WRITTEN IN THE ARCTIC: PALEOCLIMATOLOGY

Introduction

What is paleoclimatology, what are archives and proxies? Has climate change occured in the past and how do we know it? How do scientists interpret natural records? What kind of history records can be found in the Arctic, and not only there?
Paleoclimatologists seek to explain climate variations for all parts of the Earth during any given geologic period, beginning with the time of the Earth's formation.

Many related fields contribute to the field of paleoclimatology, but the basic research data are drawn mainly from geology and paleobotany; speculative attempts at explanation have come largely from astronomy, atmospheric physics, meteorology, and geophysics.

Since modern records do not outline most of Earth's climatic past, scientists must gather data preserved in nature over the millennia in paleological remains referred to as **proxy records**.

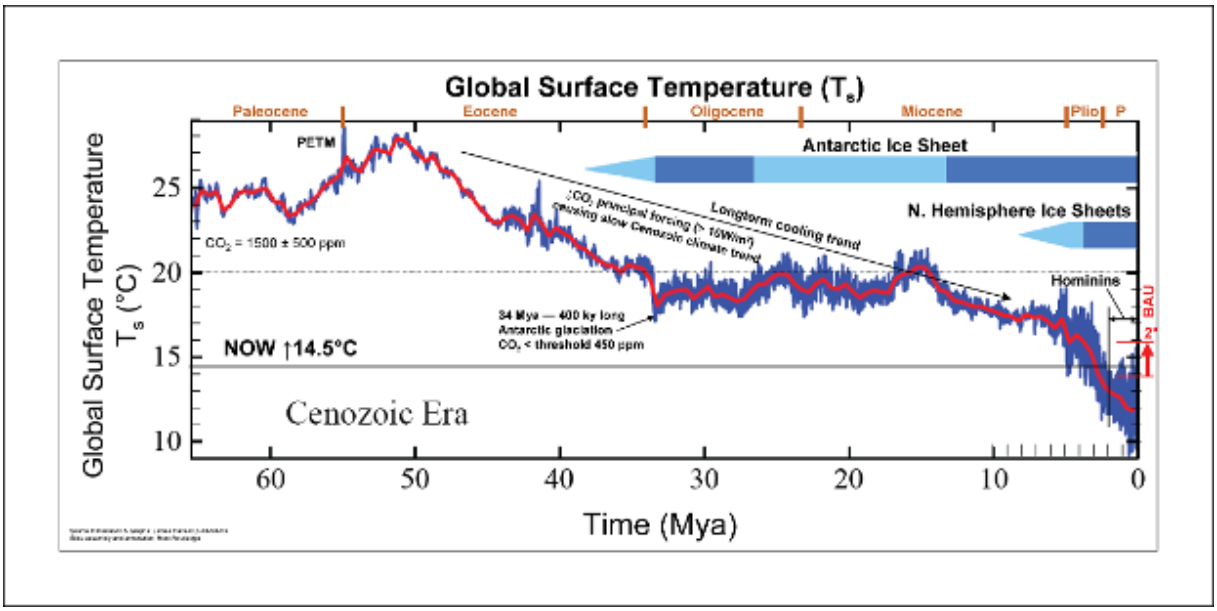
Let's take a look at the climate over the last 65 million years, since the extinction of the dinosaurs. The Ice Age cycles known to us are the domain of the last 2-3 million years. Going back even further in the past, we will see that previously the climate was much warmer.

The major climate changes in the past, before humans began to affect the environment on a large scale, took place because the climate was driven by some kind of external change that is usually called climate forcing. These forces include:

- **changes in solar radiation intensity**
- **volcanic eruptions (which usually cool briefly)**
- **rapid release of greenhouse gases**
- **changes in the Earth's orbit**.

At the border of the Paleocene and Eocene eras, 55 million years ago, there was a sharp rise in Earth temperature, a sudden global warming that led to the Maximum Thermal Paleocene and Eocene (PETM). It is believed that this could have been caused by the sudden release of greenhouse gases into the atmosphere.

EDU-ARCTIC 2: from polar research to scientific passion – innovative nature education in Poland and Norway receives a grant of ca. 240 000 EUR received from Iceland, Liechtenstein and Norway under EEA funds. The purpose of the EDU-ARCTIC 2 project is to: enhance the knowledge about nature, geography, natural resources, political specificities concerning polar regions and increase awareness of environmental issues and climate change, increase of interest in pursuing STEM education and careers due to enhancement of knowledge about scientific research, and their place in the modern world, familiarizing young people with scientific career opportunities; introduce innovative tools by way of an e-learning portal and effective methods of teaching science in schools



What was it like in the past? Solve the YES/NO QUIZ.

There were periods with much lower temperatures than now in Earth's history

Yes No

There were periods with much higher temperatures than now in Earth's history

Yes No

At some point, when Antarcic was ice free, Greenland was covered with ice

Yes No

Long term cooling trends prevail over last 65 millon years

Yes No

Global ocean level was lower 45 million years ago than 3 million years ago

Yes No

What are proxies?

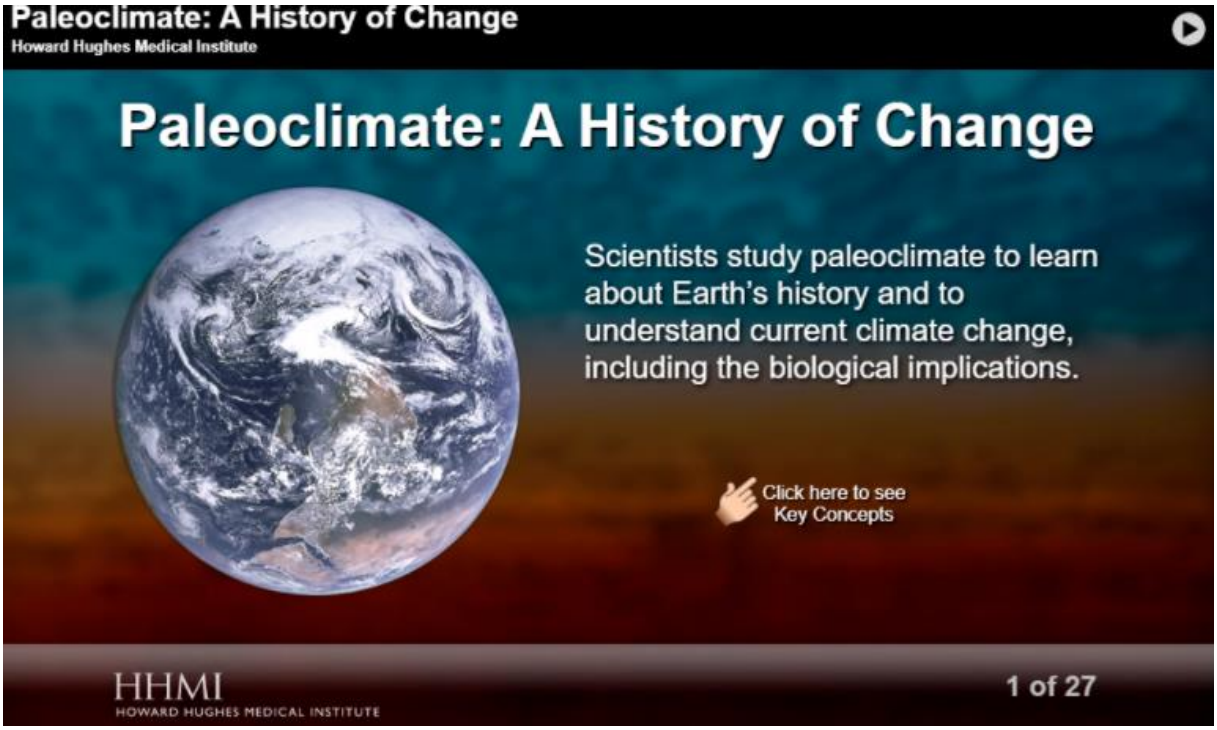
Proxy data are used to _____ the climate and ocean states from thousands to _____ of years ago. They can be thought of as nature's _____ keepers, in that proxy data come from pollen, trees, coral, ice _____, stalagtites, and ocean and _____ sediments and are preserved physical characteristics of the environment that can stand in for direct _____. Because we can't go back in time to test the air and measure how much _____ was around, and how hot or how _____ it was, paleoclimatologists heavily rely on these records to tell them something about the Earth.

WORDSEARCH: find examples of proxies:

X	G	F	O	R	A	M	N	I	F	E	R	A	C
N	R	D	S	I	Q	K	I	C	O	R	A	L	S
X	V	O	J	T	P	C	P	E	A	T	C	L	E
G	V	W	Z	G	E	Q	K	C	B	P	S	C	N
J	I	P	Y	Z	A	R	P	O	L	L	E	N	Z
L	Z	N	G	T	R	E	E	R	I	N	G	S	F
E	D	I	S	O	T	O	P	E	S	O	D	H	N
S	E	D	I	M	E	N	T	S	D	Z	F	B	G

1. **ICECORES**
2. **TREERINGS**
3. **POLLEN**
4. **SEDIMENTS**
5. **PEAT**
6. **CORALS**
7. **FORAMNIFERA**
8. **ISOTOPES**

A history of change



The history of Earth's climate over millions of years, during both warmer and colder periods, sheds light on the causes implications, and severity of current climate change.

