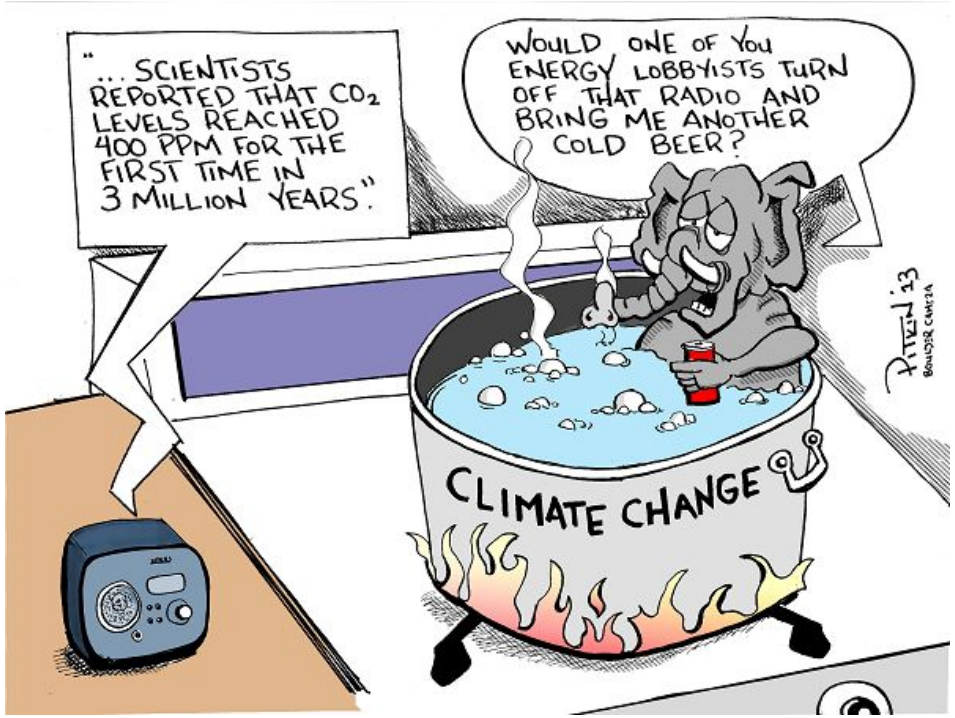

Class 9: Paleoclimate Proxies & Archives

- How do we know what past climates were like?
- What are some of the challenges in finding and interpreting records of past climates?

Learning Objectives

- Understand the concept of how proxy data are used to reconstruct past climates
- Understand the concept of a climate-proxy archives
- Explain the process by which oxygen isotopes are used to discover information about past climates
- Be able to interpret an oxygen-isotope record for past temperatures
- Identify and provide specific examples of the challenges confronted in retrieving and analyzing climate archives

Exam Report

- We are cross calibrating and looking at the first set of exams to develop rubric
- Seeing how many people could not finish the exam but analyzing question timing (and total time)
- Will likely take the rest of the week to grade because of the amount of writing and Mae Kate's return from Arizona and hosting a guest this weekend
- More soon!

Climate in the News

EDITORIAL · 15 SEPTEMBER 2019

Act now and avert a climate crisis

Nature joins more than 250 media outlets in Covering Climate Now, a unique collaboration to focus attention on the need for urgent action.

PDF version

RELATED ARTICLES

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Credit: Richard Vevers/The Ocean Agency

Coral sunscreen. When faced with potentially fatal bleaching events, some corals produce brightly coloured, fluorescent pigments in response to intense sunlight as a last-ditch effort to prevent overheating. The proteins act as a chemical sunscreen,

Credit: Elena Chernyshova/Panos

Unstable foundations. This eerie photograph shows an abandoned building overrun with ice in the city of Norilsk in Russia's far north. Russia is home to several cities built on permafrost. As the tundra

Credit: Andrew McConnell/Panos

Burst banks. Pictured here in 2010, Idle Kasow, a chief of the Korlabe village in eastern Kenya, struggles in flood water after

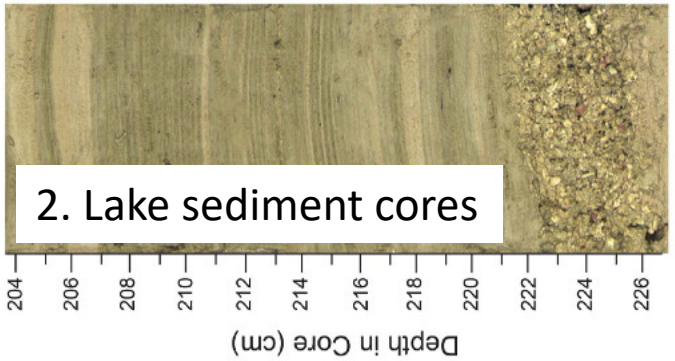
Credit: David Gray/Reuters

Running dry. This dried-up paddock on a farm near the town of Gunnedah in New South Wales, Australia, pictured in June 2018,

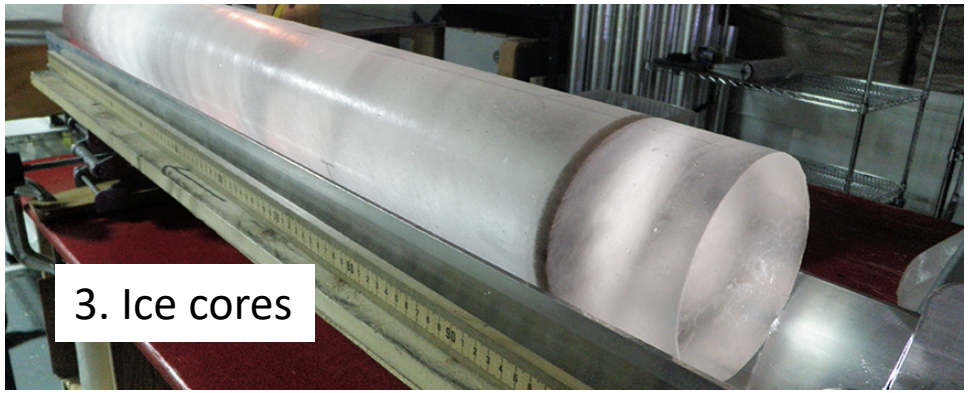
Today's Class (mapped to Learning Objectives)

1. What is a a climate-proxy archive? Some examples and how they work (also CO2 archives)
2. The mother of all climate proxies – stable oxygen isotopes - and what they tell us about past climates
3. How to interpret an oxygen-isotope record for past temperatures
4. What are the challenges confronted in retrieving and analyzing climate archives

What is a Paleoclimate Archive?

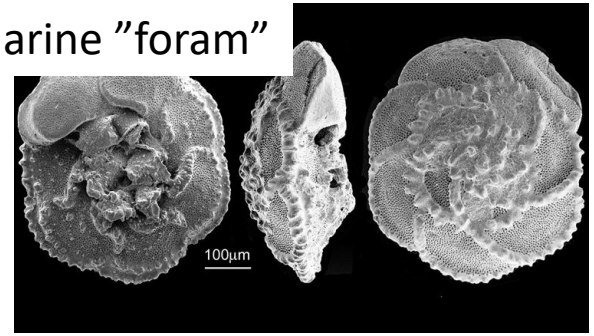


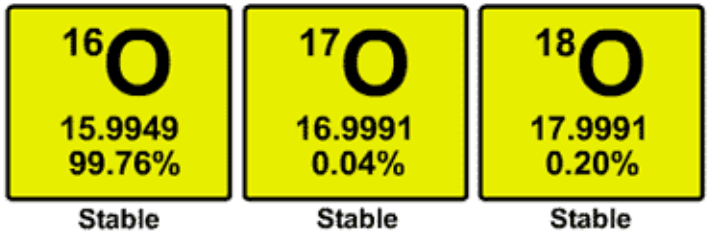
Any geologic deposit that preserves direct or indirect evidence (physical, chemical, biological, and isotopic) of past climates



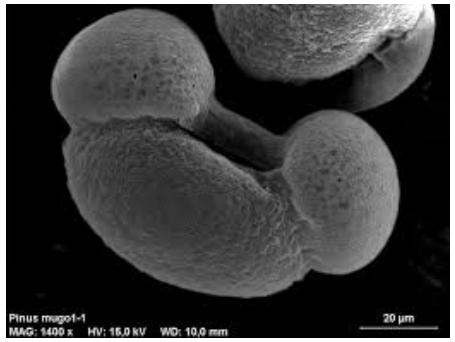
What is a Paleoclimate Proxy?

1. Marine ”foram”





6. Water Isotope systems



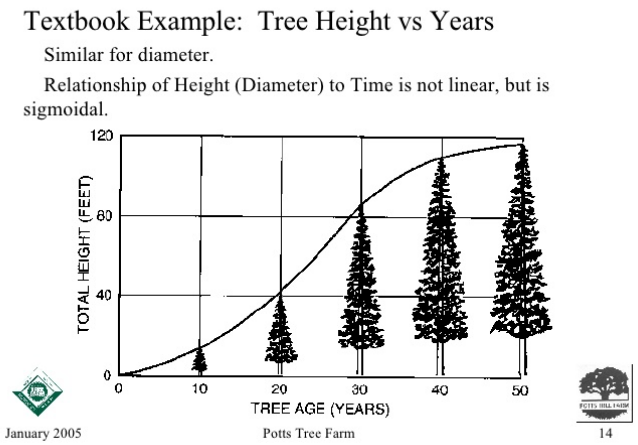
4. Pollen

A property that can be measured (physical, chemical, biological, and isotopic) and varies with changing climate.

