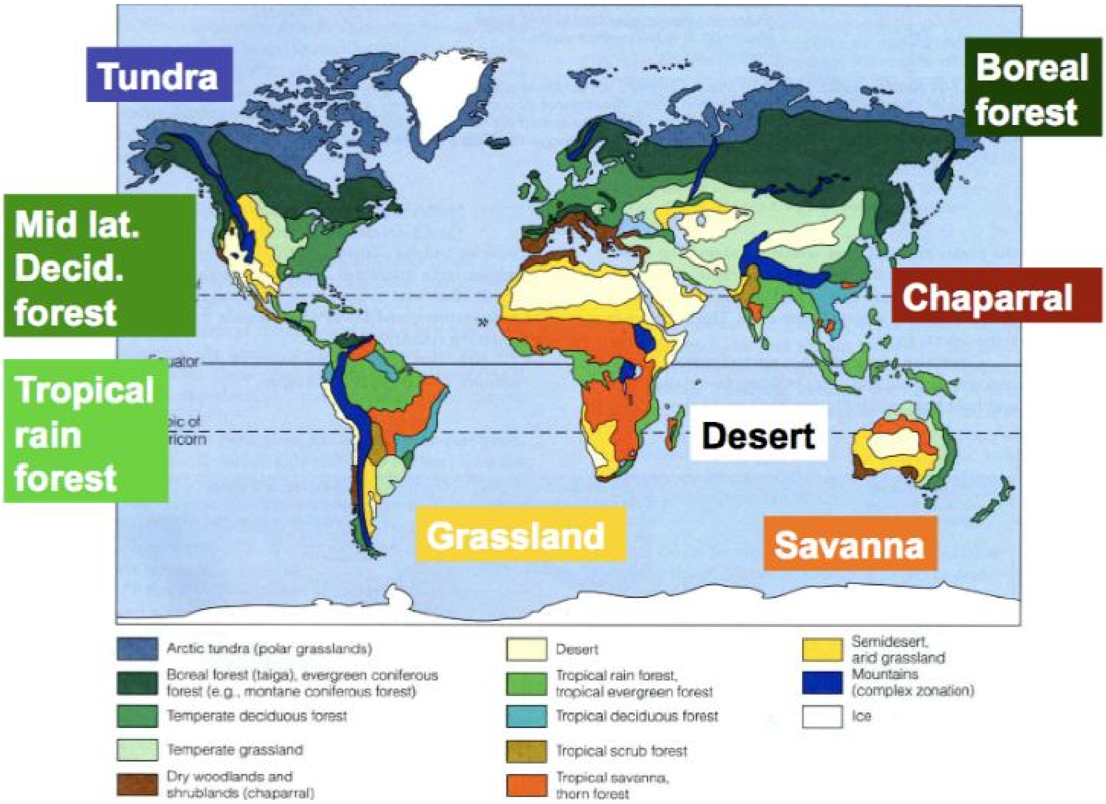
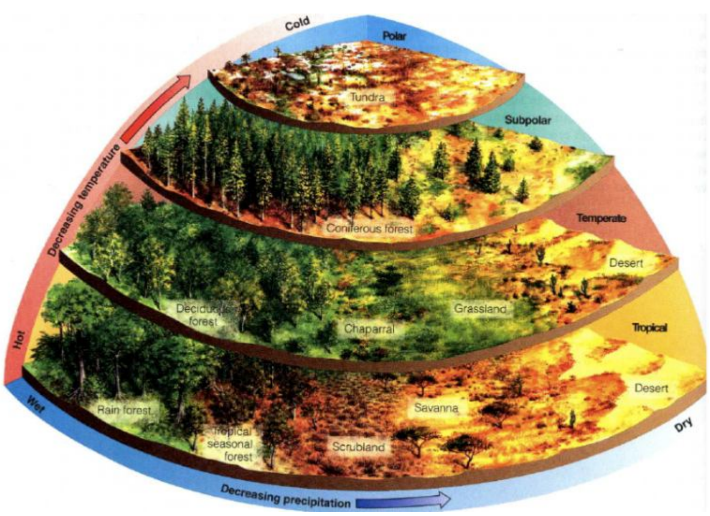
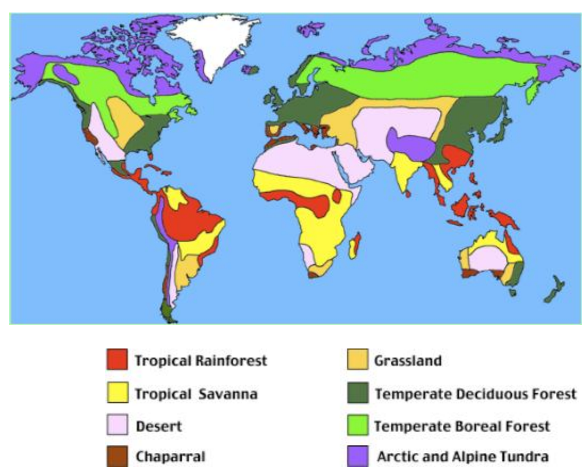
MIDTERM # 2 REVIEW