GO TO INTERACTIVE PRESENTATION:
https://media.hhmi.org/biointeractive/click/paleoclimate/

Learning from the past:

Explain how the ability to describe the pattern of ice ages over the past million years helps us to assess what is a “normal” variation in Earth’s atmosphere.

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……

Atmospheric changes in Earth’s history have caused large temperature changes through time. Explain how knowledge of these past connections between atmosphere and climate can inform us about modern-dayclimate change.

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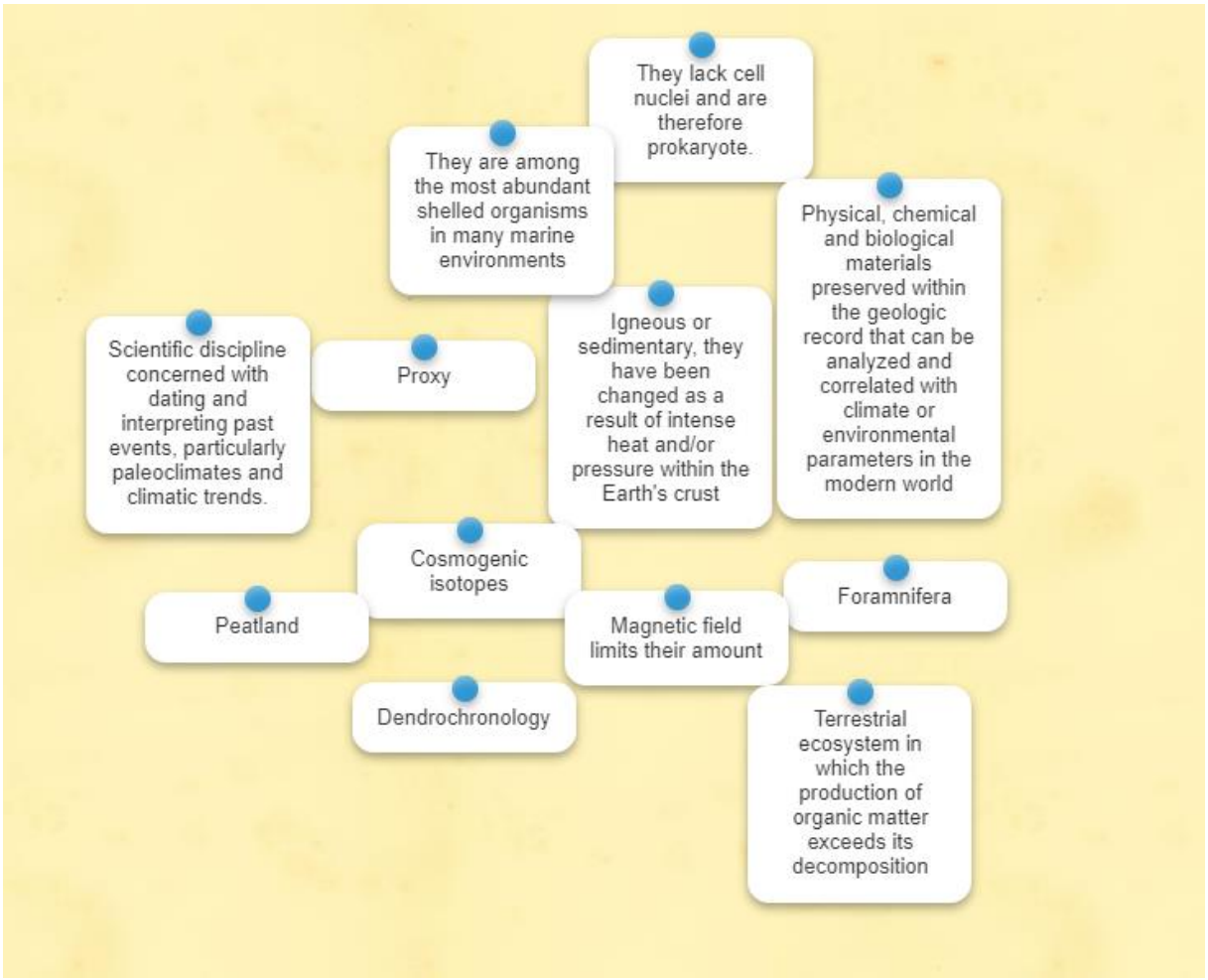
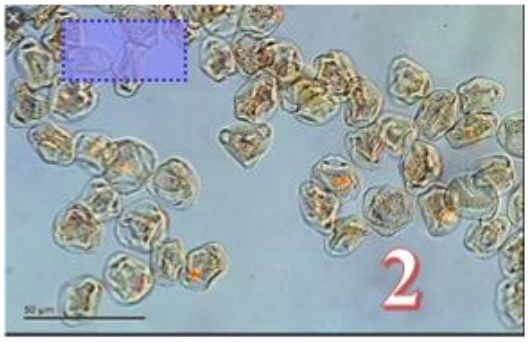
Inquiry

Meet the proxies
Match names and definitions. 2 definitions don't match any term.



Which proxy is which?

Match name of the proxy with image. Click "i" icon to learn more about each proxy.

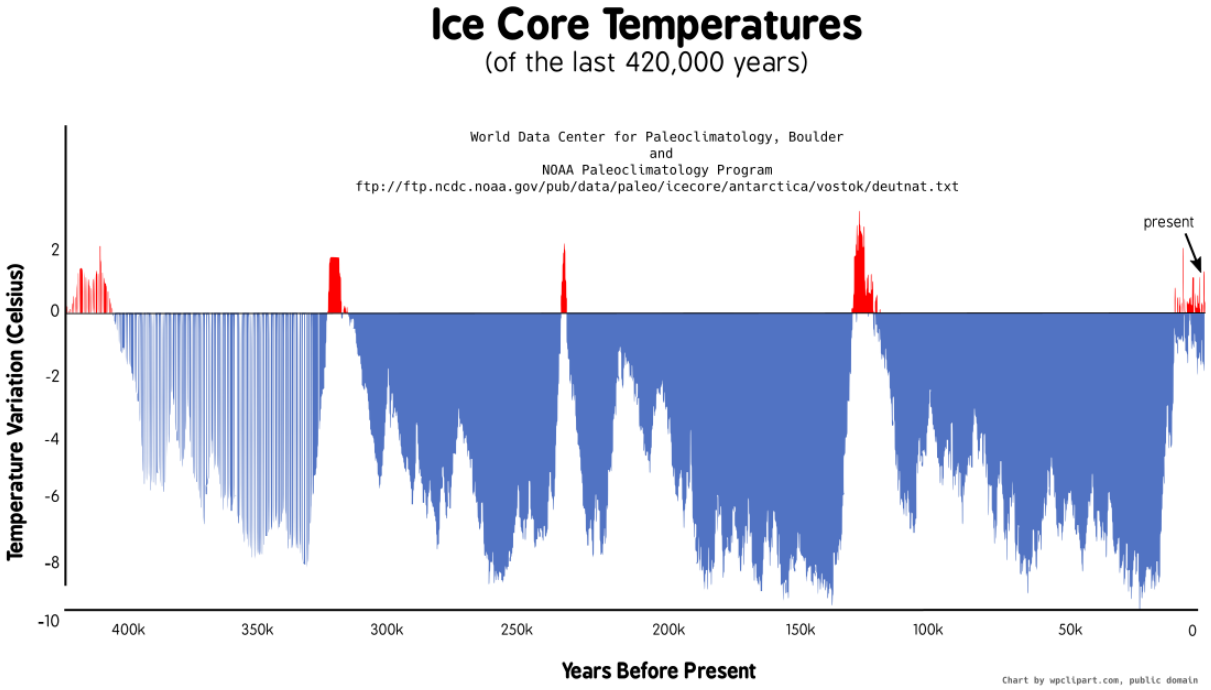


tree rings pollen peat

Ice cores

Ice, dust and air bubbles trapped in ice can be analysed to reveal how air temperature and atmospheric content of greenhouse gases such as CO2 and methane have changed over long time spans. Ice coring has been around since the 1950s. Ice cores have been drilled in ice sheets worldwide, but notably in Greenland and Antarctica, Ice cores from Antarctica can reveal temperatures 800 000 years back into the past. Ice cores from Svalbard can also be used to study climate, but these cores are trickier to interpret because summer melting is greater there than in Antarctica.

The Arctic has not been continuously iced-over for as long as Antarctica, so climate archives in the north cover less time. In glaciers at the highest altitudes in Svalbard, where summer melting is smallest, it is possible to take ice cores that go 1000 years back in time.



Why are ice cores important?