2. Iceberg debris

3. Plant fossils

5. Tree ring width



Class 9: Paleoclimate Proxies & Archives

1. What is a a climate-proxy archive? Some examples and how they work (also CO2 archives)
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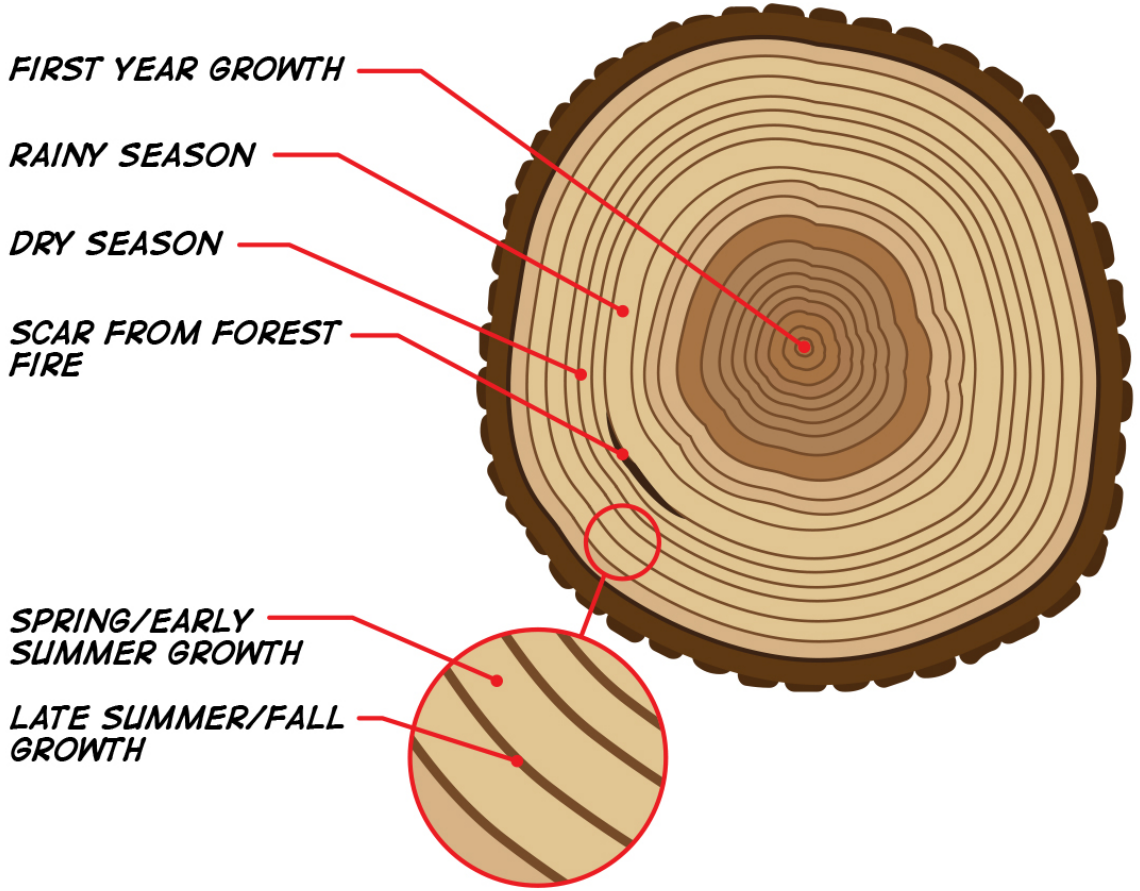
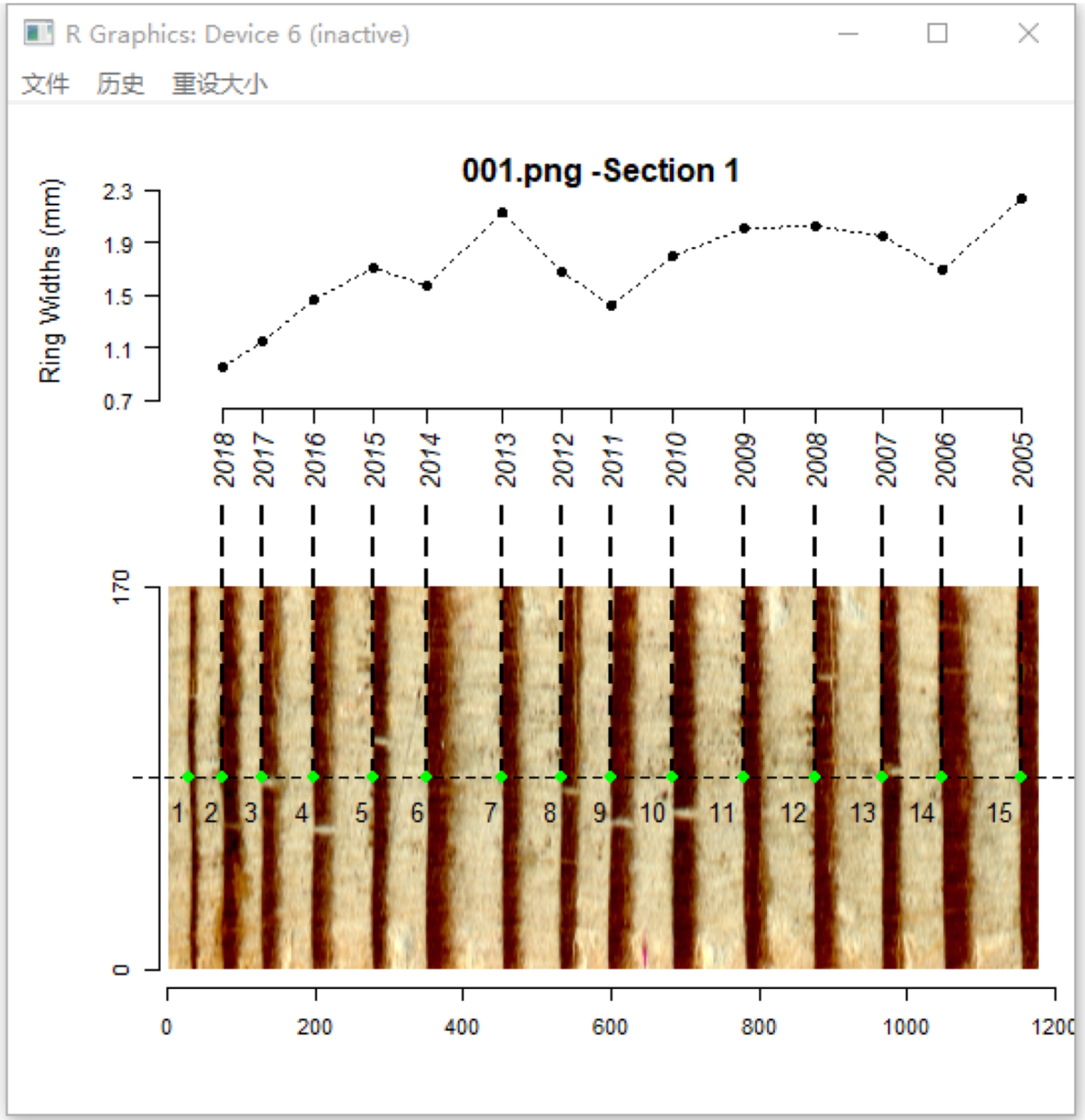
Tree-rings

- Trees add rings every year
- Ring width reflects tree age and environmental conditions
- Best for wet vs dry in most climates – fire scars also important

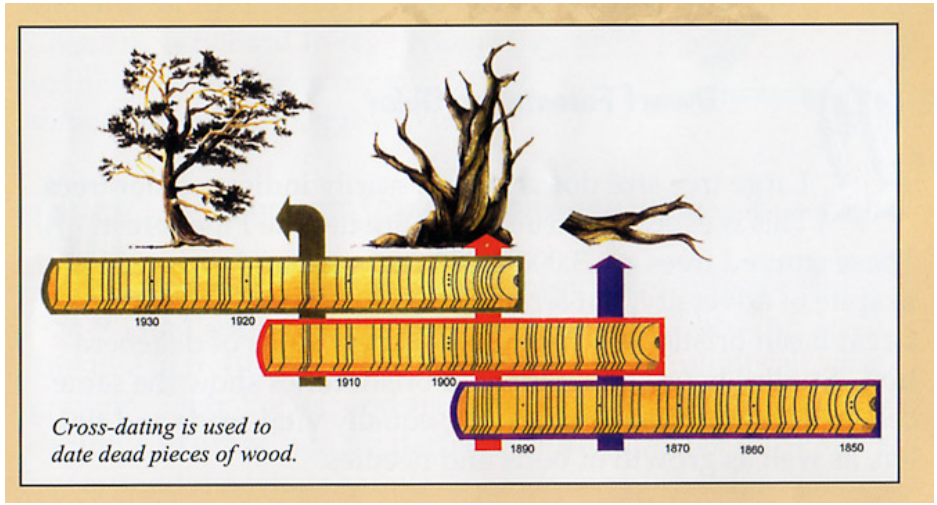


Tree coring – it’s easy



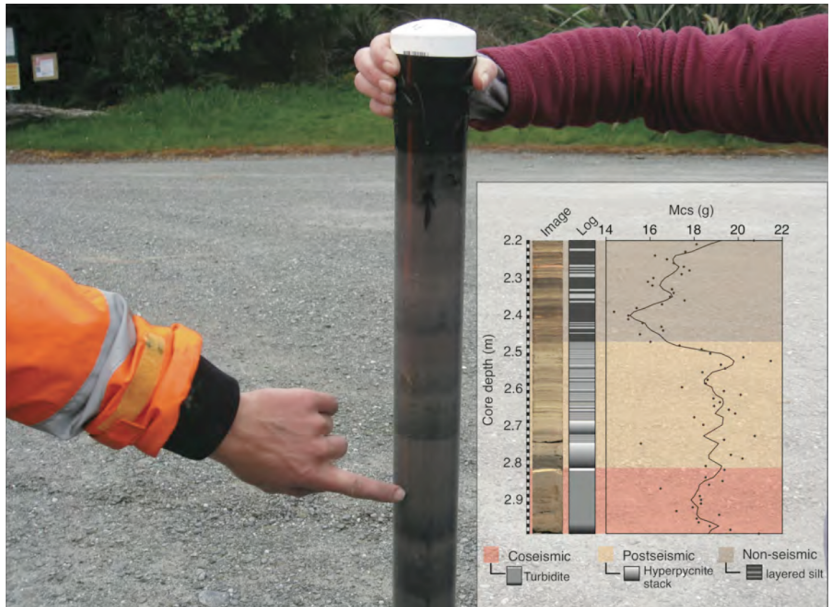
Tree-rings

- Some Bristlecone pines older than 5000.
- Cross dating takes the record back to > 9000 years in SW USA
- After 1950, faster growth rate for high elevation trees than in last 3700 yrs = warming temps



Lake sediment cores

- Lake “muck”
- Collected from rafts, boats, ice
- Analysis of plant pollen, plant macrofossils, and storm layers

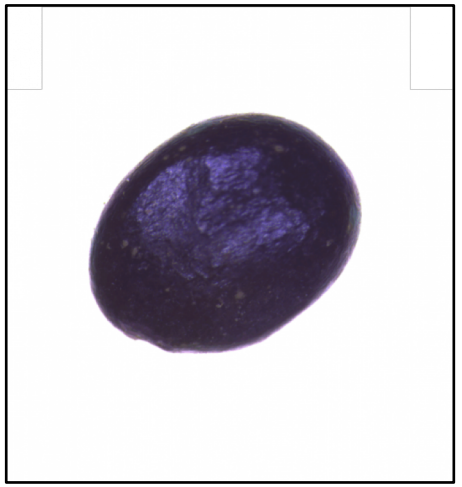


Lake sediment cores

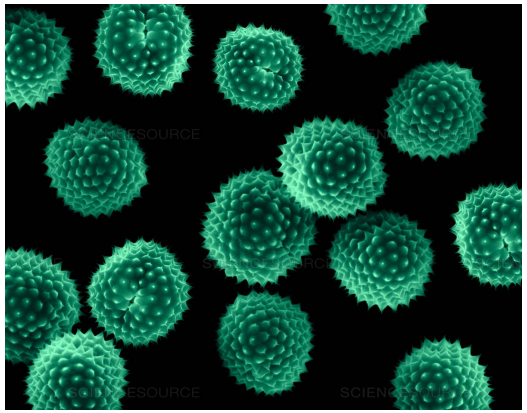
- Analysis of plant pollen and macrofossils tells us what lived there in the past
- By analogy, warmth loving plants = warm climate.

Spruce needles

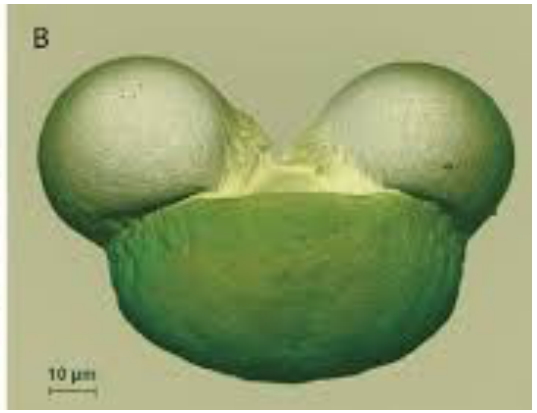
Alder seed



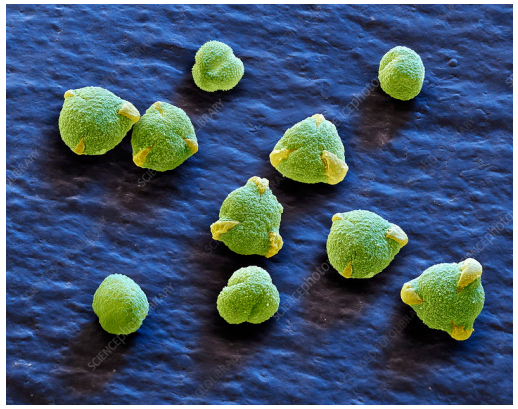
Ragweed – people!



