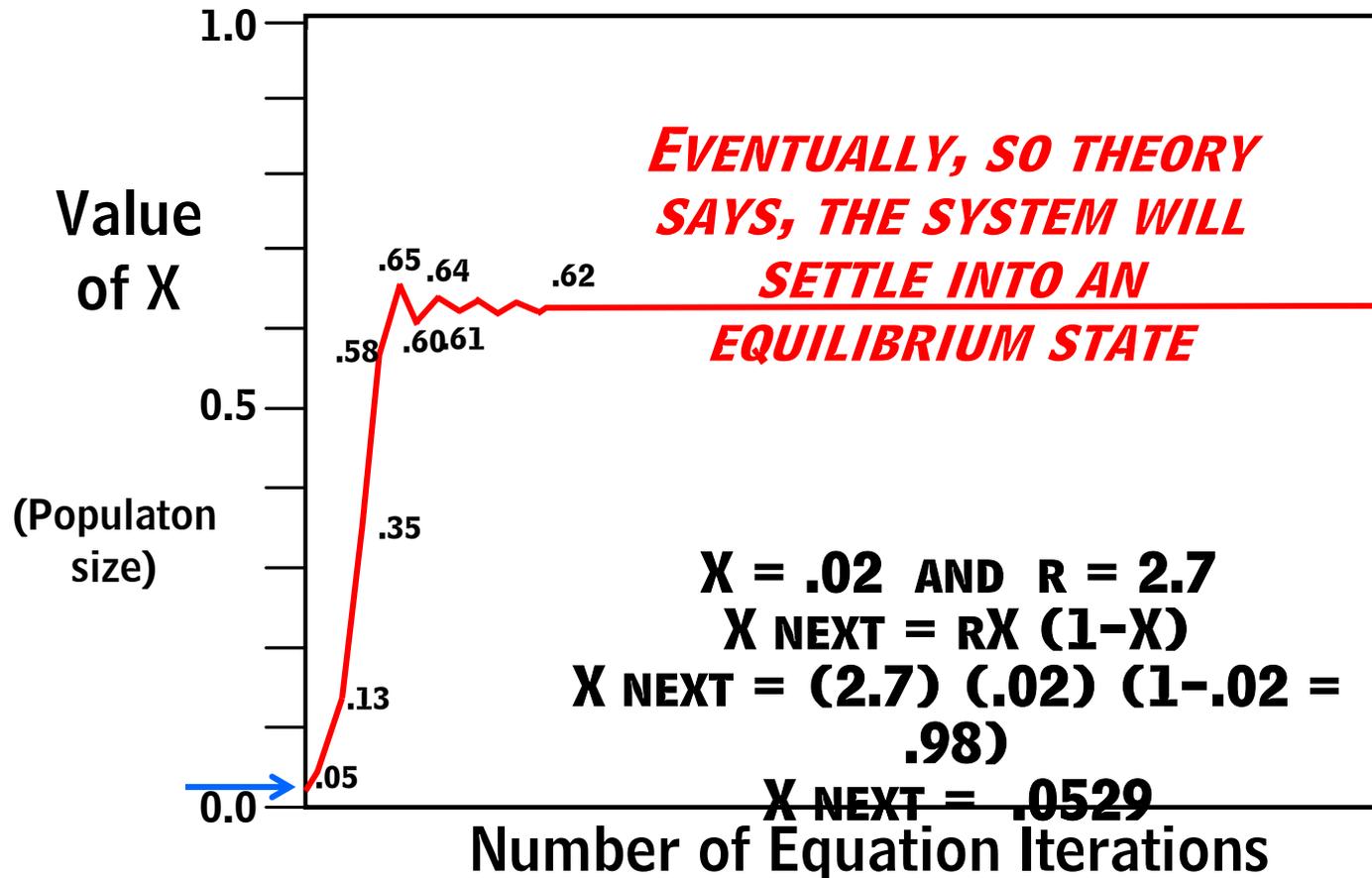
The Logistic Population Curve

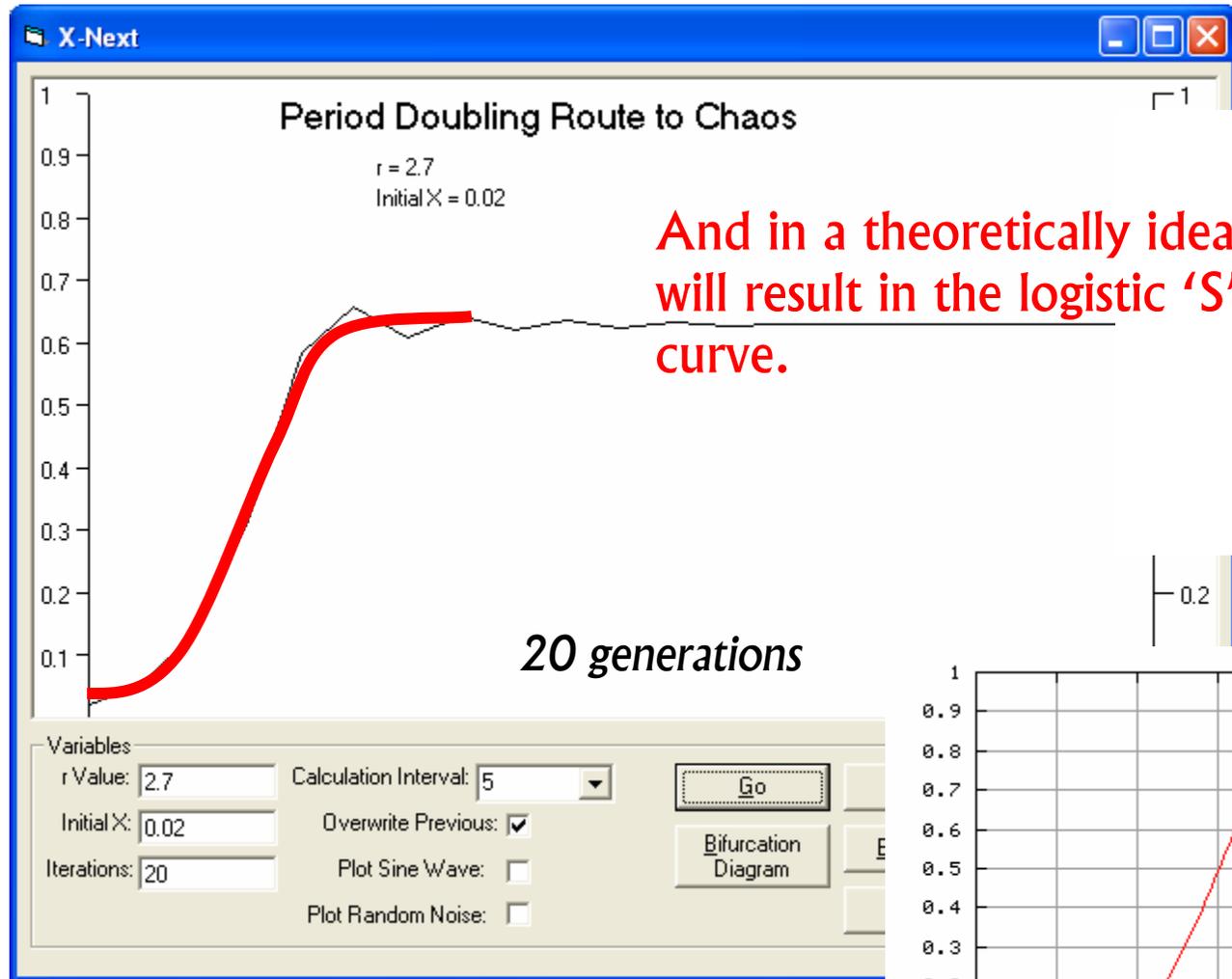
X_{next} and Deterministic Chaos

$$X_{\text{next}} = rX(1-X)$$

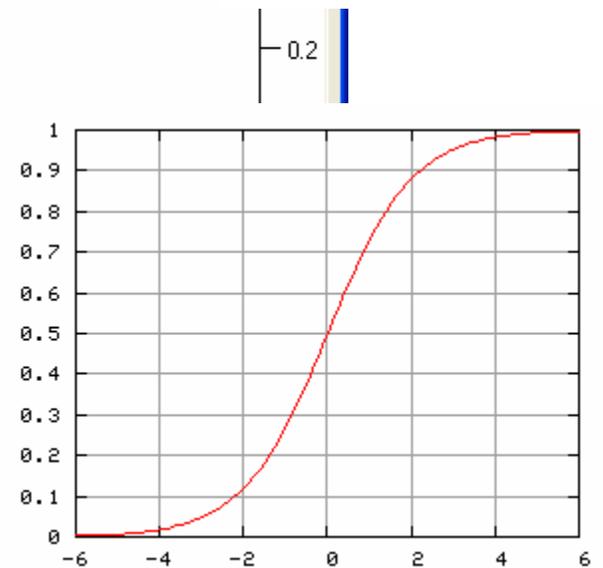
$$r = 2.7$$

ITERATION	X
0	0.0200000
1	0.0529200
2	0.1353226
3	0.3159280
4	0.5835173
5	0.6561671
6	0.6091519
7	0.6428318
8	0.6199175
9	0.6361734
10	0.6249333
11	0.6328575
12	0.6273420
13	0.6312168
14	0.6285118
15	0.6304087
16	0.6290826





And in a theoretically ideal world will result in the logistic 'S' growth curve.



There are two negative feedbacks that serve to control populations.

1. Factors inherent within the human system – e.g. murder, wars, conquest, genocide. **Human Determinism**
2. Environmental stresses – droughts, floods, environmental degradation. **Environmental Determinism**

When population levels are low – below the carrying capacity of the environment – human factors are more prominent.

When population levels expand environmental variables becomes more and more prominent.

- And, environmental influences depend in part on how high the environmental 'r' is.

r and K Selection

How to survive
in stable and
unstable worlds

Unstable Environments 'r' selection

'r' for rapid growth

When environments fluctuate quickly and dramatically massive die offs are common.

Populations fluctuate rapidly.

- *When conditions are favorable organisms reproduce rapidly resulting in rapid population growth – followed by rapid population crashes when environment changes.*
- *Very little energy is put into each individual – because of the short life expectancy.*
- *Individuals tend to be small and to mature rapidly.*

Environment controls population sizes.

Stable Environments 'K' selection

'K' for carrying capacity

When environments are relatively stable.

Populations tend to be stable.