Glaciers carry important information about ancient climate. Ice, dust and air bubbles trapped

in ice can be analysed to reveal how air temperature and atmospheric content of greenhouse gases such as CO2 and methane have changed over long time spans. Ice coring has been around since the 1950s. Ice cores have been drilled in ice sheets worldwide, but notably in Greenland and Antarctica, Ice cores from Antarctica can reveal temperatures 800 000 years back into the past. Ice cores from Svalbard can also be used to study climate, but these cores are trickier to interpret because summer melting is greater there than in Antarctica. The Arctic has not been continuously iced-over for as long as Antarctica, so

climate archives in the north cover less time. In glaciers at the highest altitudes in Svalbard, where summer melting is smallest, it is possible to take ice cores that go 1000 years back in time.

Now fill in the blanks to continue ...

The measurement of the …… composition is direct: trapped in deep ice cores are tiny …… of ancient air, which we can extract and analyse using mass ……. .

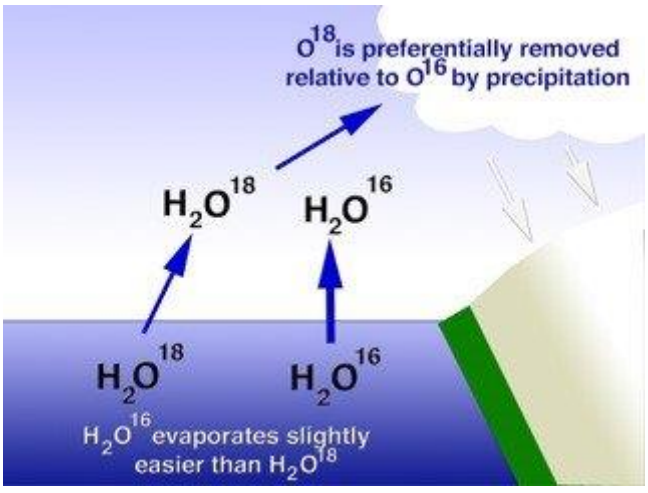
……., in contrast, is not measured directly, but is instead inferred from the isotopic composition of the water molecules released by melting the ice cores.

The isotopes of particular interest for climate studies are OXYGEN and HYDROGEN: 16O (with 8 protons and 8 neutrons that makes up 99.76 percent of the oxygen in ……) and 18O (8 …… and 10 neutrons), together with 1H (with one proton and no neutrons, which is 99.985 percent of the …… in water) and 2H (also known as deuterium (D), which has one proton and one neutron). All of these isotopes are termed 'stable' because they do not undergo radioactive decay. …… has been used to date the Dome C ice core from Antarctica.

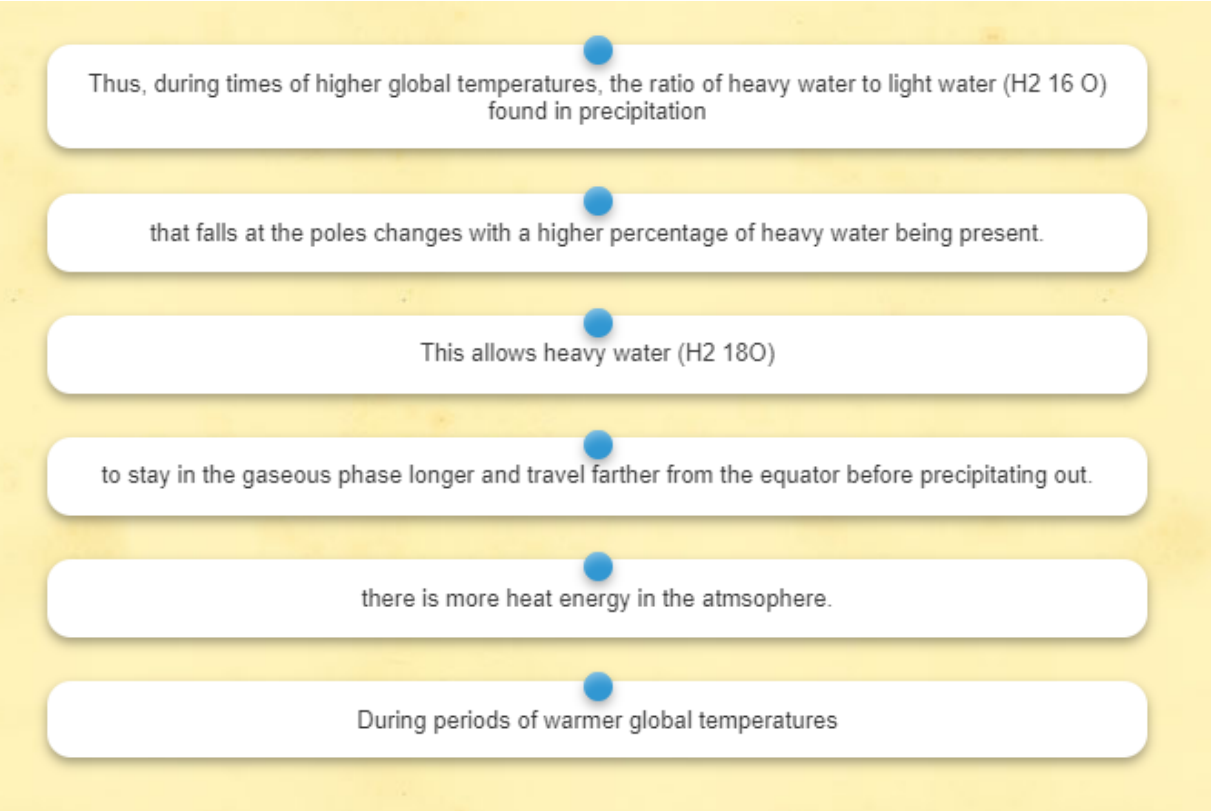
neutrons	melting	gas	Uranium	water	Temperature	hydrogen	spectrometers	protons	bubbles

Oxygen isotopes

The ratio (meaning: relative amount) of these two types of oxygen in water changes with the climate. The water-meaning ice in glaciers originally came from the oceans as vapour, later falling as snow and becoming compacted in ice. Now observe the figure below and solve the riddle.



How does it work?
Put parts parts of sentences in correct order to learn how do we read past temperatures form isotopes found in ice cores.



Greenland ice core data

You are now working with oxygen isotope data collected from twenty sites in Greenland that has been statistically averaged. They epresent conditions in the winter season (November-April) for the years 1829-1970. (reduced to data for every 5 years). Scientists have an indicator for the relative amount of H2 18O in water. It is δ18O, and is pronounced “delta-18-O”. The delta, δ, stands for “change,” and the 18O represents the oxygen18 in H2 18O. So, in ice core samples taken at the poles, a higher ratio of heavy water to light water indicates higher average global temperatures.

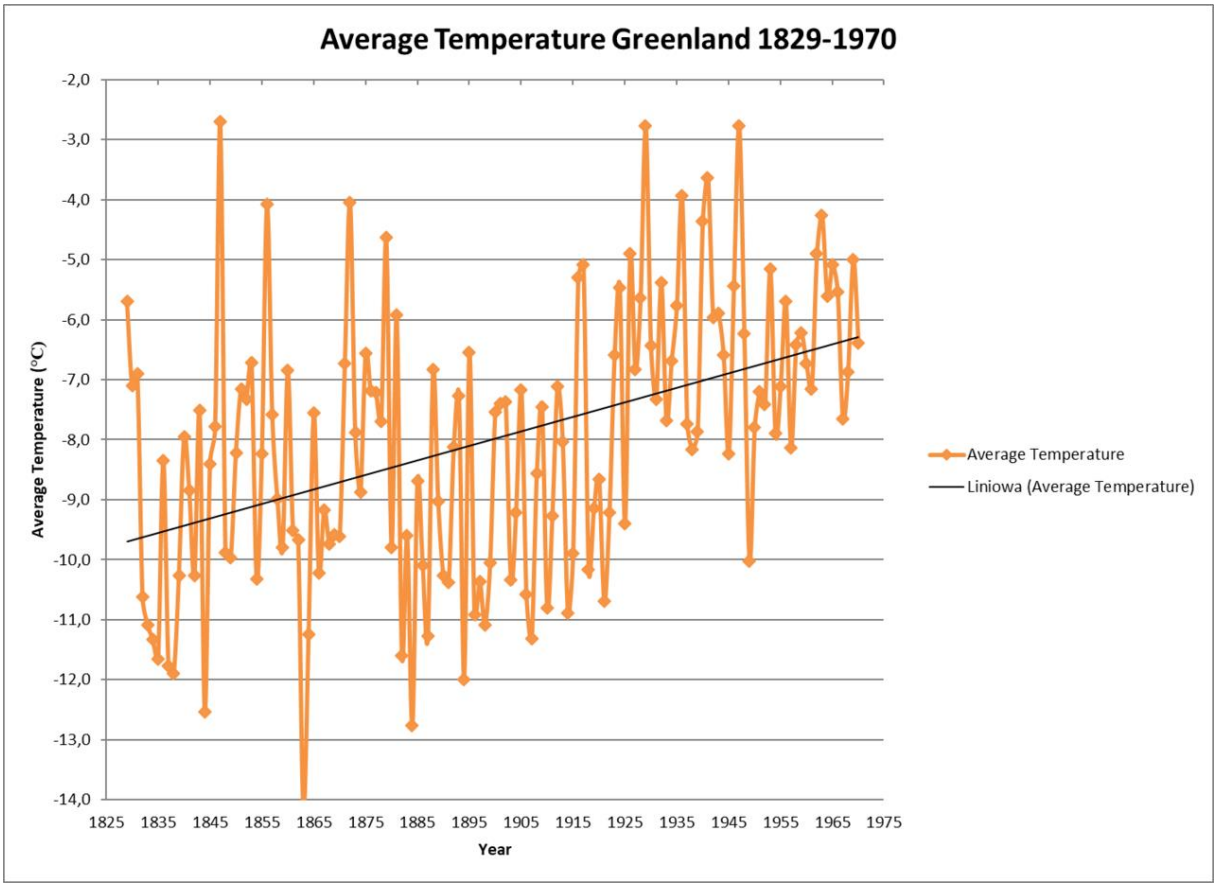
YEAR	δO18-O18/O16 Ratio
1960	**4,183**
1955	-0,506
1950	-0,539
1945	-1,803
1940	5,541
1935	2,675
1930	-0,388
1925	-1,588
1920	-1,264
1915	-3,439
1910	-2,106
1905	-2,887
1900	-4,145
1895	2,300
1890	-3,772