Pine – cool and dry

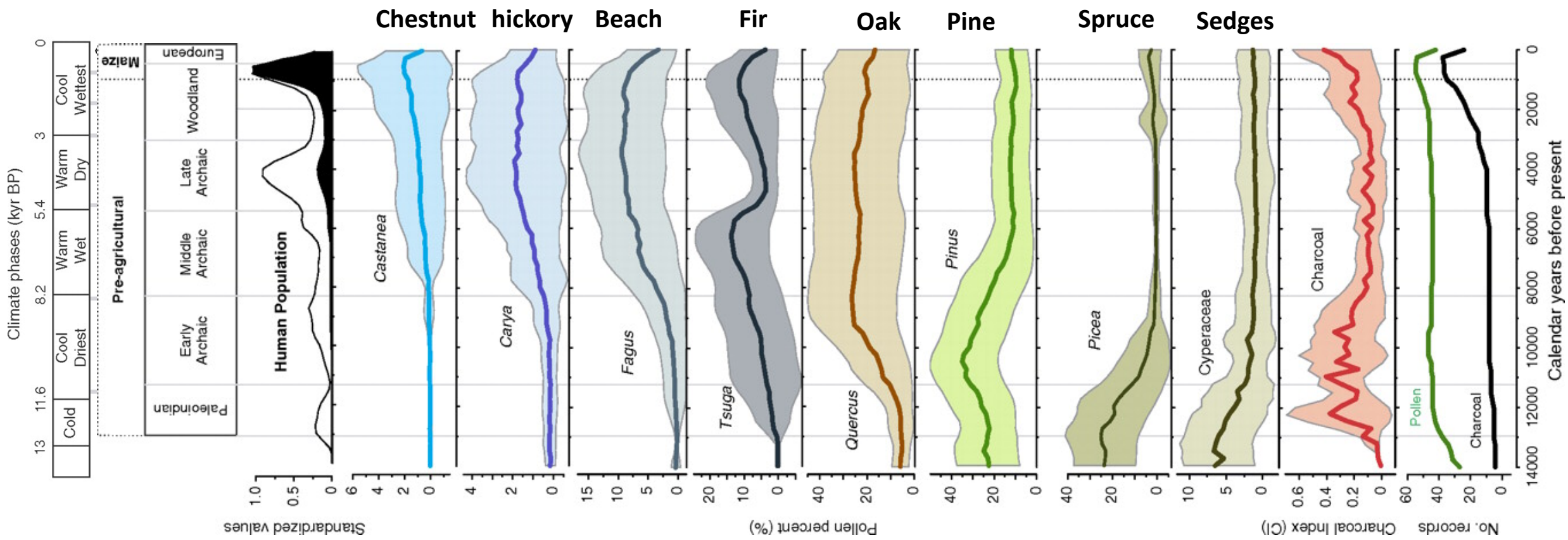


Oak - warm



Think – pair – share. Lake sediment cores which species like it cold, which like it warm?

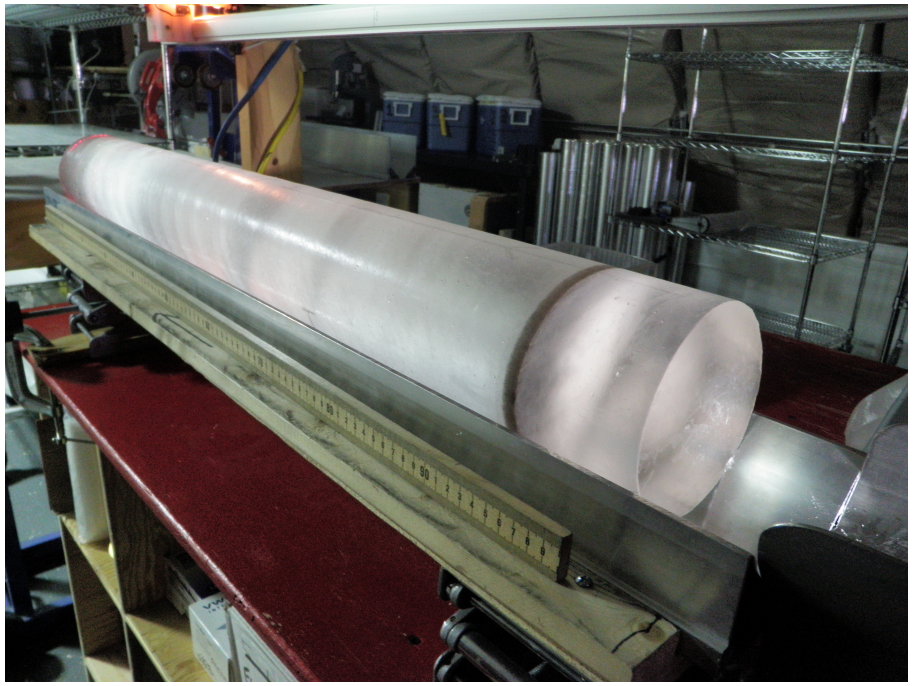
Eastern United States



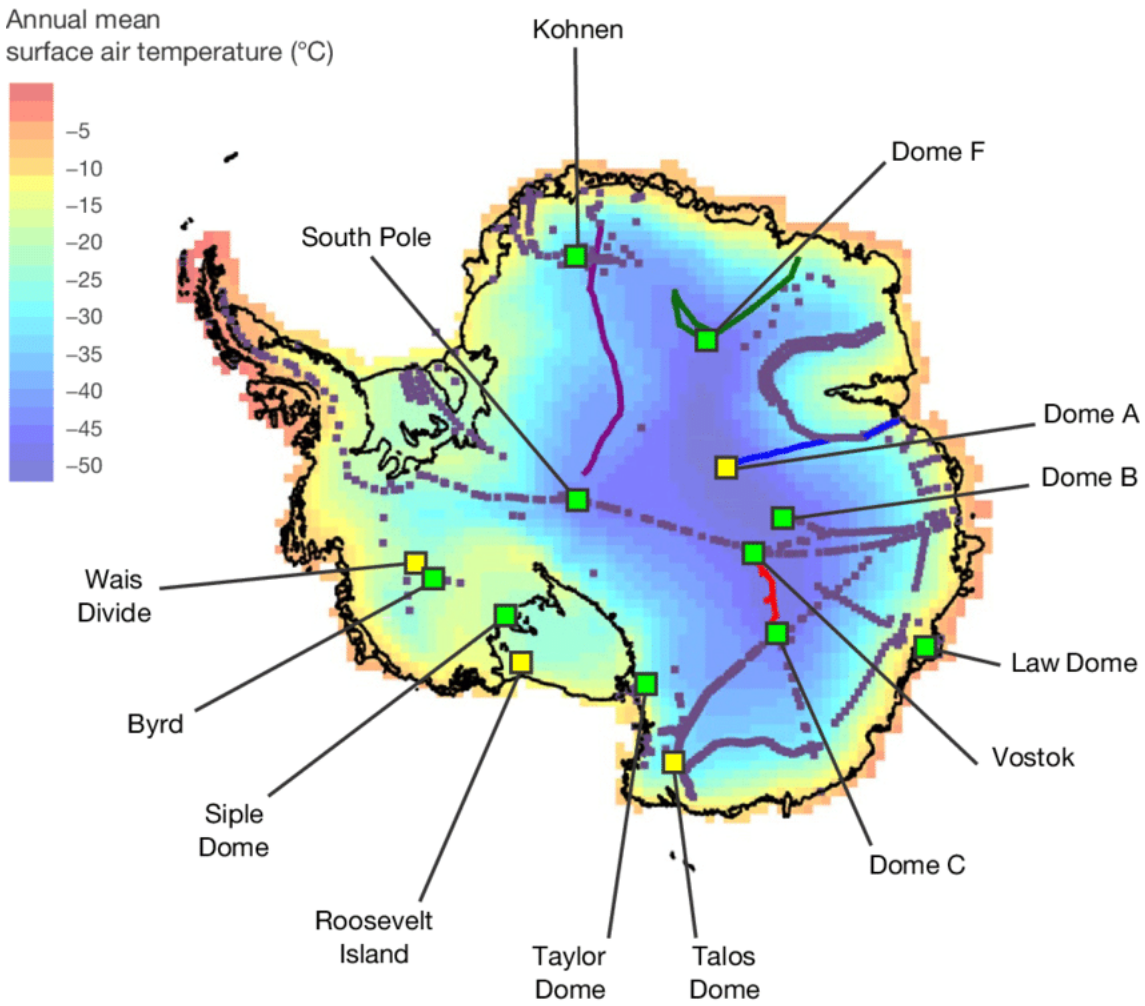
https://www.pnas.org/content/107/51/22008

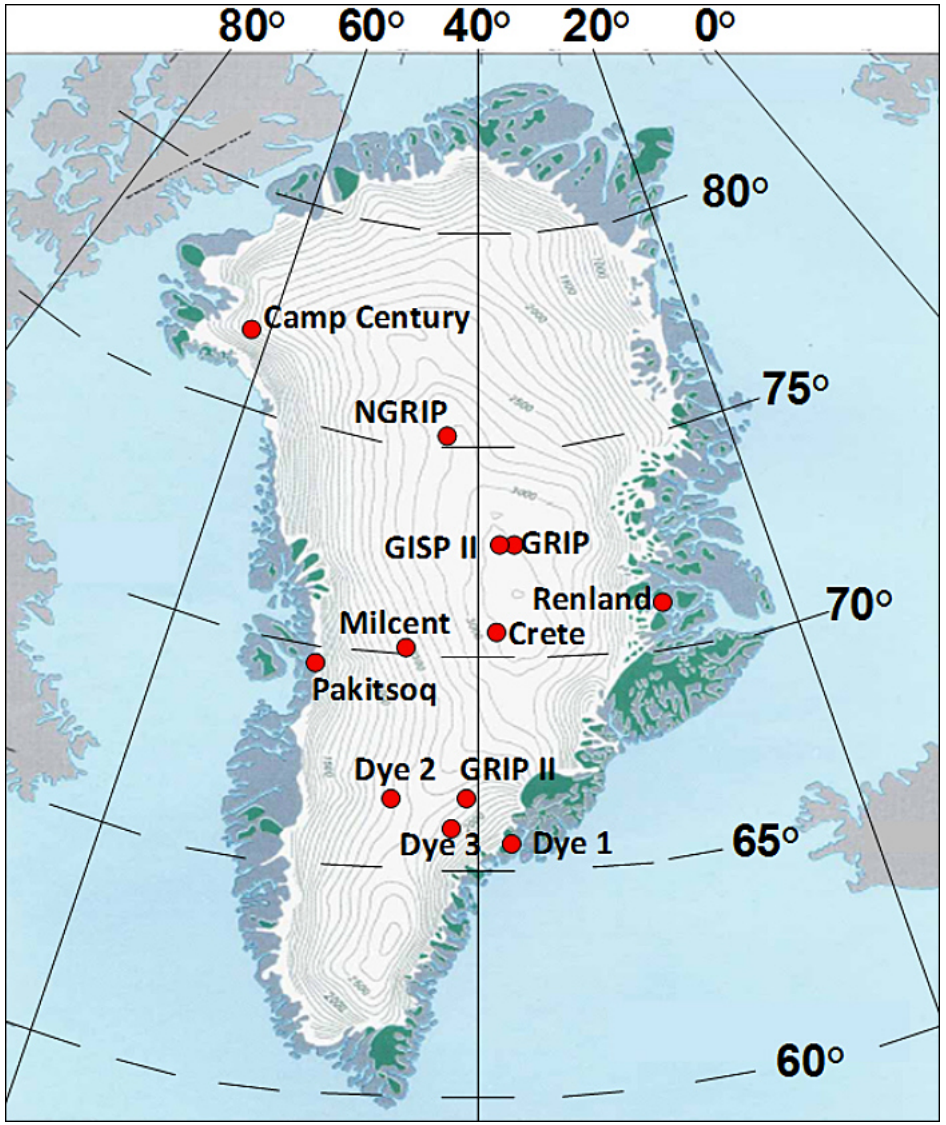
Deep ice cores, in the poles and elsewhere

- Layer counting, oxygen isotopes, and volcanic ashes give age
- Layer thickness can give snowfall



