Earth 104 final study guide

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Water

- **What is the general distribution of water on the planet?**
  Ocean has about 97.3% of Earth's water. The rest are much less. Glacial and polar ice: 2.1%. Groundwater: 0.4%. Lakes are 0.01%. Atmosphere is 0.001%. Rivers are 0.0001%.
- **Briefly describe the hydrologic cycle.**
  Matter and water cycle through this system. Water evaporates into the atmosphere which is moved by wind and condensed as rain or snow. When water is a solid, you can prevent it from going back into the oceans.
- **Why is sea level constantly changing? What is the role of ice?**
  The amount of ice (which floats on top of water) changes. If there's more ice, there's less water, so the ocean is lower. If there's *less* ice, there's *more* water, so the ocean is higher.
- **What is the importance of the hydrogen bond in terms of the special properties of water?**
  Polarity. They can absorb a significant amount of energy before they break, which leads to high heat capacity.
- **What is the difference between temperature and heat?**
  Temperature: how fast are the molecules moving? Heat: how much energy is needed to change the temperature? Temperature corresponds to state, where heat "changes" temperature.
- **What is the significance of water's high heat capacity?**
  "Oceans absorb and store large amounts of solar energy (heat)" *without changing temperature*. This heat capacity makes global temperatures less extreme.
- **How does the ocean moderate coastal temperatures?**
  "Water has high heat capacity, so it can absorb (or release) large quantities of heat without changing temperature". It takes more energy to change water's temperature than it does land or air. Water warms up and cools down more slowly.
- **What happens to temperature as a substance changes state?**
  There is a "plateau" as a substance changes state -- *only heat changes,* temperature doesn't change as you're changing the state.
- **What is the significance of the high latent heat of water?**
  It's relatively hard to change the state of water. Large amounts of water can store/transport heat within the ocean-atmosphere system.
- **What is the difference between sensible heat and latent heat?**
  "Sensible heat is what we sense from different temperatures" -- it changes

temperature. “Latent heat is the energy needed to change state (ice to water, water to vapor)” -- it doesn’t change temperature, just state.

- **Describe the thermostatic effect of ice.**
  Keeps polar regions cool even when the sun is shining on ice. Energy is put into melting ice, which means that temperature doesn’t change until all of the ice is melted. Once all of the ice is melted, energy can go into heating up the water. The insulating property of ice allows ice to form over water without affecting the temperature of the water underneath the ice. As a result, the water is much warmer than the air, because it is not affected by the cold temperatures above the ice.
- **How does the density of fresh water change as temperature decreases from 20ºC to below freezing?**
  Water occupies more space and becomes *less* dense as it freezes. This means that ice floats.
    - From 20ºC to 4ºC
        - density increases
        - water contracts
        - molecules slow down
    - From 4ºC to above freezing
        - hydrogen bonds stay in place
        - water expands
        - density decreases
    - As water freezes
        - density decreases
        - expands by 9%

Glaciers

- **What is a glacier?**
  Glaciers are thick masses of ice that form over land from the accumulation, compaction, and recrystallization of snow.
- **Briefly describe the transformation of snow into ice.**
  Snow compacts and melts to form firn. Firn then recrystallizes to make ice**.** This process takes up to ten years.
- **What is firn?**
  Snow compacts and melts to form firn (they’re like pellets). This recrystallizes to make ice. It is granular and consolidated snow that has passed through a summer melt season; also called old snow.
- **What are alpine glaciers?**
  Glaciers that form in high mountain areas; usually follow valleys formed by streams.
- **What are ice sheets?**
  Large scale ice at high latitudes. Also known as continental glaciers.
- **How do you explain the presence of glaciers at low latitudes (tropics)?**

High elevation.

- **What are some of the main differences between the Greenland and Antarctic Ice Sheets?**
  Greenland: Doesn't cover all of the continent. Flatter. Newer ice. Dry in the middle.
  Antarctica: Higher elevation than Greenland in some places. More ice. Wet-bottomed on West side.
- **What is an ice shelf? Where do we mainly find them?**
  Large, flat mass of floating ice attached to the coast (found in Antarctica).
- **How is sea ice formed?**
  First, it gets colder because of cold air (wind, etc). It then gets denser and denser, which makes it sink. It won't form if it has far to sink, because it will sink down, away from the cold air. But if it's near a coast and doesn't have far to sink, it will stay in the cold air and freeze.
- **Why is it much harder to make sea ice than ice from fresh water? What is the role of density?**
  Salinity (salt-ness) decreases the freezing point of water, so it's more difficult to freeze water. The salinity also causes the coldest water to be the most dense, so the entire body of water needs to be cooled to form sea ice. Here's a good explanation of difference in creating ice in freshwater vs. salt water.
- **What is the process of calving? What does it form?**
  Calving is when large pieces of ice fall off of glaciers. Creates icebergs.
- **What are tidewater glaciers?**
  Alpine glaciers that end in sea. Usually caused by calving. They usually originate from ice caps or ice sheets.
- **What is permafrost?**
  A layer of frozen soil that's been completely frozen for awhile (at least two years but can be *many* more, to the tune of thousands).