BIOMES: CLIMATE AND LIFE ON LAND

1. Can you locate each “biome” on a map?







2. Can you provide an example of each? Can you recognize examples of each? There are 9 types of biomes, we should know about (where are they found? What are their climatic, vegetation characteristics?):
   I. Tundra
   II. Boreal Forest
   III. Temperate deciduous forest
   IV. Chaparral, dry woodlands and shrublands (Mediterranean biome)
   V. Desert (warm and cold, and semi-desert)
   VI. Tropical rain forest
   VII. Temperate grassland
   VIII. Tropical deciduous forest and scrub
   IX. Tropical savanna

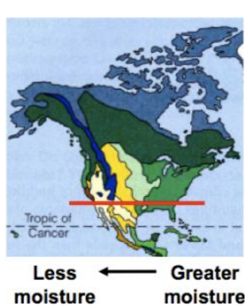
3. What type of vegetation is dominant in each?
   In N. America, where moisture is greater on the east and less moisture in the west, the following vegetations are found:
   i. Mid-latitude broadleaf deciduous forest:
      Ample rainfall, non-limiting for plant growth
      Beech, oak, maple tree
   ii. Woodland/Oak "savanna":
      Moisture becomes limiting
      Forest transition to grassland
      Read oak and grasses coexist
   iii. - Grassland; tall grass prairie:
      Moisture more limiting
      Grasses dominate with forbs, absence of trees
      - Grassland: short grass prairie, "steppe":
      Moisture more limiting
      Grasses dominate in clumps
      Soil expose
   vi. Desert/semi desert:
      Severe water limitation
      Plants have xerophytic characteristics: succulence, pines, no leaves
   In Africa, the moisture gradient goes from moist in the south to arid towards the north:
   i. Equatorial (tropical) rainforest:
      Dense canopy
      High diversity
      Light competition
   ii. - Savanna and Tropical Scrub
      Wet-dry climate: seasonal drought
      Fire regime
      Grasses, shrubs, stunted trees
      - Savanna and Tropical Scrub
      Desertification

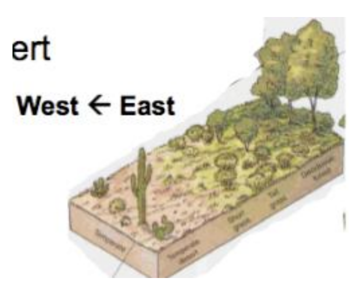
iii. Desert:
Very little rain
Sparse to no vegetation

In Europe, Arctic circle in Scandinavia to Mediterranean Sea, the gradient goes from warm in the south to cold towards the north:

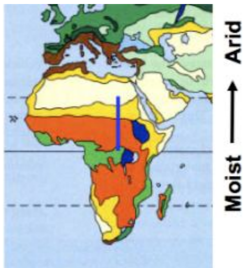
i. Ice sheets/Glacier
ii. - Tundra: physical, climatic characteristics:
Short growing season (60-80 days)
Only surface layers of soil melt during growing season
Deeper soil layers remain permanently frozen
Surface + subsurface soils are termed *permafrost*
Permafrost lead to poor drainage
Wet (marshy) habitat
Built up of organic matter in soils forming peat
- Tundra: Plant Community:
Grasses, sedges, schrubs
Slow growing (low light + short growing season)
Low growing
iii. - Boreal Forest:
Conifer trees (needle-leaves)
Evergreen (except for larch which is common in Siberia)
Spruce and fir trees
Moss understory
Permanently shaded ground surface
Fire frequency
- Boreal-leaf deciduous forest:
Longer growing seasons higher mean annual temperatures
Conifers give way to deciduous species
- Chaparral (i.e. Mediterranean forest, temperate, shrubland, scerophyll forest):
Sclerophyll vegetation, sclero (hard) phyllon (leaf)
Evergreen

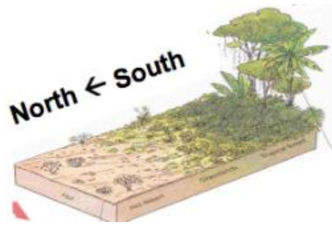
4. Can you rank the biomes by annual precipitation and temperature (i.e. order them on a gradient)?
Moisture Gradient: east to west across N. America





Moisture Gradient: Africa, equator to the tropic of cancer





Temperature gradient: Europe, Arctic circle in Scandinacia to the Mediterranean Sea

NOTE: As moisture becomes limiting:

- competition among organisms increases.
- Species less-adapted to conserving moisture are replaced by those better adapted to these conditions
- Vegetation biomass and ground cover decreases
- Plants spaces widely apart
- Xerophytic plants prevail

ICE AGES, PART 1-THE EVIDENCE ON THE LAND

1. What is a glacier?

   Glaciers are made up of fallen snow that, over many years, compresses into large, thickened ice masses. Glaciers form when snow remains in one location long enough to transform into ice. What makes glaciers unique is their ability to move. Due to sheer mass glaciers flow very slow like rivers. Some glaciers are small others can be over a hundred kilometers long.

2. What geographic climate conditions are required for glaciers to first form?

   Glaciers require very specific conditions, found in regions of high snowfall in winter and cool summer temperatures. These conditions ensure that the snow accumulated in the winter isn't lost during the summer. Amount of precipitation is important to glacier survival. It starts after the accumulation of ice, turns to ice and begins to flow outward and downwards under the pressure of its own weight.

3. Why does a glacier move, or “flow”?

    Under the pressure of its own weight and the forces of gravity, a glacier will begin to move, or flow, outwards. Valley glaciers flow down valleys, and continental glaciers (ice sheets) flow outward in all directions from a central point. Glaciers move by internal deformation and/or sliding at the base. Internal deformation occurs when the weight and mass of a glacier causes it to spread out due to gravity.

