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91413

914130

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Level 3 Earth and Space Science 2022

91413 Demonstrate understanding of processes in the ocean system

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of processes in the ocean system.	Demonstrate in-depth understanding of processes in the ocean system.	Demonstrate comprehensive understanding of processes in the ocean system.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 20

QUESTION ONE: THERMOHALINE CIRCULATION

Thermohaline circulation, also called the Global Ocean Conveyor Belt, is the part of general oceanic circulation controlled by horizontal and vertical differences in temperature and salinity.

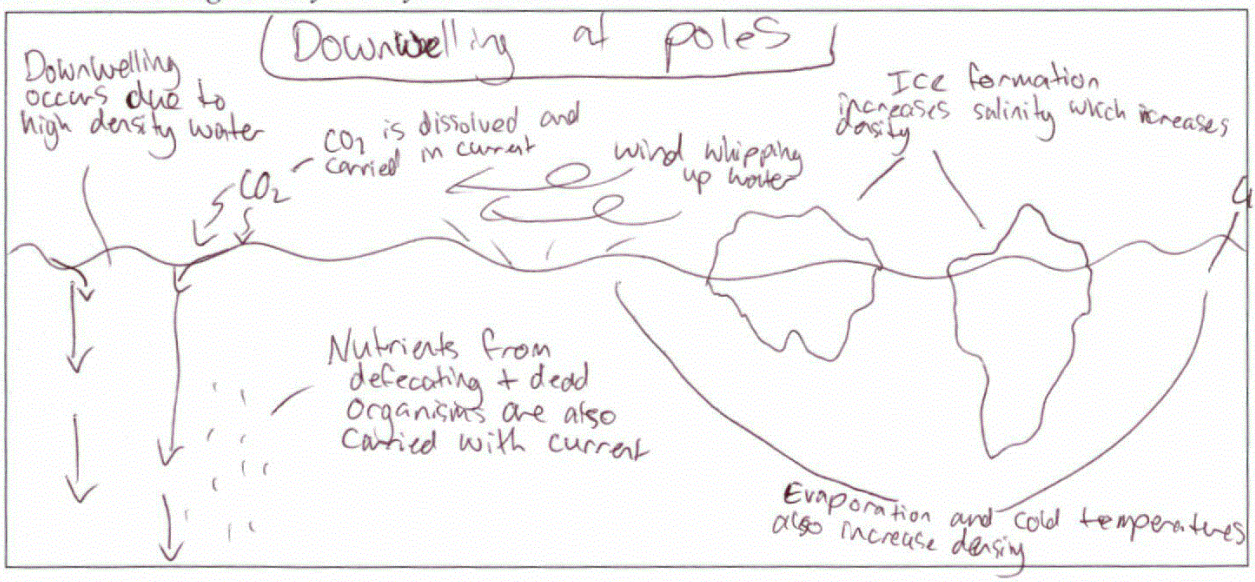
Adapted from: https://hchscollier.weebly.com/uploads/6/5/1/8/65182593/day_6_-_el_nino_la_nina_notes.pdf

Explain, in detail, the effects of temperature and salinity on the transport of matter and energy through thermohaline circulation.

Your answer should:

- include on the diagram above, labels where upwelling and downwelling occur
- explain the processes of upwelling and downwelling
- explain how downwelling drives thermohaline circulation
- comprehensively explain how heat energy and nutrients are transported through thermohaline circulation.

An annotated diagram may assist your answer.



Downwelling occurs in the higher latitudes (downwelling is the downwards movement of water within the water column, in this case, until it reaches the ocean floor) where salinity is high and temperatures (temp) are low, causing high density. The high density causes the downwelling because it causes it to sink due to more particles per unit of volume. The high salinity is caused by increased evaporation (due to high winds whipping up the water). When water evaporates, the salt is left behind so there is a higher concentration. ~~There salt is~~ It is also caused by the formation of ice in the high latitudes. As ice forms, only fresh water is used to form it, so the salt is left behind in the water and increases concentration even more. ~~This is~~ Higher salt concentration causes higher densities along with the water being very cold (due to uneven heating of Earth's surface). Lower temperatures mean that particles have less thermal energy and therefore less kinetic energy too (Ek), so aren't moving as fast and are close together so that there are more per unit of volume -> higher density. Higher salt concentration also means more particles per unit of volume so a higher density as ~~well~~ well. ~~Therefore~~ This high density water causes downwelling in the higher latitudes and drives thermohaline circulation because as it is pulled down, ~~Water~~ water from lower latitudes like the equator is pulled towards the poles to 'fill' the ↓