- *Individuals mature late and tend to have long life expectancies.*
- *Lots of time and energy are put into a slowly maturing individual.*
- *Individuals tend to be large and specialized.*

Population regulation takes place within the species itself

Unstable
Environments
'r' selection

'r' for rapid growth

Stable
Environments
'K' selection

'K' for carrying capacity

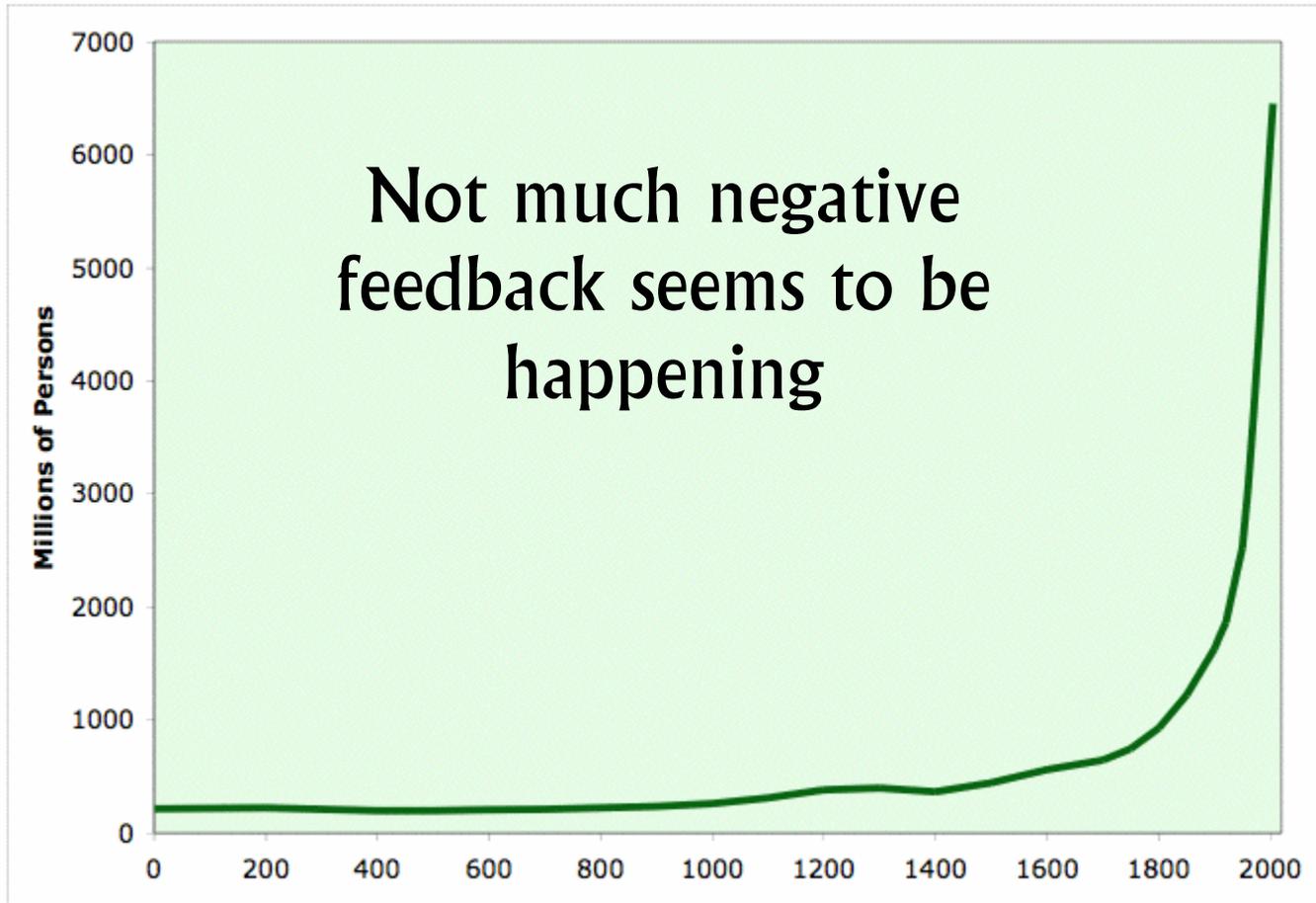
The problem is
Humans breed like 'r' selectors
But, are a 'K' selection organism.



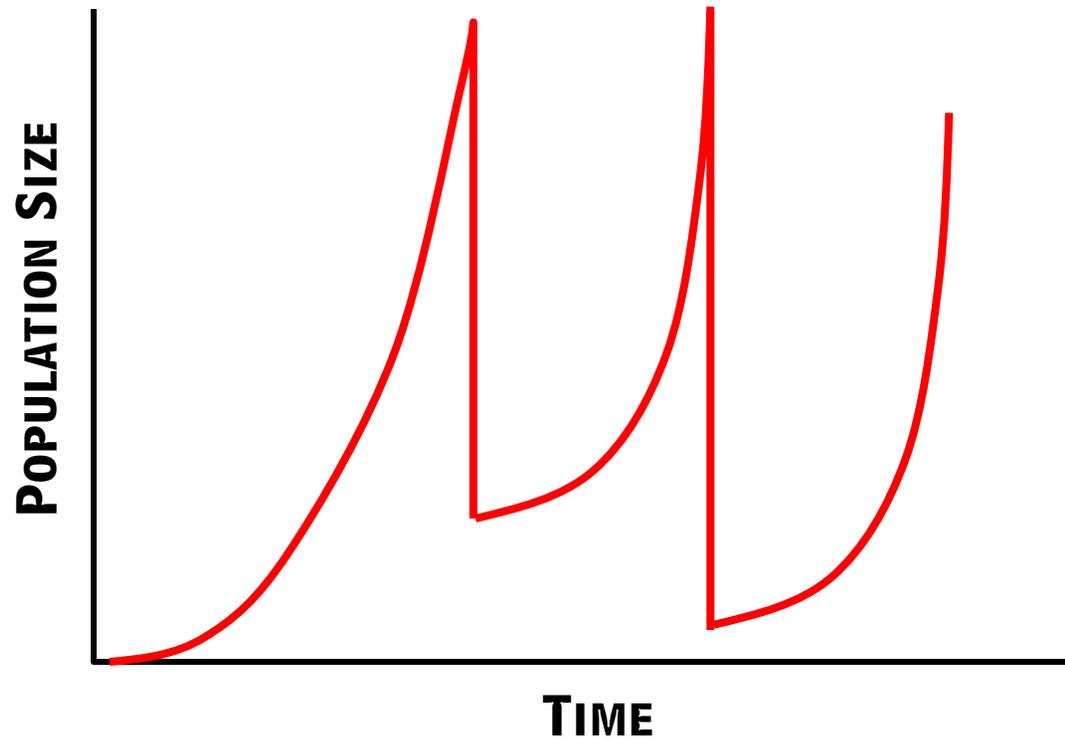
We breed, and breed, and breed

And because of technology, modern farming,
medicine, fertilizer

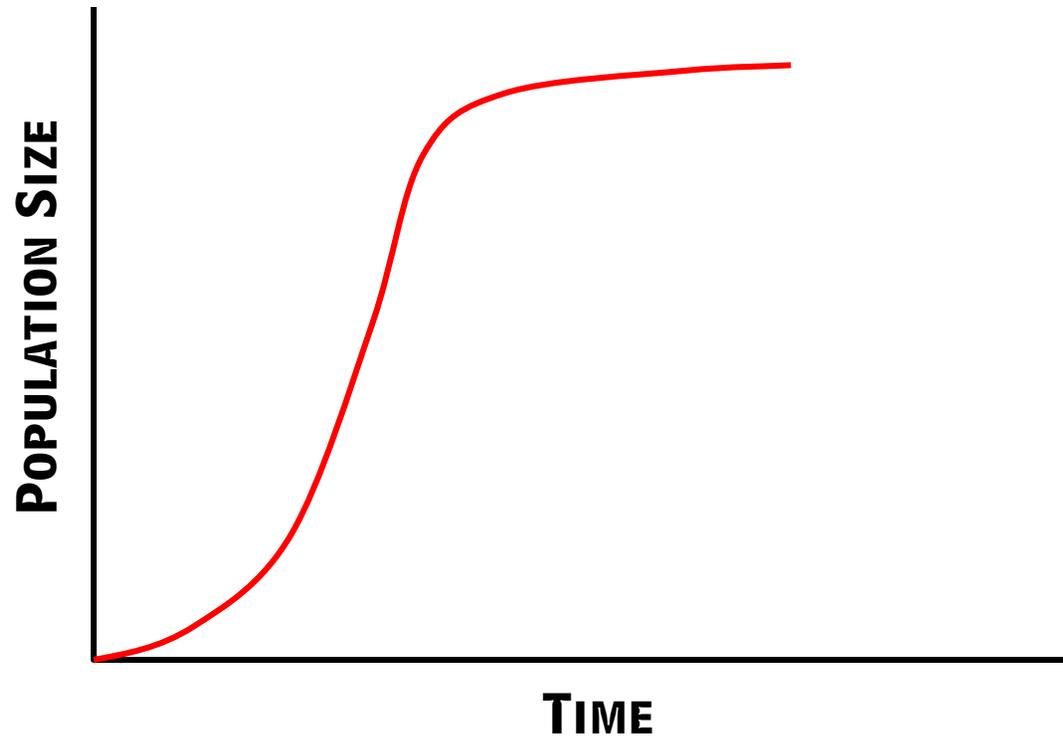
Individuals survive to old age and the population just
keeps growing, and growing, and growing.



So, if we breed like an 'r' selector, then we might expect the population cycle to go like this.



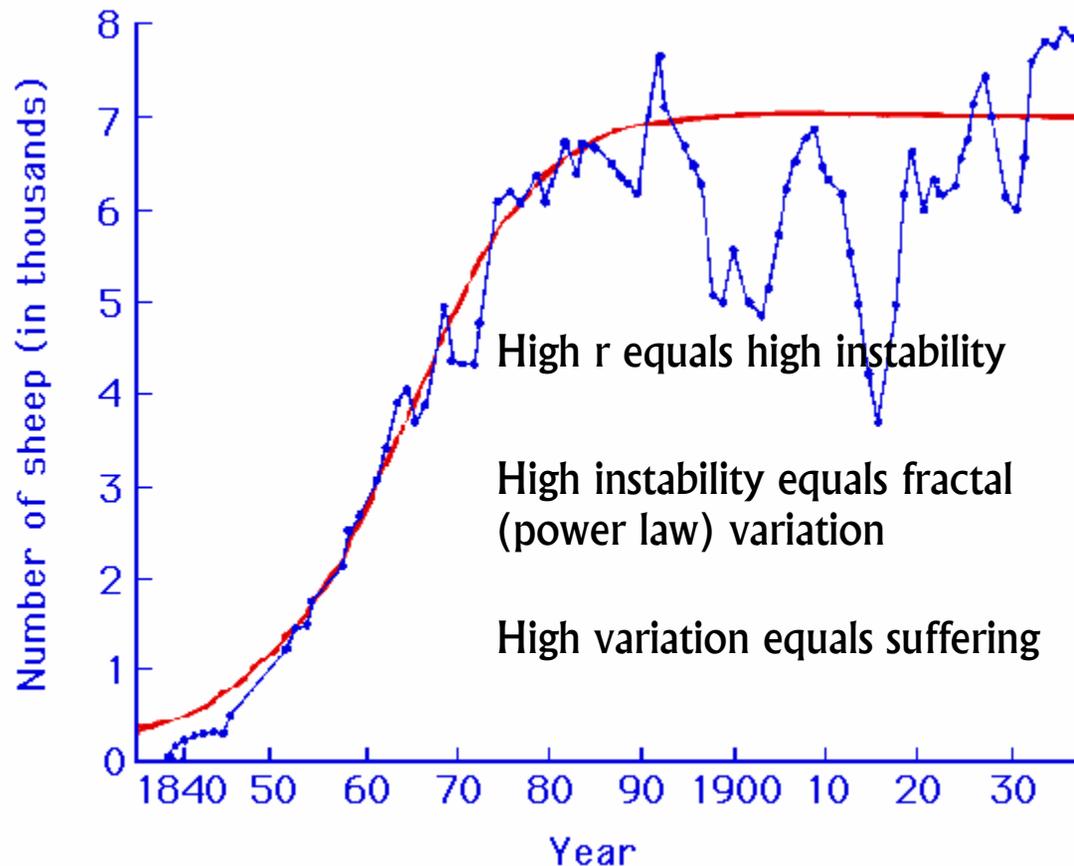
But, if we breed like a 'K' selector, then we might – theoretically - expect the population cycle to go like this.