    Sliding occurs when the glacier slides on a thin layer of water at the bottom of the glacier, (water comes from glacial melting or water that has worked its way through cracks). They can also readily slide on a soft sediment bed that has some water in it.

    - Crevasse: open fissure in the glaciers surface.
    - Moraine: a mound, ridge, or other distinct accumulation of glacial till.

4. What evidence for past glaciations exists on land (i.e. geomorphic evidence)? Be able to describe these features and know their names.

    The following are definitions:

    - Erratic boulders: seemingly out of place and distant from their bedrock source.
    - Drumlins: tear shaped hills. Their long axis follows that of the glacial advance.
    - Striations: made of rock as debris-laden glaciers passed over. With this reconstruction, direction of the glacier is possible to determine.
    - Eskers: sinuous ridges that represent the deposit of a sub-glacial water channel, (they don’t indicate movement).
    - Till: when glaciers scour way soil, leaving mostly bare bedrock or deposit.
    - Loess: new soil developed after ice retreat (?)

5. How was some of this geomorphic evidence used to support the Doctrine of Catastrophism?

    By definition a view that history of the Earth has to be explained by a series of violent events or catastrophes. Some of the geomorphic evidence is found as part of the doctrine because it fits nicely with the explanation of “a great flood”.

6. How can geomorphic features or other terrestrial evidence indicate the maximum extent of an ice sheet or the direction of its flow?

    The following are the four glacial stages in Europe and North America, (important to know→warm periods; interglacial’s or interstadials, cold periods; glacials or stadials):

    Europe: Gunz, Mindel, Riss, Wurm

    N. America: Nebraskan, Kansa, Illinoian, Wisconsinan (not completely correct).

Someone once compared the reconstruction of paleoclimates by observation of landforms to that of reconstruction f a series of lectures by reading the residues of chalk on a partially erased blackboard. Despite the incomplete nature of the record a scientist proposed the four-fold theory based on geomorphic evidence for Europe (mentioned above).

7. What configuration of the continents is prerequisite for an ice age to occur? How has this configuration changed in the past?

   Three ice ages over the last billion years: (I) Late Precambrian (~700 million years ago), (II) Permo-carboniferous (~300 million years ago) and (III) Late Cenozoic. Several commonalties to the configuration of the Earth's land masses; this explains why the Earth was susceptible to the development of large ice sheets:
   - Continental drift: this has rearranged the configuration of landmasses on the surface of the Earth. This is a slow process that results in the repositioning of continents. Feedbacks occur when substantial portion of the Earth's land area is located near poles, when snow or ice covers the land surfaces reflectivity increases. Light is not absorbed as heat, but is reflected back, which allows ice masses to accumulate.
   - Feedback: ice reflects radiation, does not absorb heat, temperature drops further, producing more extensive ice coverage, reflecting more light, etc.
   - During (II) Pangaea spanned the equator, but the southern tip was at the South Pole. Cenozoic climate began after Pangaea broke up and Antarctica shifted south, N. America and Eurasia north.
8. What theories have been proposed to explain advance and retreat of ice sheets?
   I. Change in energy output from the sun: inappropriate explanation for the slow development of major ice ages.
   II. Uneven distribution of dust particles: contradictory since theory stating that when more dust particles fall into the sun it glows more brightly causing temperature to rise.
   III. Concentration of CO_2 in atmosphere: decrease in concentration decreases greenhouse effect, thus decreases concentration, which causes cooling, and an ice age.
   IV. Volcanic eruption: these are short term therefore not enough evidence.
   V. Vertical movement in the Earth's crust: increase in land elevation would cause temperature to drop because land at high altitudes would be cooler. Process of mountain building is too slow and spatially restricted to be an appropriate mechanism. These changes can contribute but not trigger an ice age.
   VI. Antarctic Ice sheet surge: assumption that Antarctic ice sheet accumulated and collapsed episodically into the ocean. When

surrounding ocean was covered with reflective ice, temperature drop enough to trigger IA.

VII. Ewin-Donn theory: IA begin when Arctic Ocean free of ice and open to warm N. Atlantic currents. Warmer temperatures cause evaporation to increase. As atmosphere becomes moister, more snow falls on land, allowing accumulation of ice sheet. Deglaciation would begin when Arctic Ocean was frozen over, cutting off this moisture supply. If this is right, greenhouse warming might cause IA.

VIII. Stochastic Theory: small differences in climate conditions could amplify the major climate change, possible but not embraced if other explanations seem fit (example: butterfly in Brazil causes tornado in Texas).

The explanations above are not sufficiently convincing, the most convincing one is the Astronomical Theory also known as " The Croll-Milankovitch Theory". This is based on the three different orbital parameters: tilt of the Earth, the processions of the equinoxes, and eccentricity of the Earth's orbit. Tilt relative to its plane of travel about the Sun causes seasons (severity of seasons). Eccentricity can also be described as the shape of Earth's orbit, the greater the eccentricity the greater the difference in receipt of solar radiation.
To know: perihelion, closest approach to the sun.