There is more space for your answer to this question on the following pages.

on the surface (because the water has been heated so is less dense so sits on top of the colder, denser water).

space where the downwelling occurred, therefore creating big currents that travel from low → high latitudes as part of the circulation. Also, as the cold, dense water moves along the ocean floor towards the equator, this will 'push' the water up at the equator/water that is in front of it in the circulation and therefore causes the upwelling at lower latitudes. Upwelling is the process of the upwards movement of water within the water column (in this case it can be due to continental landmass, other topography etc). It can also be caused by convection currents

Nutrients can be transported (as a result of high density + low temps causing downwelling and movement of currents) from the poles to the equator via thermohaline circulation because the nutrients come from dead organisms or defecation 'raining' down from the water column and entering the current. The current transports this to the equator (transports matter because it is a current whereas waves only transfer energy), where phytoplankton can use (in photosynthesis) it and thrive. They can also use the carbon that was dissolved into the water at the poles because gas dissolves better in cold water than warm water.

Heat energy is transported to help balance out the inbalances in the temperature variation by cold water being transported to the equator to not cause overheating (from sun's direct

overhead angle), and by warm water from the equator being taken away and towards the poles so that temperatures aren't too extremely low. This transports heat energy in a circulation around the globe, to avoid extreme temperatures.

QUESTION TWO: OCEANIC CARBON PUMPS

The ocean is important in the global carbon cycle, and is an important carbon sink.

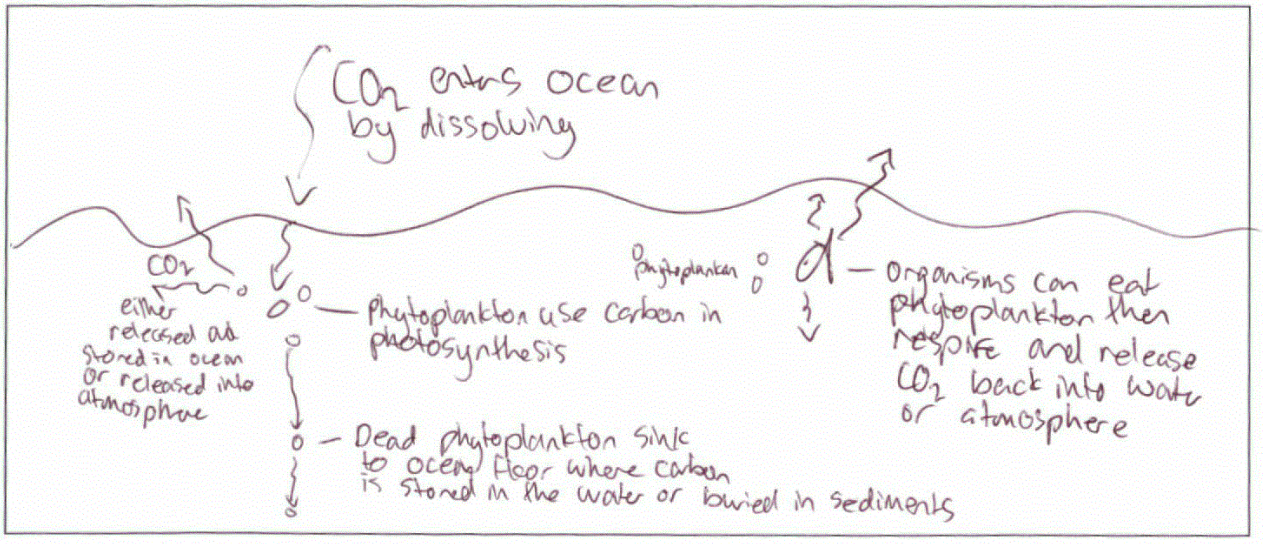
Source: https://oceanacidifcationgeog5.wordpress.com/2015/03/10/ocean-acidification/

Explain, in detail, how carbon moves into the ocean, and how changes in atmospheric carbon dioxide impact ocean carbon chemistry.

Your answer should include:

- a detailed explanation of the biological ocean carbon pump
- an explanation of the processes involved in the physical ocean carbon pump (include equations)
- a comprehensive explanation of how the biological and physical carbon pumps may change with an increase in atmospheric carbon dioxide levels.

An annotated diagram may assist your answer.