Glacial flow

- **What are the main zones of a glacier?**
  - Zone of fracture: the uppermost 50 meters of brittle ice that cracks forming crevasses
  - Zone of accumulation: area where a glacier forms
  - Zone of wastage: area where there is a net loss due to melting
- **What are crevasses, ogives, and seracs?**
  Fractures and bulges in glacier ice
  - Crevasses: deep crack
  - Ogives: 3D wave
  - Seracs: blocks or towers of ice found in crevasses, very dangerous
- **Discuss the equilibrium line of a glacier.**
  Boundary between accumulation and ablation (removal) zone. Also called the "snowline" or "firn line".

- **What is the zone of wastage of a glacier?**
  It is where there is a net loss due to melting.
  (On land)
    "downwasting"
    meltwater [ice to water] or sublimation [ice to gas] (In tidewater glaciers)
    calving icebergs/ice floats away
- **Discuss the glacial budget of a glacier.**
  Mass balance = accumulation - ablation. If there is more accumulation than ablation the glacial front advances
  Glacial front advances: accumulation > ablation
  Stationary: accumulation = ablation
  Ice front retreats: accumulation < ablation
- **How does a glacier flow? What drives the flow?**
  Glaciers flow forward. Flow is due to plastic flow (movement *in* the ice) and slipping of the mass of ice along the ground brings faster flow. Surface meltwater can make its way to bottom of glacier and "self-lubricate" to also speed up flow.
- **Explain the role of ice shelves in stabilizing ice sheets.**
  Ice shelves run aground on islands or scrape past rocky sides of bays. This friction slows ice sheet spreading.
- **How fast can ice flow?**
  A few meters per day in extreme cases. It depends on every glacier or ice sheet. No need to remember specific numbers
    - Gravity drives flow
    - Ice within a glacier continues to flow forward
    - Flow of ice is always from the zone of accumulation to the zone of ablation
- **What is the difference between wet bottomed and dry bottomed glaciers?**
  Wet-bottomed glaciers move by basal sliding. Dry-bottomed move plastically (movement in ice below 50 meters).
- **How does ice flow within an ice sheet?**
  Ice spreads under its own weight, flows outward
- **What is the role of melt water in glacial flow rates?**
  Melting subtracts from the ice sheet, maer an exact number, she says.

Sunlight

- **What is sunlight?**
  The total spectrum of the electromagnetic radiation emitted by the sun.
- **What happens to solar radiation as it moves through the atmosphere toward the surface of the Earth?**
  Wavelengths become larger, more if it is infrared?
  Land:
    transmission → reflection

transmission → absorption

Water:

transmission → refraction

Atmosphere:

transmission → scattering

- **What is albedo?**
  AKA “reflection coefficient”. It’s the percentage of diffusely-reflected sunlight in relation to surface conditions of Earth. Trees have low albedo, snow and ice has high albedo, water has low albedo. Generally: how hot is it to walk on?
- **What is the effect of cloud coverage on albedo?**
  Clouds have high albedo and “clouds dramatically [increase] Earth's overall albedo” (source).
- **How does solar input change through time?**
  It fluctuates due to orbit shape and solar altitude/angle.
- **What is the role of the shape of the orbit on changing solar radiation levels?**
  Earth’s orbit is elliptical, when it is closer to the sun there is more solar radiation (but this is not what causes seasons).
- **What is the role of solar altitude (solar angle) on changing solar radiation levels?**
  Equal size areas get different amounts of solar radiation based obliqueness, even though surface areas are equal sizes.
  - *When the sun is low*, causing small angles (like at the poles), the radiation is spread over a greater area = less intense solar radiation
  - *When the sun is directly overhead*, causing vertical angles (like at the equator), the radiation is spread over a smaller area = more intense solar radiation
- **What is the greenhouse effect?**
  When terrestrial radiation is absorbed by the atmosphere and the atmosphere is heated from below.
- **What is the difference between terrestrial radiation and solar radiation?**
  - Solar radiation: radiation directly from the sun
  - Terrestrial radiation: Earth re-radiates to the sky radiation at longer wavelengths than solar radiation.
- **Discuss the role of greenhouse gases in making the Earth a livable planet.**
  Increasing levels of CO_2 in the atmosphere has coincided with increasing temperature over time.

