19 November
2019

CIVILIZATION & CULTURAL SELF-DESTRUCTION

Homework #7 due tomorrow by 7pm

1

Ivy Mike, the first US H bomb, 1 November 1952, with a yield of 10 megatons (US Dept. of Energy)

Civilization & Cultural self-destruction

Primacy of *H. sapiens* and the Upper Paleolithic Age

The Neolithic Age and the Neolithic Revolution

Distribution of plants, animals, and mineral/metal resources

Sumer

f_c

Self-imposed limitations on a civilization's lifespan:

- Uncommunicativeness
- Overpopulation and Malthusian collapse
- Resource depletion
- Destruction of habitat
  - Nuclear war and nuclear winter
  - CO_2, ocean acidification, and catastrophic global warming

2

The Upper Paleolithic age

H. sapiens brought with them many new improvements, for which the remains grace the Eurasian **Upper Paleolithic** Age:

- Even better tools (the Aurignacian industry), including composite structures made of wood or bone and pebbles sharpened to an edge (**microlith** tools). The slightly cruder **Chatelperronian** tools might represent the Neanderthals trying to follow suit, too little and too late.

3

The Upper Paleolithic age

- New ideas, like
  - Boats: With these, *H. sapiens* colonized New Guinea and Australia about 40,000 years ago – much sooner than the Americas. For that matter, much sooner than Cyprus, Corsica, Sardinia, and even Madagascar, which also require a sea-crossing to reach.
  - (subprimate) animal friends: Dogs begin to appear around the campfires early in the Upper Paleolithic age.

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The Upper Paleolithic age

Modern *H. sapiens* have not evolved biologically since about 40,000 years ago. Instead, major developments in the species (mainly the development of civilization) has come in the form of cultural evolution.

Throughout the Paleolithic age, *H. sapiens* operated in a hunter-gatherer society, although campsites (some with storage pits) started making an appearance.

Digital reconstruction of Upper Paleolithic campsite (Garcia-Diez & Vaquero 2015)

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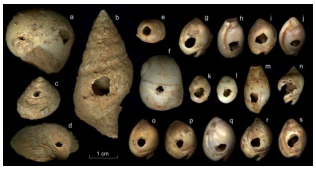
The Upper Paleolithic age

During the next two "tool" phases, the Solutrean (22 kyr ago) and **Magdalenian** (18 kyr ago) eras, they began to leave the first signs of cultural evolution in the form of representational art.

- Paintings, such as at **Lascaux** (France) and Altamira (Spain)
- Simple jewelry, like the perforated shells
- Statuettes, like the Venuses and the "lion man"



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The Upper Paleolithic age

By 15,000 yr ago, *H. sapiens* completed their occupation and adaptation to all of the habitable land of Europe, Asia, and Australia, and followed the edges of the ice sheets as they retreated north.

By this time, their multiplication had carried their population far beyond that of Africa.

The adaptation in various climates, and the lack of communication over large distances, led to a differentiation of habits in "culture" and dining during this time.

- The most notable of these is the origin of the basic families of language, since those left the most indelible mark.

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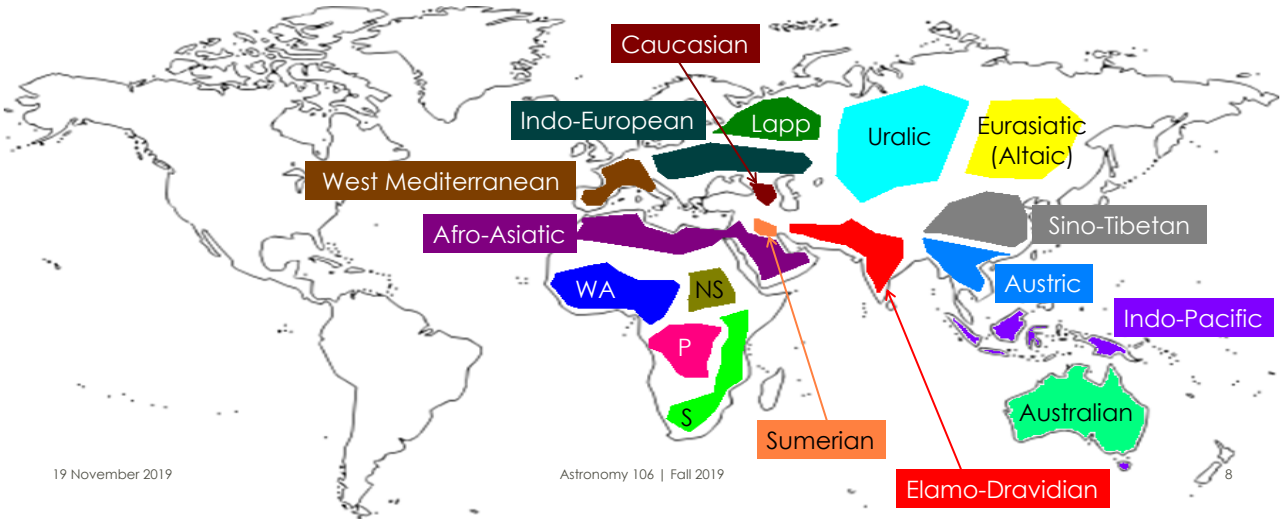
The ethno-linguistic groups, c. 15,000 yr ago



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The Neolithic age (new stone age)

By about 10,000 years ago,

- *H. sapiens* had been active in Africa for almost 400,000 years and had built up the four sub-Saharan races that exist today, each originally with its own language group.
- The earliest Eurasian establishments of *H. sapiens* had thousands of generations in which to become accustomed to the resources presented by their homelands, and by then had begun to differentiate into race-like groups as well as language groups, even though large genetic differences had not had time to happen.
- *H. sapiens* had only recently colonized the Americas.

Bands of megafauna-hunters had lived for thousands of years in Beringia, which during the W ice age was dry, non-glaciated grassland; further east was an ice cap.

At about 11,000 years ago, as the W ice age waned, a gap in the ice cap opened up from Alaska through Yukon and Alberta, and the hunters raced through, soon reaching the Great Plains.

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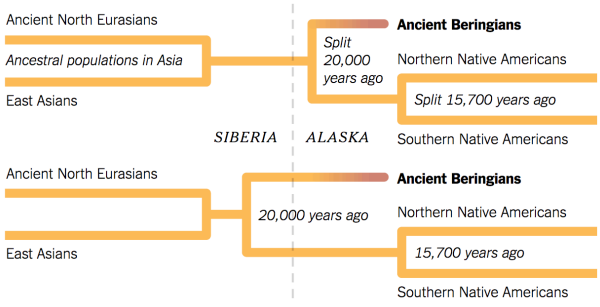
H. sapien migrates to Americas

That *H. sapien* ventured from Siberia into Alaska to reach the Americas during the end of the last ice age is no mystery – the ocean levels were much lower, enabling relatively easy passage.

There is a genetic difference between Native Americans and an extinct race called the Beringians, remains of which have been found in Alaska. Whether this split occurred before or after crossing remains uncertain.



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H. sapien migrates to Americas

After entering North America, *H. sapien* quickly moved south and expanded into South America.

The genetic differences between ancient remains found in the Spirit Cave and in Chile are incredibly minute, so this expansion was extremely rapid.

Some of the largest differences between the different races in the Americas is a result of different altitudes, not different geographic locations.