So far human population has not shown itself ready to do either.

Although there is a third option.

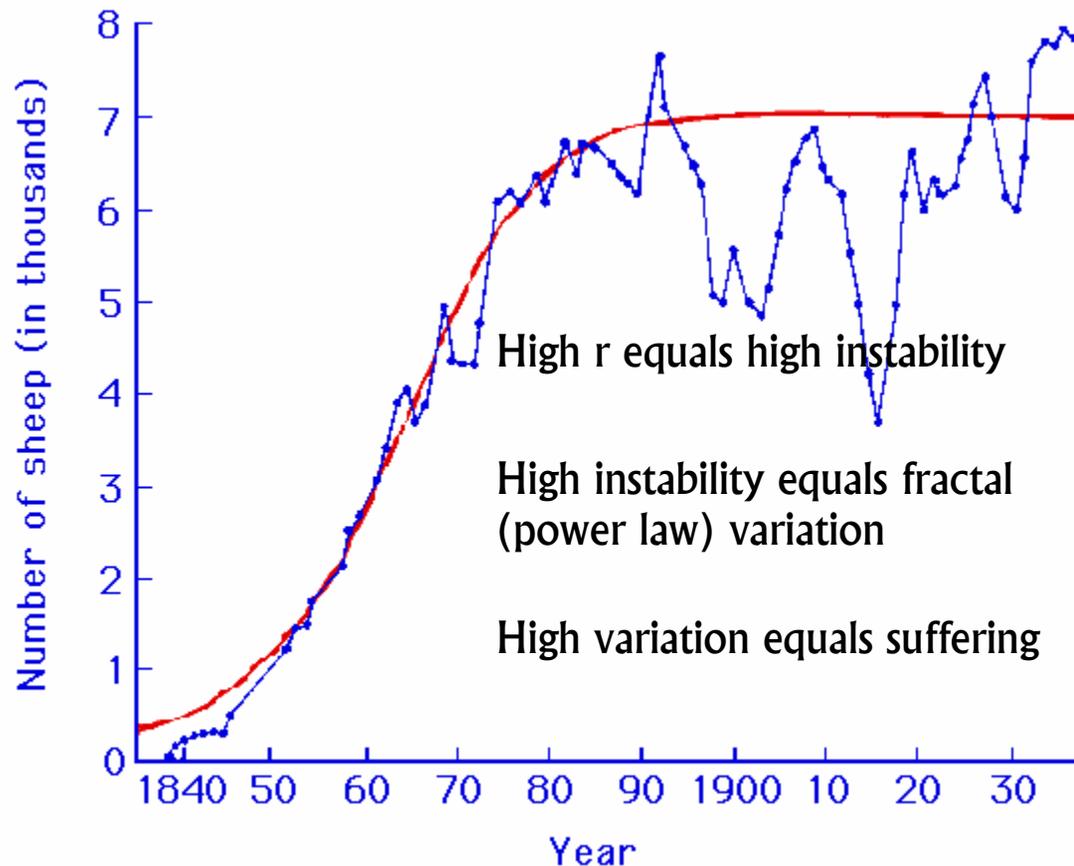
We have already observed that population growth does not follow a smooth 'S' shape



“The exponential growth phase exists because that is when the population has already begun to grow, but not a lot yet, and it rises quickly because there are no limiting factors yet and the resources are in unlimited amounts. The plateau phase begins when the organism hits its carrying capacity, which is the maximum number of organisms in a population that can be supported by the environment at a certain time, in a certain ecosystem. The transitional phase in between these two phases occurs because this is when the limiting factors in the environment start to limit the increase, slowing the population increase.”

A brave attempt to make a real population curve follow a logistic 'S' shape.

We have already observed that population growth does not follow a smooth 'S' shape

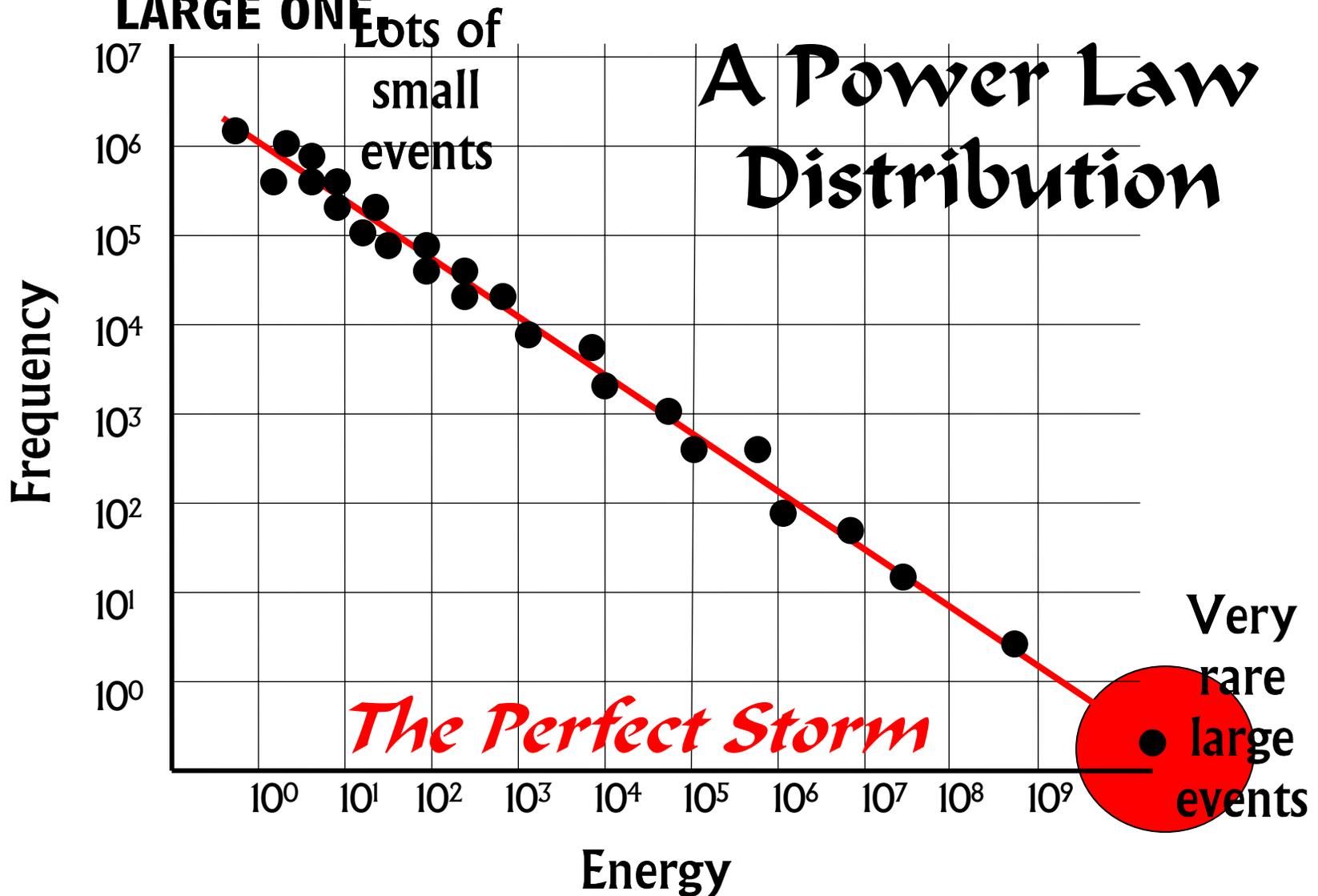


Rapid population fluctuations occur regularly, even today.

- Genocide in Darfur
- Banda Ache tsunami
- Earthquakes

So, even though the population trend has been inexorably upward it has not been smooth.

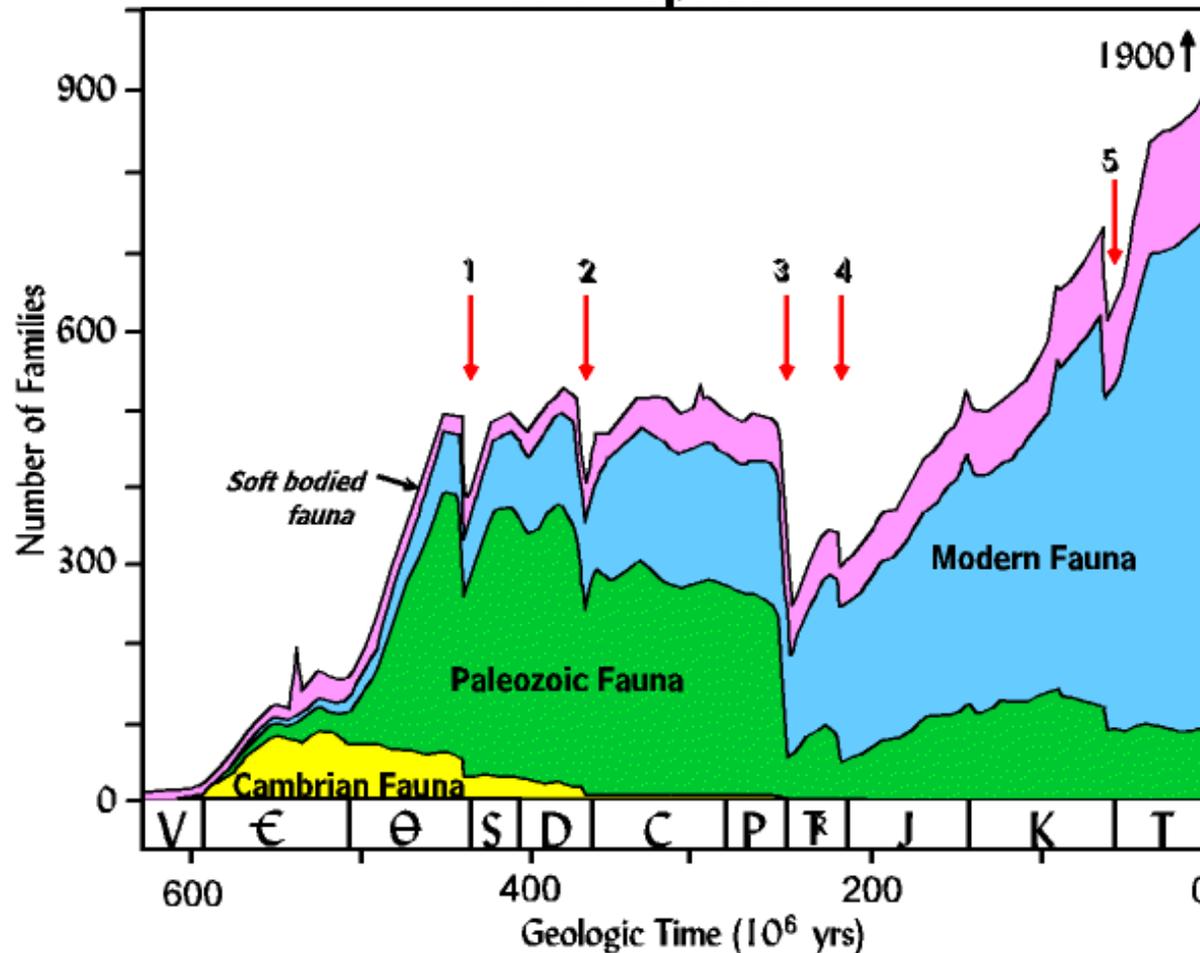
BUT, IF COMPLEX SYSTEMS FOLLOW A POWER LAW – THEN WE EXPECT THAT AMONG ALL THE SMALL DIE OFFS THERE SHOULD OCCASIONALLY COME A VERY LARGE ONE