Plate tectonics

- **What is an Ice Age?**
  A "geological period of long-term reduction in the temperature of the Earth's surface and atmosphere, resulting in an expansion of continental ice sheets, polar ice sheets, and alpine glaciers".
- **What is the Polar Position Hypothesis?**

1. Ice sheets should appear at continents when they are at polar positions.
2. No ice sheets should exist anywhere on earth if there are no continents at polar positions

- **What are the problems associated with it?**
  There have been times where there have been continents in polar positions, but no ice sheets
- **What is the Theory of Plate Tectonics?**
  Continents are not stationary, but drift around the earth's surface on rigid plates. The oceans are essentially the holes left behind.
- **How do continents move apart and get closer together?**
  Continents move apart because of divergent boundaries -- more oceanic surface forms between them. They get closer at convergent boundaries.
- **What are Rodinia, Pannotia, and Pangea?**
  There was a time where all the continents were together: this was Rodinia (very roughly 750 to 600 mya), then Pangea (260 mya). Pannotia is another, between Rodinia and Pangea -- I'm not sure it exists (hypothetical supercontinent described by Ian W.D. Dalziel as Wikipedia says).
- **What are the main events of the present spreading cycle?**
  From the Powerpoint:
  - began about 200 million years ago
  - at that time there was a single landmass or supercontinent called Pangea, and a single ocean called Panthalassa
  - about 180 million years ago Pangea began to break up
  - by 150 million years ago Laurasia and Gondwana were separated by a narrow east-west-trending sea
  - about 135 million years ago the south atlantic began to form
  - about 70 million years ago the atlantic ocean was well developed
  - about 50 million years ago, Australia separated from Antarctica and the Mediterranean Sea formed
  - about 40 million years ago, India collided with Asia
  - About 20 million years ago, Arabia moved away from Africa forming the Gulf of Aden and the Red Sea

CO_2

- **What is the CO_2 hypothesis?**
  - CO_2 is causing global warming. More CO_2 happens because of volcanoes, which appear when plate tectonics happen.
  - In an ice house state the climate is much more sensitive to CO2 atmosphere content
  - Slight jump in CO_2 levels = bigger jump in temperature compared to greenhouse state

- **What is the difference in climatic conditions between the Cretaceous and present?**
  Cretaceous was warmer (which was about 145 to 66 million years ago, according to Wikipedia).
- **Why is the climate more sensitive to CO_2 atmospheric concentration changes at low CO_2 levels?**
  We would expect low CO_2 concentrations with low temperatures. We also know that during a greenhouse state when CO_2 is extremely high there isn't a large change in temperature. As we switch to a greenhouse state we come to a place in the climate where we lose sensitivity to CO_2 changes. If there are low CO_2 levels and it is changed to an ice age state it makes a much larger difference with temperature than when the CO_2 is already large.
- **How is the overall trend of CO_2 level (and atmospheric T) changes in the last 55 Myr?**
  It's been increasing recently, but it's up and down. It goes up and up, then drops suddenly, then repeats. It's been decreasing.
- **How is the trend in the last ~200 yr?**
  Carbon dioxide is increasing, and so is temperature. It's been somewhat exponential.
- **What is the link between CO_2 atmospheric levels and atmospheric temperatures?**
  High CO_2 = higher temperatures. Roughly curved, like the left half of a hill. At very high CO_2 concentrations, it doesn't increase temperature as much.
- **How is it possible to measure past atmospheric gas levels from ice cores?**
  Air is restricted as depth increases, so air bubbles are trapped
- **What is the main reason for the difference in ice presence between Antarctica and the Northern Hemisphere?**
  Sea ice differs between the Arctic and Antarctic, primarily because of their different geography. The Arctic is a semi-enclosed ocean, almost completely surrounded by land. As a result, the sea ice that forms in the Arctic is not as mobile as sea ice in the Antarctic. Although sea ice moves around the Arctic basin, it tends to stay in the cold Arctic waters.
- **How is CO_2 added to the atmosphere over million of years time scales?**
  Volcanoes and plate tectonics (convergent and divergent plate boundaries)
- **How is it removed?**
  Chemical weathering -- CO_2 will be broken up into carbon and oxygen.
- **What is the role of chemical weathering?**
  - Breaks down rocks and increases CO_2 removal
  - Initial change ➜ warmer climate ➜ increased temperature, precipitation, vegetation ➜ increased chemical weathering ➜ increased CO_2 removal by weathering ➜ reduction of initial warming
  - Initial change ➜ colder climate ➜ decreased temperature, precipitation, vegetation ➜ decreased chemical weathering ➜ decreased CO_2 removal by weathering ➜ reduction of initial cooling
- **What are processes can be responsible for this long-term changes in CO_2**

atmospheric concentrations?
Human emissions, plant respiration, air-sea gas exchange, microbial respiration and decomposition**,** photosynthesis