ICE AGES, PART 2-THE EVIDENCE IN THE ICE AND OCEANS

1. How can foram species be used to reconstruct paleoclimates?

   Most "forams" have a calcium carbonate (CaCO3) shell. Although comprised of just a single cell they are variable and we can differentiate species by the shape and pattern of their shell. They provide two types of evidence useful to paleoclimate studies: taxonomic evidence (species present in a sample) and isotopic content of the shells recovered from a sediment sample. Forams adapt to a particular range of temperatures. Some prefer cold and other warm environments, they also adapt to benthic (live in bottom of the ocean) or pelagic (live as part of oceans plankton).

2. Why does the oxygen isotope ratio in forams or glacial ice reflect changes in ice volume during the Pleistocene?

   First thing to know is that oxygen has two isotopes: O-16 (lighter, more common) and O-18 (heavier, less common). The heavier isotope move more slowly, and any molecule which incorporates the heavier isotope moves more slowly than the same molecule that has the lighter.
   "Delta" is the ratio of the rare isotope expressed as rare/abundant. The lower the amount of the rare isotope in a substance the lower the delta number.
   During "meteorological distillation" proportionately more of the light oxygen isotope evaporates from the ocean. Lighter water molecules move more quickly into the air. In this way glacial ice has more O-16 and oceans become

depleted of O-16 and enriched with O-18. Thus the ratio of O-18/O-16 closely tracks the proportion of the world's water locked up in ice sheets.

3. What are some of the complications using forams for interpretations of paleoclimates and how have they been avoided?
   In the shells of planktonic forams we actually get two signals, temperature and ice volume. This makes things complicated, but investigators discovered that ice volume increase and temperature decline happened about the same times. There is no way to separate these, therefore some researchers prefer to work with benthic and/or tropical forams. This is because ocean bottoms have little variability in temperature, and the tropics do not have the seasonality that complicates things at high latitudes.

4. How does oxygen isotope record compare to the earlier 4-stage model of glaciation?
   Oxygen isotope chronology shows multiple fluctuations in ice volume and many more than originally assumed from early terrestrial evidence (4-stage glacial model). The 4 –stage model was an oversimplification of the paleoclimate pattern during Quaternary, compare to the one made from oxygen isotopes.

5. How was the mechanism for major climate change over the Quaternary confirmed?
   The use of change in tilt of the Earth (obliquity), orbital eccentricity and precession interact with each other helped make the "real" model. Although oxygen isotope model doesn't match exactly the ETP (the three factors) there are some obvious similarities.
   Once the statistical proof (spectral analysis, technique use to detect the patterns of ETP) was made the Croll-Milankovitch theory became again the accepted paradigm for explanation of the major climate fluctuations in the Quaternary.

6. How do changes in the Earth's orbital parameter affect climate? On what time scales do they operate? How do they interact?
   Tilt: severity of the seasons; warmer summers and cooler winters. Tilt changes between about 22 and 25 degrees on a cycle of about 41,000 years.
   Eccentricity: also known as shape of the Earth's orbit. This shape is elliptical; bit over time becomes more or less elliptical. Greater the eccentricity, the greater the differences in receipt of solar radiation. This cycle is predictable, and the eccentricity, and it varies on cycles of 100,000 and 400,000 years.
   The closest approach to the sun is called perihelion, making the northern hemisphere winters slightly milder. The timing of the perihelion gradually shifts 1 day every 60 years → precession.
   The effects of these astronomical variations changes at different locations on the Earth.

Changes in the level of land and sea

1.) What biotic (biome-level) changes resulted from increased aridity during the last glacial maximum?

Maximum extent of all ice sheets: 26,500-20,000 years ago

Europe-North America: 4 km thick
Asia: ice free but under periglacial conditions and eventually covered by loess deposits (Loess: accumulation of wind-blown silt and lesser and variable amounts of sand and clay)

Many regions were drier during last glacial maximum.
Rain forests of central and western Africa were also reduced in area, as compared to today.
Because of the aridity over northern Asia, ice sheets were not as extensive as one would expect, based simply upon temperatures

2.) What are the eustatic and relative sea level?

Water came (by way of evaporation then precipitation) from the world ocean. Loss of this volume of water had a noticeable impact on the level of the ocean water (sea level), decreased between 80-120 m.
Eustatic sea level: changes in global sea level (due to changes in water volume).
Reduction in sea level exposed some critical connections between landmasses.
While eustatic sea level was changing the elevation of the land was also changing. Shifts in land surface are referred to as **isostatic** changes. The elevation of the shoreline is a function of both eustatic and isostatic changes and their combined contributions give us "**relative sea-level**"

3.) How had the elevation of coastal land changed as a result of glaciation and deglaciation? What are the terms for these changes?

If land was stable the sea level would simply reflect the volume of water in the ocean basins. However, most landmasses have not been stable, particularly when subjected to glaciation and deglaciation. Weight of glacial ice is a significant load on the Earth's crust and during glaciations caused in depression of the Earth's surface.
The surface responds somewhat like a balloon (of course, much more slowly) and the depression caused by the ice forced the land to rise outside the area under pressure. This increase in the ice is termed **forebulge**, also referred to as a **peripheral bulge** by some. These various changes in the Earths crust are referred to as isostatic changes.
When sea levels dropped, this "load" decreased, resulting in a slight uplift of the continental shelf. The uplift of the continental shelf would have contributed to the decrease in relative sea level experienced during the last glacial maximum.

By comparing sea levels records from many regions, we can make some good estimation of isostatic effects on sea level.