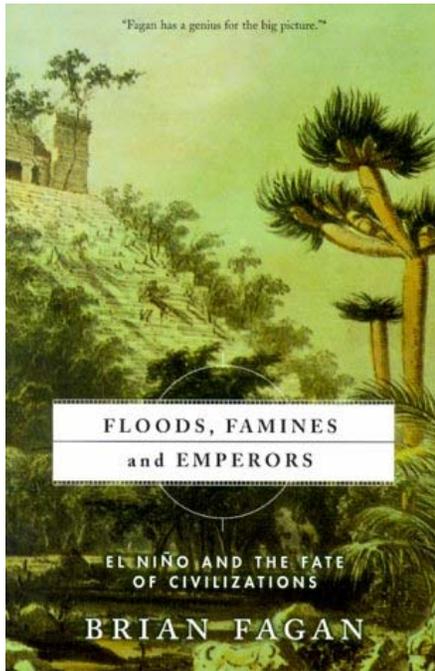


WHICH IS EXACTLY WHAT WE SEE WHEN WE LOOK AT DIEOFFS (EXTINCTIONS) OVER LONG ENOUGH PERIODS OF TIME TO SEE WHAT IS REALLY HAPPENING

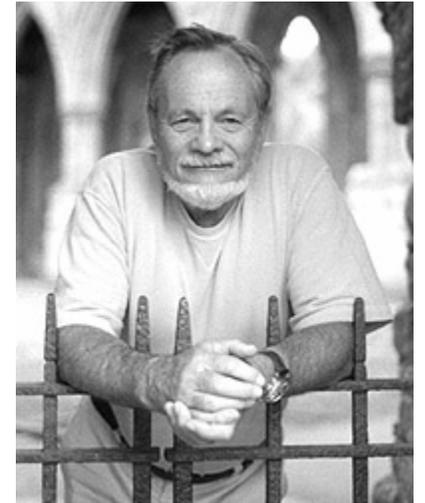
Diversity of Invertebrate Organisms

J.J. Sepkoski





“It has become fashionable in some circles to believe that human innovation will always triumph, and that population, with its inevitable needs for food, space, and waste disposal, may therefore expand indefinitely.”



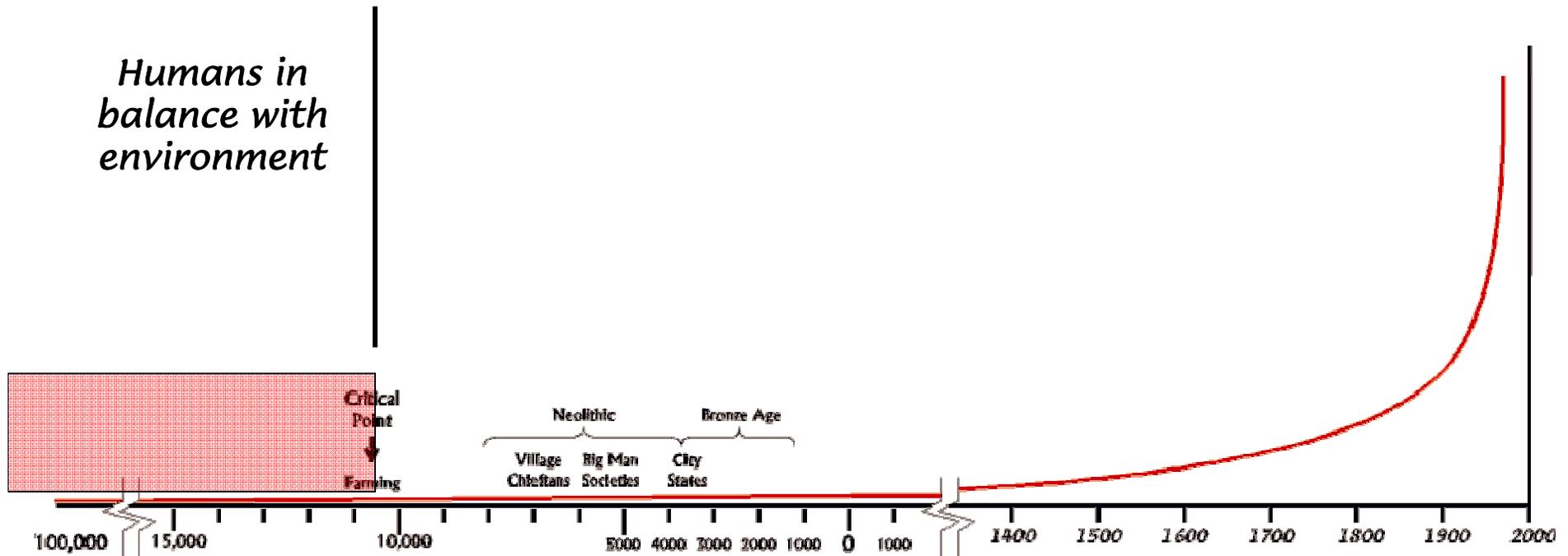
“It this were true, it would mean that humanity has entered a new and unprecedented era.”

Sustainable Growth

“However, archaeologists of the future may find this belief in infinitely bountiful technology as quaint and touching as a magical faith in divine kings.”

Human Sustainability, or Lack Thereof

Human Population Growth Curve



Before 15,000 years ago the ability of the world's environment to support animals and people still exceeded the needs of the human population.

Stone age people lived in tiny family bands and occupied home territories extensive enough for them to be able to move around freely, even over large distances, using highly flexible survival strategies. (77)

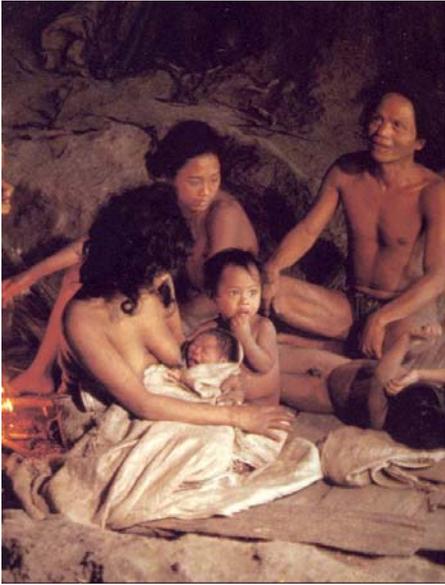
Foraging Tribes



A pantribal association of elder men in the tribe who met to discuss important issues affecting their tribe.

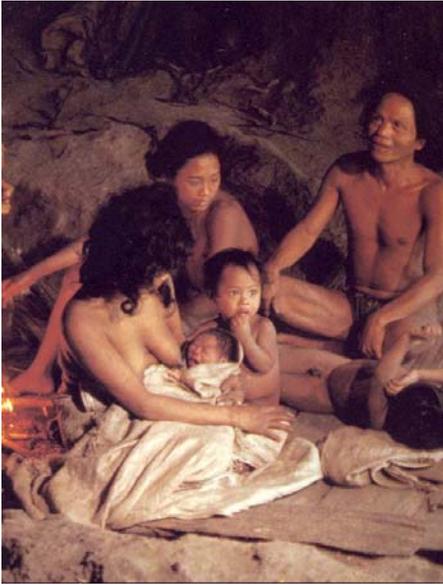
No single person in charge, although men usually made all the larger decisions.

If a small African foraging band experienced two consecutive drought years, they simply moved . . .



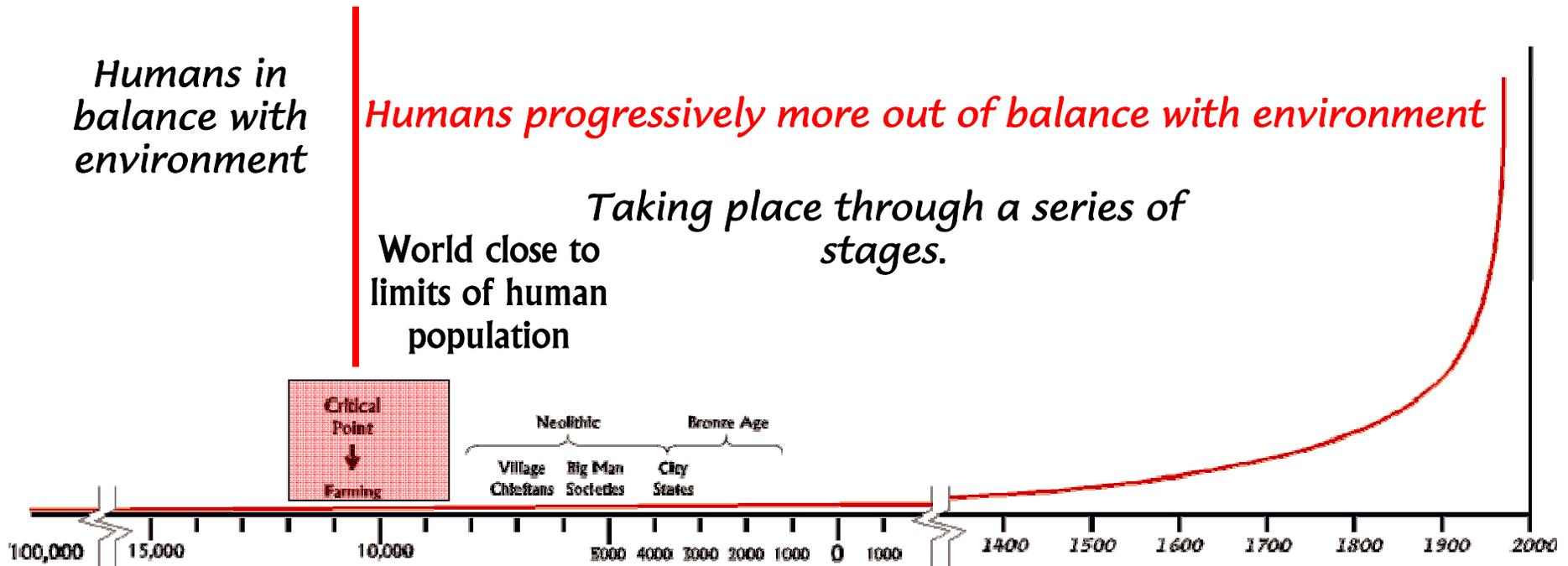
Fifteen thousand years ago, most Stone Age people lived in tiny family bands and occupied home territories extensive enough for them to be able to move around freely, even over large distances, using highly flexible survival strategies.