Carbon can move into the ocean in two ways: a biological pump or a physical pump. The physical pump is when CO_2 is directly dissolved into the water where it is then converted into carbonic acid ($CO_2 + H_2O \rightarrow H_2CO_3$) and can further be converted to bicarbonate. (This increases the acidity of the ocean which affects all organisms within the ocean either directly with dissolving of calcium carbonate shells or indirectly through the food chain and therefore will also affect all terrestrial organisms as well).
The biological pump is when carbon enters the ocean when phytoplankton require it for photosynthesis ($6CO_2 + 6H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6O_2$). It can then be released again into the water by respiration of phytoplankton ($C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$) or respiration of organisms that feed on phytoplankton. It can also enter the ocean when they die so stay in the mixed layer where all phytoplankton live, or they can sink to the ocean floor where the carbon is released and can be stored there for thousands of years (can also re-enter atmosphere from respiration or be stored for millions of years when the phytoplankton are buried in ocean floor sediments and converted to carbonate and possibly eventually limestone because they have calcium carbonate, $CaCO_3$, shells which help form limestone after extreme heat and compression + millions of years).
As CO_2 increases in the atmosphere,

There is more space for your answer to this question on the following pages.

so will temperature because CO_2 is a greenhouse gas. This will therefore cause the ocean to warm as well. Warmer water can't absorb as much CO_2 and it also can't hold as much either, so as a result, more CO_2 will accummulate ~~dust~~ in the atmosphere and increase warming even more! ✓ and the physical pump will slow down

As less carbon is available in the ocean, less is available for phytoplankton to use in photosynthesis. Therefore they will begin to die off along with all organisms on Earth. This is because not only are they at the bottom of the food chain in the ocean so if they die then all marine organisms die as well, but they also produce half of the world's O_2 which all ✓ (most) organisms rely on to stay alive (for respiration). Therefore the biological pump will also slow down. More CO_2 also means more absorbed (to a point of saturation) which will increase oceanic carbonic acid and therefore its effects on marine organisms too (dissolve calcium carbonate shells of phytoplankton even more & faster, causing them to die off sooner).

QUESTION THREE: OCEAN SURFACE SALINITY

Average ocean surface salinity

Adapted from: https://salinity.oceansciences.org/smap-salinity.htm

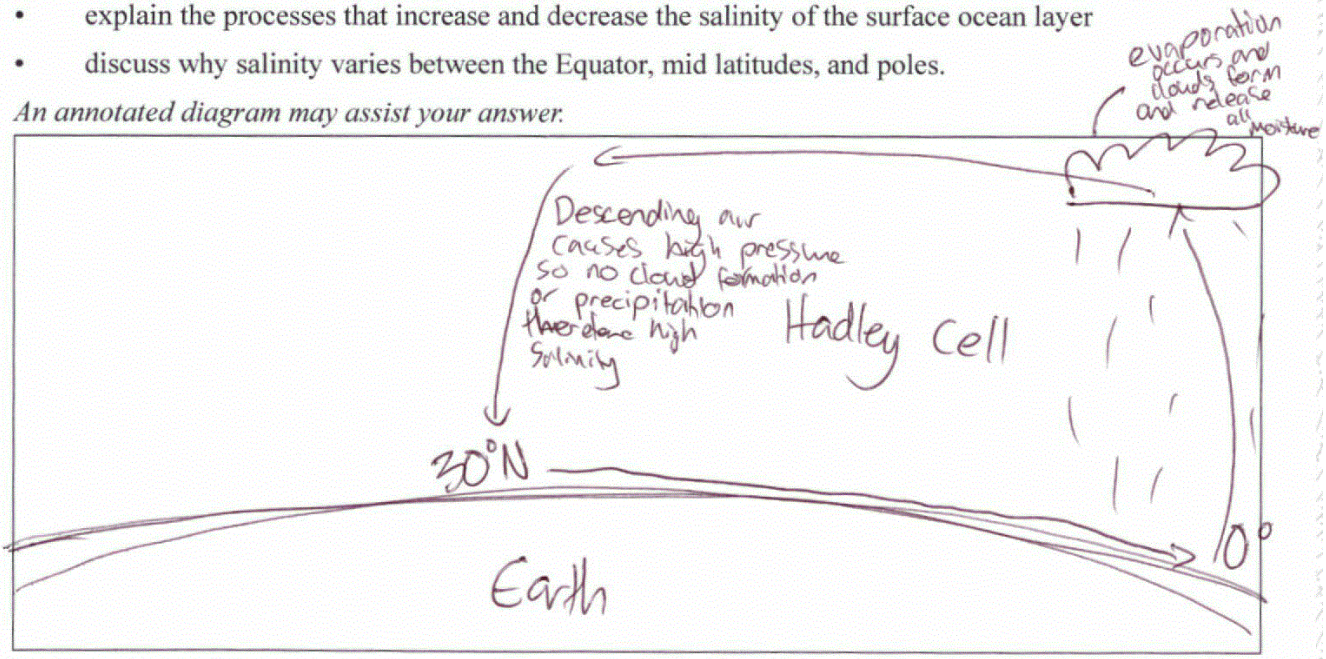
The ocean contains a large amount of salt in solution. The above map shows how the salinity of the surface layer of the ocean varies globally.