1885	-1,642
1880	-0,357
1875	1,464
1870	-1,419
1865	0,784
1860	-1,009
1855	0,382
1850	0,373

TRUE OR FAKE?

Now look at the graph below, showing changes in temperature in Greenland.

Compare this graph with data from ice cores (see table). Do you think this is a correct graph? Explain.



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Tiny but mighty

Solve the quiz about one of the most fascinating proxies!

FORAMINIFERA represent a group of marine, microscopic, shell-producing organisms belonging to the Procaryota		
	TRUE	FALSE
Some calcareous, planktonic species of foraminifera have different morphotypes		
	TRUE	FALSE
Often these morphotypes involve the colour		
	TRUE	FALSE
In case of Neogloboquadrina pachyderma, when ocean water temperatures are cooler than 8° to 10° C, forams add these new chambers in a counterclockwise spiral ("left-coiling").		
	TRUE	FALSE
Their microscopic size (.1 mm - 1 cm) and wide geographic distribution in both modern and ancient seas result in the availability of billions of their shells through drilling		
	TRUE	FALSE
When studying forams, we never study isotopes		
	TRUE	FALSE

Research

Ice Core Drilling
A group of scientists is drilling through Arctic ice to find out what's happening in the middle of the ice field, and how that could affect all of us.

LINK TO THE VIDEO: https://youtu.be/fHWnoGl79y4

How to handle an ice core?

Drilling an ice core is a tough task. Since core samples are needed, researchers cannot simp[ly destructively bore through the ice sheet, thedrill has to be hollow. Also, as they’re carving our ice cores with a hollow drill-head, they have to collect the ice cuttings in order to keep the borehole open. Additionally, to lubricate the drilling process and fill the void left by the coring, they usually use an ester-based drilling fluid, that smells a little bit like a coconut.

To unlock the information inside an ice core, researchers in the lab may melt or crush the sample bit by bit; each deeper layer represents a slightly earlier time in the Earth's climate history. The ice arrives in small strips, about 1-by-1 inch apiece, which are smaller slices of the roughly three-foot-long, coffee-can-wide pieces a drill pulls out of a glacier.

Sometimes researchers are studying actual bubbles of the early atmosphere, trapped in the ice as it formed. To collect them, they crush the sample under a vacuum hood, which keeps other air out while they pull the newly released air into vials.

Scientists run melted samples through various instruments—mass spectrometers, scanning electron microscopes, gas chromatographs—to find tiny pieces of pollution, like sulfates, traces of metals, or radioactive fallout, or natural aerosols like dust or volcanic ash.

Because every clue in the ice, whether a grain of sea salt or an air bubble, is so miniscule and the measurements must be incredibly precise, any analysis must be done in a "clean room"

setting. The researchers wear body suits and multiple layers of gloves; the room must have ultraclean filters and vents to keep the air pristine.

The embedded pebbles and dingy ice tell researchers that this portion of the ice core is from the bottom of the glacier, right above bedrock. This chunk comes from the first ice core drilled at Mt. Hunter, Alaska; the core's total length was 682 feet. Photo by Mike Waszkiewicz.

Watch the video and answer the following questions:

1) What makes Greenland a perfect source of ice cores?

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2) What is the TIME RESOLUTION of data provided by ice cores?

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3) Give 3 examples of information about past conditions that ice cores can deliver

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4) Give 1 example of technical problems in working with ice cores

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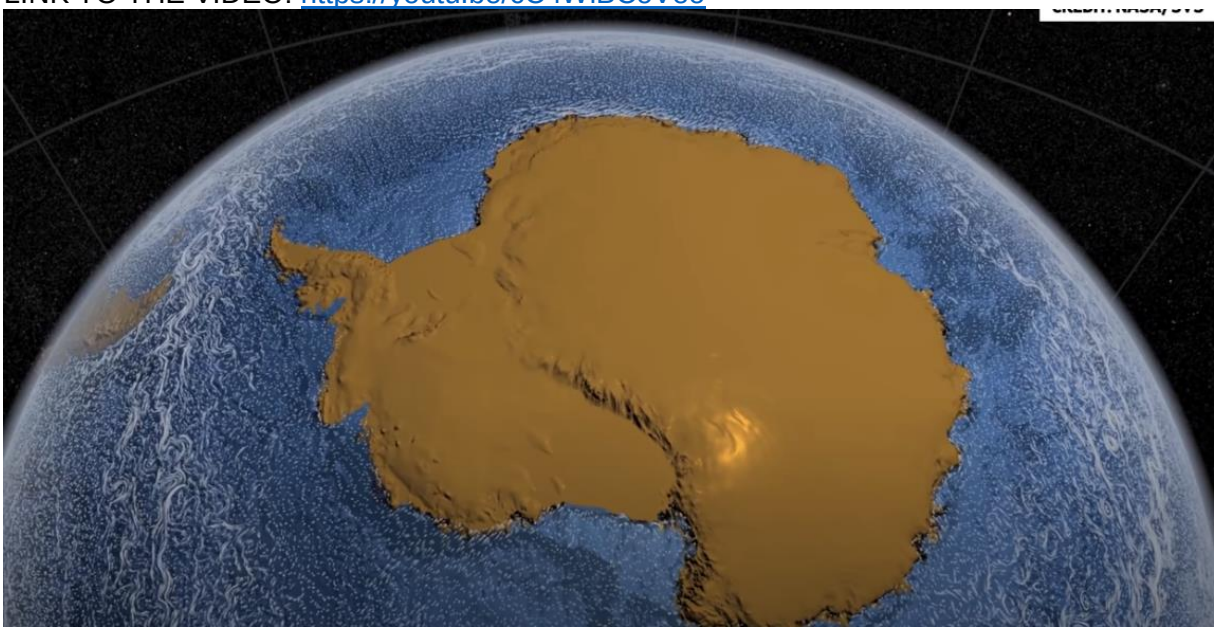
When Antarctica was green

Before the start of the Eocene Epoch about 56 million years ago--Antarctica was still joined to both Australia and South America. And it turns out that a lot of what we recognize about the southern hemisphere can be traced back to that time when Antarctica was green.

LINK TO THE VIDEO: https://youtu.be/cC4WiBCoVeo



How do we know- the study

Was Antarctica a ...subtropical paradise? Yes, 53 million years ago, replete with palm trees, summer highs near 25°C and frost-free winters sitting near 10°C despite the endless darkness.