Our Stone Age ancestors were opportunistic, accustomed to sudden climatic change, and able to adapt to it in ways that became impossible when populations rose rapidly after the latest Ice Age. Until about 11,000 years ago, when farming appeared, earth's population had not yet reached the critical point where it exceeded the natural carrying capacity of the land. Experience, low population densities, and the sheer flexibility of human existence allowed Stone Age foragers all over the world to ride with the punches of the global weather machine. P 77



For hundreds of thousands of years, there was plenty of room for people to move around – to come together in plentiful months and disperse in times of scarcity. They always had mechanisms to help one another, as well as the space to disperse when famine threatened. P 244

Human Population Growth Curve



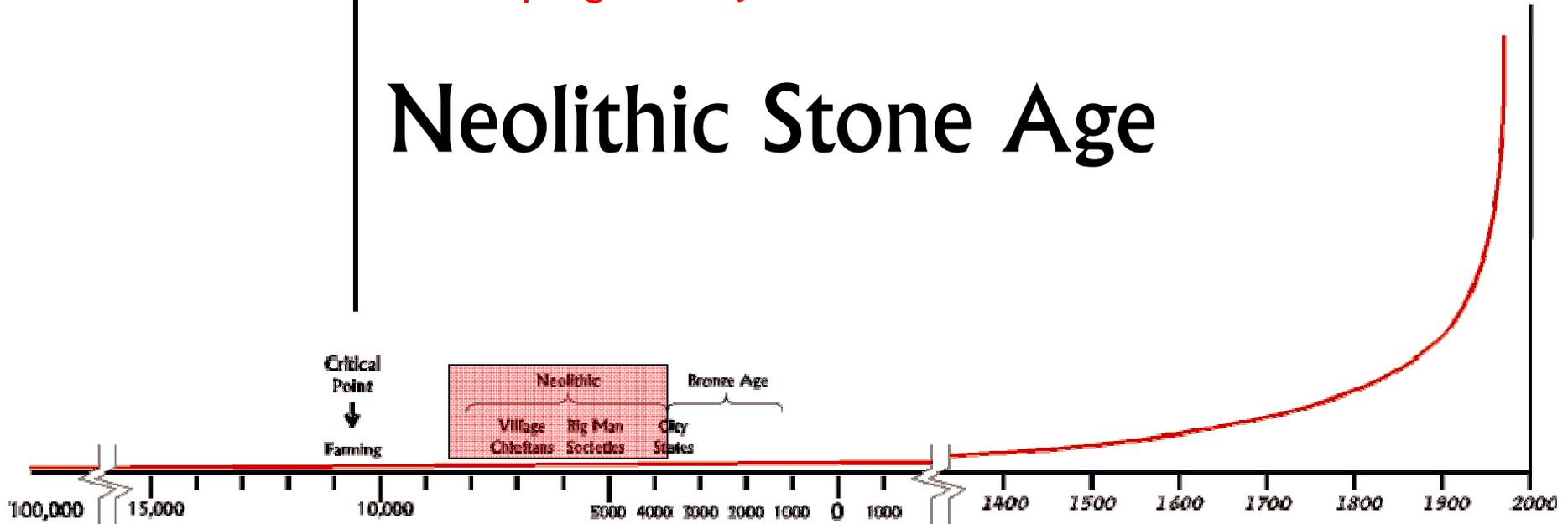
Until about 11,000 years ago, when farming appeared, Earth's population had not yet reached the critical point where it exceeded the natural carrying capacity of the land.

The critical point was crossed when humans learned to plant crops, rather than just gather them.

Human Population Growth Curve

Humans progressively more out of balance with environment

Neolithic Stone Age

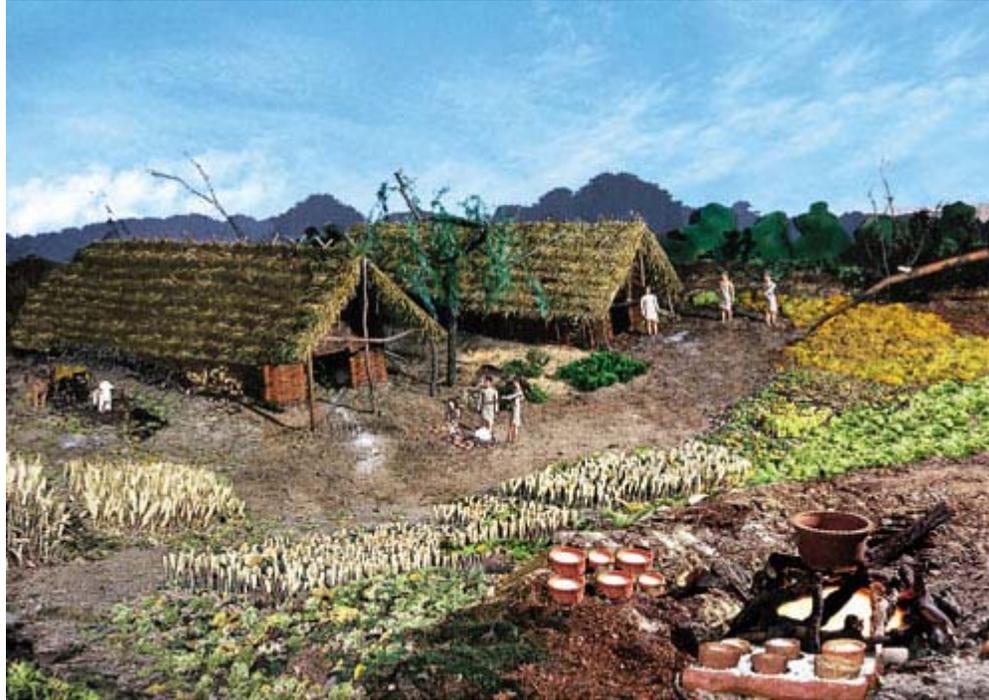


Hunter-gatherers begin crowding into small territories and permanent camps along rivers and lakes.

Environment became "full". Few environments on earth can support more than one or two foragers per square kilometer.

Even the most prosperous of these Stone Age groups were far more vulnerable to sudden climate change than their predecessors had been, simply because they could not move. 81

Neolithic Farming Village



The model of a Neolithic village (5500-3500 B.C.) was made following archaeological findings in the Wieliczka area.

Mehrgarh Neolithic Farming Village



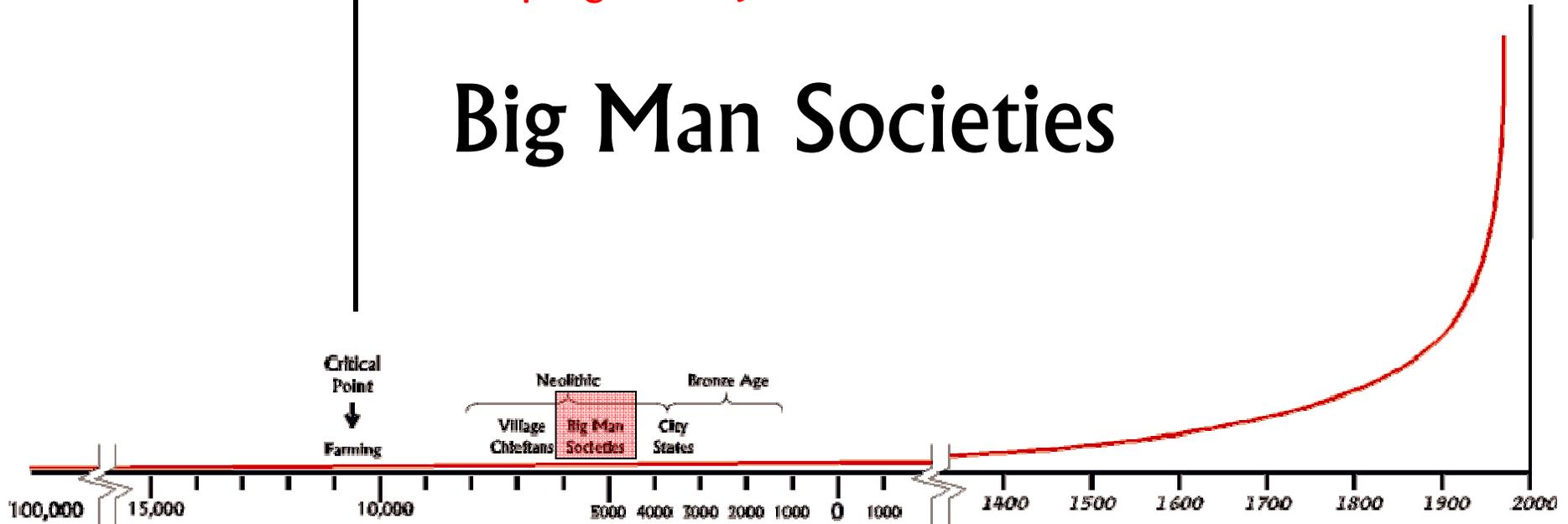
Mehrgarh, one of the most important Neolithic (7000 BCE to 3200 BCE) sites in archaeology, lies on the "Kachi plain of Baluchistan, Pakistan, and is one of the earliest sites with evidence of farming (wheat and barley) and herding (cattle, sheep and goats) in South Asia."

Early Mehrgarh residents lived in mud brick houses, stored their grain in granaries, fashioned tools with local copper ore, and lined their large basket containers with bitumen. They cultivated six-row barley, einkorn and emmer wheat, jujubes and dates, and herded sheep, goats and cattle. Residents of the later period (5500 BCE to 2600 BCE) put much effort into crafts, including flint knapping, tanning, bead production, and metal working. The site was occupied continuously until about 2600 BCE.[]

Human Population Growth Curve

Humans progressively more out of balance with environment

Big Man Societies



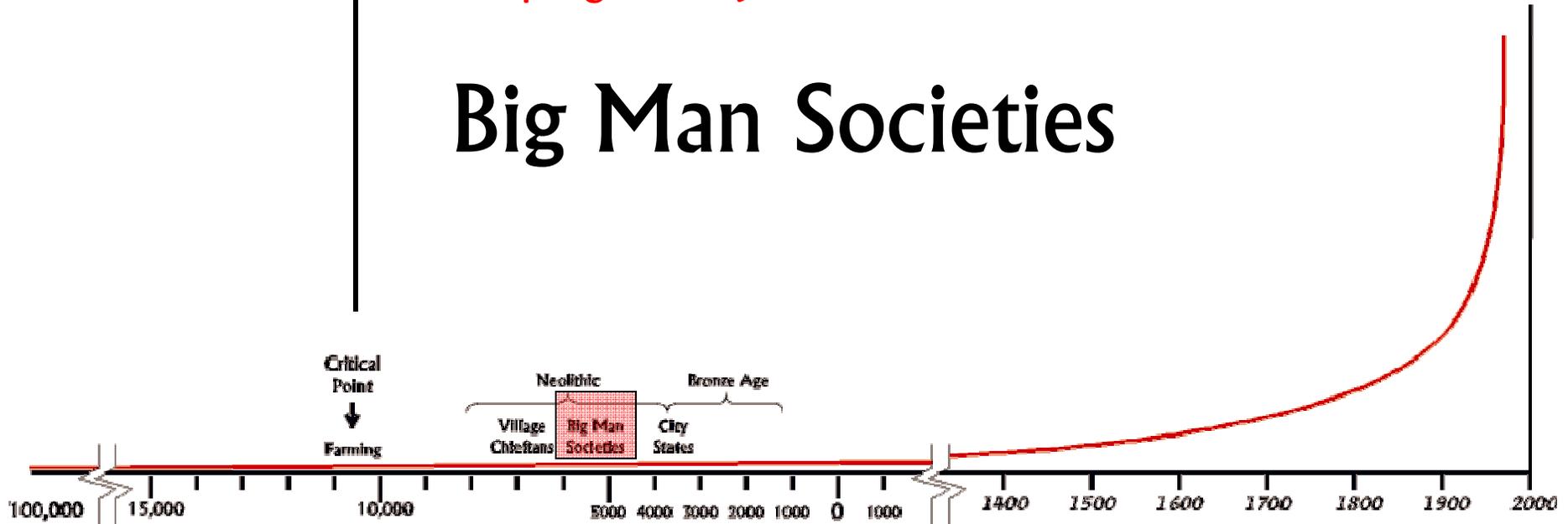
As farming expanded people lived close to one another for longer periods of time, even if they did not get on well together.