Present day shoreline of Maine and New Brunswick are below sea level. Why? The land surface had been depressed from the weight of the ice sheet and eustatic sea level rose faster than the land. The eventual rise in elevation of such areas is called **rebound,** as the land surface is rising back to its original position. (carries evidence of marine submergence)

4.) What caused the Champlain Sea to develop?

The rise in eustatic sea level not only caused submergence of what constitutes today's coastlines, but along with isostatic depressions, created inland seas. At about 10.5 k years BP the **Champlain Sea** covered the present day St. Lawrence River Valley and much of the surrounding land (inc. Montreal) Under this sea lays a thick layer of marine clay. Clay is unstable and allows differential sinking of building foundations.

5.) What factors today contribute to increased relative sea level rise?

The increase in relative sea level, which floods the land, is referred to as transgression, the reverse process, a decline in relative sea level, is termed regression. Regression occurred as ice sheets grew and eustatic sea level declined.

Maine: sea level went from +70 to -50 (125 m change)

Altough the volume of ocean water generally was increasing (eustatic rise) the Maine coastline was rebounding (uplifting) at an even faster rate. As the isostatic "adjustments" of the region showed (after 8k years BP) the increase in eustatic sea level became the dominant process.

Warming of oceans increase sea levels. (as ocean T increase ocean water will become less dense and the volume it occupies will also increase= thermal expansion)← most significant factors in future sea level rise.

The change in volume is not linear and varies with salinity of the sea water.

Changed in glacial ice adds to isostatic changes and affect not only relative elevation on affected shoreline but also the shape of the ocean basin.

6.) Can you give an example of how scientists have had to adapt to sea level change?

Not sure for this one:

The process of isostatic uplift causes the waters of James Bay to shallow, eventually connecting offshore islands to each other and the mainland.

As coastlines move seaward traditional sites for harvesting fish and geese must be abandoned.

Megafaunal Extinctions: The mammoth almost made it

1.) What are the arguments that support the role of humans in Pleistocene megafaunal extinctions?

(note: NA= North America)

Humans caused extinction by hunting → "overkill hypothesis"?

But some archeologists have argued that there were far too few humans present to be able to remove all the populations of all the species. Others argued that their hunting technologies were still too crude.

Counter arguments (humans DID cause extinction of animals): humans rapidly developed rather effective technologies and arrived in NA with them. Because of their sudden arrival to NA, animals were not scared of the danger posed by human species and were easy targets. It is also possible that human populations rapidly increased and their rates of harvest were faster than rates of reproduction of the large animals (Blitzkrieg Hypothesis).

One hunting strategy suggested is that early peoples would have herded animals off cliffs and into canyons.

Combination of factors that resulted in this great extinction. No one factor alone could be responsible and humans certainly played a role.

Additional factors to consider:

-human hunting may have significantly reduced the pop. of species that were important because they modified the ecosystem thus maintained habitat for other animals (caused further environmental change)

2.) On what basis can one argue that climate change, alone, is unlikely to have caused Pleistocene megafaunal extinctions?

During Pleistocene 97 genera of large animals, megafauna, went extinct worldwide. Early hominins (a term used for ancestors of Homo Sapiens) evolved in Africa and eventually spread to other regions. During the last glacial maximum mammal diversity of the North American continent was much higher than today, and about 11,000 years ago many went extinct. Most of the extinct species are mammals larger than 44 kg. (saber toothed cats, mammoths, mastodons) Some animals went extinct in NA but survived elsewhere (horses, tapirs)

The period after the last glacial maximum was one of dramatic change: ice sheets melting, filling and draining of glacial lakes, melting of permafrost, changes in seasonality and shifts in flora and fauna. Perhaps these animals could not adapt to the changes in the landscape or were left with habitats so reduced in area that their population were no longer self-sustaining. Some scientists think that these climatic and ecosystem changes caused the extinction at the end of the Pleistocene. It is difficult to invoke climate change as the sole cause of the megafaunal extinction.

3.) What are TWO different ways that removal of a single species could have contributed to population decline of other species?

Some animals whose physical actions maintain environmental conditions (habitat) critical for the support of many other species (habitat modifier)

Ex1)In the Everglades wetlands of South Florida, alligators create depressions in the mud. During the dry season, these depressions become water holes, critical to the survival of other inhabitants of the Everglades. If the alligators disappeared, many other species would be endangered.

Ex2) African elephant remove trees from the landscape, keeping forests back or in an open condition (savanna). In their absence, some regions would become forested rather than the open savanna found today-the latter a habitat to which many other animals are adapted.

As the prey populations plummeted their predators starved and predator pop also declined.

4.) How might relations of predator-prey populations be a factor in extinction?

As predator populations faced greater food shortages they came into greater competition with humans or may have hunted humans when preferred prey was scarce. To reduce this new danger, humans may have targeted predators. In the absence of predators, prey populations (for instance those not targeted by humans) may explode, increase so rapidly that the environment could not sustain their numbers, resulting in mass starvation and population crashes.

(Lowest number of Pleistocene megafaunal extinctions occurred in Africa. Many argue that extinctions in Africa and central Eurasia were milder because humans coevolved with megafauna there for hundreds of thousands of years)

5.) When did extinctions occur on Polynesian Islands?

6.) What are the similarities between the Pleistocene megafaunal extinctions and Polynesian extinctions?