Orbital cycles

- **What is obliquity? What happens during a cycle? What is the significance of obliquity and its cycle?**
  The tilt of the Earth on its axis. During a cycle the Earth tilts either towards or away from the sun. These tilts cause the seasons (among other things, but this is the biggest).
- **What is eccentricity? What happens during a cycle? What is the significance of eccentricity and its cycle?**
  The shape of Earth's orbit. Puts Earth closer or farther away from the sun. Responsible for changes in solar radiation
- **What is precession? What is its significance? What happens during the precessional cycle?**
  Axis of rotation wobble. Changes the amount of solar radiation during seasons (can cause cold winter or hotter summer).
- **Which orbital conditions are ideal for ice growth?**
  Small tilt with minimal sun in the summer and maximum sun in winter
- **What is insolation? What does it depend on? How does it change over the surface of the Earth?**
  Insolation is the amount of solar radiation received at the top of the atmosphere. It depends on the obliquity cycle, the eccentricity cycle (the changing shape of the orbit), and the precessional cycle. Insolation changes over the surface of the Earth monthly due to latitude. Lower latitudes are less variable than higher latitudes. From September to April the equator has the highest insolation in the Northern Hemisphere. From April to September it has the lowest. But because the equator is the least variable, it still has relatively high insolation.
- **What two factors determine the development of a glaciation?**
  1. Orbital-scaled changes in summer insolation. If there's not a lot of insolation, it gets colder, so glaciers are more likely to form.
  2. CO_2 concentrations have to be low enough that it gets colder.
  Isn't this what she said in class: insolation change and temperature
- **What is the role of temperature?**
  Colder temperature means more ice.
- **How does the glacial response to orbital variations change during the different phases of a glaciation?**
  Preglaciation Phase
    No ice accumulates
  Small glaciation Phase

Ice accumulates during the summer insolation minima
Ice completely melts during the insolation maxima

Large Glaciation Phase
Ice persists during weak summer insolation maxima
Ice only melts during strong summer maxima

- **What is the significance of CO_2 changes during glacial/interglacial cycles?**
  As CO_2 increases, ice volume decreases. As CO^2 decreases, ice volume increases.
- **How can CO_2 levels change significantly during glacial/interglacial cycles?**
  Slight changes in surface water temperature and salinity can have drastic effects on CO_2 levels.
  - cooling by 2.5ºC → -22ppm
  - increase salinity by 1.1% → +11ppm

  Water cools causing CO_2 to levels to drop. But it also causes an increase in salinity, which would raise CO_2 levels. BUT, the water cooling has a larger effect than the change in salinity. So even though salinity increases CO_2 because of cooling, the decrease in water temperature overall leads to lower CO_2 levels.
- **What is the biological pump? How does it change during glacial times?**
  The sum of a suite of biologically-mediated processes that transport carbon from the surface euphotic zone to the ocean's interior. During glacial times it pumps more.

Present

- **What is an ice age?**
  A geological period of long term reduction in the temperature of the Earth's surface and atmosphere resulting in expansion of continental ice sheets, polar ice sheets, and alpine glaciers
- **What are a glacial and an interglacial?**
  Glacial: Advances in ice**.**
  Interglacial: retreats of ice (what we are in now)
- **What do we know from oxygen isotopes about climatic changes that happened in the Cenozoic?**
  They were fairly constant. Build up of continental ice sheets. There was a constant decrease in deep water temp.
- **What is the Wisconsin Glaciation? When did it take place?**
  The last glacial period when ice sheets covered much of North America and Europe as well as parts of Northern Asia and southern South America. It took place between 110,000 and 10,000 years ago.
- **What is the Laurentide Ice Sheet?**
  The ice sheet that covered most of Canada and most of the northern United States
- **How did the current ice age start? What were the conditions leading up to it?**
  TODO the actual answer. Our current ice age started about 3 million years ago.
- **What is the situation today in terms of ice coverage for ice sheets, alpine**

glaciers, sea ice, and permafrost?
Everything is decreasing/melting

- **What is the likely culprit?**
  Human CO_2 emissions.
- **What are the predictions in terms of sea level change?**
  Possible total sea level rise of 79 m. Will definitely continue to increase even if it doesn't reach that point
- **What is glacial rebound?**
  The process by which the surface of a continent rises back up after an overlying continental ice sheet melts away and the weight of the ice is removed