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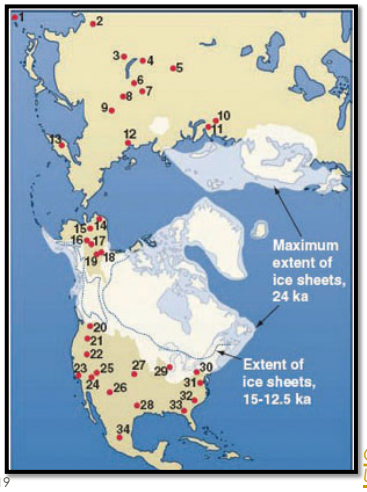
The Neolithic age (new stone age)

There, they comfortably maintained their upper-Paleolithic lifestyle for a long time, as they finished off all the horses and mammoths. Some continued to move south.

Richer homelands endowed some of the groups with advantages that sped them toward sophistication. Adoption of sophistication moves them out of the Paleolithic Age into the **Neolithic Age**.



CSFA, Texas A&M U.

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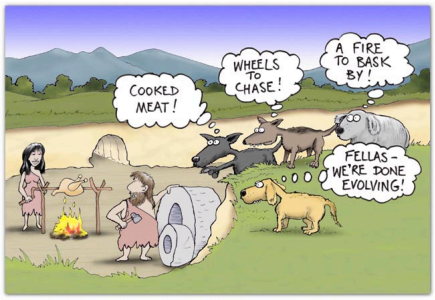
The Neolithic age (new stone age)

The new features of the Neolithic include:

- Abundant and tasty animals that do not mind living around humans.
  - **Domestication**, both to provide food sources more reliable than the hunt, and eventually to provide beasts of burden. Not just taming…
  - This is a double-edged sword: more intimate contact with animals meant more crossing over of animal **diseases**. Hinders, but also builds immunity in survivors.
- Digestible, carbohydrate-rich food that can be stored for months without spoilage.
  - Domestication here means determining the right seeds for edibility and high productivity, planting, and selecting seeds of the best outcomes for replanting.



Forget the experts: domestication of the dog only took about 8 seconds.

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The Neolithic age (new stone age)

- Useful minerals: rocks, gems, and eventually metals.
  - Stone tools predominated for a long time, even after the appearance of metal ones.
  - Copper is the first "domesticated" metal: colorful ores, low melting point, easy to cast or hammer.
  - Bronze – a lower-melting point copper alloy – is harder and holds an edge better and is possible to make inadvertently while smelting copper.

The use of metals in tools marks the end of the Neolithic age.

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The Neolithic revolution

For those surrounded by relatively rich supplies of animal, vegetable, and mineral resources, it did not take long to realize that to exploit them effectively required a new social order that differed from the tribal structure of hunter-gatherer cultures.

- Larger bands began to form and to establish fixed residences near tilled fields.
- The increased person-power led to even larger projects, such as the construction of irrigation systems.
- The consistently better-fed populace grew much faster than before.

This is called the **Neolithic revolution** and led straight to **civilization**.

- The revolution happened at different times in different places. To understand why and how, consider the distribution of resources:

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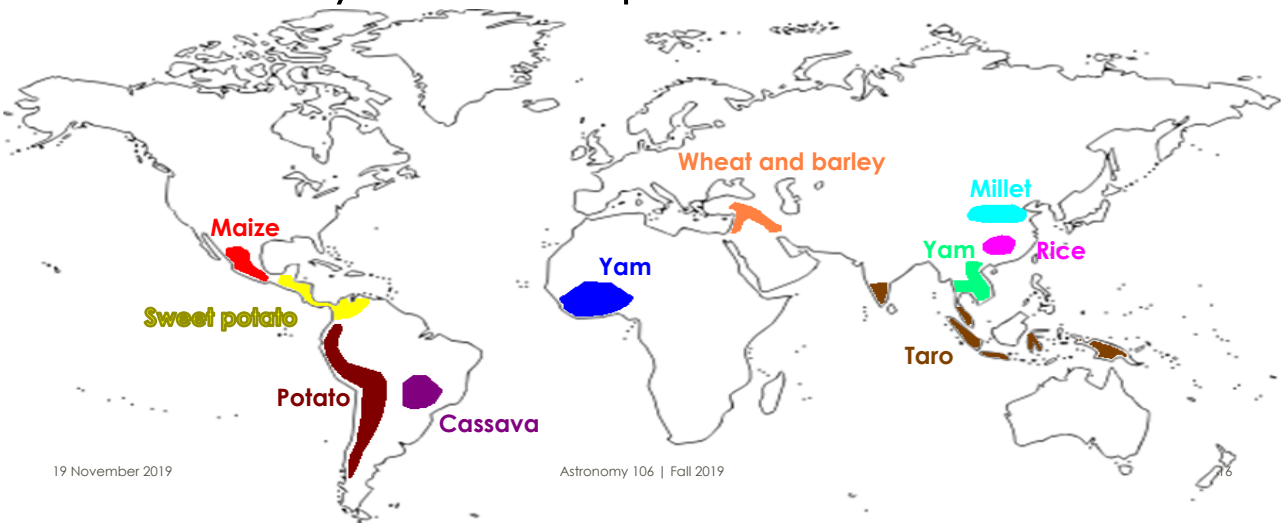
Native ranges of the staple carbohydrate crops



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Not all carbohydrate crops are equal

They differ in their other nutrients and their ease of storage.

- Some, like cassava, are very poor in protein.

They differ in resistance to diseases and pests.

Above all, though, they differ in the population they can sustain: simply calories per acre.

Crop	Calories per unit farm area [wheat = 1]
Potato	3.5
Rice	2.8
Sweet potato, yam	2.0
Barley	1.4
Sorghum	1.2
Wheat	1.0
Maize	1.0
Oats	0.8
Millet	0.5

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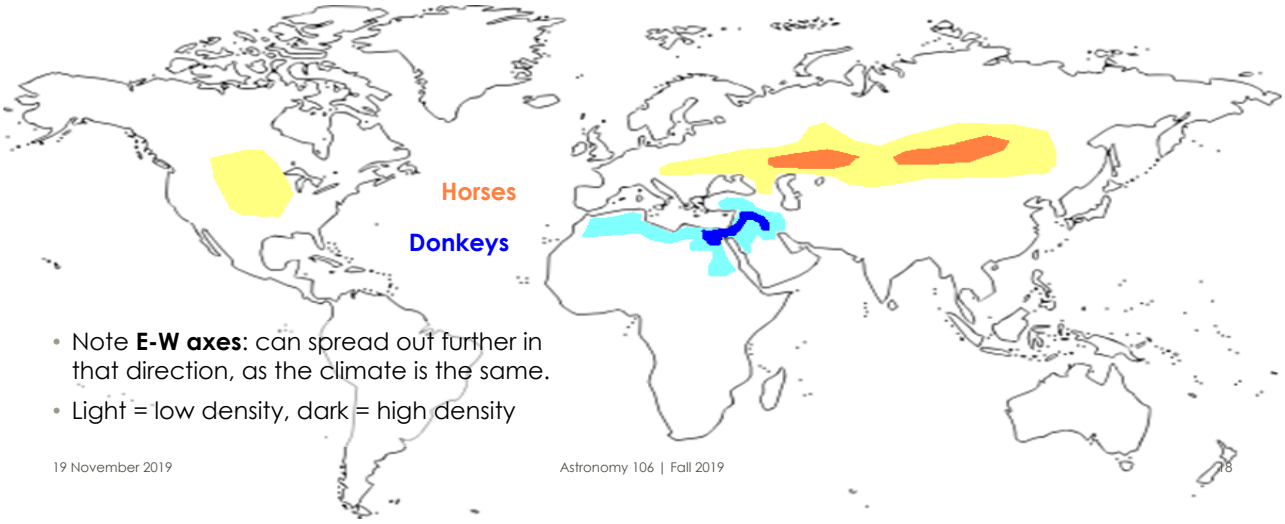
Native ranges of large equines