Daniela: I cant find info for these two questions (5 and 6) Have you seen any of this in the readings of the course pack?? I don't have time to read anything more……

7.) What is Burney's recipe for disaster?

Environmental change lowers the threshold or sensitivity of animal populations to pressures of human hunting and to human introductions that pose a threat to a species population.

Enormous Lakes and serious erosion: the story of the melting ice

1.) What is catastrophism?

Catastrophism is the idea that Earth has been affected in the past by sudden, short-lived, violent events, possibly worldwide in scope.

One of the key differences between catastrophism and uniformitarianism is that to function, uniformitarianism requires the assumption of vast time-lines, whereas catastrophism can function with or without assumptions of long timelines.
Today most geologists combine catastrophist and uniformitarianist standpoints, taking the view that Earth's history is a slow, gradual story punctuated by occasional natural catastrophic events that have affected Earth and its inhabitants.

2.) Why did the findings of Bretz seem to be rejected of the Principle of Uniformitarianism?

Channeled Scablands-northwestern United States. Holes are nearly 180 feet deep ad nearly a mile long. Cliffs are 340 feet high. Bretz carefully considered the size, spacing and placement of these features and argued that they had to be caused by movement of large volumes of water over fairly short time periods, in events that lasted only days.
The geological community rejected his theories and continued to believe that the Scablands were the result of long, slow erosion. They could not be convinced, as there was no evidence for a source of such large volumes of water.
Bretz ideas were close to that of Catastrophists who believed that the Earths features were molded by a series of catastrophic events. For Bretz theory to be accepted scientists needed to recognize examples of cataclysmic floods as well as the source.

3.) How can the landscape modifications of cataclysmic events be explained through the Principle Uniformitarianism?

It is now recognized that drainage from glacial lakes has been responsible for not only shaping our physical landscapes but for some abrupt climate fluctuations.
Glacial Lake Missoula, the source of floodwaters that created the Channeled Scablands. The lake was contained by rising ground to the southwest and by the ice sheet to the northeast. Ice dams float since ice is less dense than water.
Cataclysmic floods such as those released from Glacial Lake Missoula are called *jokulhlaups.* If we accept that such events are regular, albeit rare occurences, then some would maintain that the Principle of Uniformitarianism continues to holds true. Melt water played a role in abrupt climate change.

4.) How is the distribution of aquatic life in Canada related to glacial lakes?

Glacial lakes have played another role in shaping today's environment. They served as transcontinental passages for the migration of aquatic organisms, facilitating re-population of waterways in regions previously covered by glacial ice. The sequence and timing of glacial lakes changes in size, shape and location was critical to migration of aquatic organsims, esp. in the northward spread of fish from their waters of refuge to new waterways formed as ice retreated.

Largest glacial lake was Glacial Lake Agassiz. A majority of fish living in the interior of Canada and northern US have ancestors that at some point lived in Lake Agassiz. It was a “hub” of the migration routes allowing fish to migrate from the Mississippi River and its tributaries to the south and from a southwest refugium (location of an isolated or relict population of a once widespread species)in the Yukon when it was linked to Lake McConnel.

THE YOUNGER DRYAS

Q. What was the Younger Dryas and when did it occur?

A. The Younger Dryas was a short duration cold event, recognized from evidence in northwestern Europe; a *stadial*. (A *stadial* is a cold period occurring within a glacial or interglacial time. Warmer time between *stadials* is referred to as an *interstadial*.) In UK, the Younger Dryas was referred to as “Loch Lomond” *stadial*.

11 000 years B.P., palynologists discovered pollen in sediments from Dryas octopetela, an arctic wildflower, demonstrating a return from tundra. This points to an abrupt cooling of the climate in Western Europe.

Q. What types of evidence are there for the Younger Dryas?

A. 1975, bob Mott of the Geological Survey of Canada reported a similar abrupt cooling event in the Maritime Provinces of New Brunswick and Nova Scotia. The pollen record from lake sediments not only confirmed warming followed by cooling, but there was a clear stratigraphic record.

Glacial tills were covered by peat or soil, signifying warming and landscape recovery. The peat and soil layers, however, were thin and in turn, covered a second till deposited during a re-advance of the small remnant glaciers left in the region.

Cooling on both sides of the Atlantic was confirmed to have occurred at the same time through Carbon-14 dating. The cooling was restricted to the lands bordering northern North Atlantic.

A simple explanation for this cooling: As temperatures warmed, large ice sheets began to break up, dropping icebergs in the North Atlantic. The icebergs floated east across the Atlantic, cooling the temperatures around them.

In 1990, Dorothy Peteet found an important change in pollen assemblages in the Alpine Swamp, New Jersey using most recent techniques in Carbon-14 dating. Pollen indicating temperate forests (including oak) occurred in sediments dating just before 11000 years B.P. The pollen assemblage demonstrated boreal forest – pollen coming from spruce, fir, and birch trees. This showed an abrupt climate reversal.

The consensus: The Younger Dryas was not restricted to the Maritimes of Canada and northwest Europe.

Paleocology and the use of Palynology is used for reconstructing past vegetation. Palynology, along with carbon-14 dating provided critical evidence for the Younger Dryas climatic event.

Q. How quickly did the climate change to Younger Dryas conditions?

A.