Whereas once they had simply moved away, now they needed firm leadership, based on more than just long experience, that took account of public opinion and ensured an equitable distribution of food supplies in times of need.

Human Population Growth Curve

Humans progressively more out of balance with environment

Big Man Societies

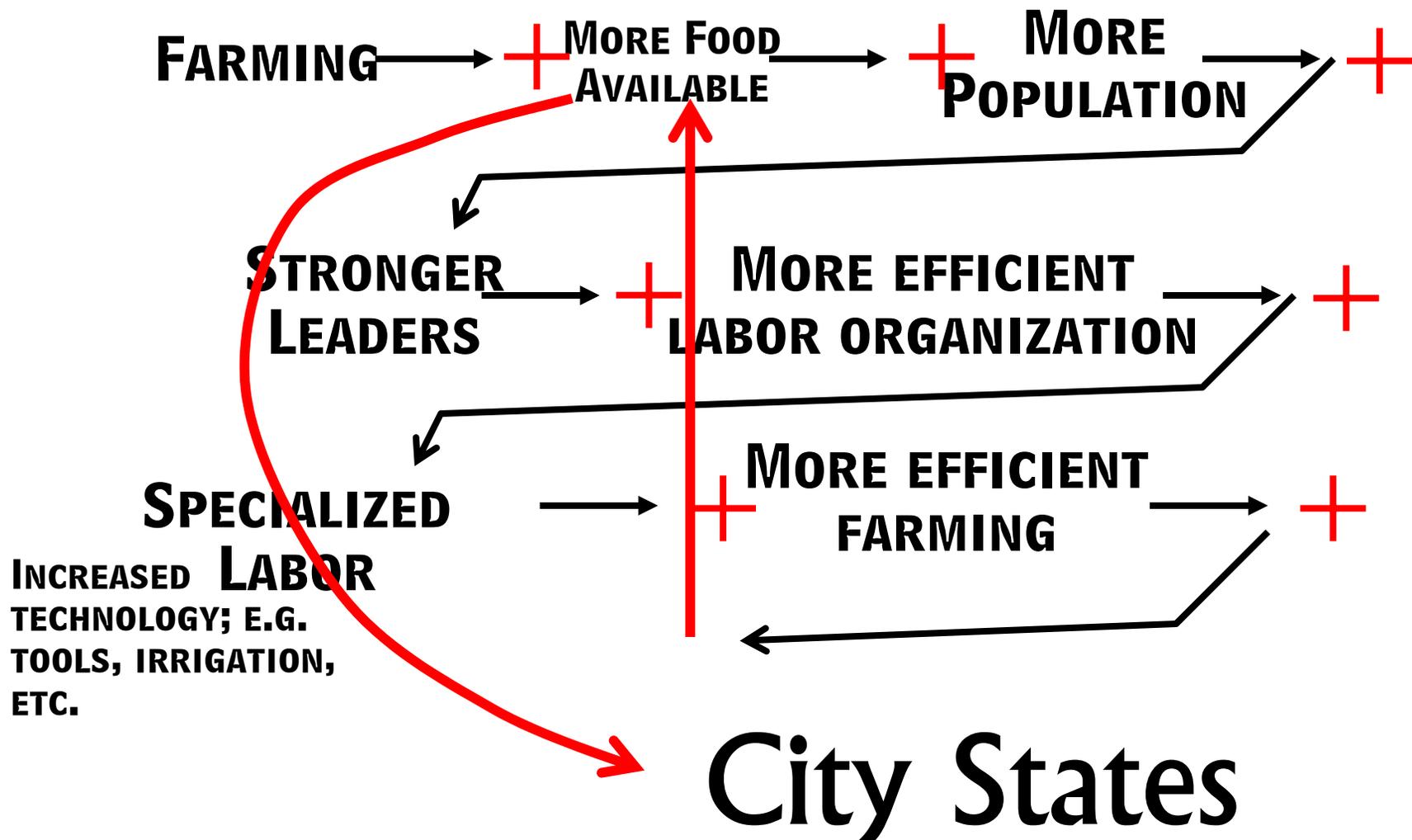


Crowded into somewhat larger communities than foraging camps, people now also needed leaders to mediate disputes over domestic matters and foraging rights.

Groups of tribal elders were not able to work efficiently in the expanding urban population, especially as populations grew to the point where people could not have a personal relationship with everyone else in the community.

Establishment of Positive Feedback Loops

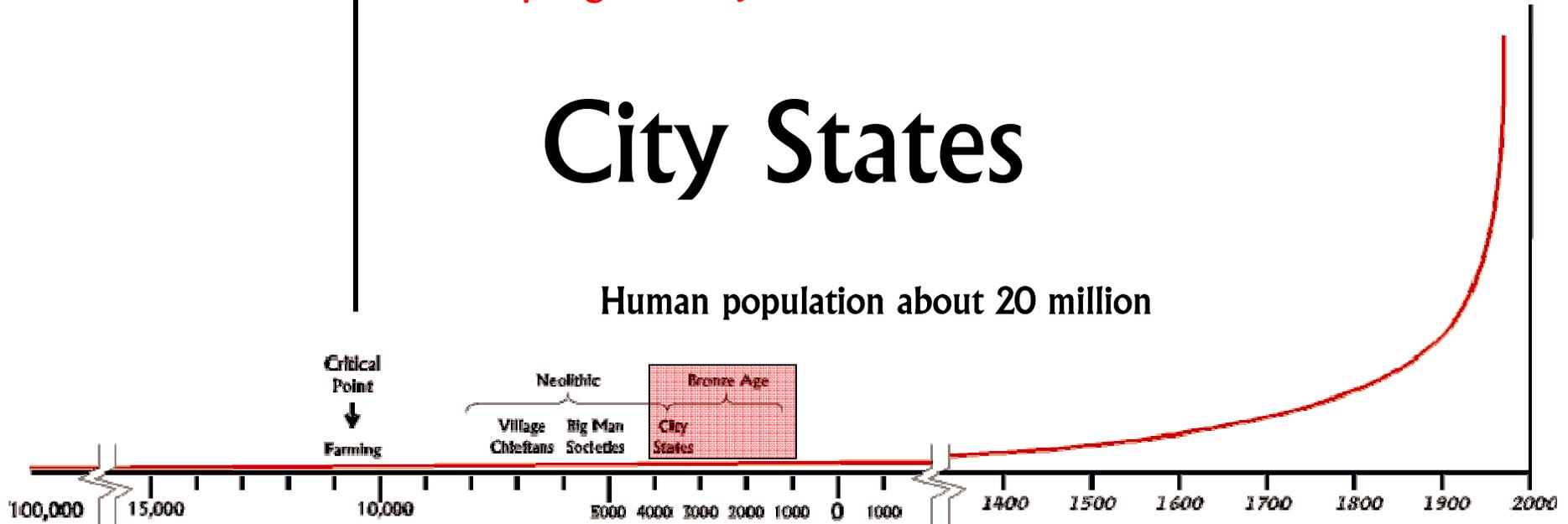
Once we moved from hunter-gatherer to farming in settled communities a series of positive feedbacks began to drive the evolution of human society.



Human Population Growth Curve

Humans progressively more out of balance with environment

City States



About the year 3000 BC there begins accelerating population growth that has not ceased to this day.

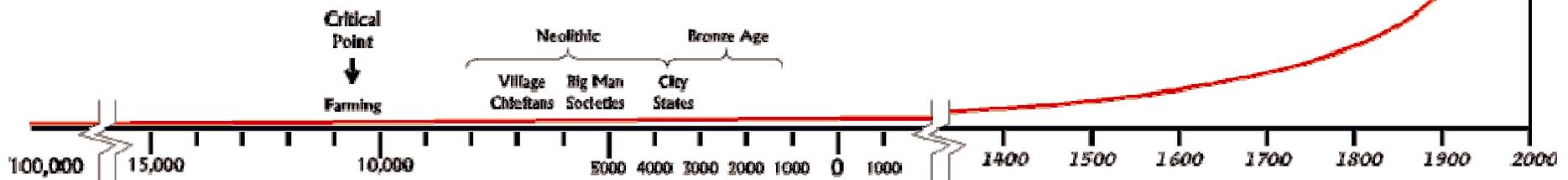
Farming turned aside a slow-burning population crisis with such success that six thousand years later farming had become the dominant lifeway throughout Europe and Asia.

But the new strategies required not village kin leaders and chiefs, but authoritarian rulers with exceptional supernatural powers. 51

Social Stratification

As local populations grew the society began to become highly stratified.

- Kings and Pharaohs, who take on personification of Gods.
- Court officials
- Artisans and scribes



- The masses, poor and ignorant

Society becomes very top heavy and top down.

Flexibility declines and social stratification becomes more rigid.

- There is no consensus building. The God-King is all powerful and cannot be voted out of office.

This was the moment when urban populations in circumscribed environments require highly productive agriculture just to survive, let alone make it through drought cycles or natural disasters.

They have placed many of their economic eggs in a single basket. A strategy that worked well until El Niño or other climatic anomalies brought drought or torrential rains that swept away in a few days the work of generations.

Summary

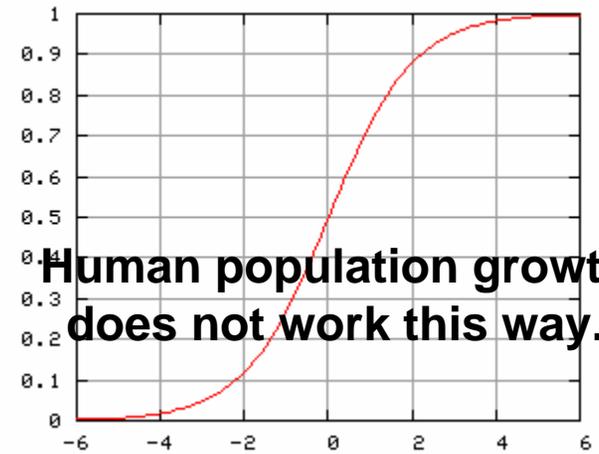
Self Organized Criticality
highly shock sensitive

increasing
loss of flexibility

subistence farming population growth irrigation increasing technical solutions

When carrying capacity is exceeded and technology or social engineering cannot restore the balance, all humanity can do is disperse – if there is the space to do it..