It was because of the anomalous warm bubble known as the Eocene, when soaring atmospheric carbon dioxide levels drove the global average temperature to increase by 5°C. It's not only carbon dioxide that needs to be taken into account, either. During the early Eocene when these palm fronds lined the shore, Antarctica and Australia were still connected at the surface. It wasn't until millions of years later that the powerful Antarctic Circumpolar Current took shape, a strong ocean current that essentially prevents energy or heat from moving in and out of Antarctica, and one of the major reasons why the polar continent is so cold today.
But how do we know? Thanks to paleoclimate proxies!
Drilling into an offshore site near Wilkes Land, a part of eastern Antarctica that lies south of Australia, a team of researchers collected sediment from deep below the sea floor that was

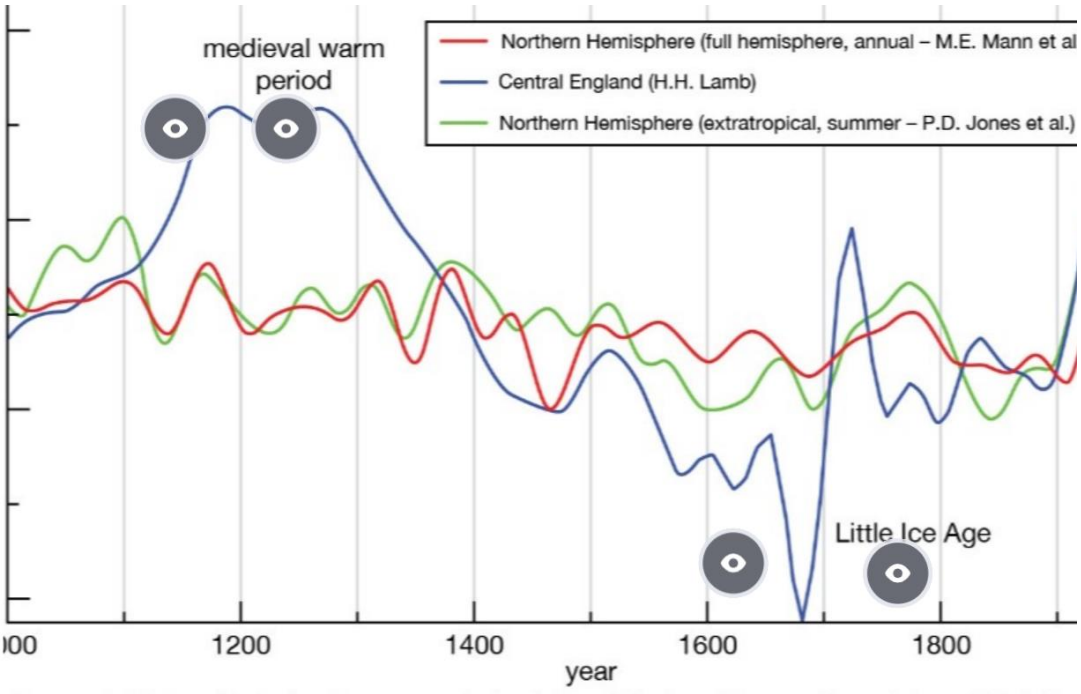
laid down and subsequently buried over the past 53 million years. In that ancient material the researchers found “pollen and spores and the remains of tiny creatures.
READ THE STUDY: https://www.nature.com/articles/nature11300

Environmental history

Environmental history is a rather new discipline that came into being during the 1960’s and 1970’s. Historians started to look for the origins of the contemporary problems, drawing upon the knowledge of a whole field of scientific disciplines which had been developed during the preceding century. For environmental - climate and vegetation history scientists rely on written sources, paintings, photographs and recorded instrumental observations.

Historical documents contain a lot of information about past climates but also descriptions of the landscape used to reconstruct climates and landscape change dating back several hundred years back in time. Observations of weather and climatic conditions as well as the landscape and resources such as forests and peat deposits (for fuel) can be found in farmers, travellers and gamekeepers diaries, newspaper accounts, ships logs and other written records.
Landscape paintings or photographs can provide information about woodland cover, use of the land and perceptions of landscapes. When properly evaluated, historical data can yield both qualitative and quantitative information about past climate and landscape change.

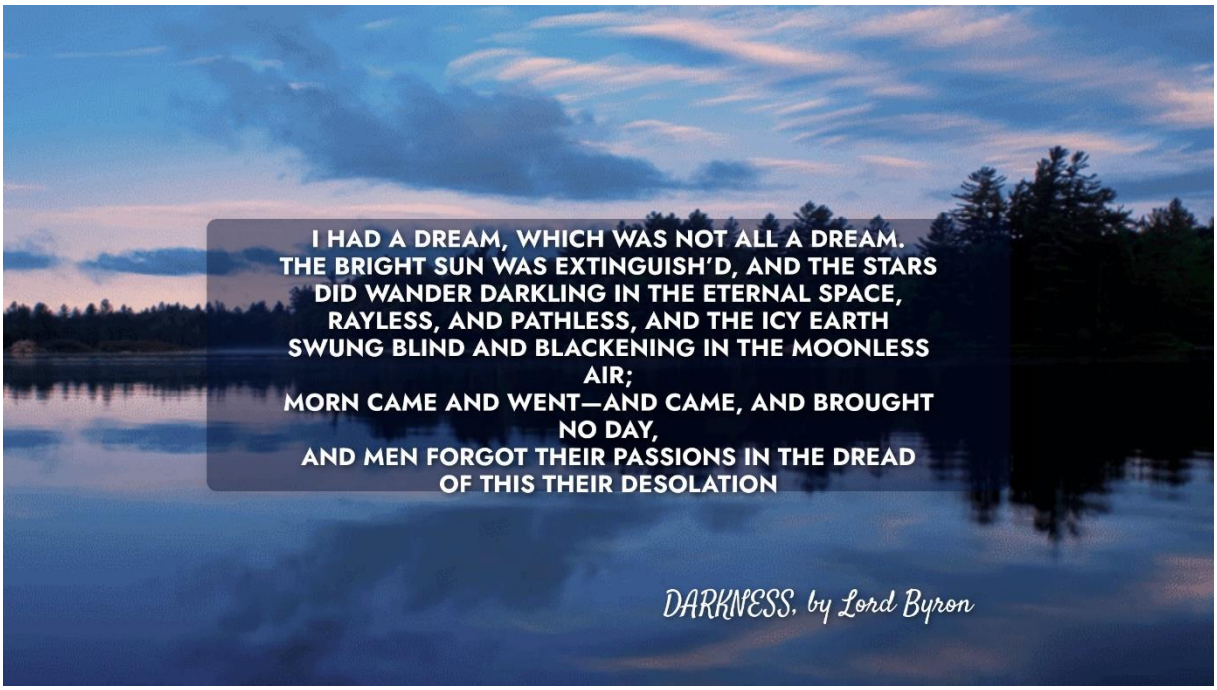
Check the INTERACTIVE IMAGE and click to learn more about MEDIEVAL WARM PERIOD and LITTLE ICE AGE
LINK TO INTERACTIVE IMAGE:
https://view.genial.ly/60f563da0ddd920db23678e5/interactive-image-changes-in-the-past

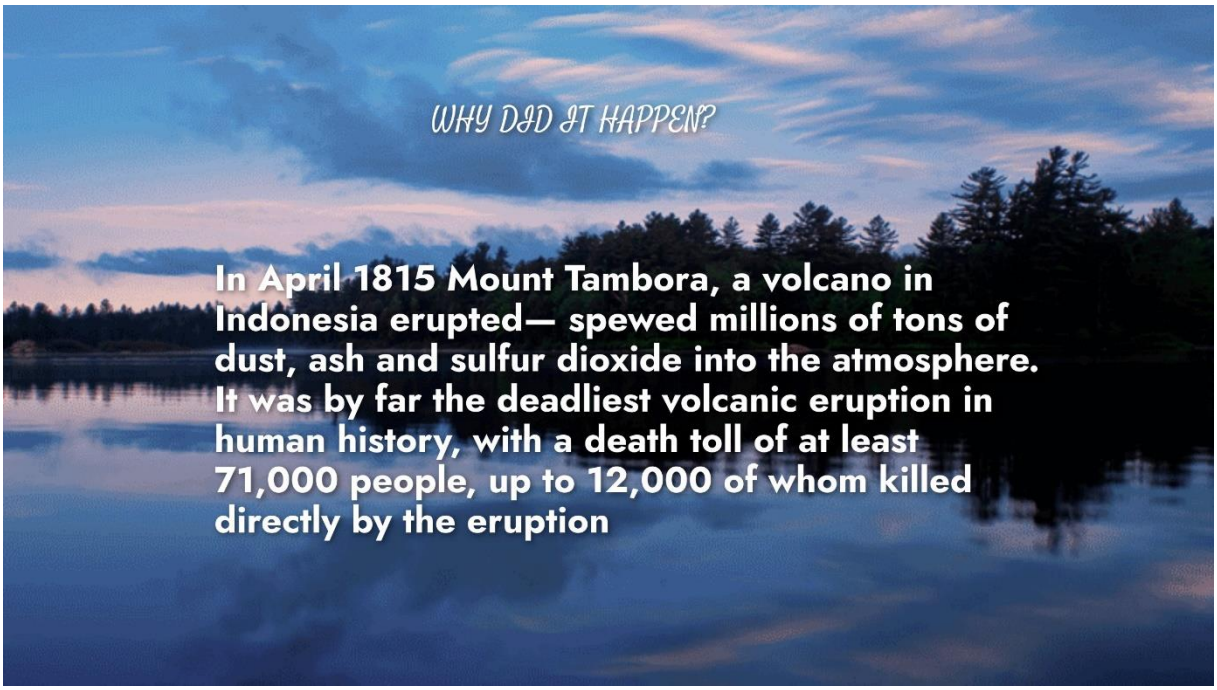


Year without summer

What happened in 1816 and what does it have to do with environmental history?