Both large ice caps have been drilled repeatedly





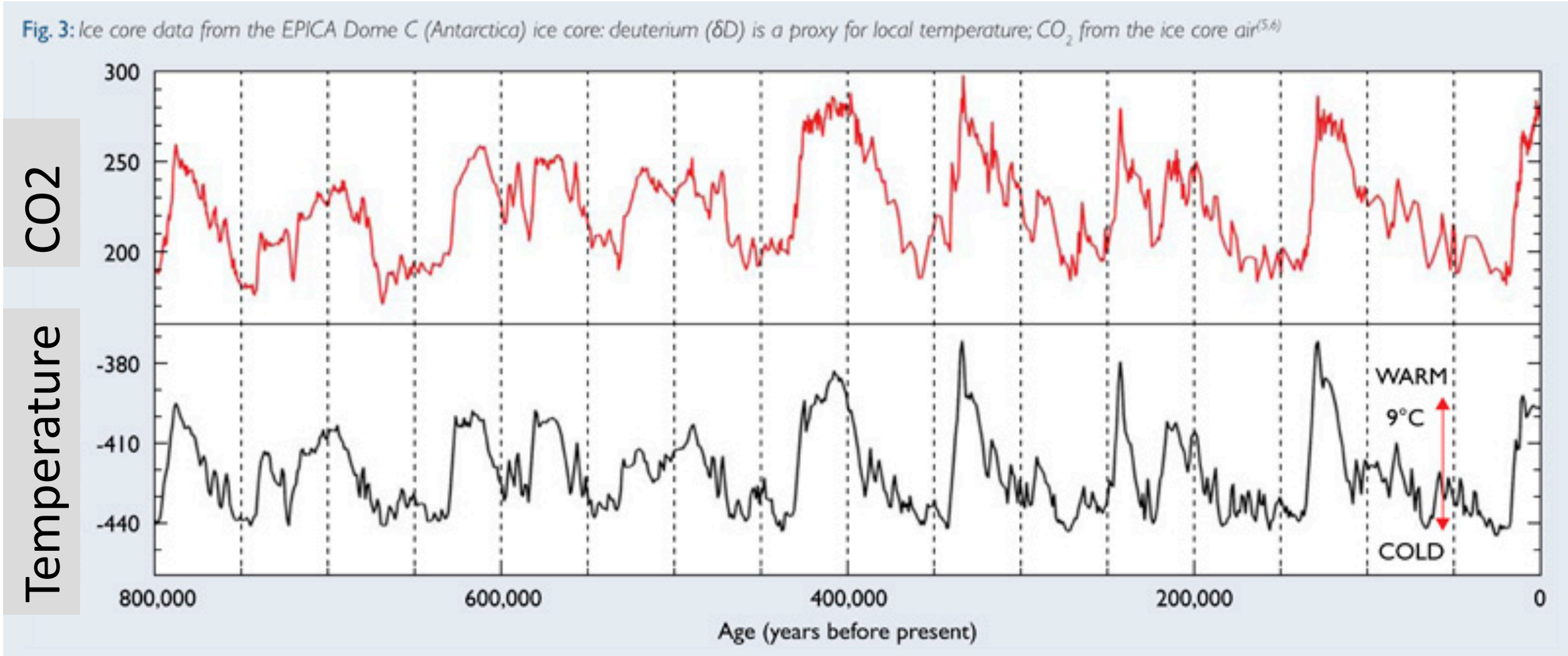
Ice caps in the tropics hold a special record of paleoclimate

Lonnie Thompson was at his desk on May 1 when the phone rang. He walked next door to his wife's office.

"My heart is here," he told her.

He underwent the transplant that evening.

Think, pair, share – How much does CO2 vary naturally? How different is today's atmospheric CO2 than it has been for 800,000 years? How is CO2 related to temperature?



Interesting ways to measure CO2 in the past atmosphere

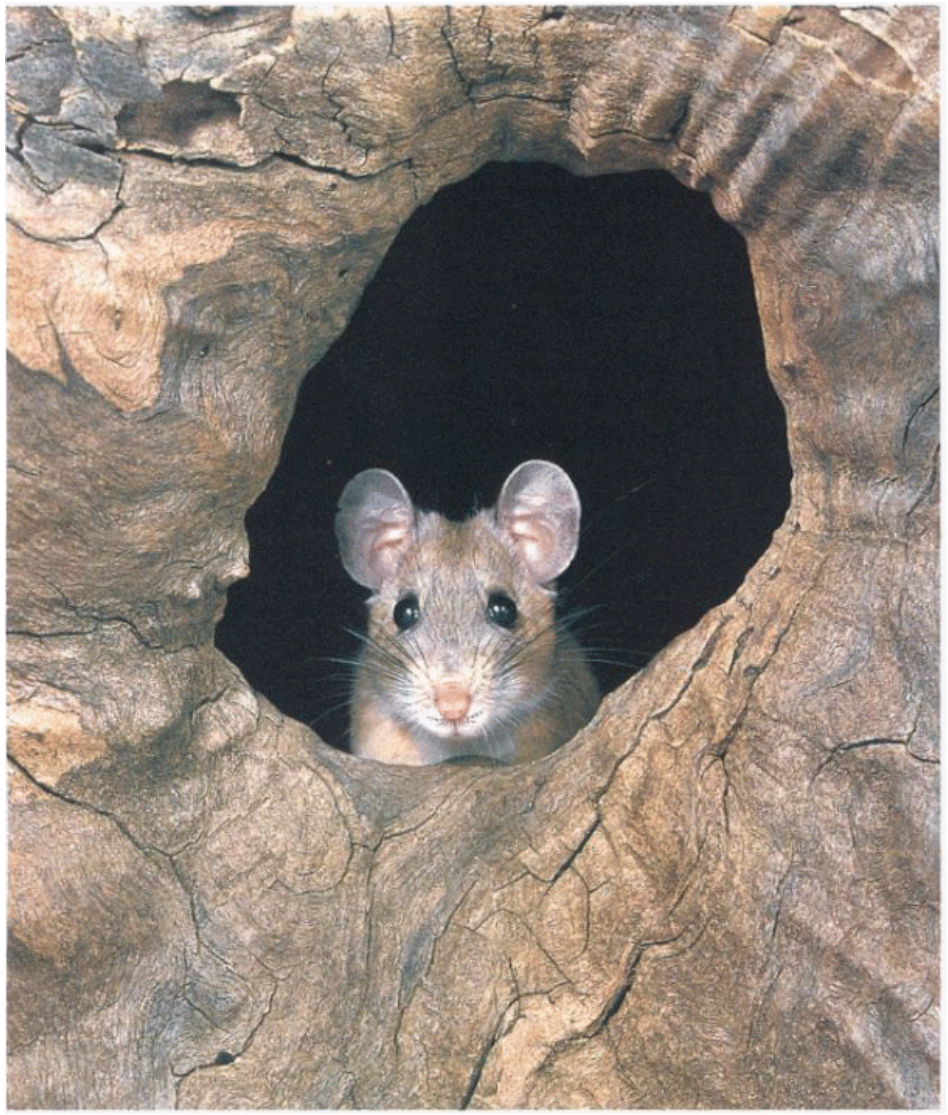
Leaf stomata become less frequent as CO2 levels rise

Sealed buttons hold ancient air

Trapped gasses in ice cores give CO2 levels in the past

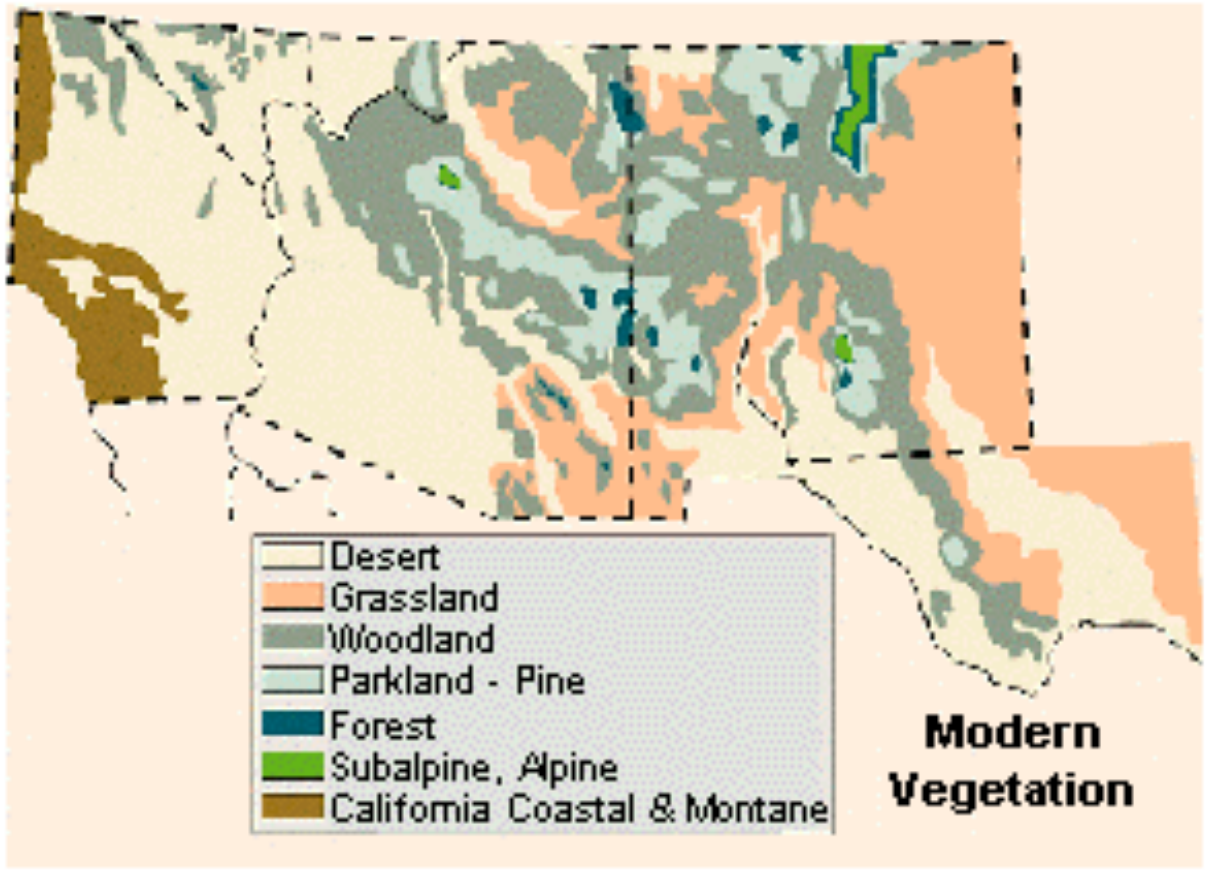
Packrat middens

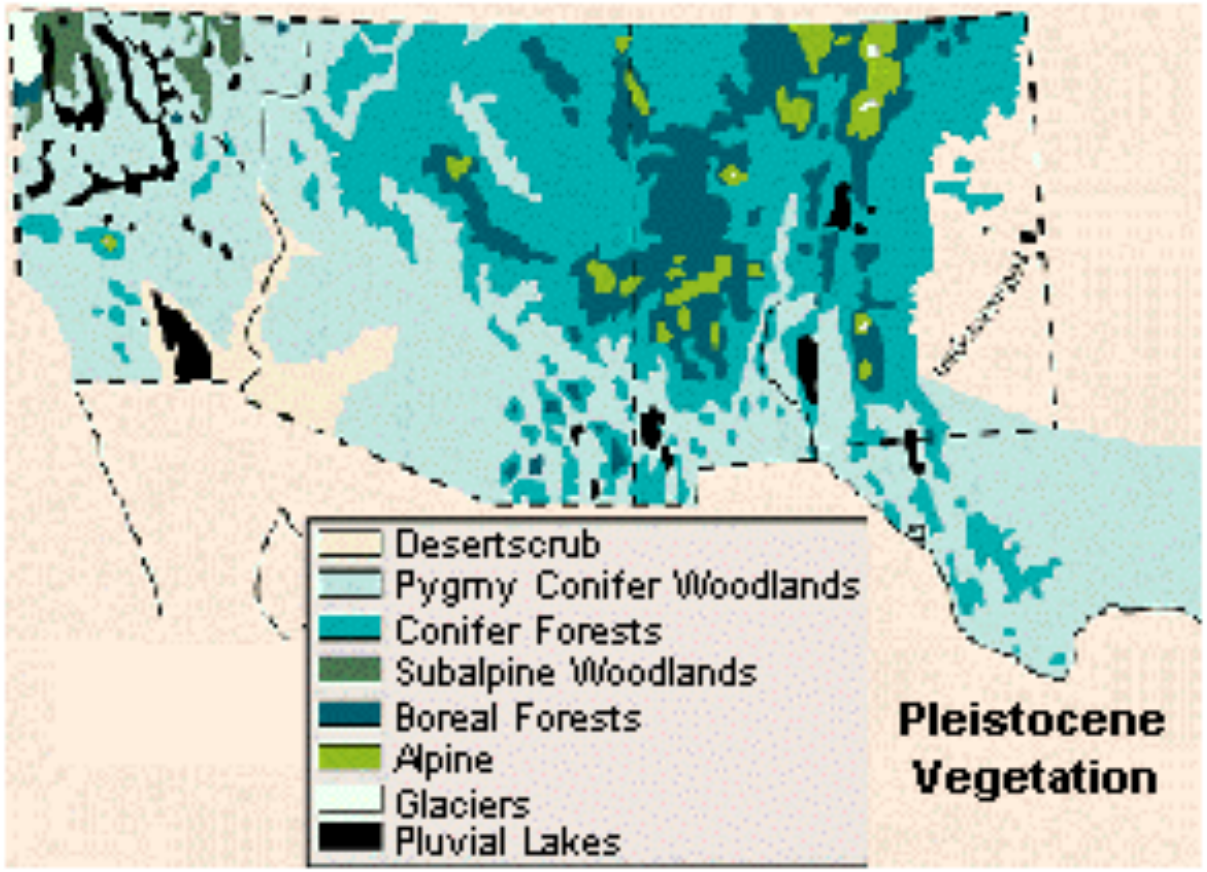
- Crystallized at urine (amberrat)
- Easy to date (using radiocarbon)
- Contain pollen and macrofossils allowing ecosystem reconstruction