Antarctic development

- **In which hemisphere did ice appear first during the Cenozoic? Why?**
  Southern. Because most of the continent is above sea level and the Arctic is an ocean surrounded by land
- **What are the main characteristics of the East Antarctic Ice Sheet?**
  Largest ice sheet, sits entirely on land, and well insulated from global climate change
- **Why did ice appear first in East Antarctica?**
  Higher elevation - receive less solar radiation; majority of continent above sea level
- **What are the main characteristics of the West Antarctic Ice Sheet?**
  Contains less water, ice shelves are grounded at several points on offshore islands, more vulnerable to warming, and became extensive around 2 mya
- **What is the role of the Tibetan Plateau in cooling the climate?**
  In the last ice age, the Tibetan Plateau was covered by an ice sheet. This ice sheet, due to its low latitude, reflected more radiation than normal therefore projecting a high albedo, cooling the climate. More recently, monsoon precipitation on the Himalayas becomes trapped on one side of the Plateau and forces warm air to rise, cooling the climate on the other side of the Plateau. It subtracted heat from the atmosphere.
- **What is the role of ocean circulation in establishing the presence of ice in Antarctica?**
  Ocean circulation forces the warmer water (less dense) to rise towards the tropics while the cooler water (more dense) circulates away from the tropics towards the poles.
- **What tectonic changes brought to the presence of ice sheets in Antarctica?**
  As the Tasman-Antarctic passage opened as a result of tectonic plates moving, Antarctica became isolated and ice began to form as a separation from other land masses exacerbated the formation of ice sheets in Antarctica. This separation prevented subtropical waters from interfering with sea ice formation.
- **What is the role of the presence of sea ice around Antarctica in ice sheet development and preservation?**
  The sea ice traps the heat below the ice rather than escaping into the air and keeps the

air above the sea ice cooler.

Last Glacial Maximum

- **What was the Last Glacial Maximum (LGM) and when did it occur?**
  18,000 years ago, during the Wisconsin Glaciation
- **What was the Wisconsin Glaciation?**
  Most recent major advance of continental glaciers, such as the Laurentide ice sheet.
- **What are Marine Isotope Stages?**
  Alternating warm and cool periods in Earth's paleoclimate deduced from oxygen isotope data.
- **What are Dansgaard/Oeschger (D/O) events?**
  Rapid climate fluctuations that occurred 25 times during the last glacial period.
- **According to CLIMAP how were sea surface temperatures at LGM different than today?**
  At LGM, the sea surface temperatures were much higher than they are today.
- **How were sea level and vegetation different than today?**
  During the LGM, there were vegetation changes because the binomes were pushed south due to the presence of ice sheets. Deserts expanded in many areas around the equator. The sea level was lower.
- **Why did some areas of the Earth dry up during LGM? How do we know?**
  Since a large portion of the water was locked in glaciers during the LGM, this left a great deal of land that is today, underwater. We can see this as a result of sand dunes and knowledge of the depth of the ice/glaciers.
- **Why did the jet stream change? How do we know?**
  During the LGM the jet stream split into two arms. The jet stream brings with it humidity and rain. The massive ice dries out conditions right near the ice sheets, but because of the jet stream the southwest was very wet, which is how we know that the jet stream changed.
- **How and why did the North Atlantic cool during LGM (and glacial times in general)?**
  Began to form after a prolonged cold stage with increased precipitation. Has something to do with the fact that sea ice formation stopped the surface current flow of warm water to the north.
- **How did deep water circulation in the North Atlantic change during LGM?**
  The rate and location of water’s creation has changed.
- **Why do we not see big changes in Antarctica?**
  Surrounded by cold sea water and ice insulating it from warmer waters.

Quiz answers

Quiz 1

1. If our planet were without its ocean but otherwise the same as it is today, would surface temperatures be more or less extreme? More extreme
2. Salinity decreases the freezing point of water, so it's more difficult to freeze water
3. High elevation allows glaciers to form in tropical latitudes
4. Ice shelves stabilize ice sheets
5. Earth is closest to the sun during the Northern Hemisphere's winter

Quiz 2

1. The inclination of the earth's axis causes distinct seasons
2. Ice exists for many reasons (insolation is not the only reason)
3. Continents move apart because of divergent boundaries, more oceanic forms
4. CO_2 concentration is released *over millions of years is* through volcanoes and active plate boundaries and other stuff
5. Current ice age started about 3 million years ago, not when ice appeared on our planet

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Enjoy!