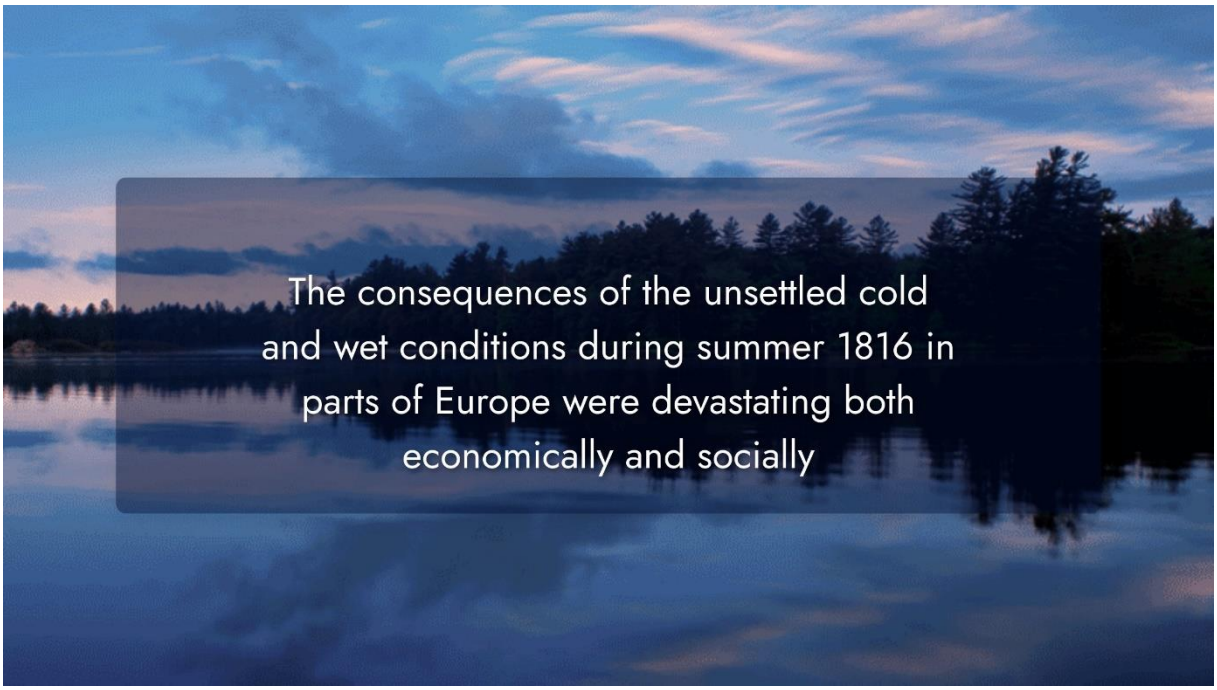
Watch the video presentation. You can pause it anytime to read more carefully.

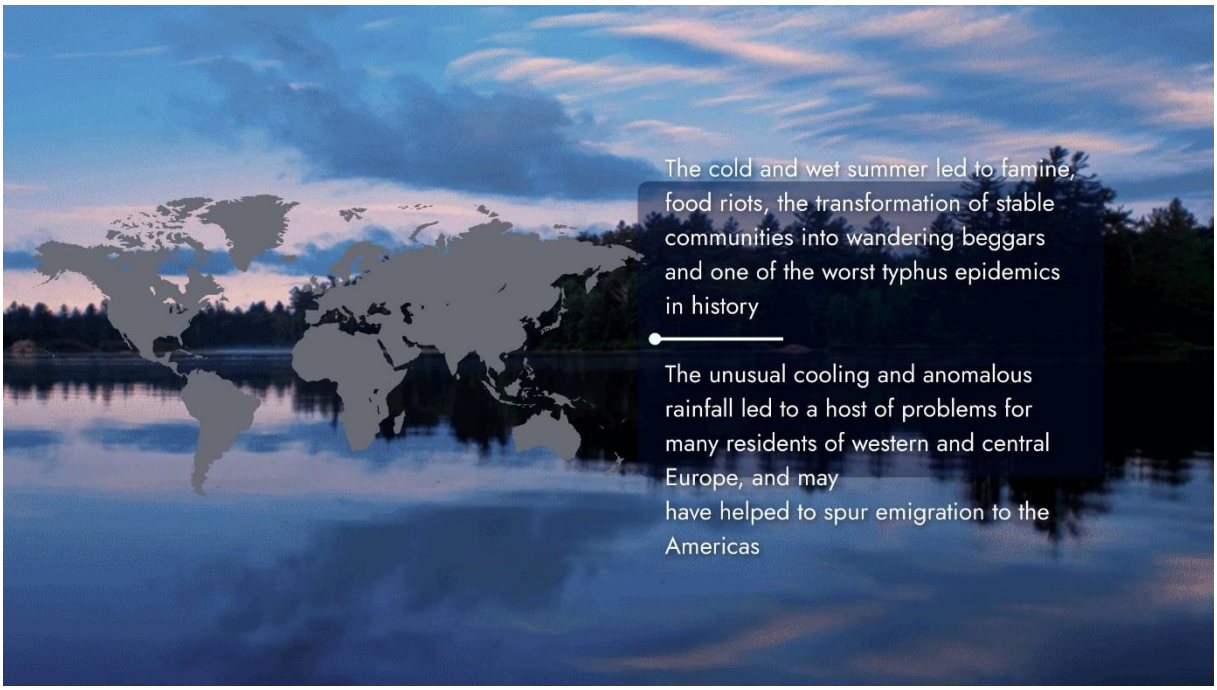

I HAD A DREAM, WHICH WAS NOT ALL A DREAM.
THE BRIGHT SUN WAS EXTINGUISH'D, AND THE STARS
DID WANDER DARKLING IN THE ETERNAL SPACE,
RAYLESS, AND PATHLESS, AND THE ICY EARTH
SWUNG BLIND AND BLACKENING IN THE MOONLESS
AIR;
MORN CAME AND WENT—AND CAME, AND BROUGHT
NO DAY,
AND MEN FORGOT THEIR PASSIONS IN THE DREAD
OF THIS THEIR DESOLATION
DARKNESS. by Lord Byron


WHY DID IT HAPPEN?
In April 1815 Mount Tambora, a volcano in Indonesia erupted— spewed millions of tons of dust, ash and sulfur dioxide into the atmosphere. It was by far the deadliest volcanic eruption in human history, with a death toll of at least 71,000 people, up to 12,000 of whom killed directly by the eruption


WHAT HAPPENED THEN?
Because these aerosols float above the altitude of rain, they don't get washed out. Instead they linger, reflecting sunlight and cooling the Earth's surface, which is what caused the weather and climate impacts of Tambora's eruption to occur more than a year later.
It temporarily changed the world's climate and dropping global temperatures by as much as 3 degrees


Was it the same everywhere?
The effects were not uniform.
In June, July and August of 1816, temperatures were persistently cold — 2 to 4°C below the 1951–1980 reference period— over western and central Europe and the western Mediterranean. But in eastern Europe, western Russia and parts of eastern Scandinavia, summer temperatures were normal or slightly warmer than average


The consequences of the unsettled cold and wet conditions during summer 1816 in parts of Europe were devastating both economically and socially



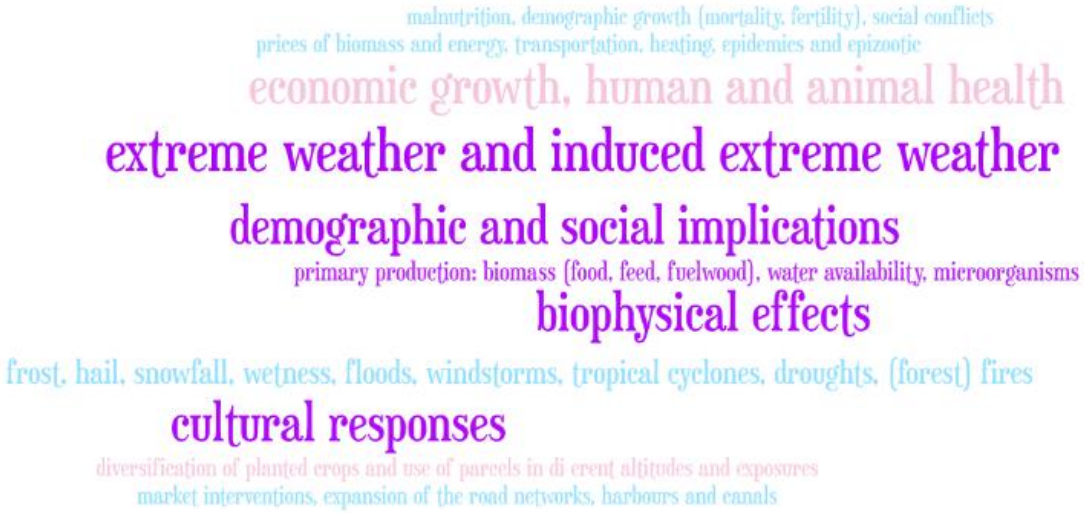
LINK TO VIDEO PRESENTATION:
https://view.genial.ly/60f56fe1dc97e30de4487c77/video-presentation-year-without-summer