Packrat middens

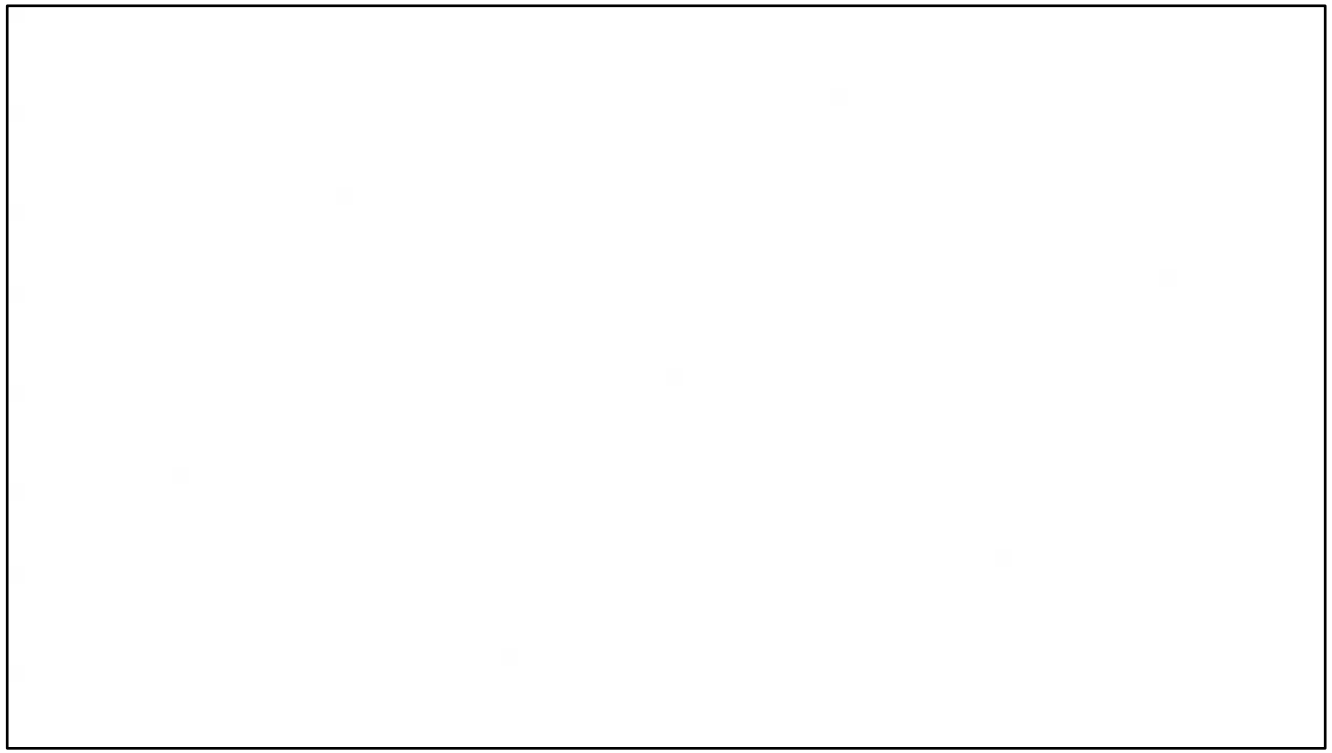
- Useful to 40,000 years
- Found in arid and semiarid regions
- Show dramatic cooling and moistening of desert SW USA





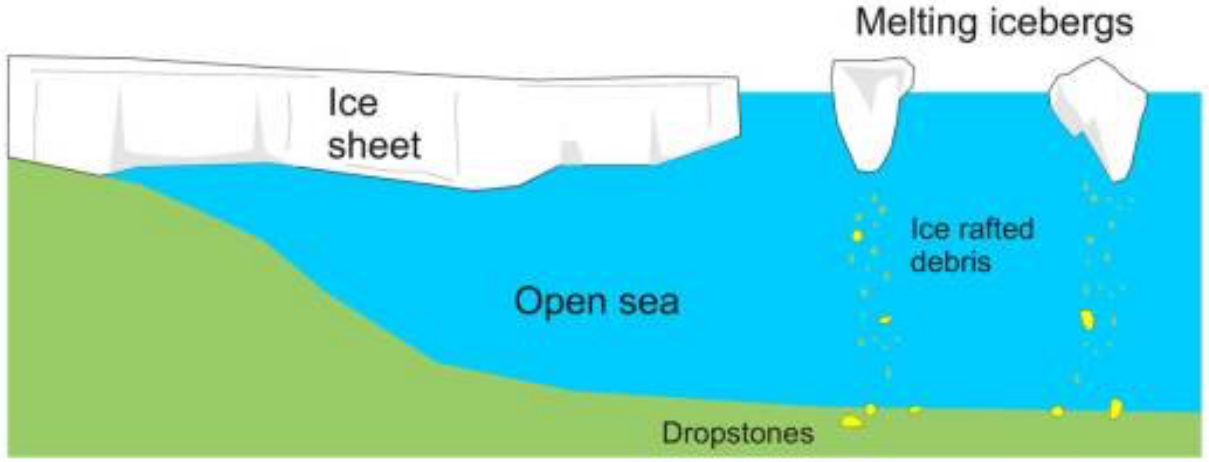
Ocean sediment cores

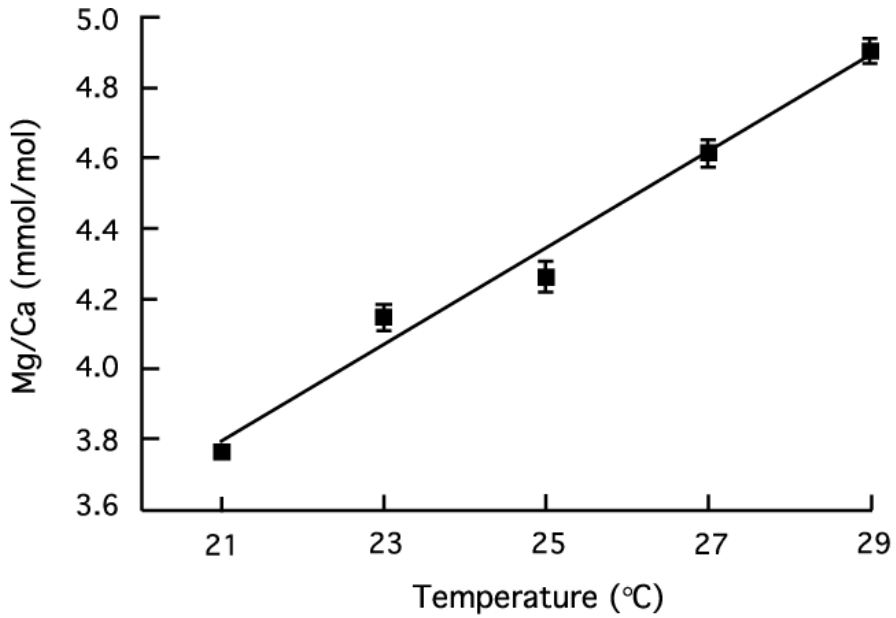
- Near continuous records
- Preserve a variety of climate proxies
- Can be dated by various means



Ocean sediment cores

- Information in sediment (glacier debris)
- Chemical and isotope composition of foraminifera (single cell organisms with calcium carbonate shell)

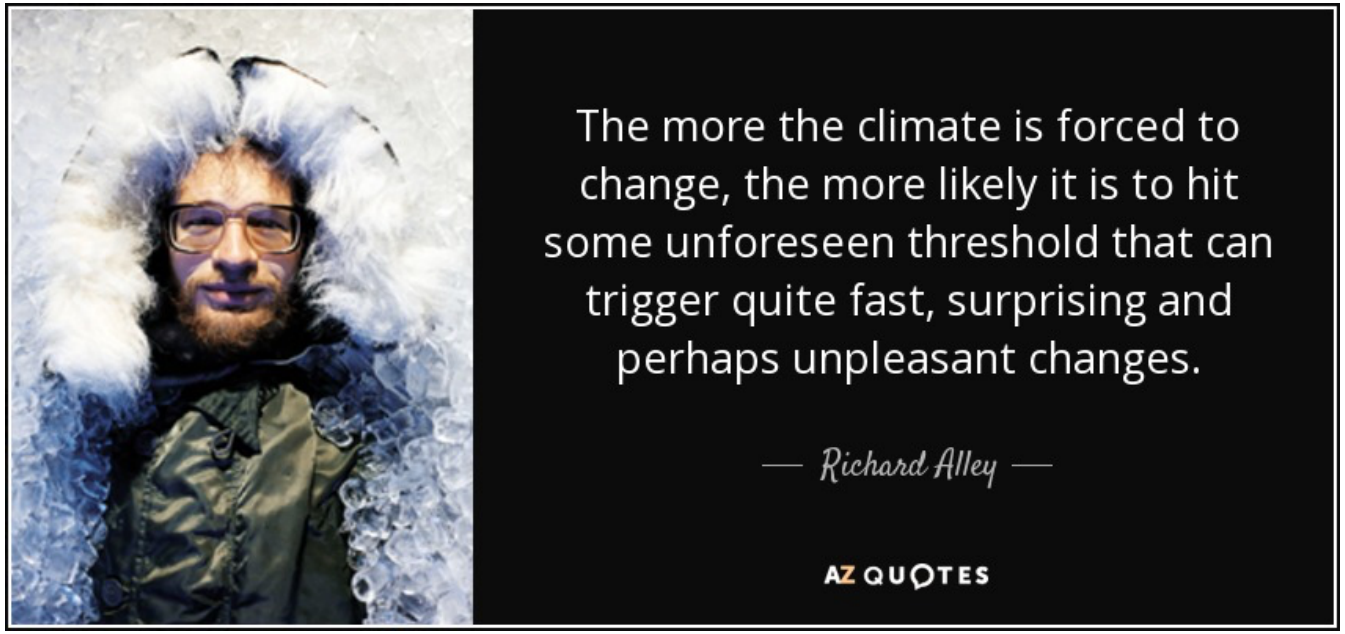


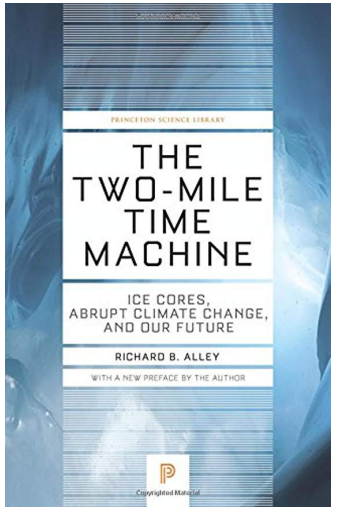


^{16}O	^{17}O	^{18}O
15.9949	16.9991	17.9991
99.76%	0.04%	0.20%
Stable	Stable	Stable

Richard Alley – Mr. Greenland

https://www.youtube.com/watch?v=PKDVC4HJg7c





Alley is a Professor of Geology at Penn State who has worked on Greenland for decades. He was instrumental in recovering and interpreting the GISP2 ice core that went 3000+ meters to the base of the ice sheet. He's the author of Two-mile time machine, a popular book about ice cores.