Explain, in detail, the factors that affect the global variations in surface ocean salinity.

Your answer should:

- explain the reasons why the ocean contains salt
- explain the processes that increase and decrease the salinity of the surface ocean layer
- discuss why salinity varies between the Equator, mid latitudes, and poles.

An annotated diagram may assist your answer.



Runoff from high-mineral areas (like mountains etc) enters rivers which eventually enter the ocean. These minerals contain salt and cause the ocean to also contain salt.
Evaporation is a large contributer to increased salinity levels like in warm areas like the equator as well as areas with high wind like the arctic. Evaporation at the equator is high because the sun is directly overhead, meaning $1m^2$ of heat energy produced from the sun covers $1m^2$ of the Earth's surface at the equator so temperatures + UV radiation is high. These high temperatures cause high amounts of evaporation which leaves salt behind, increasing its concentration (water vapour is only fresh water) to around 36-38ppt along/around the equator. High winds in the arctic also increase evaporation because the wind whips up the water, causing it to evaporate and increase salinity due to higher concentrations of salt (around 36ppt and 37-38ppt in some areas). Ice formation in the arctic as well as cold temperatures also increase salt concentrations here (explained in question one). The reason that the Arctic and Antarctic vary so much is that most of the Antarctic is a landform so not as much ice formation occurs here as the Arctic that has no landforms. As ice melts in summer + warmer months in Antarctica, this freshwater enters the ocean, decreasing salt

There is more space for your answer to this question on the following pages.

concentrations (compared to arctic) by increasing fresh water (33-34.5ppt in/around Antarctica). While although the arctic also expeiences ice melt, Antarctica coves a larger area so there is more ice melt to occur.
Areas like the Mediterranean have high salinity (38ppt) because it is completely enclosed so evaporation has a huge effect on it because more fresh water can only be added by outflow or precipitation which may not have a large effect on it. The mid latitudes are similar to the equator because they still experience/receive a fair amount of UV radiation from the sun and therefore quite a bit of evaporation as well. However here (at and around 30°N and 30°S) is where cold, dry air descends due to the Hadley circulation cell, so since the air is dry, there is no moisture for rain to fall and decrease salinity by increasing fresh water. Also, since the air is descending, it creates a high pressure area so it is hard for clouds to form because there is little/no rising water vapour to form clouds.
Salinity in mid latitudes is often higher than directly along the equator due to this reason. Because as air rises over the equator from evaporation, it has a lot of moisture in it and releases this moisture in the form of rain which adds

freshwater to the equator and therefore decreases salinity. However in the mid latitudes, since all the moisture was released over the equator, there is little to no rain/precipitation to decrease salinity and so therefore salinity is very high.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

Standard	91413	Display ID NSN		**Total score**	20
Q	**Grade score**	**Annotation**			
1	E7	The candidate has comprehensively explained how nutrients are transported via thermohaline circulation. This includes a source of nutrients, how they return to the surface and their effect on the area where upwelling occurs. A comprehensive understanding of the vertical movement of water is present but ideas around the horizontal movement contributing to THC needed development to secure an E8 grade.			
2	M6	The candidate has clearly explained the biological pump and physical pump alongside the effect of increased atmospheric CO_2 on the ocean carbon pumps. Overall, this is a good answer, but it has not been supported by accurate chemical equations/explanations to be awarded excellence points.			
3	E7	The candidate has comprehensively explained how evaporation and ice formation (also see Q1 response) lead to increased salinity of water before explaining how precipitation reduces salinity. Each of these processes are clearly linked to the locations mentioned in the question to secure the E criteria.			