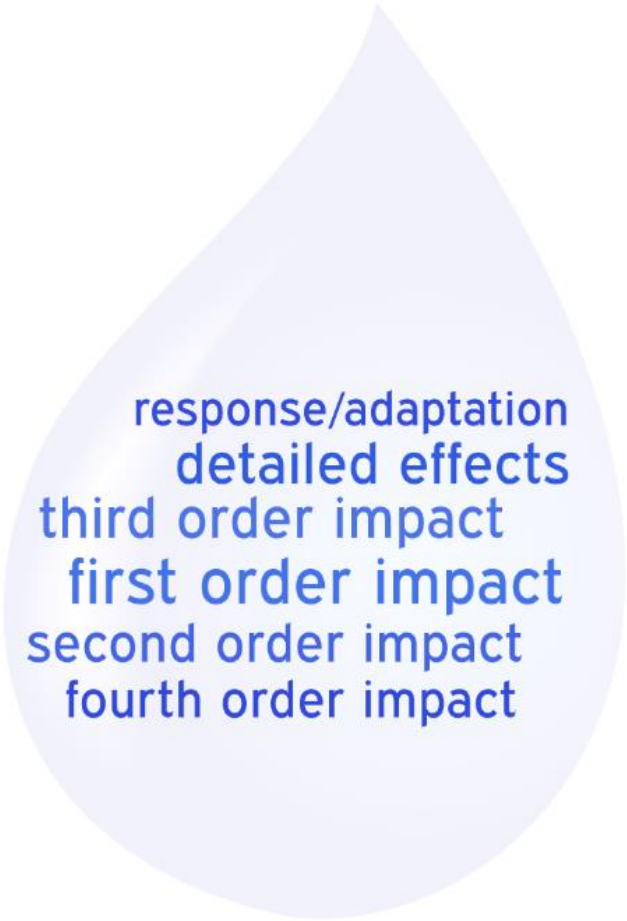
The chain of events

Use concept mapper to create a chain of events, from causes to consequences. Use predefined links to define impact. For each huge process (5 processes in total) there are detailed examples, for 4 processes there are responses/adaptations.

Inspired by: a commentary by J. Luterbacher and C. Pfister, in NATURE GEOSCIENCE | VOL 8 | APRIL 2015.

CONCEPTS (5 processes, examples, adaptations)





Activities

Which proxy will bring us answers?

Paleoclimate proxy records are sources of data that tell us about past climates. They are especially useful in helping us learn about climate during periods prior to human records. Tree rings, ice cores, and sediment deposits in lakes and seas are just a few examples of paleoclimate "proxies".

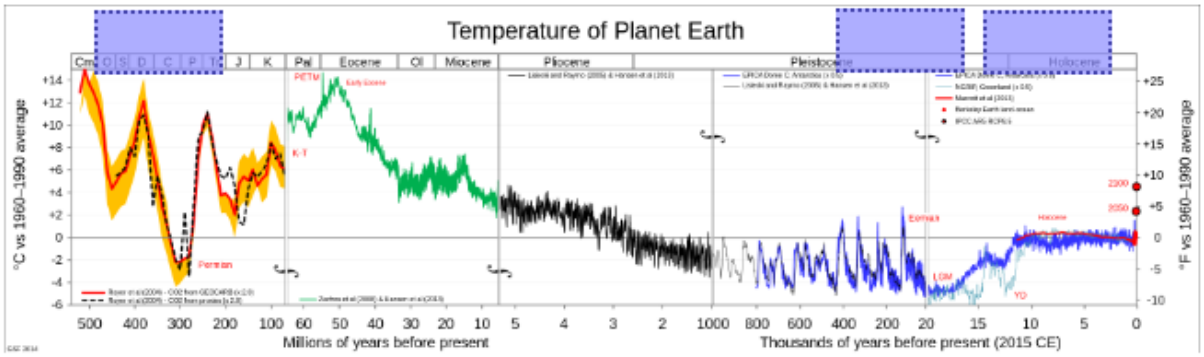
Two factors related to time are important measures of paleoclimate proxy data:
SPAN- range of time for which data from a given type of proxy exists. Tree ring records span the most recent few thousands of year; ice core records go back as much as hundreds of thousands of years; and fossils can be up to hundreds of millions of years old. If we are interested, for example, in studying the Medieval Warm Period (10th to 14th centuries AD), tree ring data could be very useful. However, if we want to know about the climate during the last days of the dinosaurs (around 65 million years ago), even ice core records would be of no use. The span of a proxy record tells us how far back in time the record allows us to peer.

RESOLUTION - tells us how much detail is to be found in a given type of proxy data. Each ring in a tree corresponds to a growing season, so tree ring records provide a resolution of one

year. We can use tree ring data to assemble a climate record with an annual resolution; we can know what conditions were like each year. Ocean sediments, on the other hand, have resolutions on the order of a century. The uppermost layers of ocean sediment can be disturbed by currents or by creatures burrowing through the sand, so short-term trends in sediment types can get blended over time. So we can tell, using ocean sediments, whether two centuries had different climates, but we can't determine what the decade-by-decade trend was like.
Typically, records that have information about the distant past tend to have poorer resolution than do records of more recent times. Data sets that have large spans tend to have lower resolutions, while records with short spans tend to have better resolutions. Our knowlege of paleoclimates gets blurrier the further into the depths of time we plumb. Scientists must be aware of spans and resolutions of different record types when looking for data about a specific time in history. The records must span the time period of interest, but they must also have fine enough resolution to address the issue being studied. Scientists often use multiple data sets that span the period of interest, but that have different resolutions. This makes it more challenging for the scientists to make "apples-to-apples" comparisons between the findings based on one type of record and the findings based on a different type.

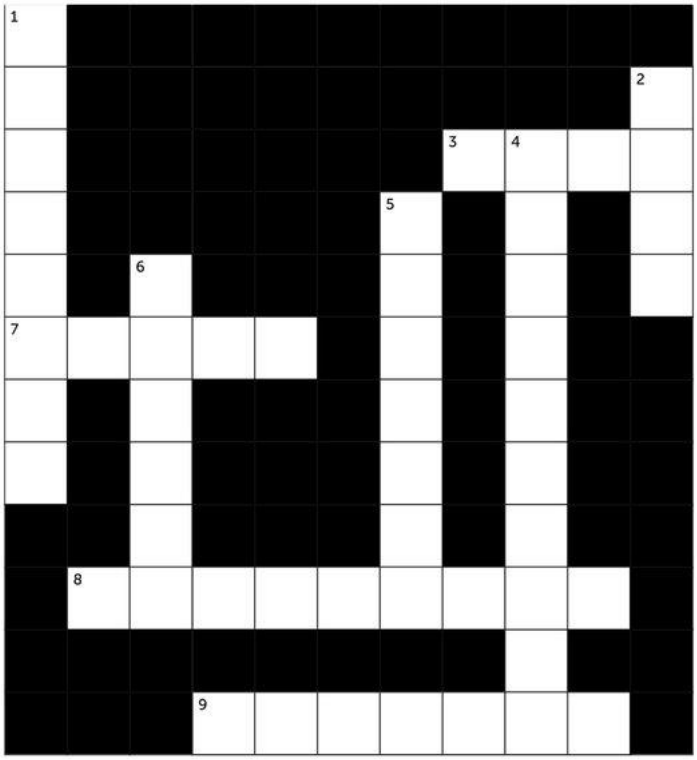
So ...which proxy can bring us answers about which period of time?

tree rings peatland foramnifera



Criss-cross puzzle

Solve the crossword, either online: **https://puzzel.org/pl/crossword/update?p=-MezBeL8E** or printed version.



POZIOMO

3 Dendrochronology is based on observation of ...rings

7 Since modern records do not outline most of Earth's climatic past, scientists must gather data preserved in nature over the millennia in paleological remains referred to as ...records

8 The oldest data can be obtained from ice cores drilled in ...

9 The major climate changes of the past, before humans started influencing environment on large scale, occurred because the climate was driven to change by some external change, which is typically called a climate ...

PIONOWO

1 18O an 16O are 2 oxygen ...

2 Near-natural peatlands can store large quantities of water thanks to the sponginess of ... and the buoyancy of the vegetation.

4 The ... of a record can be quantified as the time difference $\Delta t = t2 - t1$ between two adjacent samples t1 and t2. The smaller Δt the higher the ...

5 Peat is the accumulation of ... material (e.g., plants or mosses) that has been formed on the spot and has not been transported after its formation

6 By analyzing pollen from well-dated sediment cores, scientists can obtain records of changes in vegetation going back hundreds of thousands, and even millions of years

FIND THE DATA

Go to the NOAA (National Oceanic and Atmospheric Administration) website:
https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/ice-core

Using -> interactive map, find records from Austfonna, an ice cap located on Nordaustlandet in the Svalbard archipelago in Norway, from an ice core drilled in 1999.

Check out the data and answer the questions

What is the time period covered by data from this ice core?

……
……

Explain the name of the B column (d18O per mil) - **do your own search**

……
……

Based only on this dataset with no other infomation about other factors, answer the questions:

Was it COLDER in 1410 or 1646?

1412	1646

Which decade was warmer?