One can extract paleoclimate information from:

A. Rat nests and fossil leaves
B. Pollen grains and ice cores
C. Ocean sediments and tree rings
D. All of the above
E. None of the above

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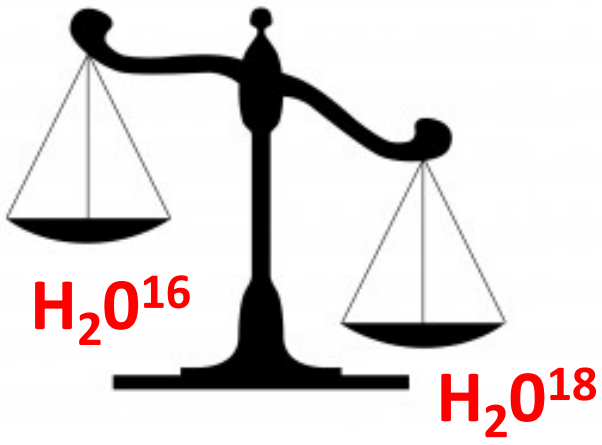
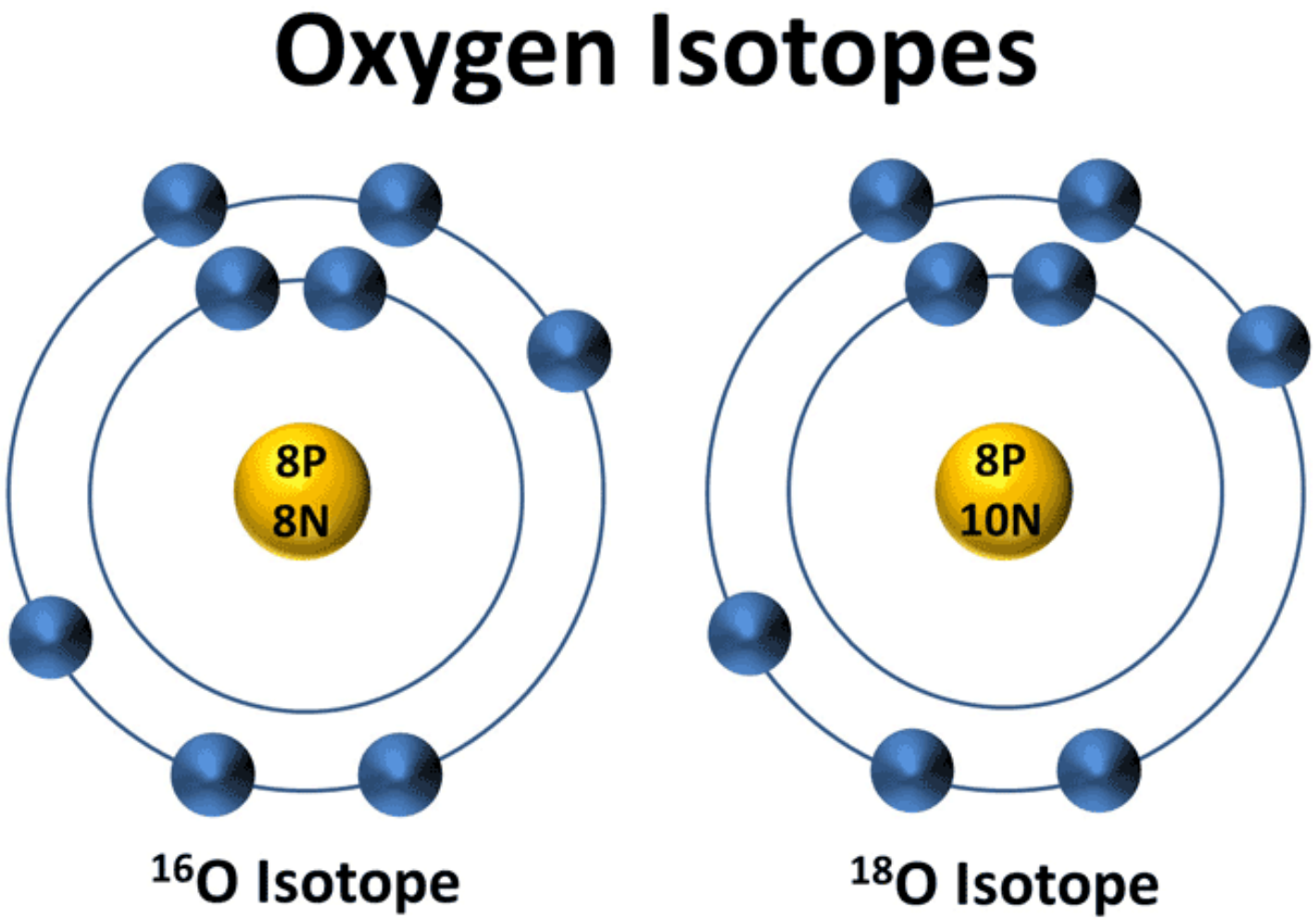
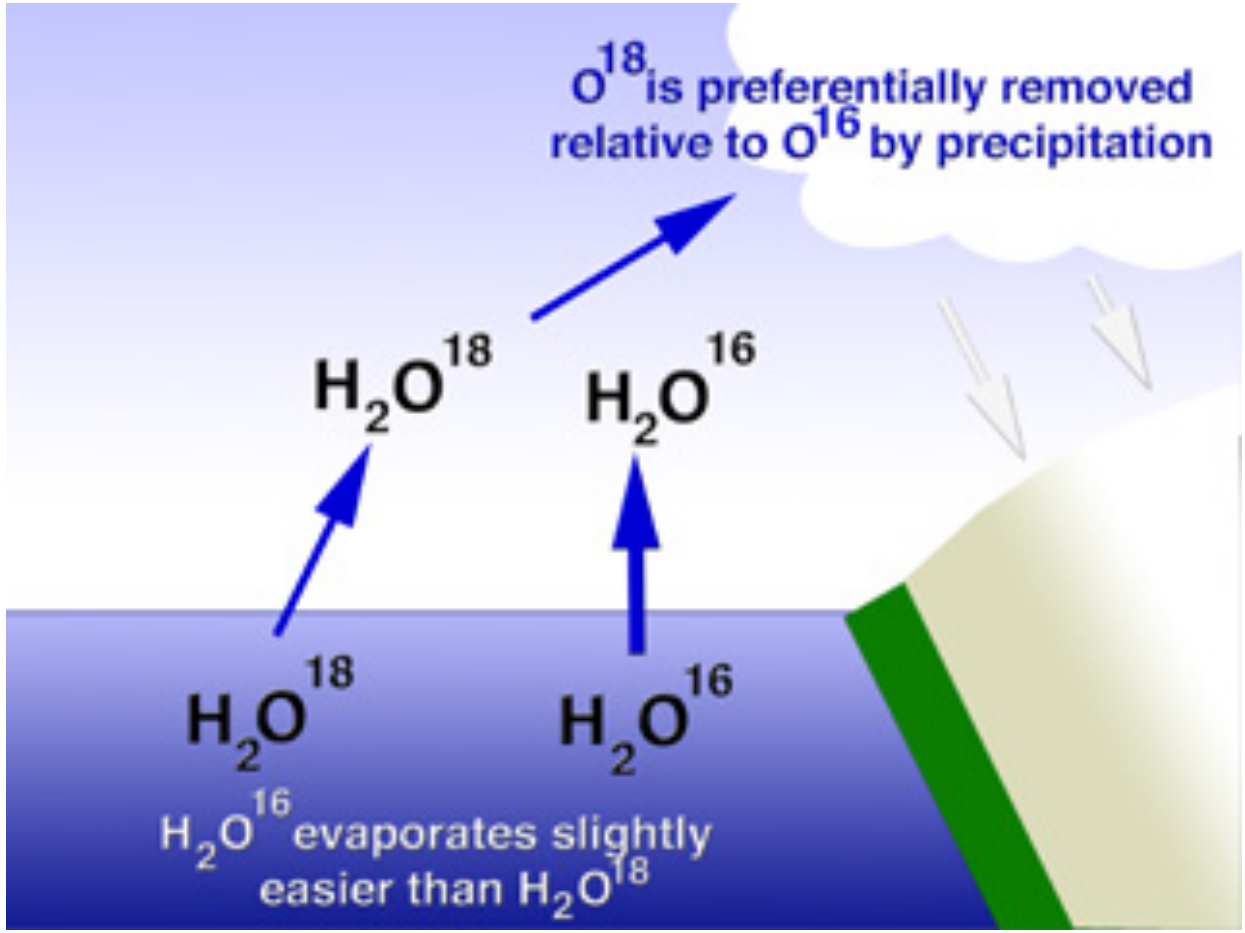
An isotope is the same element (same number of protons) with different numbers of neutrons.

^{16}O	^{17}O	^{18}O
15.9949	16.9991	17.9991
99.76%	0.04%	0.20%
Stable	Stable	Stable

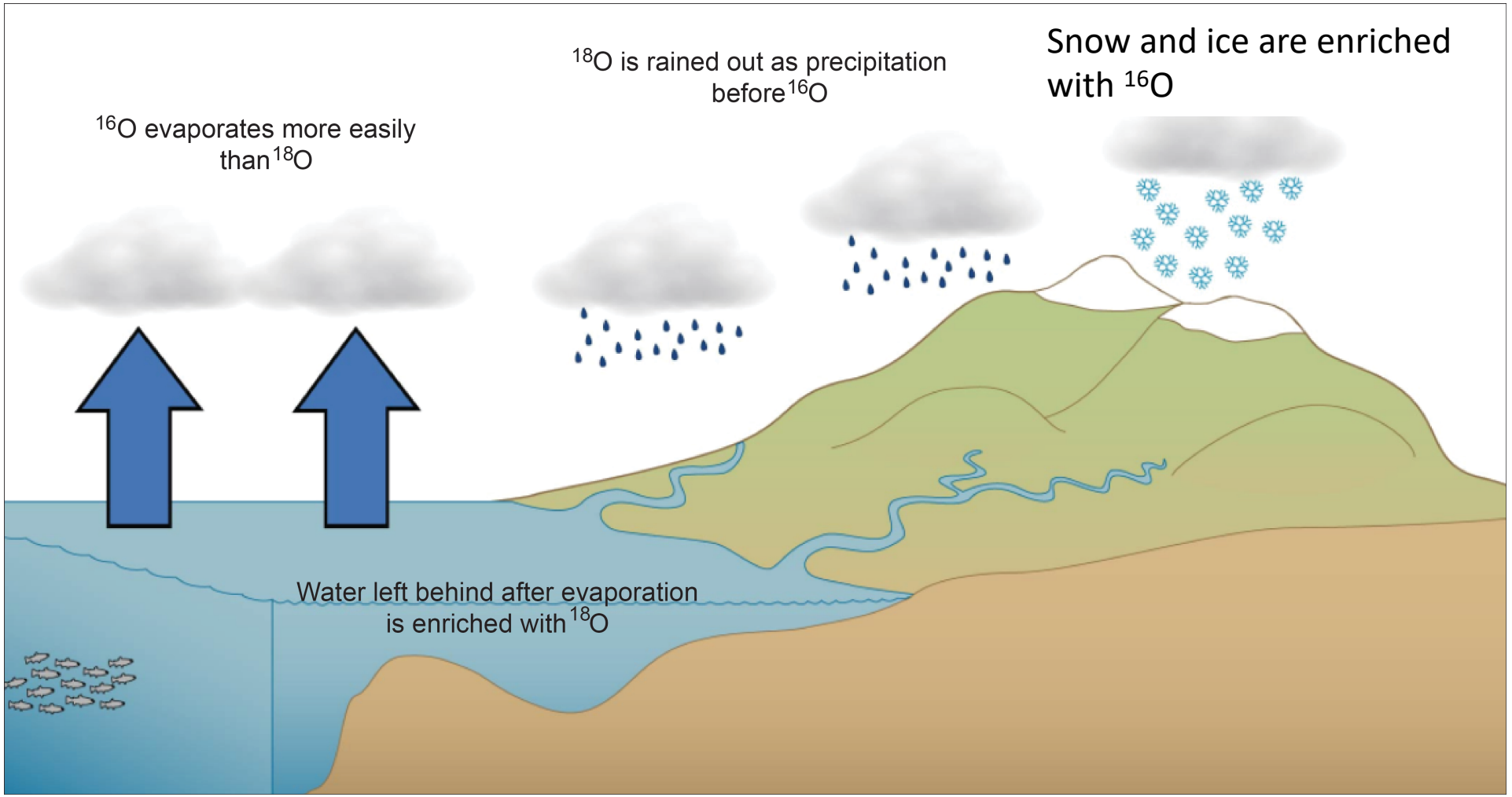




Isotopes matter because evaporation and condensation differ for lighter and heavier water