- Note **E-W axes**: can spread out further in that direction, as the climate is the same.
- Light = low density, dark = high density

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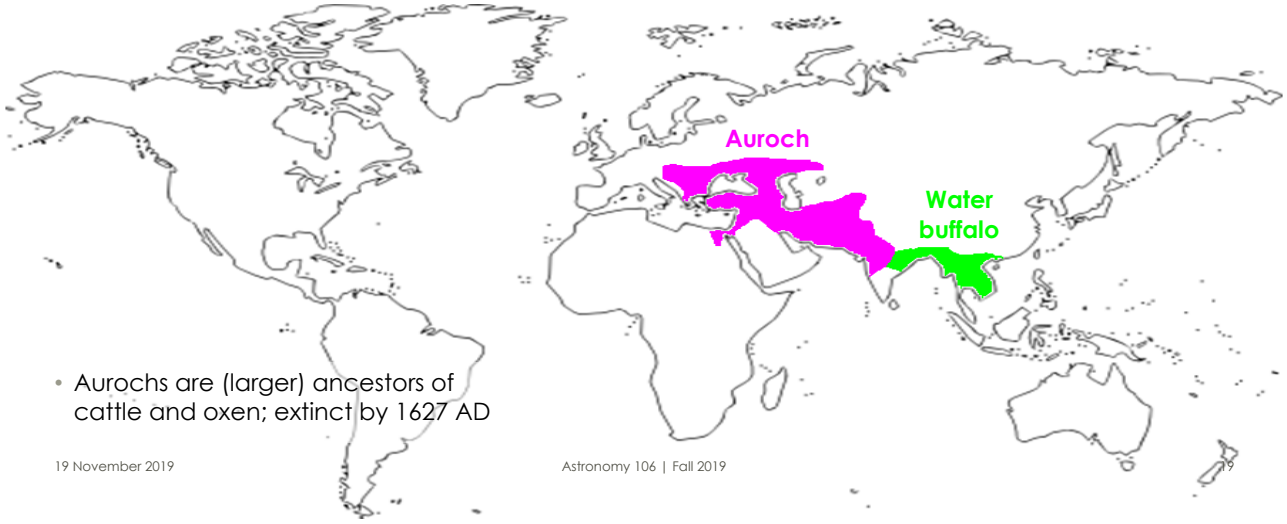
Native ranges of large bovines



- Aurochs are (larger) ancestors of cattle and oxen; extinct by 1627 AD

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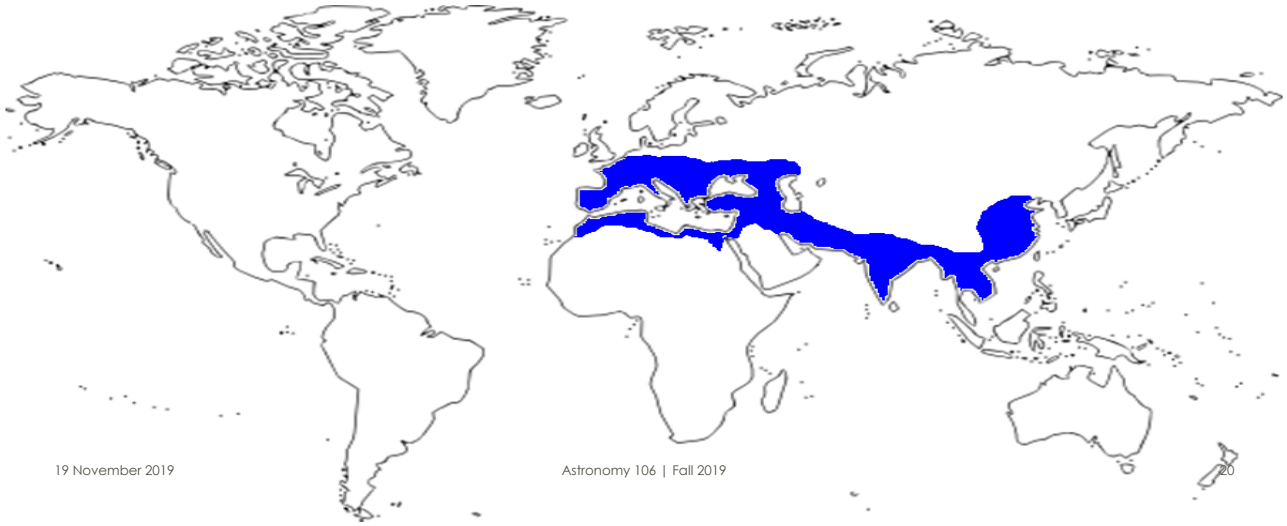
Native range of swine



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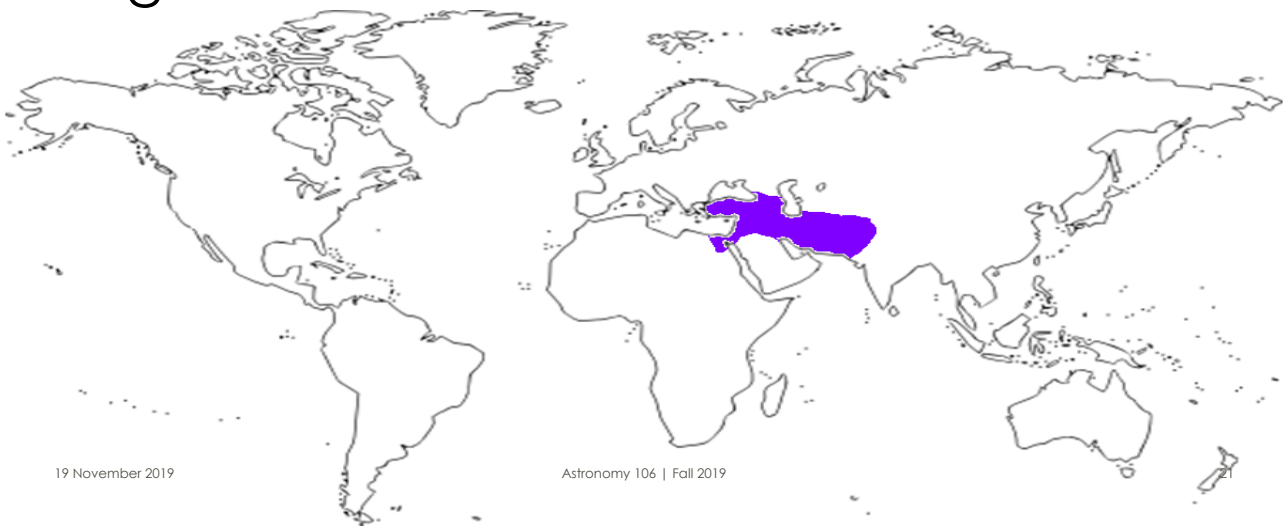
Native range of common ("bezoar") goats