If there is not the space, then

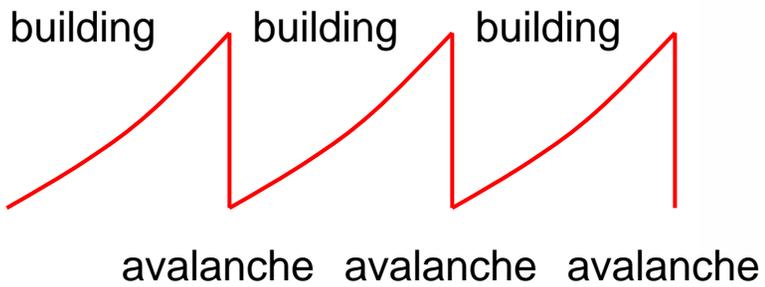
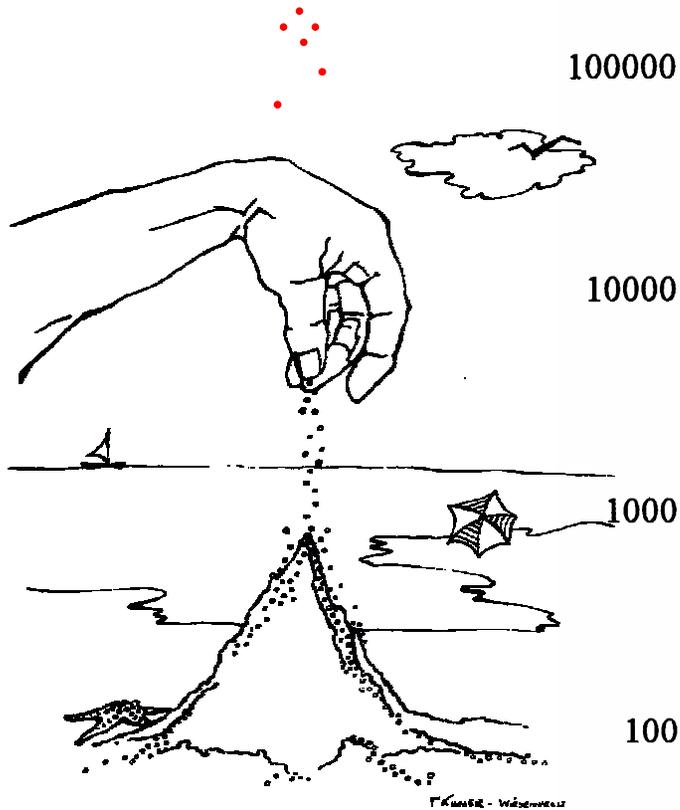


Human population growth does not work this way.

This curve is deceptive. It is so long it looks smooth. But like all complex systems it is fractal.

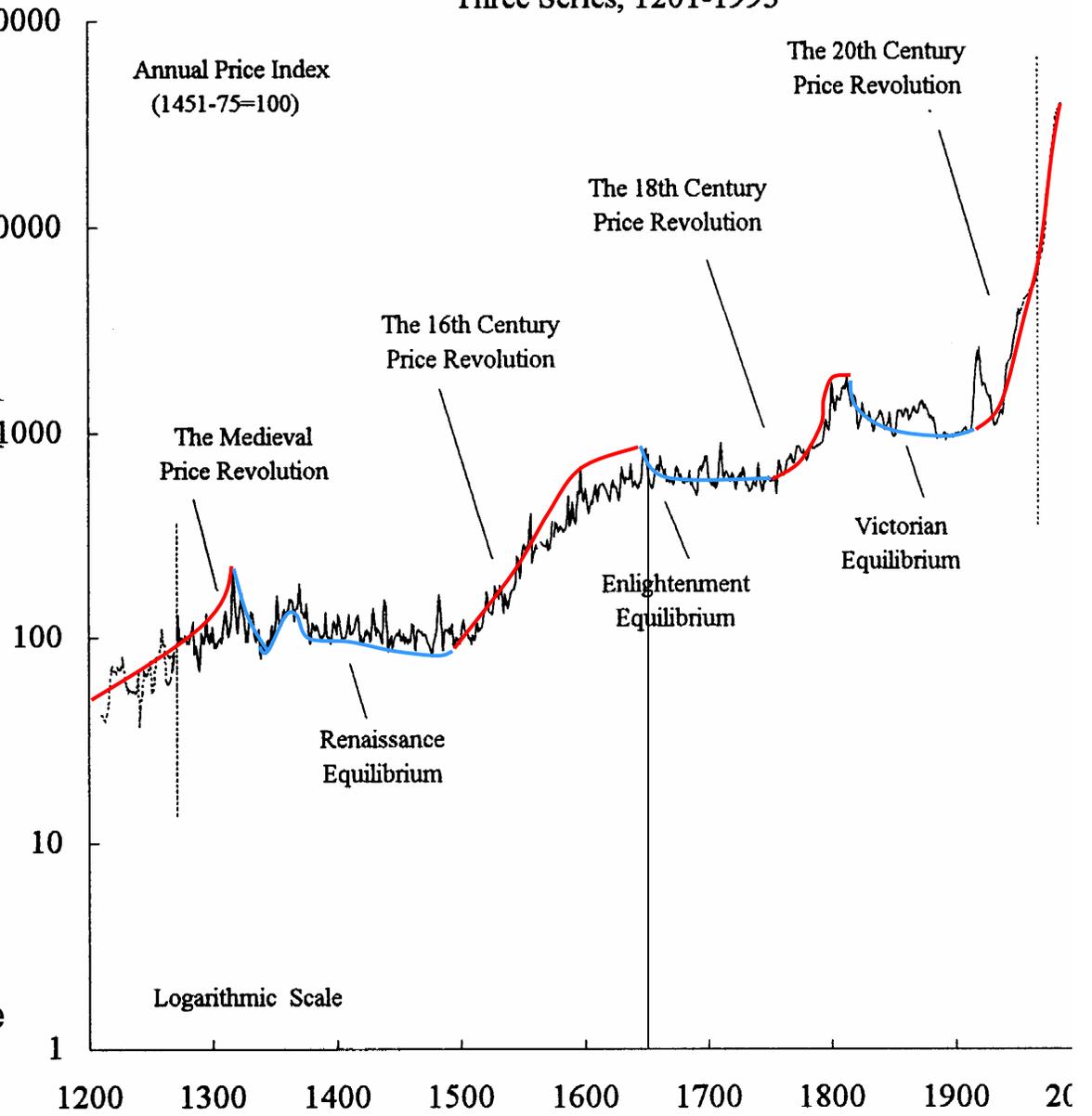


FRACTAL SAND SUPPLY



The Price of Consumables in England

Three Series, 1201-1993



Annual Price Index
(1451-75=100)

The 20th Century
Price Revolution

The 18th Century
Price Revolution

The 16th Century
Price Revolution

The Medieval
Price Revolution

Victorian
Equilibrium

Enlightenment
Equilibrium

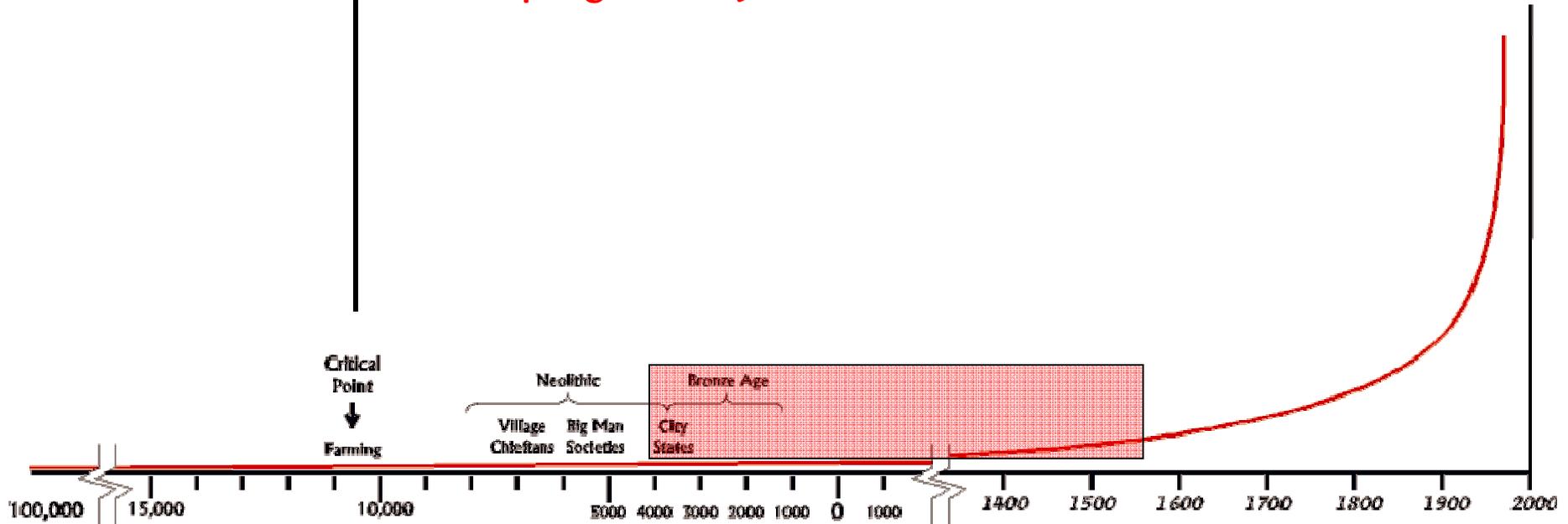
Renaissance
Equilibrium

Logarithmic Scale

1200 1300 1400 1500 1600 1700 1800 1900 2000

Climate and Culture

Humans progressively more out of balance with environment

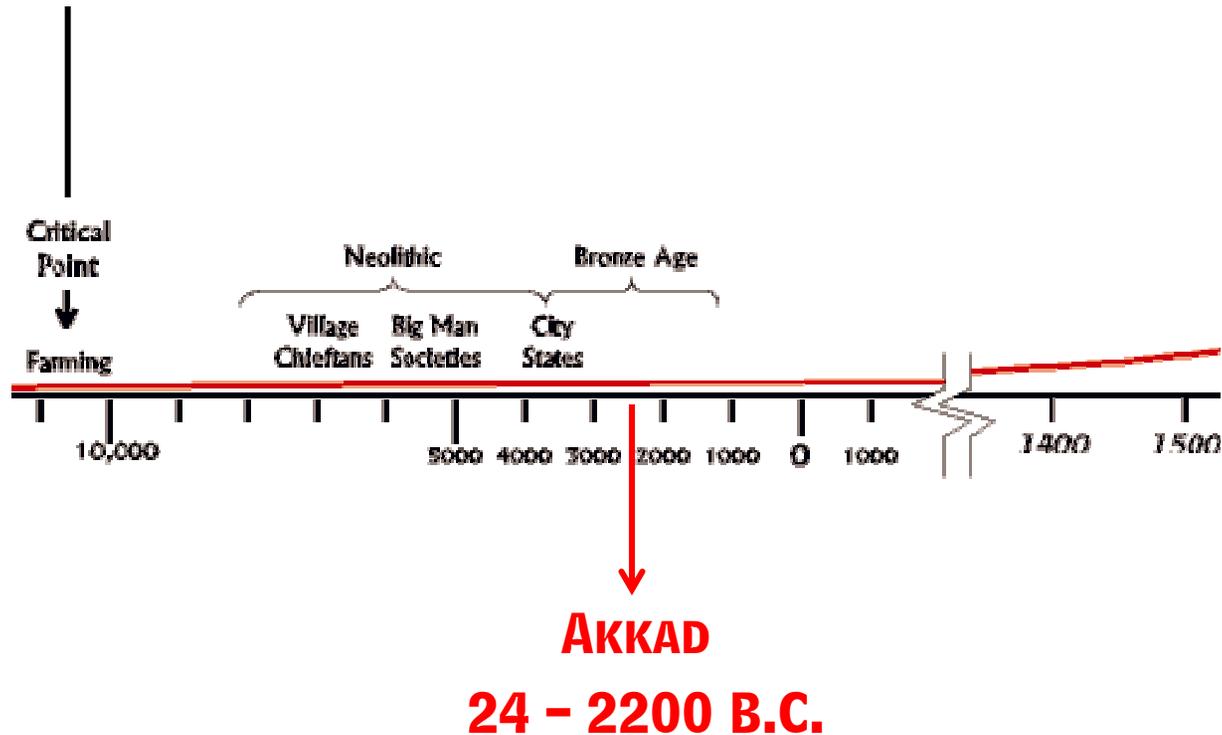


This was the moment when short-term climatic shifts became important in human affairs. Dense urban populations in circumscribed environments require highly productive agriculture just to survive, let alone make it through drought cycles or natural disasters.

