**Part 2: How Scientists Date the Earth**

Part one is a reader by Richard Dawkins that had 21 reading questions that you should finish before you start this. Your answers need to be turned in.

Part two, this section, gives examples of published research that uses some of these techniques. The following contains context for each article, the links for each article, and some questions for you to write answers for. Section 1 examines droughts, Section 2 California Mega Floods.

**Section 1**

**The Use of Tree Ring Analysis and Recently Developed Isotopic Analysis to Compare Recent Droughts in Europe and the Southwest United States to the Hydroclimate History of Each Region**

The use of isotopic analysis of tree ring data gives more precise and accurate proxies of past hydroclimate conditions. Please recall from the reader written by Dawkins that you just went through **that isotopes of elements, whether they be carbon or oxygen (for our purposes here), vary in their number of neutrons; the number of protons define the atomic number for each element.** This [excerpt](https://www.preventionweb.net/news/european-summer-droughts-2015-most-severe-over-centuries-not-only-multi-year-droughts) from another related study explains:

Tree-ring stable isotope records are very climate-sensitive fingerprints of summer moisture conditions. They are largely independent of tree species, tree age and site location. As such tree-ring stable isotopes differ from the more classical dendrochronological parameters of tree ring width and wood density…

The climate signals contained within carbon and oxygen isotope ratios tree rings, originate from slightly different processes:

The carbon isotope ratios 13C to 12C in tree rings come from the way plants function during photosynthesis. This process is controlled by tiny openings in the leaves called stomata. The plants use the stomata to regulate the amount of CO2 they take in and the amount of water vapor they transpire into the atmosphere. During photosynthesis in leaves and needles the CO2-fixing enzyme preferentially takes up CO2 with the lighter 12C. **When it is dry, trees close their stomata to conserve water, which also limits the amount of CO2 they take in and causes them to take up CO2 with the heavier 13C** for conversion into sugar and finally tree-ring cellulose.

The oxygen isotope ratios 18O to 16O in tree rings are affected by physical processes that involve the atmosphere's need for moisture, based on factors such as air temperature and humidity, as well as the amount, source, and history of rainfall. In addition, during plant transpiration isotopically lighter (less 18O) water vapor transferred to the atmosphere while isotopically heavier water (more 18O) remains in the leaves and needles imprinting the oxygen isotope signature of tree-ring cellulose. **Drought usually increases plant transpiration leading to more 18O in the tree rings**.

With this in mind, open this link:

<https://www.blogs.uni-mainz.de/fb09climatology/files/2021/03/Buentgen_2021_NatureGS.pdf>

And then answer the following questions:

1. In the abstract just after all of the co-authors names, the year that the tree ring record goes back to, expressed as either Common Era (CE), and Before Common Era (BCE) is:
2. “We find that the combined inverse (C and O isotope) values correlated with the June through August Palmer \_\_\_\_\_\_\_\_\_\_ Severity Index.” This is an indicator that the isotope analysis is a good proxy for drought itself.
3. The authors write that “Our reconstruction demonstrates that the sequence of recent European summer droughts since 2015 CE is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the past \_\_\_\_\_\_\_ years. (fill in the blanks)
4. Just finishing the abstract: “This hydroclimatic anomaly is probably caused by anthropogenic \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and associated changes in the position of the summer \_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_.
5. Reading the first paragraph after the abstract – comment on impacts of

the summer heat waves

and drought spells

river levels & agricultural production

1. Go to Figure 4. This is their reconstructed Palmer Drought Severity Index up through 2018 CE. In the page just before Figure 4, first column, they summarize the graph, saying “We provide statistically robust evidence that the most recent drought extremes between 2015 and 2018 are not only unprecedented during the period of proxy–target overlap, but also in the context of the past\_\_\_\_\_\_\_\_\_\_\_ years. (fill in the blank)
2. See also Supplementary Data 2 (page down until you find it): list below the seven driest summers in their reconstruction. How many of those seven were during the European drought period 2015-2018?
3. And just to put your answer for the previous question in context, again, how many total years did the analysis cover? (yes it is four digits) Are you amazed?

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**This 500 Year Old Tree in California Has a Story to Tell**

Link: <https://www.nytimes.com/interactive/2022/07/20/opinion/ancient-trees-climate-change.html>

California also is home to what three other world leading trees? (each “est”)

1

2

3

About how far back does that states rain gage records go? So the tree to be discussed is then a proxy record of rainfall - imperfect though, of course.

Identify the season when earlywood is formed, and then the season that latewood is formed, together with the relative size of cells of each.

Earlywood:

Latewood:

You can see that the thickness of each ring is related to the amount of water available for growth, of course. You can also see that sometimes there is a period of several drier than average years, and that one such period began in 2013. Do you recall when the warming oceans also laid the foundation for the devasting densovirus that is believed to have killed almost all of the entire sunflower sea star population on the Pacific Coast of North America? These are connected events. The blocking Pacific subtropical high pressure system that caused the drought in the forests also blocked much wind mixing over the nearshore waters on the California Coast.

How many cells formed in 2014, 2015, and 2016?

In this vein, how many cells formed in the year 2021?

Another study showed that there has not been a drier period going back at least how many years? (link just above the green graphic)

That study analyzed the rings of thousands of\_\_\_\_\_\_\_\_\_\_\_\_ trees and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ wooden beams from around the Southwest to reconstruct a 12-centuries-long timeline of climate extremes. From your Dawkins reading, in the section about tree rings, what is this technique called? (starts with a “d”)

Continuing on with the same article with the beautiful tree ring illustrations, the author writes: We have spiked the climate system, releasing heat-trapping carbon dioxide into the atmosphere faster than at any other time in at least the past \_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ years.