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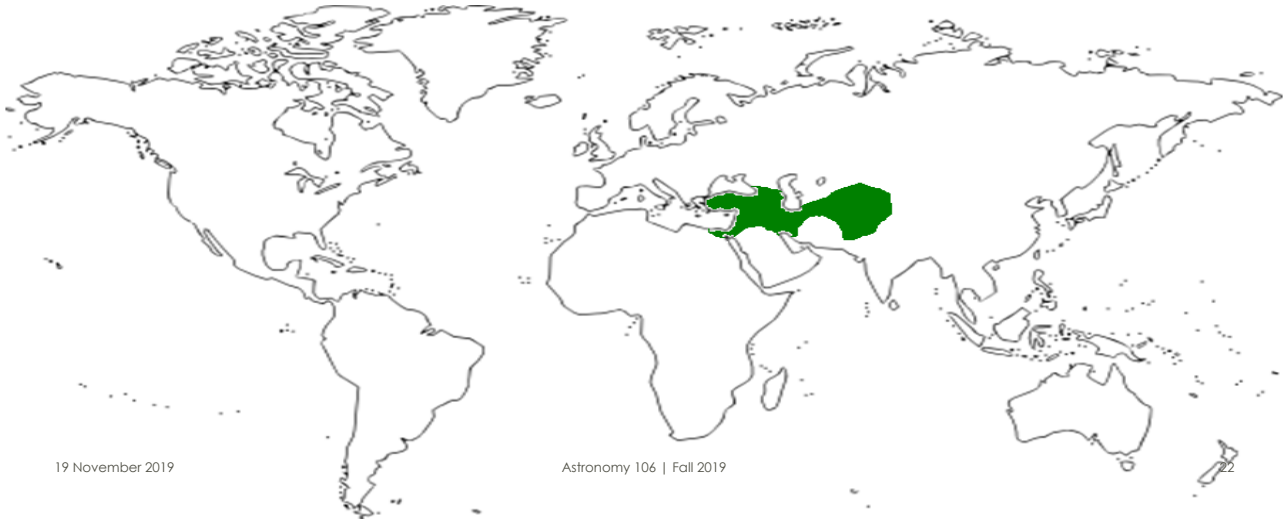
Native range of common ("mouflon") sheep



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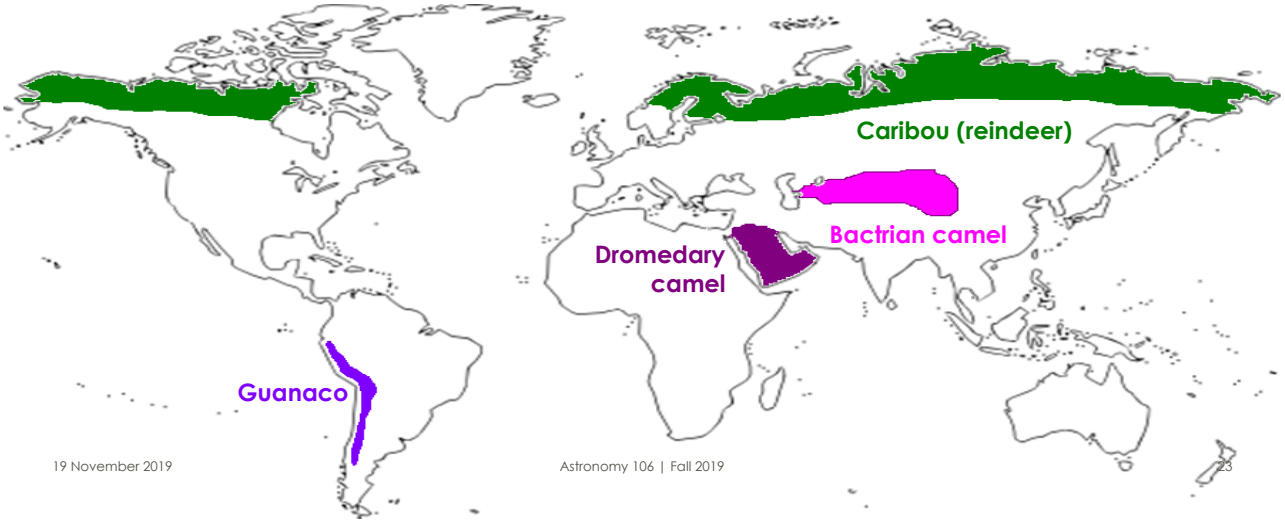
Native range of other large mammals



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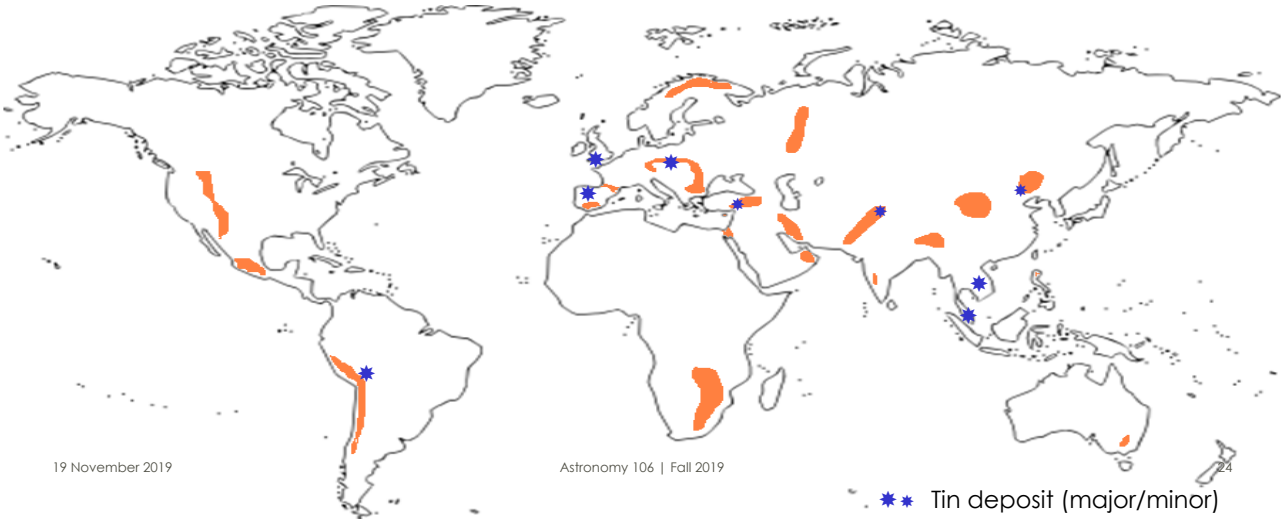
Easily-accessible copper and tin



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Question!

Describe the native resources of the continental United States.

A. Rich in resources; even in the beginning, a Land of Opportunity.
B. Only a few domesticate-able animals, but well endowed besides that.
C. Better bring your own.

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Question!

Describe the native resources of Central America.

A. Rich in resources; even in the beginning, a Land of Opportunity.
B. Only a few domesticate-able animals, but well endowed besides that.
C. Better bring your own.

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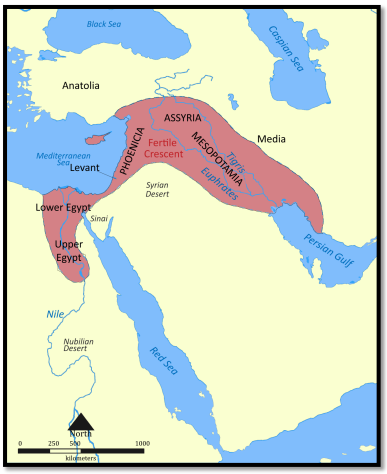
Luck of the draw

Given these distributions, it is no wonder why civilization became established first in the places that it did.