Changes in abundance of 13 pollen types over time are shown above. From left to right, you see the abundances of different pollen types in a single sample. On the right, you see pollen zones: groups of levels, or times that contain similar abundances of pollen types – similar past vegetation types.

The Laurentide Ice sheet was found near the Alpine Swamp. The general vegetation that can be found there is tundra.

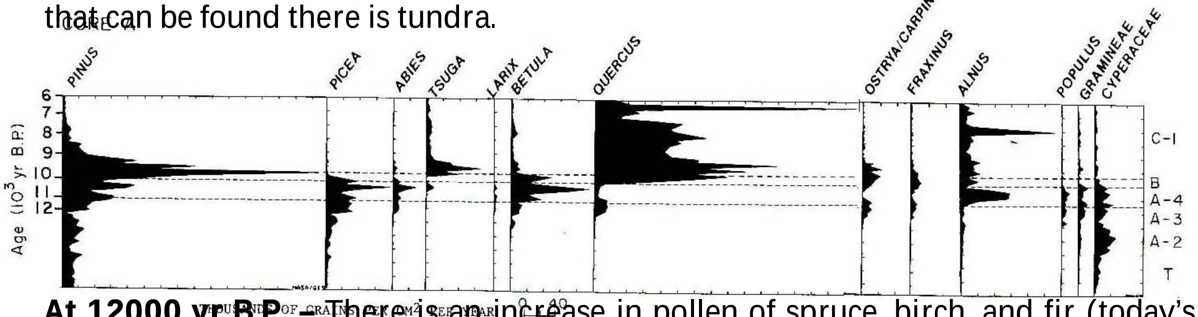


FIG. 3. Pollen influx diagram of selected species from Core A, Alpine Swamp, New Jersey. Independent boreal species increases during the A-4 pollen zone suggest that a climatic cooling took place approximately 11,000–10,000 yr B.P.

At 12000 yr B.P. – There is an increase in pollen of spruce, birch, and fir (today's elements of boreal forest). There are also increases in oak and shrubs that are found in warmer climate of the temperate deciduous forest. – This suggests recovery of vegetation as the climate is warming.

At 11,000 yr B.P. – There is an abrupt decline in the vegetation representing temperate forest. The decline of oak and pollen occurs as spruce, birch and fir pollen increase. – This suggests a period of cold climate appropriate for boreal vegetation but too cold for species of temperate deciduous forest.

10,000 yr B.P., There is less spruce, fir, and birch pollen. Increase in oak and Ostrya/Carpinus pollen shows a warming of a climate enough for species of temperate deciduous forest to thrive.

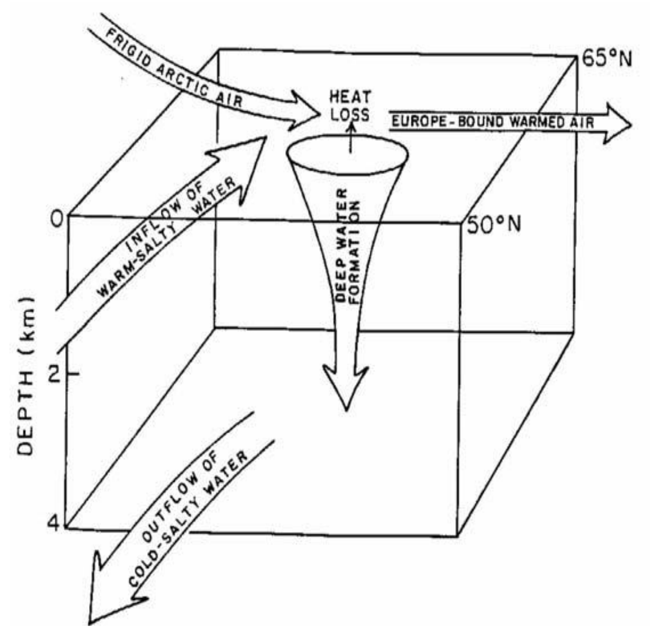
Looking at the maps of Dr. Art Dyke, at the time of the Younger Dryas, Alpine Swamp was in transition between mixed forest and boreal forest. Such transition is sensitive to climate change. The younger Dryas was found to not be just a change in climate restricted to the northern North Atlantic, but showed evidence in Alaska and Sea of Japan.

Q. What theories have been proposed to explain the cooling during the Younger Dryas?

A. *The Second Theory.*

Widespread cooling attributed to the Younger Dryas could no longer be explained by icebergs. The newer theory was based on Thermohaline Circulation.

Thermohaline Circulation: *"Ocean currents continually exchange water throughout all the oceans and from the surface to the depths like a conveyor belt. Currently, Warm water flows north towards Iceland along the East coast of the US. Warm water becomes cooler and increases its salinity by exchanging heat with the cooler air. In the north, water becomes more dense at the surface than in the deep, sinking and flowing south along the atlantic. Flowing past the Horn of Africa, it continues to the North Pacific upwelling at the surface. This water then moves south passing Asia and Australia reaching the Gulf Stream in the Atlantic off Central America."*



Production of North Atlantic Deep Water (NADW) – *Water that sinks and travels south along the ocean bottom – Process responsible for delivery of 10^{21} calories of heat per year through evaporation to the northern Atlantic Region. Atlantic Ocean receives a portion of the total discharge from the world's rivers of heat, however, evaporation is greater than runoff from land and precipitation, an imbalance that increases salinity in the North Atlantic. The surface temperature over such waters is at 10°C, where NADW is at 2°C. 30% of heat produced by solar radiation over the Atlantic in the region north of 35°N is released to the atmosphere. –* ***"Meridional Overturning"****.*