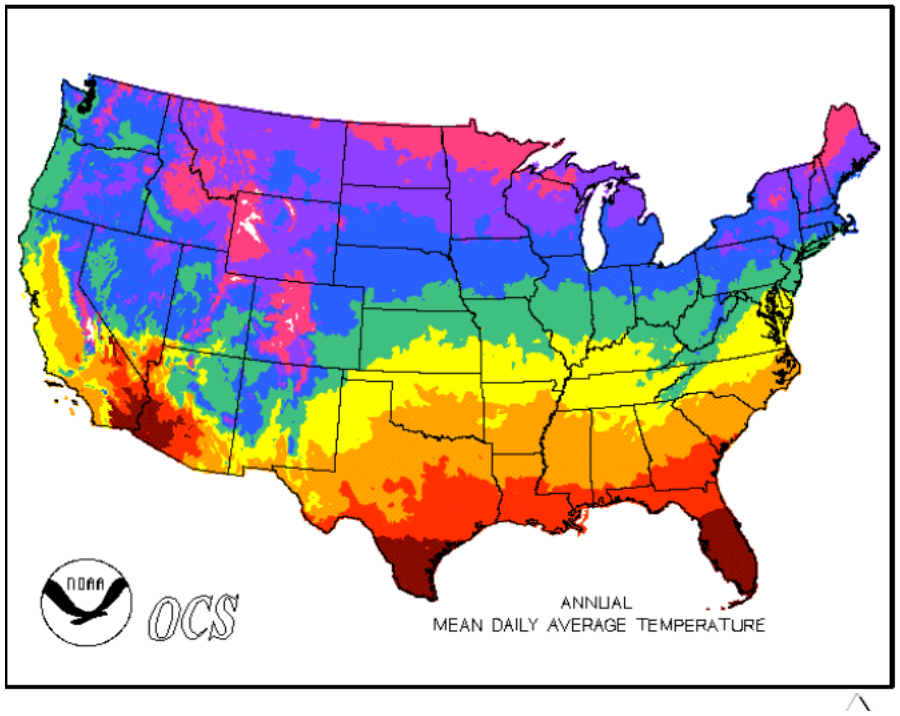


Oceans have lighter water than ice caps

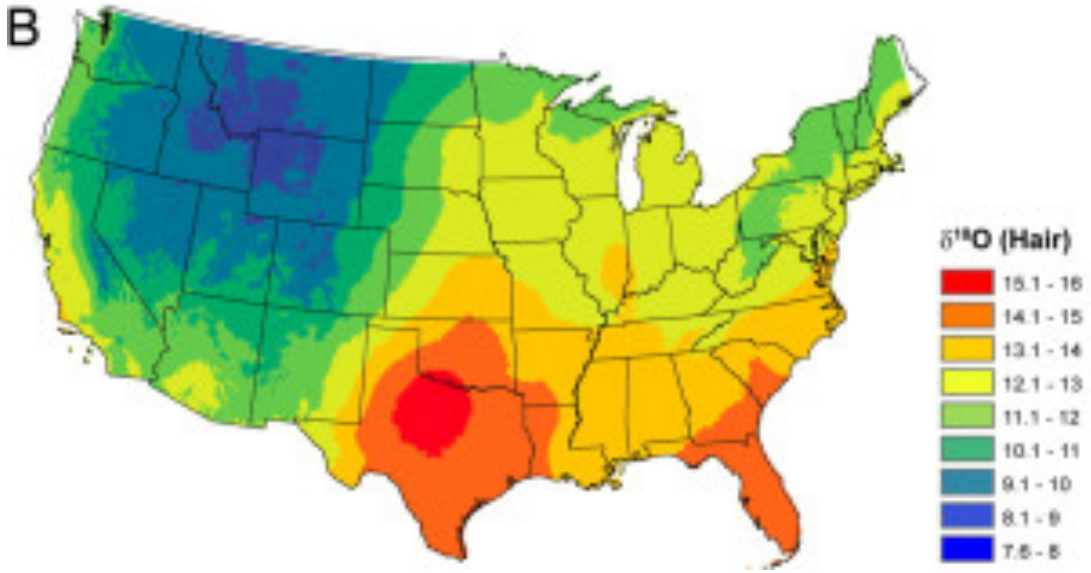


You are what you drink and eat….

Average temperature



Oxygen isotopes of hair



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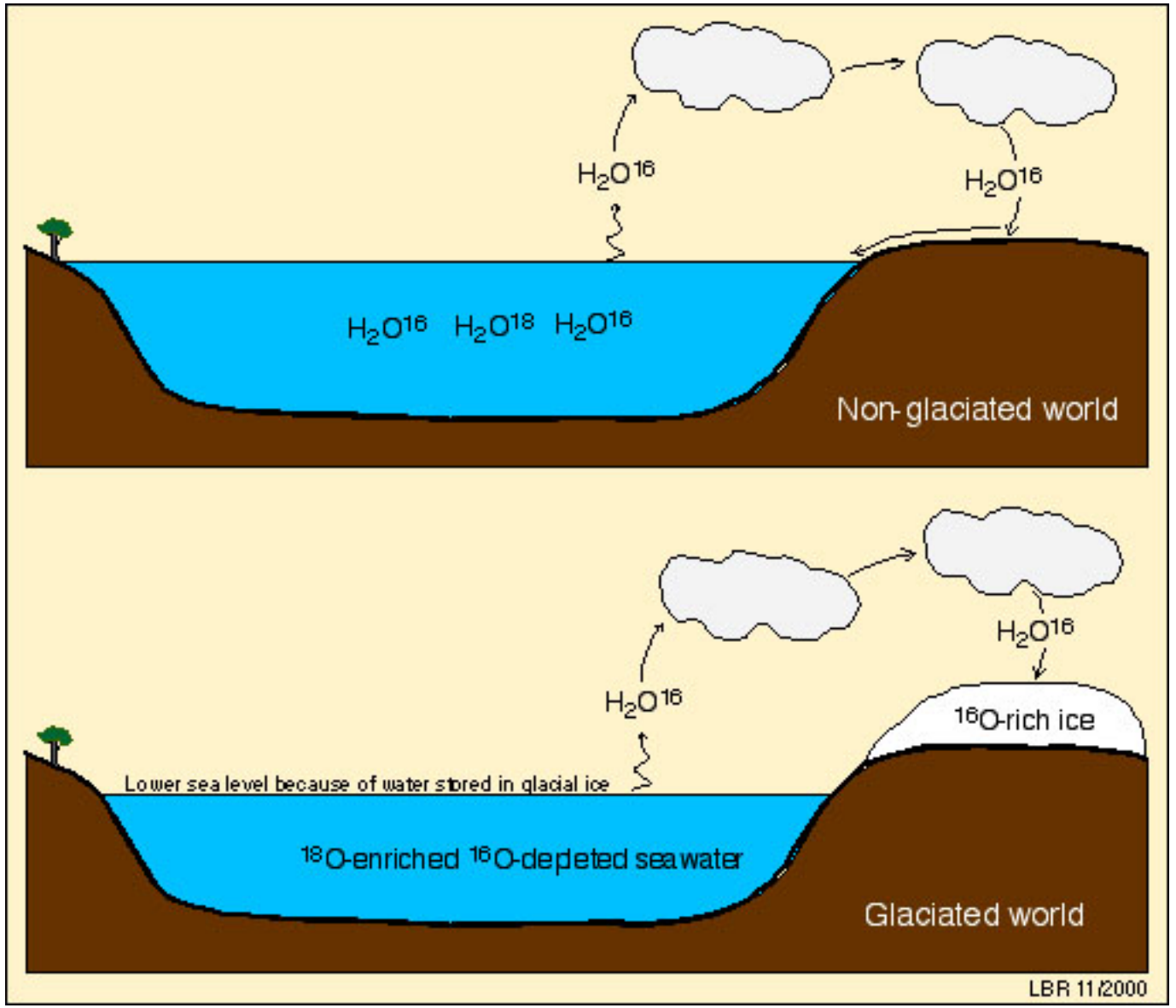
Glaciers store light water, oceans keep the heavier water

Forams keep a record of Oxygen 18/16 in their <u>shells</u>

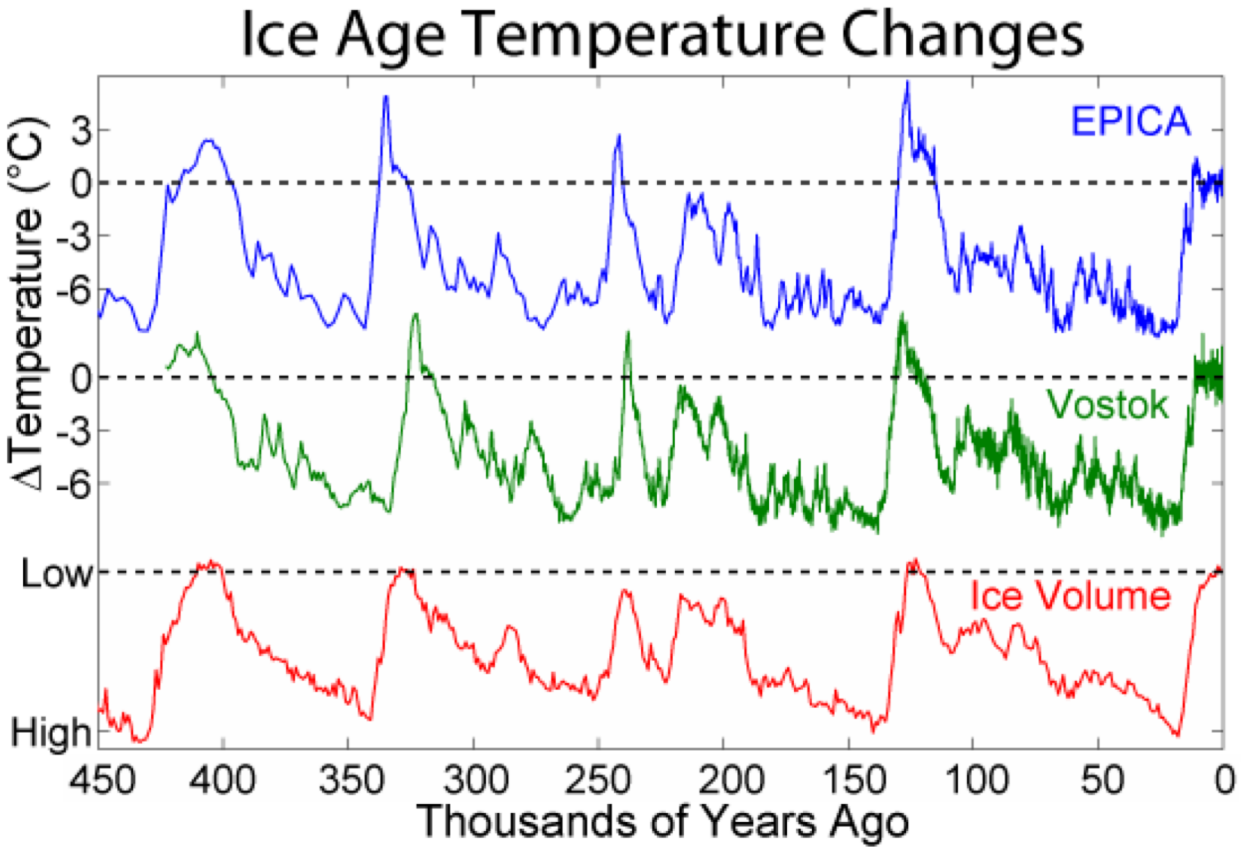
Ice cores keep a record of Oxygen 18/16 in their <u>water</u>

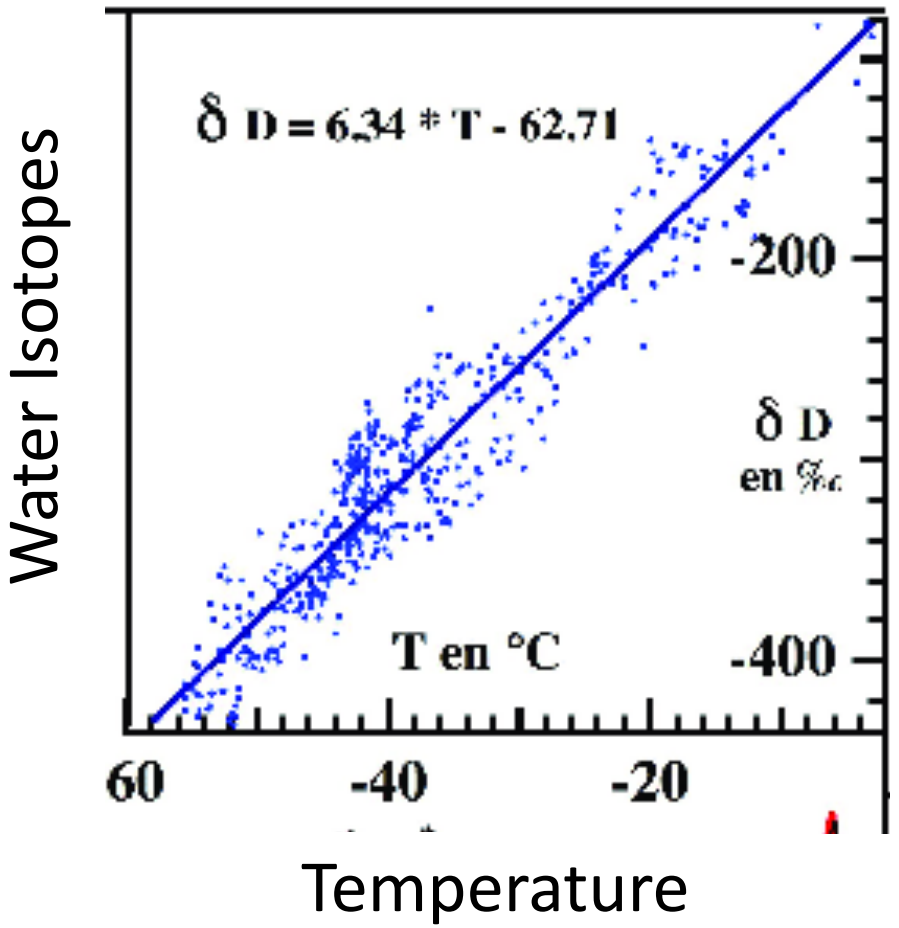


Check in: The water molecules in ice caps….