- **The Fertile Crescent**: good grain resources, great animal resources, room to spread out successfully from the native habitat of the plants, a great fertile plain with big rivers in its midst. Stone and metals a long walk away.
- The Nile and Indus valleys: lacked only the grains at first, better stone and mineral resources than the Fertile Crescent.
  - Adjacent to the Fertile Crescent, so it did not take them long to get wheat and barley.
- The Yellow River plain: not the best of grains or animals but enough of each to get started. Adopted rice rather late from their southern "proto-Austro-Thai" neighbors.



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Luck of the draw

And why it lagged in places

- Africa: lots of large mammals, but none of them easy to domesticate; N-S axis, long way between crops and metals
- Europe, north Asia: too far from the good crops
- Americas: Mostly too little time, but having only one large domesticatable mammal and a N-S axis did not help.

Success at mammal husbandry

Continent	Candidates	Domesticated
Eurasia	72	13
Sub-Saharan Africa	51	0
Americas	24	1
Australia	1	0

Candidate: herbivorous or omnivorous mammal, > 100 lb. After Jared Diamond (1997), *Guns, germs, and steel*

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The winners: candidates for independent emergences of civilization

Sumer: agriculture and animal husbandry by 8000 years ago, literate by 5500 years ago. All other Eurasian civilizations *may* have learned the main skills of civilization from Sumer.

Egypt: agriculture by 7000 years ago, literate by 5000 years ago.

"India" (the Punjab and the Indus valley, e.g. Harappa and Mohenjo-Daro): agriculture by 6500 years ago, literate by 4700 years ago. Linked by many busy trade routes with Sumer.

China (Yellow River plain): agriculture by 7000 years ago, literate by 4500 years ago. Written language similar to Sumer's.

Mesoamerica: agriculture by 3200 years ago. Never quite got literate, but invented pictographs 2000 years ago and had complex calendrical inscriptions 1200 years ago. Only civilization guaranteed to be independent of Sumer.

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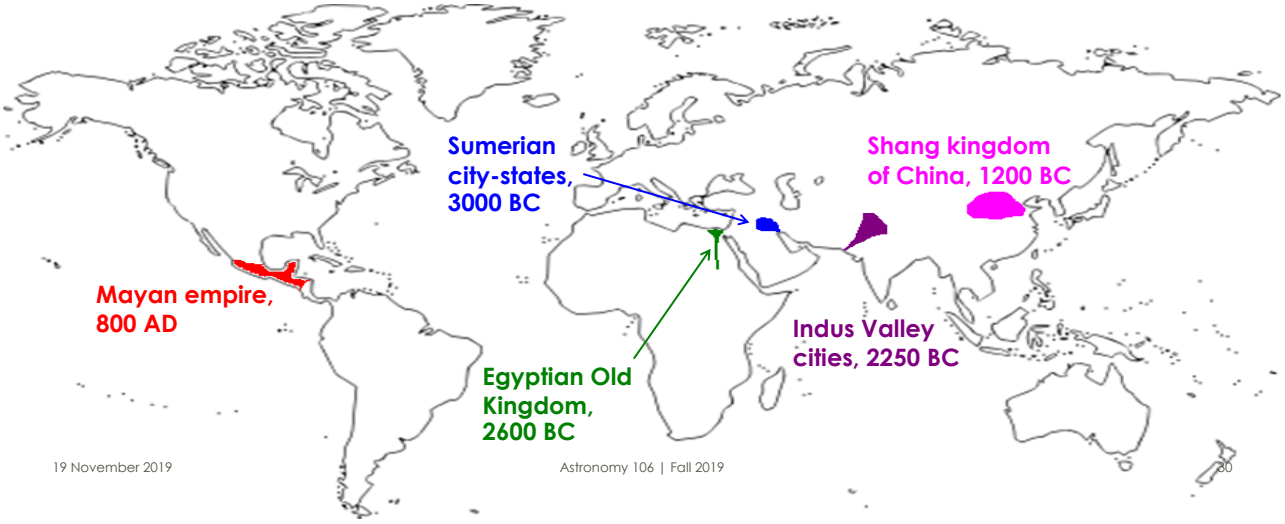
The winners



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Some Sumerian inventions

Urban specialization of occupations; thus, leisure

Writing, both pictographs and script (cuneiform)

The wheel, both for potters and carts

Irrigation (large scale)

Copper tools

Bronze: first arsenic bronze, then tin bronze after trade commenced

Arithmetic and accounting

Astronomically-derived calendar

Tanned leather

Kiln-dried brick masonry

Hand tools: hammer, chisel, brace, bit, nails

Waterproof and sail-powered boats

Glue

Swords and armor

Sandals and boots

Beer (long credited to the Egyptians)

Trade (probably)

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Civilization and f_c

By this, we mean technological civilization that, like ours, would develop the capability to communicate with others.

Once intelligence evolved, the production of civilization took much less time (1 Myr) than the evolution of life (600 Myr) or intelligence (3.2 Gyr) did. And from Sumer to us is much shorter (6000 yr).

- **Intelligence does not run out of time to civilize.**

We even had a little bad luck: from the place in which humans evolved, it was difficult to get to the resources required to build civilization.

As most will agree: once a civilization like the classic ones is produced, **evolution of a technological civilization is inevitable**.

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Civilization and f_c

Considering the good and bad luck to somewhat offset each other, we may consider the "statistical" answer offered by the Earth:

- Two independent loci of intelligence developed on Earth, both mammals: one land-based (hominids), one ocean-based (cetaceans)
- One of those developed civilization. This suggests $\boxed{f_c = 0.5}$
- The result is quite uncertain – and only barely makes it into the Speculation category – but at least it seems clear that **we would expect f_c to be larger than f_i**, and Earth offers confidence that f_c can be a large fraction.
- Compare to Drake's original guess: $f_c = 0.01$. There are still good arguments for small f_c, but not as many as for small f_i.

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Shooting ourselves in the foot

Technological civilizations can collapse and/or lose the ability to communicate with those on other planets by two general means: self-inflicted damage and natural disasters. First, we will discuss the self-inflicted damage, of which there are four main types listed below in order of increasing danger.

1. Loss of interest in searching for other civilizations while retaining technological capability
2. Population growth to the point of societal collapse
3. Depletion of resources within reach of the civilization
4. Destruction of the habitability of the planet(s) on which the civilization resides

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Being uncommunicative

Just because a civilization *can* communicate with others far away does not mean that it will. Best local analogy: China.

- China has been a leading civilization, capable of exploring far past its borders, continuously for about 3500 years.
- Yet, for almost all this time, it not only denied interest in other cultures but has been proud of that.
  - E.g. the Qing Dynasty's Qianlong Emperor, in refusing the British request to exchange ambassadors in 1793:

"This request is contrary to all usage of my dynasty… I set no value on objects strange or ingenious, and have no use for your country's manufactures."