Wallace Broecker, eminent paleooceanographer claimed that the conveyor belt shut down at the beginning of the Younger Dryas yielding a climate reversal. 3% of the ice present during glacial maximum equals twice the amount of freshwater evaporated from the Atlantic in a 100 year period. With this water entering the Atlantic, salinity and density reduces and surface water stops sinking. – *In essence, this would put a wrench in the conveyor belt and half the release of heat.*

The drainage of glacial lakes would result in large inputs of water. Drainage of proglacial lakes was not only episodic, but also variable in direction. Prior to the younger Dryas event, Glacial Lake Agassiz drained south into the Mississippi River Valley and eventually to the Gulf of Mexico. The eastern ice melted and drainage now continued east through the St. Lawrence River Valley into North Atlantic. These fresh waters would have stopped the conveyor belt. Once the freshwater stopped flowing, the unbalance in salinity returned, driving the conveyor belt: ***water moves from a lower concentration of solute to a higher one – until concentrations are equal.***

A short cooling event at 8200 yrs B.P. was found in the Labrador Sea due to the lack of deep water formation. Northward drainage under the Laurentide Sheet through Hudson Bay was believed to be the trigger for the halt of the thermohaline circulation – the cold event. It was suggested that Glacial Lakes Agassiz and Ojibway drained drastically through Hudson into the Labrador Sea.

Q. How did a change in evidence of this event result in different theories for the cooling?

A. Due to the lag in the response of some palynological indicators, (with rapid climate change, pollen wouldn't be produced until the plants and trees mature and grow) an annual record was required (a paleo record of high temporal resolution) such as the ice cores. Using this method, it was found in the ice core record of the Younger Dryas that the time required for the transition to the cooler stage was only 20 years. The previous explanation of icebergs was no longer sufficient to justify such rapid climate change. This led to the development of the theory that was based on: drainage of the glacial lakes, and climatic feedback with the ocean's thermohaline circulation. (Answer also refers to Q2 of this lecture - **What types of evidence are there for the Younger Dryas?**)

Q. How do the theories proposed to explain the Younger Dryas represent a paradigm shift?

A. Despite the fact that there remains no ice sheets in the North American continent, the melting of Arctic sea ice or the Greenland ice cap due to global warming could cause a change in ocean salinity and/or production of North Atlantic Deep Water. Higher precipitation due to warmer temperatures could also decrease salinity of seawater.

Should the conveyor belt be stopped according to such theories, the Greenhouse world would quickly shift to an ice age world in only a few years. From past events such as the Younger Dryas 11000 yr B.P. and the cooling event of 8200 yrs B.P, such climate changes occur in human time-scales – *10 to 20 years*.

Q. How can palynology help us to detect past climate change?

A. ***Paleocology:*** *It is based on the "Principle of Uniformitaranism" –*

- *"Fossils can be identified to a meaningful level of taxonomic resolution".*
- *"Ecological affinities (environmental conditions in which they are most commonly found) of the organisms which produced the fossils were not different from the past".*
- *"We understand the modern environmental factors that govern the distribution of present day plans and animals. Thus we can determine past climatic conditions from the fossil organisms found in a deposit."*

Palynology: *The study of pollen and spores. Pollen is the male gamete produced by a flowering plant. Without pollen, there would be no seed and no new plant. Of course the pollen is transported by insects or by wind, must land on a female flower and fertilize it before a seed can be produced –* ***wide dispersal of pollen does not mean the species of its parent will also be widely dispersed.*** *Spores are produced by plants which do not have flowers but reproduce by forming spores which can grow into a plant – Ex: A fern is a spore-producing plant. Pollen and Spores vary in shapes and sized and are differentiated by shape, size and surface texture, along with pattern of spines, ridges and/or holes on their surface.*

Pollen and spores are made of organic compounds that are very resistance to decomposition, thus they are easily preserved in the sediment record – for millions of years. According to the Principle of Uniformitaranism, "the fossil assemblage is not biased by contamination or differential preservation". Although not all species of plants have pollen that preserves as well, palynologists have been able to determine which these are and take different preservation into account in their interpretations.

Q. What are some of the limitations of palynology and how do scientists deal with these?

A. Pollen and spores are made of organic compounds that are very resistance to decomposition, thus they are easily preserved in the sediment record – for millions of years. According to the Principle of Uniformitaranism, "the fossil assemblage is not biased by contamination or differential preservation". Although not all species of plants have pollen that preserves as well, palynologists have been able to determine which these are and take different preservation into account in their interpretations.

The contamination issue is dealt with by selecting appropriate types of depositions for study of pollen assemblages. The best depositions are found where there is little mixing and low rates of decomposition: Ex. Mud at the bottom of the ocean, lakes and marshes – Water keeps the mud anaerobic (without oxygen) reducing the rate of decomposition preserving organic matter such as pollen. New sediment is added every year to the surface of the mud, incorporating fossils of organisms at the time of decomposition. With the wet environment, the substrate is undisturbed with very little mixing of the mud. The mud is removed while preserving the layers or stratigraphy. This is done using either a tube or larger devices. Law of Superposition: the deepest sediment is the oldest.