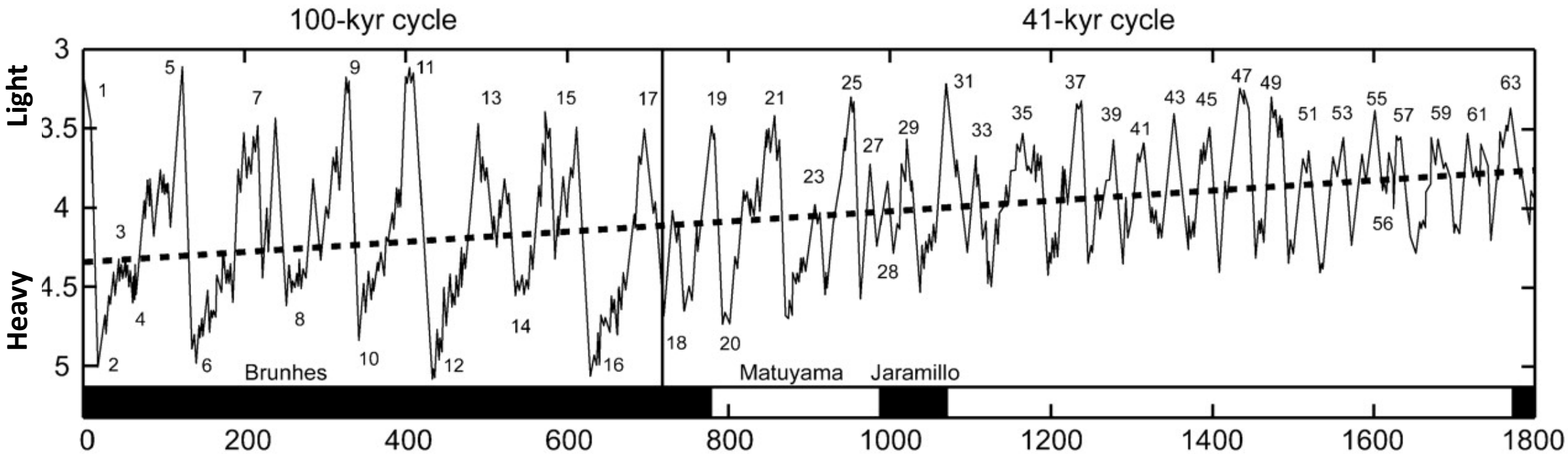
A. Are heavier than the water in the ocean on average.
B. Are lighter than the water in the ocean on average.
C. Have the same average weight as the water in the ocean
D. All have the same mass since they are water

Temperature and the isotopes of water are related…if you measure isotopes, you can estimate temperature

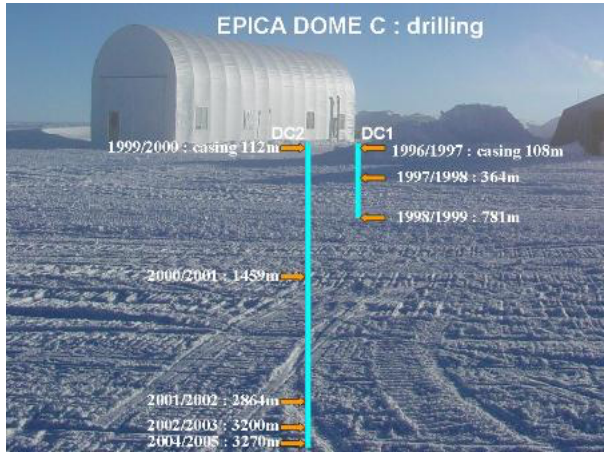


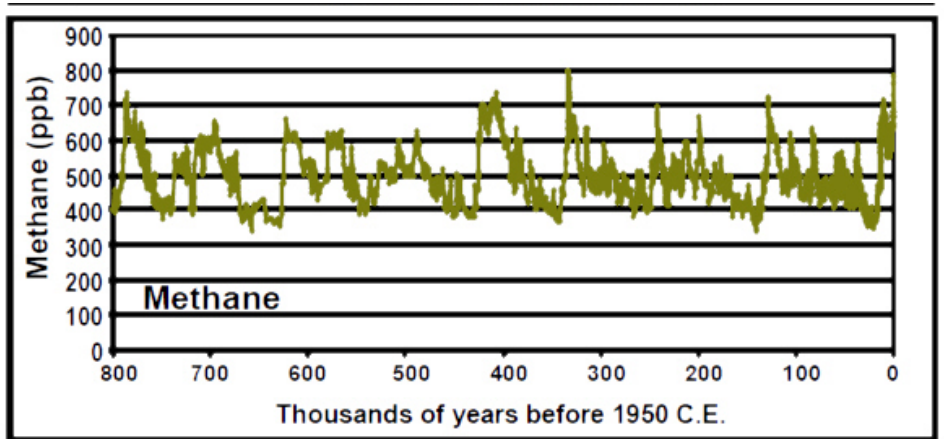


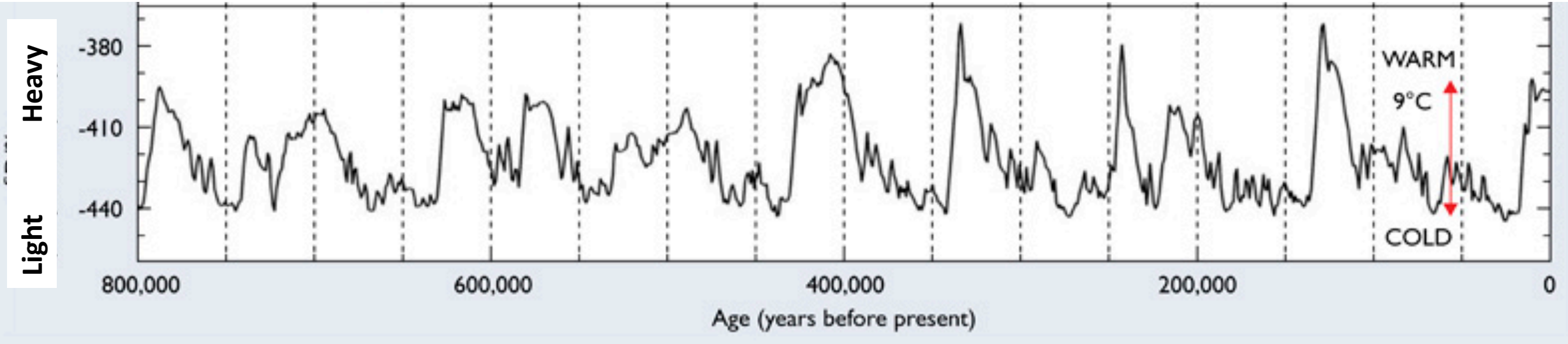
Ocean isotope records show the pacing of ice ages and go way back in time…tens of millions of years



Ice core isotope records show the pacing of ice ages but go back less than a millions years







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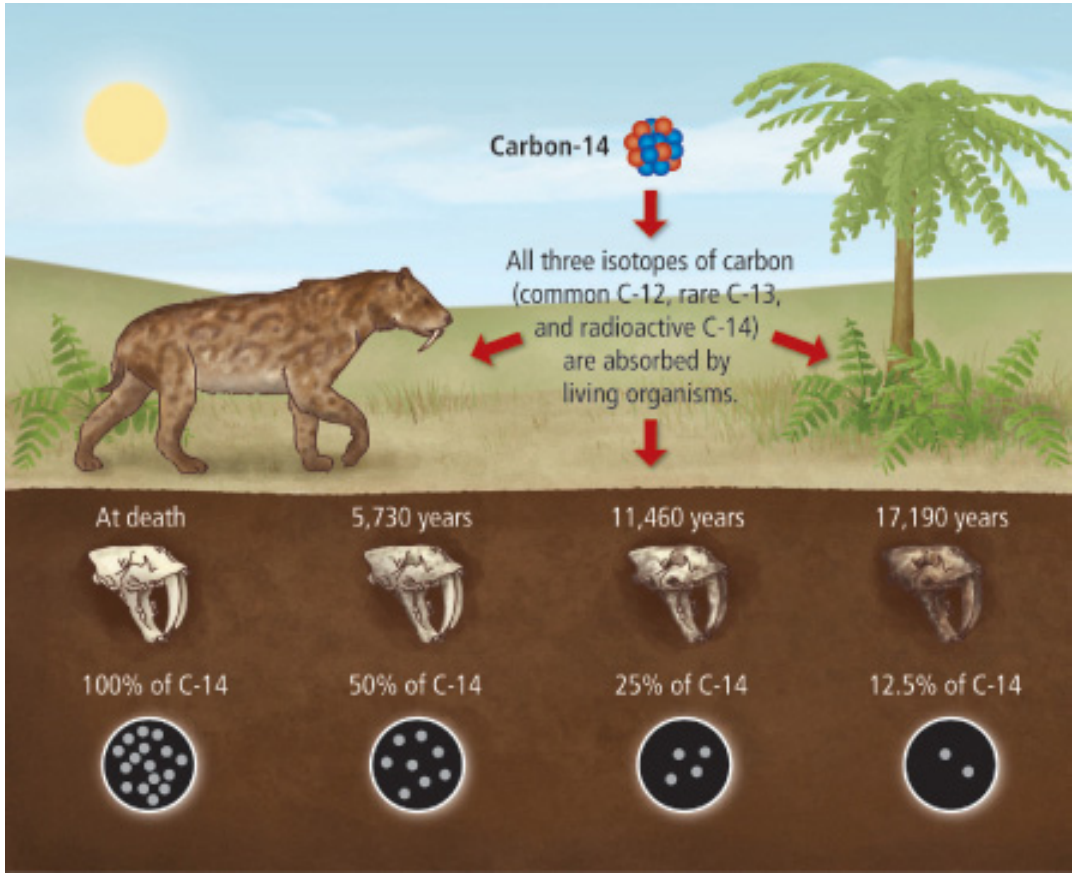
There are uncertainties to paleoclimate proxies

- Non analog vegetation assemblages (don’t match anything we know today)
- Multiple influences on isotope changes
- Transfer functions – from change to temperature
- Combined effects of temperature and precipitation (e.g. glacial response)

Age of records can be tricky to establish



- Radiocarbon dating is critical but limited to 50 ky – last glacial cycle
- Annual deposits can skip years (layers of sediment, tree rings and ice layers

Cost and difficulty of recovering archives

Vostok station, Antarctica, basal ice may be 800,000 years old! Beneath it is a subglacial lake.

- Deep ice core drilling – 50 million Euros (60 million dollars)
- Deep sea drilling – $150,000 per day
- Lake coring - $100,000 for Lake Champlain
- Tree coring – cheap! $100 coring device and lots of time

Added reading (this one is fun!)

ANNALS OF SCIENCE JANUARY 7, 2002 ISSUE

ICE MEMORY

Does a glacier hold the secret of how civilization began—and how it may end?

By Elizabeth Kolbert December 30, 2001

Next time - Paleoclimate I - Industrial & Holocene records

Make sure to read
READ: Kolbert article and Ruddiman Chapters 3, 17, and Appendices 1 & 2;
QUIZ 3