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Being uncommunicative

- In the early years of the Tang Dynasty (618-907 AD), the borders of China were advanced along the Silk Road as far as modern Kazakhstan, but China lost interest in further advancement after losing a battle (Talas River, 751 AD) to the Arabs of the Abbasid Caliphate, never establishing a permanent political relationship with the West.
- The third ruler of the Ming Dynasty, the Yongle Emperor, sent his vizier Zheng He – in a fleet of 1500-ton ships – on seven voyages of exploration and tribute collection (1405-1423 AD) that made it as far as East Africa: the only explorations in Chinese history.

Although China was capable of communication, her communicative phase was short: $L = 18$ years, 0.5% of the possible lifetime.

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Question!

If there are other civilizations nearby in the Galaxy, should we try to communicate with them?

A. Yes
B. No

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Overpopulation & collapse

Thomas Malthus famously remarked (1798) that population seems inevitably to increase faster than its means of subsistence – food – can increase:

> "The power of population is so superior to the power of the earth to produce subsistence for man, that premature death must in some shape or other visit the human race… should [armies] fail in [their] war of extermination, sickly seasons, epidemics, pestilence, and plague advance in terrific array, and sweep off their thousands and tens of thousands. Should access be still incomplete, gigantic inevitable famine stalks in the rear, and with one mighty blow levels the population with the food of the world."

On this basis, Malthus expressed worries about the viability of several nations, and one of his chief worries was Ireland. Soon, Ireland became the exemplar of this form of collapse.

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Overpopulation & collapse – Ireland

From the early 1700s on, Ireland, with a population of 7-8 million, was on the edge of being able to feed itself. Ireland's poor relied almost exclusively on potatoes for nutrition.

When a blight destroyed the potato crop two years in a row (1845-46), two million people died, three million emigrated, and the Irish nation was virtually destroyed.

Although Malthus was certainly correct about Ireland, there was an interesting additional evolutionary factor at play: only a few varieties of the ~100 different strains of potatoes in the Andes had made it to Europe.

- This left the crops vulnerable to a well-aimed disease that would not have been a problem in a more diverse plant population.

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Overpopulation & collapse

Two examples on a larger scale:

- By the end of the third century AD, both the Roman and Han Chinese empires were populated near the limit of their subsistence.
- Repeated epidemics and probably a minor cooling of global climate sent both empires into tailspins from which neither recovered; their civilizations and influence were destroyed.

Earth can feed a maximum of about 20 billion; the current population is over 7.7 billion and doubling every 55 years.

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Resource depletion & collapse

Resource-abuse-related micro-examples in the collapse of civilizations on Earth (Diamond 2004):

- On **Easter Island**, Polynesian colonists, unused to the timescale for tree growth in more temperate climates, systematically deforested the island and left themselves without transportation or fishing vessels. Probably about a 70% population loss.
- The **Greenland Norse** practiced forms of farming, shipbuilding, and weaponry, developed in Scandinavia, that were unsustainable in Greenland; unsustainability became catastrophic when they ran out of wood and iron, ceased to be visited from Iceland, and endured worsening climate (the Little Ice Age) in the late 15th century.

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Resource depletion & collapse

Globally, we are now using technology that is based upon access to resources we are using unsustainably, mostly in the realm of nonrenewable resources like petroleum and natural gas. Petrochemicals provide, among other things,

- Our highest-energy-density fuels, without which aviation would be much more difficult
- Plastics, without which modern technology is scarcely imaginable
- Fertilizers, important in maintaining the high crop yields upon which we have come to depend

A sudden collapse of either technology or population may attend the exhaustion of this resource if we are not careful.

- At the largest sober estimate, we currently have approximately 10^4 petagrams (Pg) of carbon in the form of coal, oil and natural gas underground.

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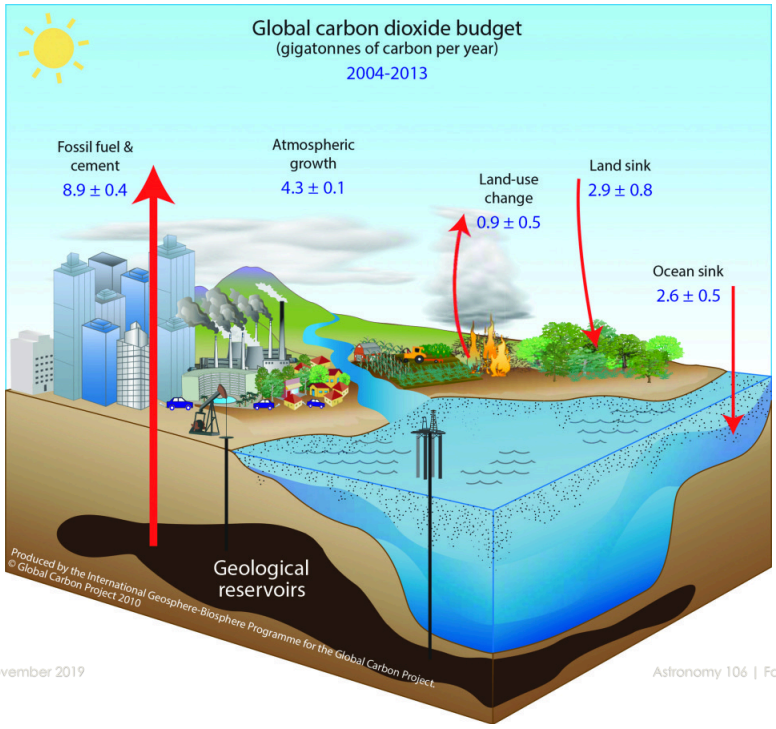

Resource depletion & collapse

Woods Hole Research Center

Le Quere et al. (2009)

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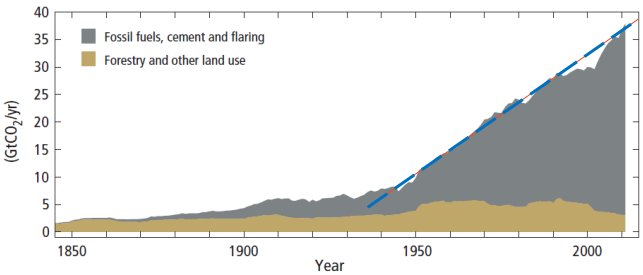
Resource depletion & collapse

We currently use 7.7 Pg of this per year, mostly for energy. At this rate, the fossil hydrocarbons will last 1300 years.

But, the burn rate is increasing roughly linearly, doubling every 22 years. At this rate, 10,000 Pg would last only 138 years.

So saving some would be a good idea – and not just because running out would be a bad thing…



Global anthropogenic CO_2 emissions (IPCC #5)

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Destruction of habitability

For over sixty years, humans have held the power to destroy their habitat by three primary means. We will discuss two (the third is the pollution of air and fresh water).

1. Weapons of mass destruction, such as **nuclear weapons**. From 1965 to 1985, the arsenals of the USA and USSR contained about 60,000 warheads, totaling 40,000 megatons. This is the same as
   - Five Class 5 hurricanes, though more concentrated
   - Impact of a few-km diameter asteroid
   - 200 large volcanic explosions (e.g. Krakatoa 1883)

   But, worst of all,
   - Ten times as much as would completely destroy every large city in each country

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Destruction of habitability

Results of all-out nuclear war
- Aimed preferentially at cities, so population would be preferentially destroyed
- H-bomb-destroyed cities would very efficiently turn to dust, which would scatter and rise into the atmosphere
- This would prevent the sunlight from reaching the ground (50-90% of it), causing temperatures to drop and stay low for several years: **nuclear winter**
- The nuclear winter would cause a progressive collapse of the food chain, very similar to prehistoric extinctions
- This outcome is accurately portrayed in many movies

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What do you think will get us first?