1911-1920	1450-1461

What values would you expect if the ice core was drilled 20 years later? Explain.

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Would it be a good idea to compare it with dendrochronological data from the area? Why?

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JENGA QUIZ!

LINK TO ONLINE QUIZ: https://view.genial.ly/60f58ff00ddd920db2367bae/interactive-content-jenga-quiz-paleoclimatology

QUESTION 1/5

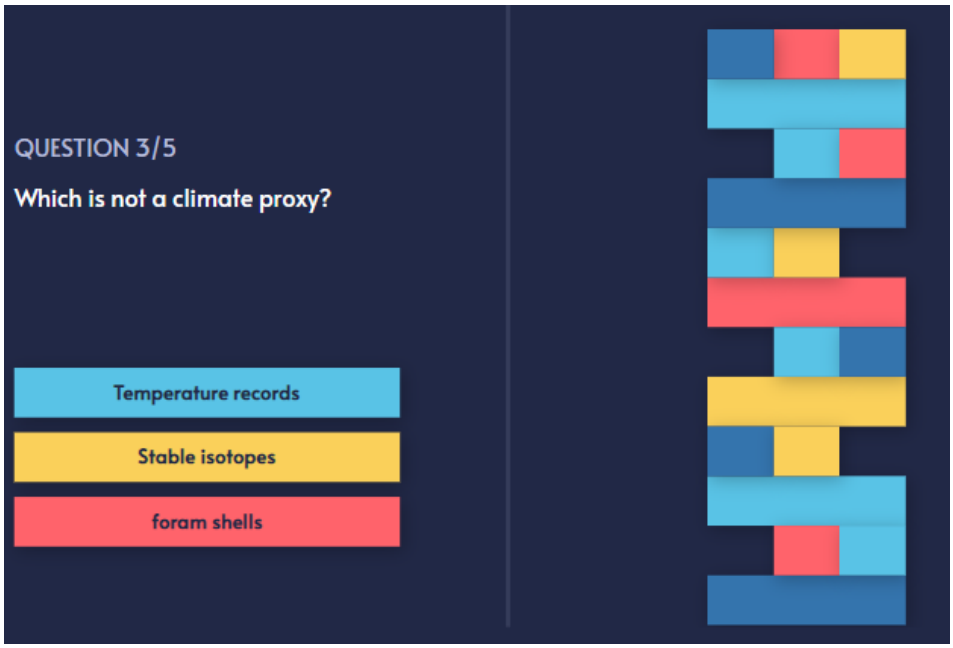
Scientists observe the thickness of a tree's _____ to learn about past climate conditions.

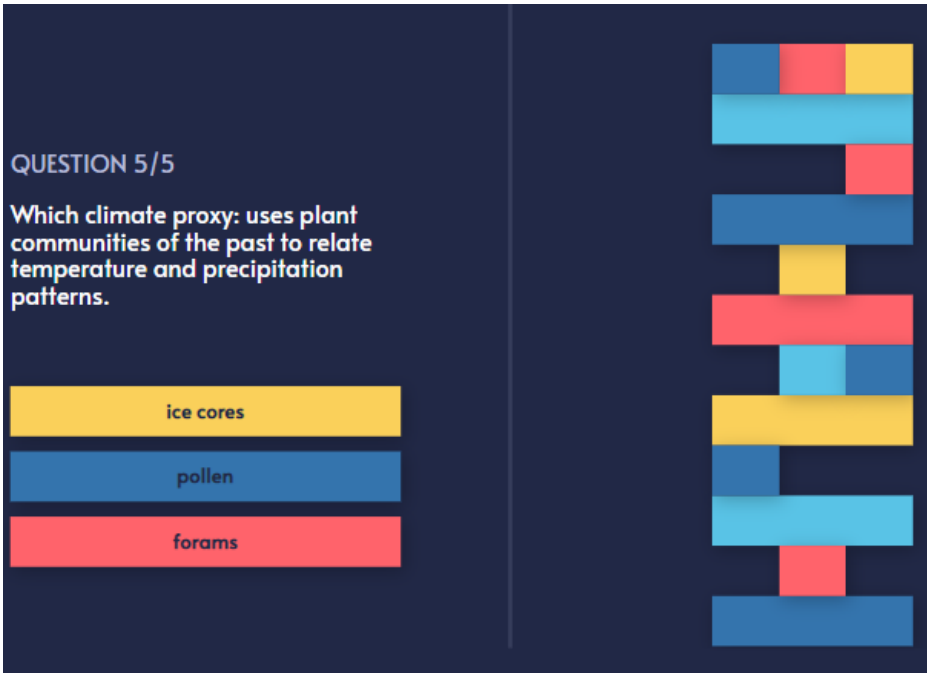
- roots
- rings
- bark

QUESTION 2/5

a large-scale atmospheric pressure see-saw in the North Atlantic region is called

- North Atlantic Belt
- North Atlantic Oscillation
- North Atlantic Wave


QUESTION 3/5
Which is not a climate proxy?
Temperature records
Stable isotopes
foram shells



Wrap-up

Science journal
Read this (imaginary) newspaper clipping.

Science Jou

Monday, August 30, 2021

Old journal discovered in th

An incredible discovery was made in a small village in England. Apparently an old journal was hidden in the attic of an old house. The earliest entries come from 1715. The author is believed to be a young girl who made meticulous notes about everyday life and weather conditions. Some of the entries could almost serve as climate logs "Severe frost from 24th November to 9th February. Frost fair held on the Thames. The Thames was completely frozen for about two months". 25th January: ice on Thames in London lifted by some 14ft by a flood tide but did not break. Much fog. July 26th. Very very dry summer, worrying about the crops".

The owners claim to have no knowledge about the origins of this precious finding. Historical records, such as ship logs, or sometimes even artwork can be a valuable source of information about past climate.

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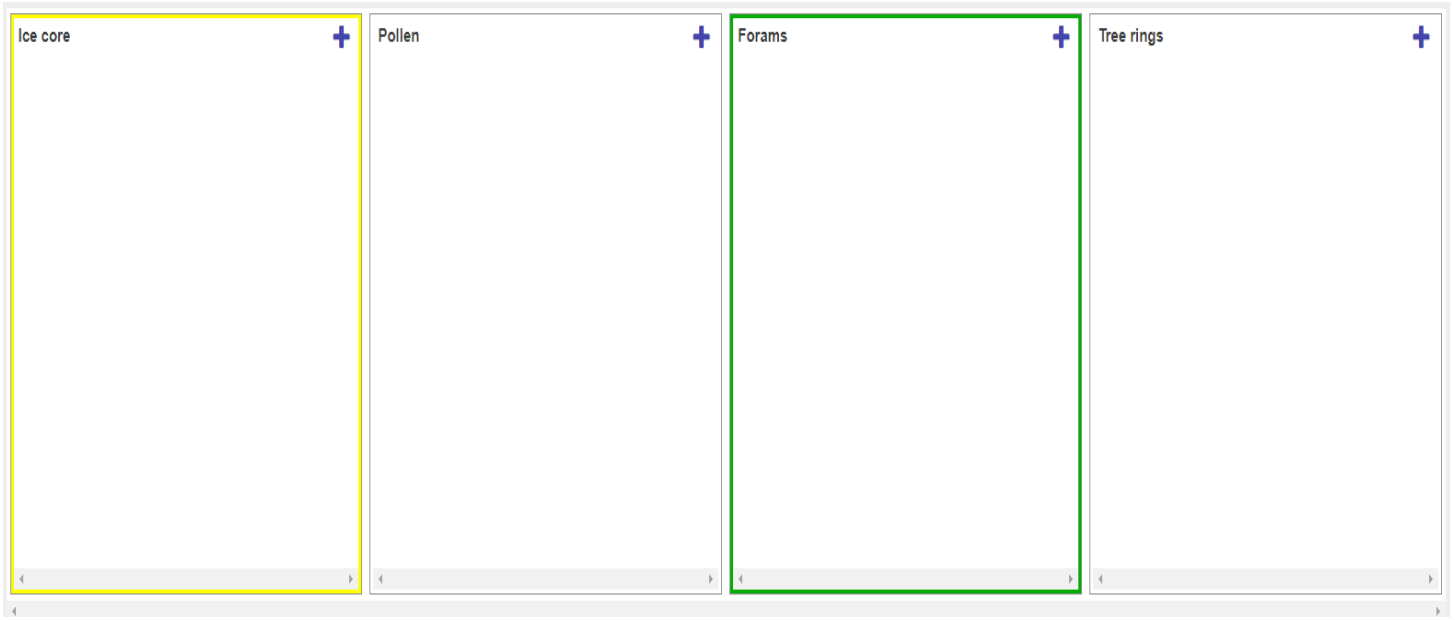
For this exercise, let's make it simple and assume that the conditions described in the journal were pretty much similar in Northern/Western Europe.

Now, imagine what types of proxy records could be found for 1715/1716. Describe, what kind of data we could expect. Do your own search!



What are the three most important things you would like to remember from this material? Write them down.

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