What are the characteristics of blue oaks that make them so useful to dendrochronologists?

What is the point of the graphic that showed the growth rings of blue oaks at different elevations?

What happened to the low elevation blue oak illustrated, in the years 2014 and 2015?

Near the end of article: “Climate change will push the blue oak’s survivable range\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.”

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**Section 2**

**The Use of Sediment Analysis to Estimate Timing of Central Valley of California Mega Floods**

Source literature: <https://www.scientificamerican.com/article/megastorms-could-down-massive-portions-of-california/>

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ evidence shows that truly massive floods…have occurred in California about every \_\_\_\_\_\_\_ years. The most recent was in \_\_\_\_\_\_\_\_\_\_\_.

What was its financial impact on the state?

Such floods were mostly caused by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ rivers, which are described as narrow bands of \_\_\_\_\_\_\_\_\_ vapor about a \_\_\_\_\_\_\_\_\_\_\_ above the ocean that extend for \_\_\_\_\_\_\_\_\_\_ of miles.

Moving past the abstract…

The floods whose rains began on Christmas Eve in 1861 continued unabated for \_\_\_\_ days.

California’s Central Valley received much of this water, and it turned into an inland sea, \_\_\_\_\_ miles long and 20 miles wide. Downtown Sacramento was submerged under 10 feet of brown water filled with debris from countless \_\_\_\_\_\_\_\_\_\_\_\_\_ on the regions steep slopes.

California today is much more vulnerable today for many reasons, one being that parts of the Central Valley have dropped \_\_\_\_ feet in elevation because of extensive \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_.

You might be wondering if these floods affected Oregon, particularly the Willamette Valley if you now live here. For an answer, just browse [this document](https://www.oregonhistoryproject.org/articles/historical-records/the-great-flood-of-1861/) for a few minutes.

Straight from article: In 1998 researchers Yong Zhu and the late Reginald Newell found that an average of about \_\_\_\_ percent of all vapor transport toward the poles occurred in just \_\_\_\_\_ or \_\_\_\_\_\_ narrow bands, distributed somewhat randomly around the globe, that moved west to east across the middle latitudes. To describe these bands, they coined the term “\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_.”

Climatologists and other scientists are concerned about the public not understanding the magnitude of risks from such events. They are going back 2000 years in time, sifting through evidence archived in sediments from \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_, marshes, and submarine basins.

As floodwaters course down slopes and across the landscape, they scour the \_\_\_\_\_\_\_\_, picking up \_\_\_\_\_, \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_ and carrying that material in swollen currents. When the rivers slow on reaching a floodplain, marsh, estuary, or ocean, they release their loads of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_:

first the larger \_\_\_\_\_\_\_\_\_\_\_\_

then the \_\_\_\_\_\_\_\_\_

and finally the (smaller) \_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_.

Reflect on what is written above. The largest materials can only be carried by strong currents, so as a river starts entering a flatter valley from the steeper mountain river gorges, it slows down, depositing the larger material first, and as it continues to slow down, smaller and smaller materials are deposited.

What may eventually bury these flood deposits (during more normal weather)?

Scientists extract \_\_\_\_\_\_\_\_\_\_\_\_ cores from these sediments and back at the lab, analyze the preserved layers and date what happened when.

Radiocarbon dating of such deposits is accurate within about \_\_\_\_\_\_\_\_ years. (but other techniques and lines of evidence can sometimes better pinpoint time periods).

Marsh core studies reveal deposits from massive flooding around A.D. \_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_, and \_\_\_\_\_\_\_.

Sediment cores taken from beneath San Francisco Bay itself also indicate that in 1400 the bay was filled with freshwater…indicating a massive flood.

Sediments offshore of Santa Barbara remain remarkably undisturbed over thousands of years for what reason? (explain)

What is it about these particular sediments that give an annual dark and spring light and winter dark pattern that makes these a bit more like tree rings?

These Santa Barbara sediment cores reveal how may megafloods? And with what approximate spacing?

And here is the beauty of the scientific process: what did Ingrid Hendy find more recently (the article you are reading was written in 2014)?

This is how science works: we get closer and closer to the truth (generally), the longer a particular problem is worked on. In this example, using sediments form the Central Valley, from San Francisco Bay, and offshore marine deposits, and utilizing somewhat different dating techniques, a “triangulation” approach is a way of increasing the quality of information that is produced by scientific research.

On what basis do the authors of this Scientific American article state that the “three earlier floods” of year 440 and year 1418 must have been far worse than any we have witnessed? Explain.

Continuing in this vein of accumulating more and more relevant studies, two other studies about megafloods are described briefly, on focusing on a small lake near the Sacramento River, and other of narrow canyons in \_\_\_\_\_\_\_\_\_\_\_\_\_\_ Mountains. \_\_\_\_\_\_ particularly enormous deposits were laid down in 1600 and 1750, once again \_\_\_\_\_\_\_\_\_\_\_\_ with the other data.

Summarize the “unsettling bottom line” found in the next paragraph:

View Holocene Research file, pages 5 and 6, found in the 201 ODS folder at <https://people.wou.edu/~mcgladm/>

This will give you a landscape perspective of the research about the mega floods topic!

**Section 3 (for some future class. Not you!)**

Ice Core Analysis in High Elevation Tropical Glaciers and Ice Sheets to Investigate Global Climate Change and El Nino Events