Question!

A. Overpopulation
B. Exhaustion of energy resources
C. Exhaustion of other technological necessities
D. Nuclear destruction
E. Other

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Destruction of habitability

2. **Emission of carbon dioxide gas.** The concentration of CO_2 in the atmosphere and the oceans is governed by the following interlocking cycles:
   - **Plants.** CO_2 is removed from the atmosphere by **photosynthesis** at a rate proportional to the number of plants.
     - In turn, plants return CO_2 to the atmosphere as they use photosynthetic energy (**respiration**).
     - But not all: plants **sequester carbon** as they grow and add to the Earth's soil when they die – as soil, and over longer terms as **coal, oil, and natural gas**.

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Destruction of habitability

- **Ocean.** CO_2 dissolves in water, producing carbonic acid (H_2CO_3), or in solution hydronium (H_3O^+) and bicarbonate (HCO_3^-).
  - Not that readily in ocean water: only about 10% of an increase in atmospheric CO_2 gets dissolved (Revelle & Suess 1957), but enough that the near-surface acidity of the ocean is significantly affected.
    - About 40% of the CO_2 added since 1750 is still in the atmosphere; 30% is dissolved in the oceans.
  - Carbonic acid in rain weathers rocks and adds calcium to the runoff.
  - In addition to photosynthesis, several microorganisms in the ocean **sequester carbon** by converting calcium and carbonic acid into calcium carbonate ($CaCO_3$) in shells and coral. They also respire some CO_2.
  - Some of the shells and coral are **subducted** on ~10 Myr timescales, along with the rest of the ocean plates; some is included as **limestone** in the continental plates.

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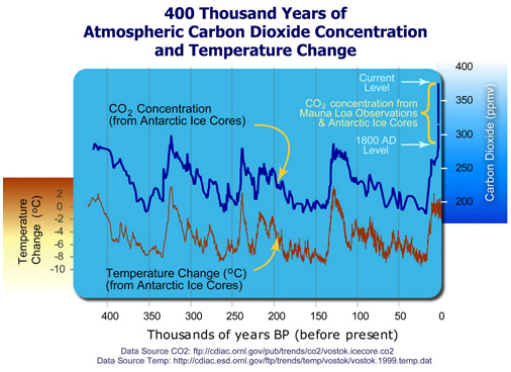
Destruction of habitability

- **Burning fossil fuels and carbonate rocks.** In all, about 20% of the carbon underground is currently in the form of coal, oil, and gas; most of the rest is in the form of limestone, which is burned to make concrete. This sequestration of about 93% of Earth's carbon was vital in producing the atmospheric conditions in which our species evolved. But now,
  - We burn fossil fuels into CO_2, currently at a rate of 7.7×10^{15} g (7.7 Pg = petagrams) of C per year.
  - Concrete manufacturing adds another 0.3 Pg/yr of C in CO_2.
  - This is about 4% of the annual traffic of carbon among the air, plants/soil, and the ocean…
  - …and is added too fast to be completely taken up by plants and the ocean, so 70-80% of it stays in the atmosphere.
  - Using air bubbles trapped in ice, the concentration of CO_2 in the atmosphere is accurately measurable for about 400,000 years into the past.
  - Such measurements show that **atmospheric CO_2 has increased very sharply since the Industrial Revolution** and is now the highest on record.
  - This increase can confidently be ascribed to fossil-fuel burning.



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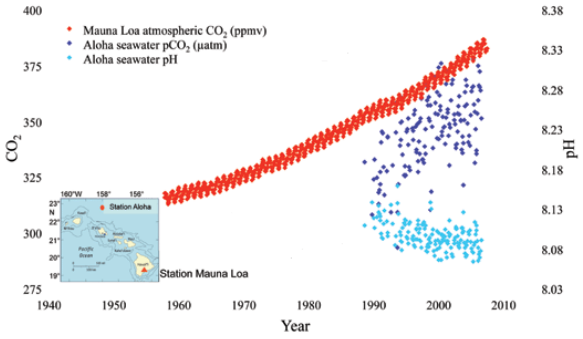
Destruction of habitability

- Why is this a worry?
  - Dissolved CO_2 is reducing oceanic pH significantly and steadily.
    - In concert with this, **acidification** has caused a decline in many aquatic species – in particular, many species, like coral, that are involved in turning carbonate ions into carbonate minerals.
  - More famously, the global surface temperature – which is also measurable for the past several hundred thousand years – has also increased to historic highs over the last 100+ years in step with the atmospheric CO_2 increases.
- There is no previous **global warming** of the observed magnitude for hundreds of thousands of years.



Doney et al. (2009)

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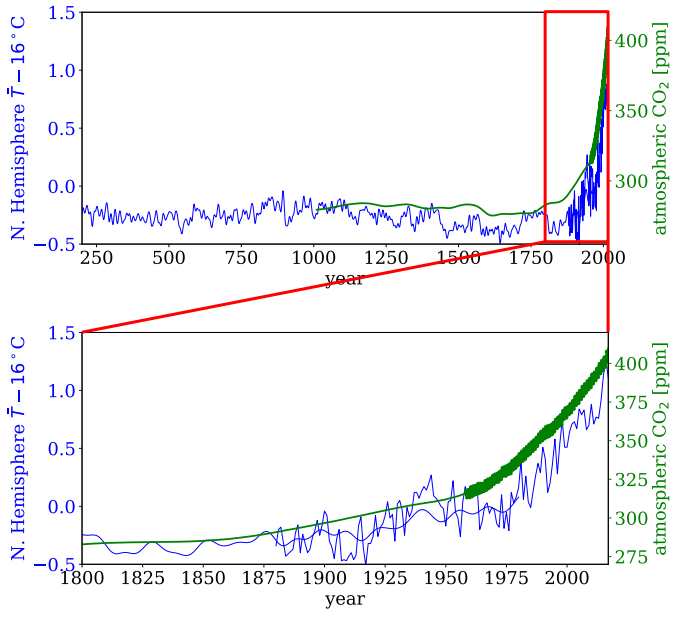

CO_2 atmospheric concentration

Mann & Jones (2003)

MacFarling et al. (2006)

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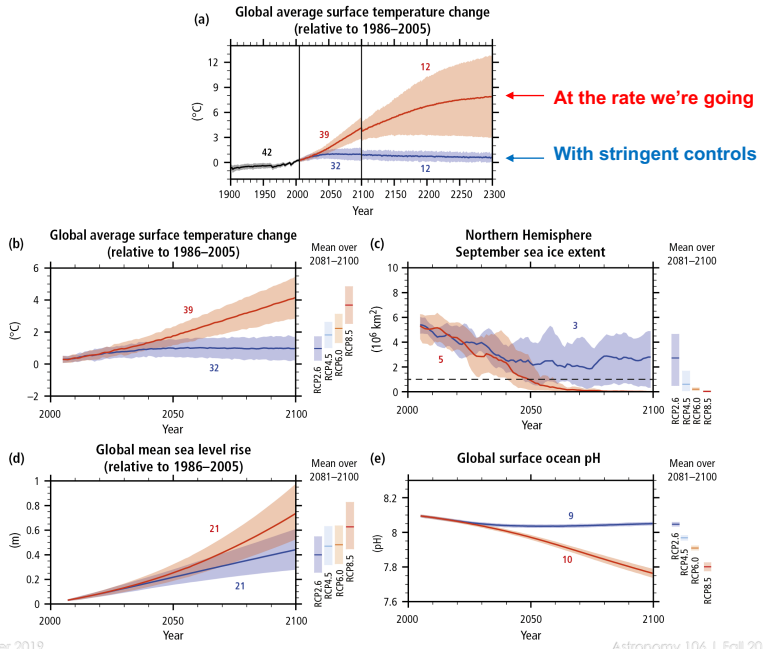
Destruction of habitability