Increasingly, agriculture became a matter of irrigation systems and canals, large-scale communal projects, taxation, and centralized grain storage 91

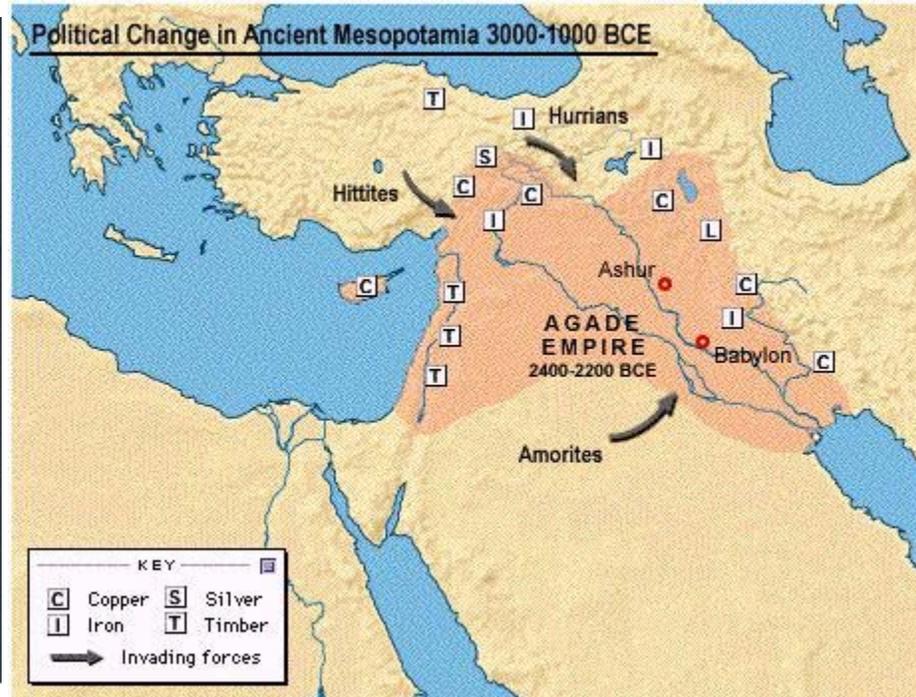
Climate and Culture

Humans progressively more out of balance with environment



Empires rise, and then collapse.

Early City States Akkadian (Sumerian) Empire



Sargon of Akkad gradually conquered the area between the Tigris and the Euphrates rivers around 2300 BC.

2334 - 2193

Early City States

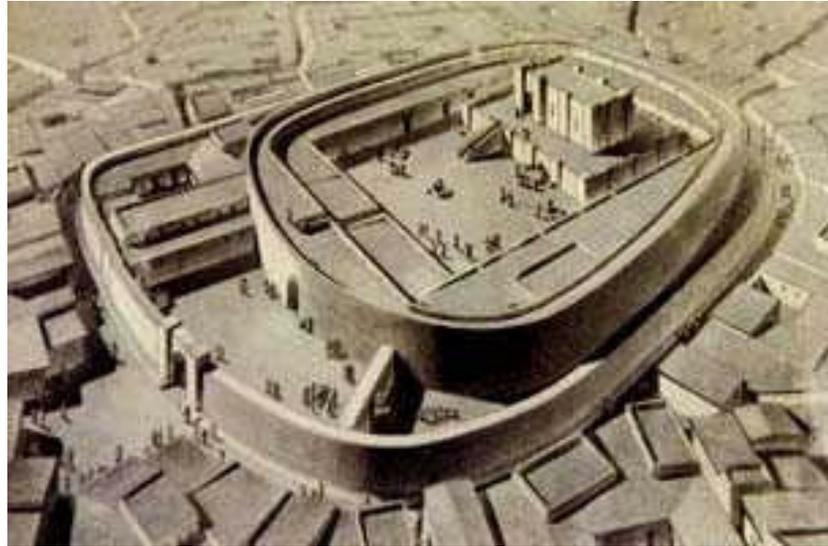
Akkadian (Sumerian) Empire



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Early City States
Akkadian Empire



Early City States

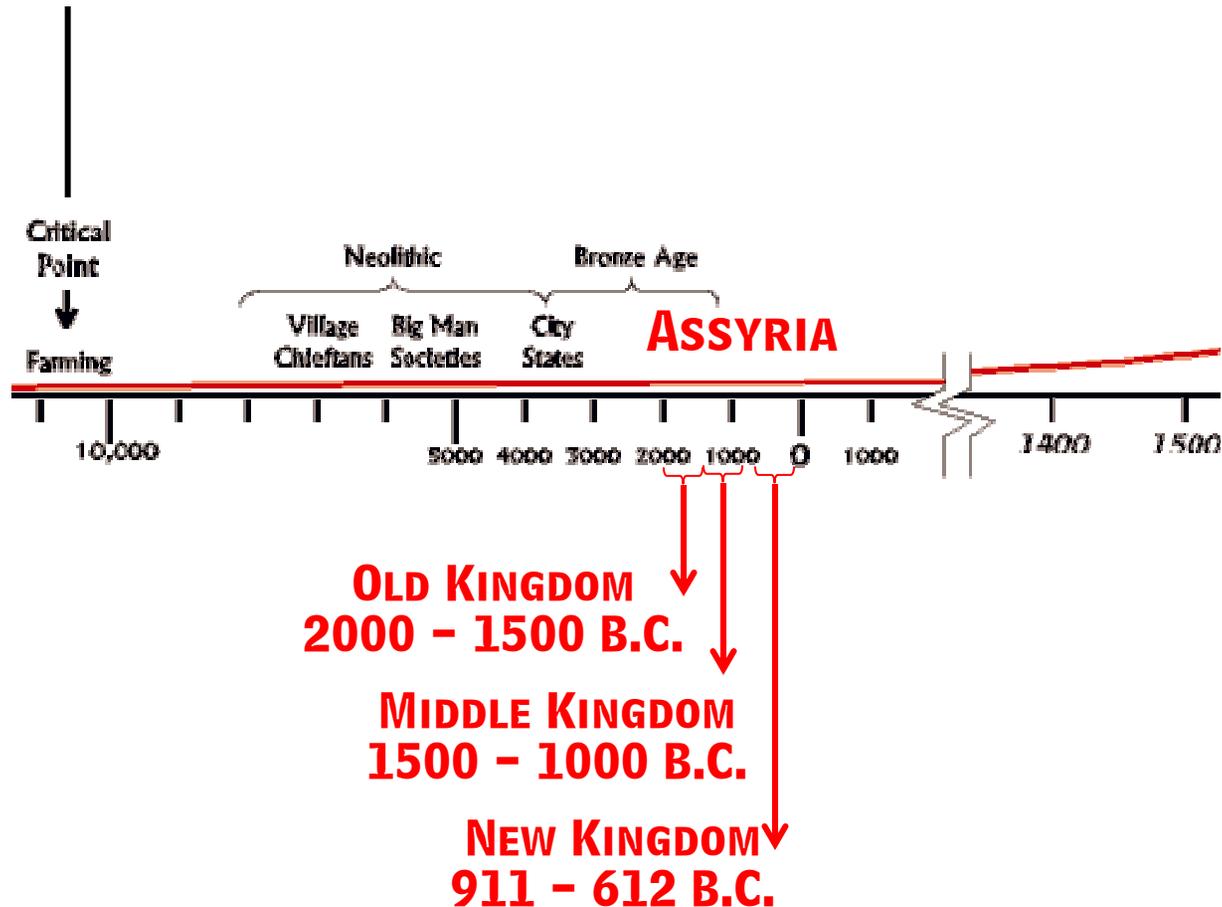
Akkadian (Sumerian) Empire



He also helped to unify his empire by making his daughter Enheduanna the high priestess for life of the moon god Nanna at Ur, and also the high priestess of the sky god An at Uruk.

Climate and Culture

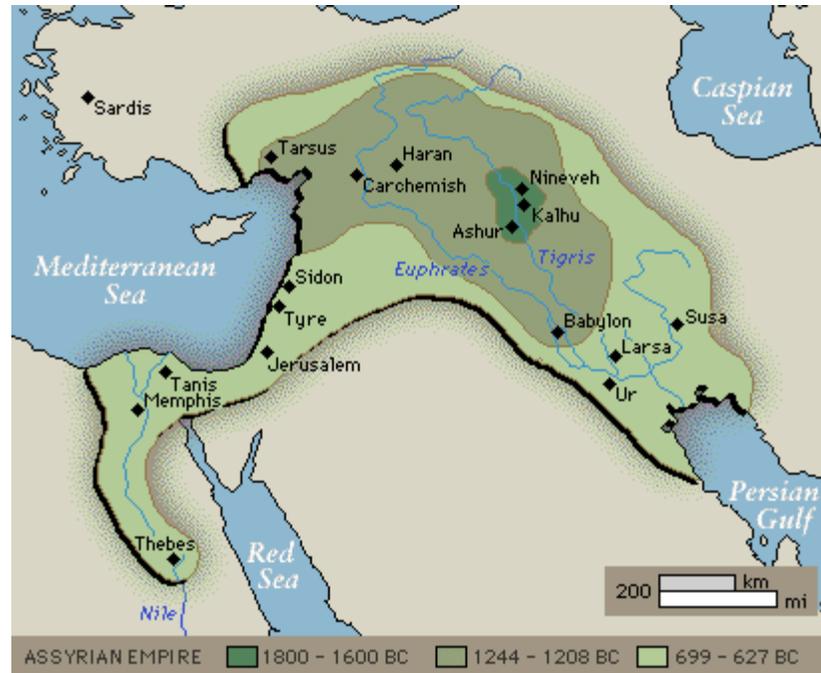
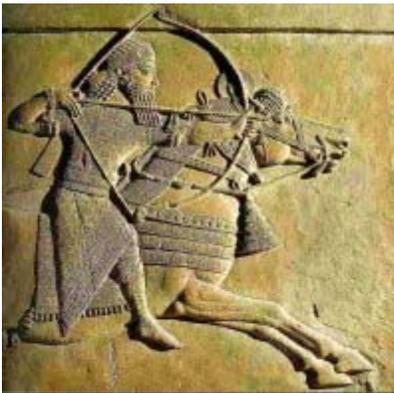
Humans progressively more out of balance with environment



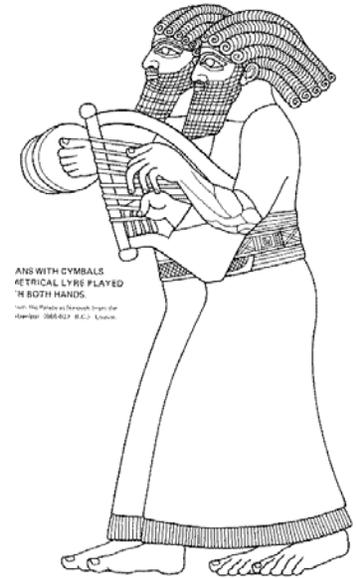
Empires rise, and then collapse.

Early City States

Assyrian Empire



~ 2000 - ~ 612



The Assyrian kings controlled a large kingdom at three different times in history. These are called the Old (20th to 15th c. BC), Middle (15th to 10th c. BC), and Neo-Assyrian (911–612 B.C.) kingdoms, or periods, of which the last is the most well known and best documented.

Early City States

Assyrian Empire