- If the current trend of oceanic pH keeps up, a substantial fraction of ocean life will die and the global food chain will collapse on a relatively short time scale.
- If global warming keeps up, the polar ice caps will vanish, raising the sea level by hundreds of meters, rendering vast areas at low latitudes uninhabitable.
  - The gains in habitable areas at the poles would not offset the losses at the lower latitudes.
- Global warming is caused by the **greenhouse effect** of the additional atmospheric CO_2. It is possible, though considered unlikely, that a **runaway greenhouse effect** could result from putting a large fraction of the underground carbon back into the atmosphere.
  - That would make Earth like Venus: completely uninhabitable.



Destruction of habitability

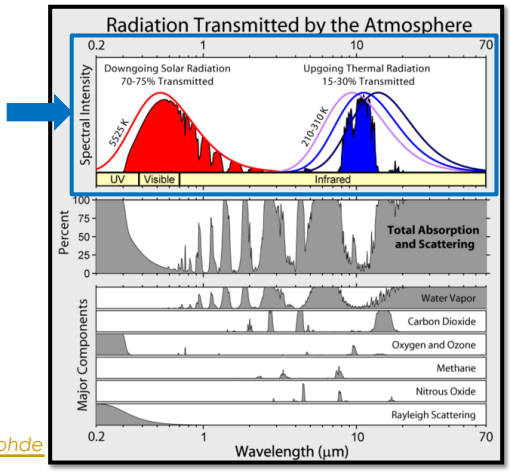
IPCC #5

The greenhouse effect

As we saw early in the semester, the planets emit most of their light at infrared wavelengths.

The rocky planets would all be brightest near a wavelength of 10 μm.

Solar heating arrives mostly at visible wavelengths, where the atmosphere is transparent.



Created for Global Warming Art by Robert A. Rohde

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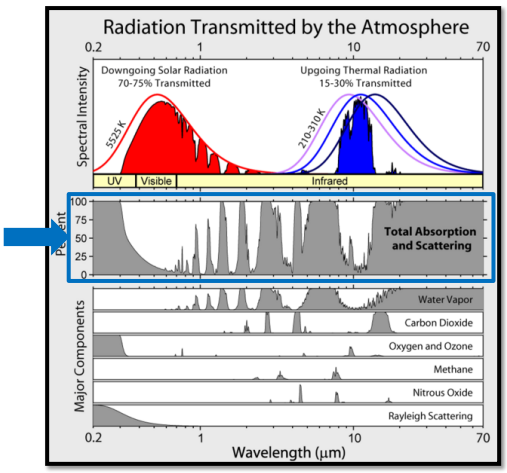
The greenhouse effect

Infrared light is absorbed very strongly by molecules in the atmosphere, notably by water and CO_2.

- Some CO_2 is traded for methane (CH_4) in animals and decaying vegetation.

Light from the surface can only escape directly into outer space through "windows," of which the most important lie at wavelengths 8-13, 4.4-5, and 3-4.2 μm.



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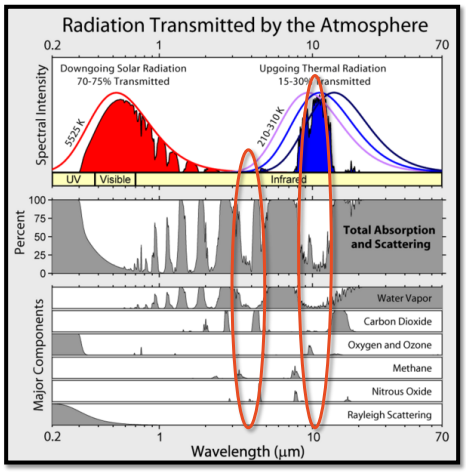
The greenhouse effect

Increasing CO_2 per H_2O in the atmosphere tends to close the 3-5 and 8-13 μm windows.

- Methane absorption also narrows these windows, but CO_2 is the big malefactor.

Hotter blackbodies shine more at shorter wavelengths, so if not enough light escapes and 3-5 and 8-13 μm, the **surface heats up** until enough of the emission leaks out in the shorter-wavelength windows.



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The greenhouse effect

Water produces the strongest greenhouse effect. **If there is liquid water on the surface**, water's greenhouse effect can be self-stabilizing, as water droplets form clouds that reflect the sunlight, depending upon the altitude at which the clouds form. (CO_2 and CH_4 form neither droplets nor clouds at the pressures and temperatures of Earth's atmosphere.)

If temperatures rise,

⇒More water evaporates into the atmosphere

⇒More clouds form

⇒Albedo increases

⇒Less sunlight reaches the surface

⇒Temperature drops

On Venus, sunlight and the greenhouse effect were sufficient to evaporate all of the water, leaving no liquid bodies on the surface: all water *and* all CO_2 stayed in the atmosphere.

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The greenhouse effect on Venus

Under solar ultraviolet illumination, water molecules high in the atmosphere readily dissociate, producing atomic hydrogen and oxygen.

- Oxygen goes on to rapidly react with other molecules; hydrogen, not so much.

Hydrogen is too light to be retained by Venus's gravity (or Earth's), so it escaped relatively quickly.

- Soon, there was no more water, or possibilities for making water: a dead world.
- All the carbon and oxygen wound up in CO_2, the atmosphere pressurized, and the greenhouse effect cranked up to 735 K: a *sterilized* world.

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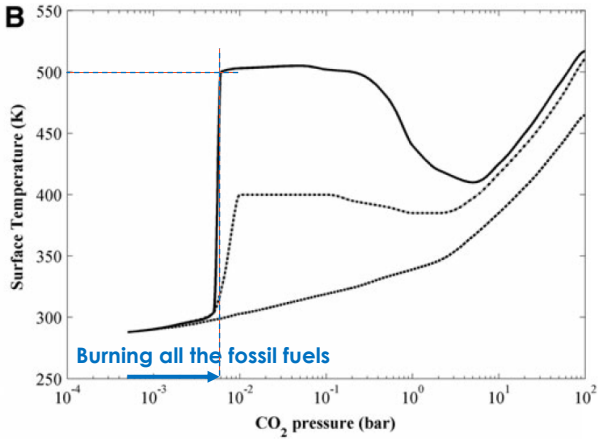
The greenhouse effect

Recent estimates for greenhouse-effect increase with increasing atmospheric CO_2 (Ramirez et al. 2014):

- Burning all our gas, oil, and coal reserves at the present rate would increase the atmospheric CO_2 by a factor of 12, possibly raising the surface temperature to about 500 K (440°F).
- This would sterilize the Earth, but it would not lead to a loss of the planet's water. Life could try again someday.



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What do you think will get us first?

Question!

A. Killing the oceans
B. Melting the ice caps and restricting habitats to the poles
C. Runaway greenhouse effect
D. All of the above will happen in rapid sequence.
E. None, as we will prevent them.
F. Who cares, the robots will have taken over by then.

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