Assessment Schedule – 2017

Scholarship Earth and Space Science (93104)

Evidence Statement

ONE

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
Well labelled, accurate diagrams are considered as evidence. The answer must relate primarily to phytoplankton rather than the carbon cycle. Equations may help an answer but are not essential. *At least one well-developed point on the long-term consequences of a warming ocean and ocean acidification was needed for scholarship.* **Key points:** • Phytoplankton are the primary producers of marine food webs. Each species is adapted to particular levels of water properties such as water clarity, temperature, nutrient content and salinity, and changes in these properties change the species that live in a given part of the ocean. • Carbonate is an essential but scarce building block for many species of phytoplankton. These species need access to carbonate in surface waters because sunlight doesn't penetrate very far into the ocean. **Importance to carbon and rock cycle:** • Phytoplankton use carbon dioxide (from the atmosphere) dissolved in the surface of the ocean to photosynthesise, to produce oxygen and organic carbon compounds. As well, many species combine calcium ions with carbonate ions to form the calcium carbonate that is used to make the delicate skeletons / platelets / shells. The carbonate ions are produced from a series of (equilibrium) reactions starting with dissolved CO_2 and water, $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons 2H^+ + CO_3^{2-}$ • When the phytoplankton die or are eaten, their remains (organic carbon compounds and platelets) eventually sink to the ocean floor to become layered with ocean floor sediments which all eventually cement together forming sedimentary rock (such as limestone and shale). These rocks store carbon for a very long / geologically long / millions of years period of time, linking the carbon and rock cycle. • Sedimentary rock, especially limestone, can be melted during the formation of magma, releasing CO_2 back into the atmosphere by volcanic eruptions. This rock can also be metamorphosed into marble (and other metamorphic rocks) and also uplifted, eroded and weathered. • Carbon-rich sediments may also act as a source of carbonate if the ocean above	Very little understanding of question with very little development of ideas. Resource booklet copied only.	Shows some understanding of question with only some development of ideas. Some synthesis and integration of the processes.	Good understanding of question with good development of ideas. Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context. Must show a good sense of geological time.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication • Must show an excellent sense of geological time. • Must show integration of ideas e.g. cycles.

becomes depleted in carbonate. This is because the atmosphere / ocean / and sediments (before they become rock) act as a huge buffer over long time periods.

Long-term consequences of warming ocean and ocean acidification:

- The greater the amount of phytoplankton the more carbon can be locked away in sedimentary rock and / or vice versa over geological time.
- Changes in any oceanic properties, such as temperature or salinity, will change the distribution and abundance of many species over shorter time periods because of the sensitivity of certain marine species. This may affect the health of marine food webs because different species of phytoplankton may have different nutrient levels, potentially affecting consumers.

The amount and variety of phytoplankton are reduced by:

- Warmer surface water which results in less dissolved CO_2 and therefore less carbon capture by phytoplankton photosynthesis. Also, less dissolved carbonate ions are produced which means that certain species cannot make calcium carbonate platelets, reducing, in the long-term, the amount of carbon that can be locked away in sedimentary rocks.
  $2H^+ + CO_3^{2-} \rightarrow H^+ + HCO^{3-}$
- Warmer ocean means more layering resulting in less upwelling of carbonate from the deep to replace depleted carbonate in the surface water. The phytoplankton put more energy into trying to make platelets and less into growth and reproduction. Photosynthesis slows and their numbers go down, reducing the amount of carbon that can be locked away in sedimentary rocks.
- Ocean acidification which results in a lower pH / increase in H^+ / H_3O^+, and consequently less carbonate ions. This results in less species able to make calcium carbonate platelets favouring those species that don’t make platelets. This will also reduce the amount of carbon that can be locked away in sedimentary rocks.
- Ocean water with a lower pH could also weaken platelets by reacting / corroding the $CaCO_3$.
- A warmer ocean may also result in a deeper thermocline, reducing upwelling along coasts, on the Equator, and along fronts (where different water masses / waters with different densities meet), resulting in less carbonate ions coming to the surface.

TWO

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
Well labelled, accurate diagrams are considered as evidence. **Conditions that make the Antarctic Circumpolar Current (ACC) strong and cold:** • The surface of the ACC is driven by persistent westerly winds formed by the Ferrel cell. The momentum of the wind is transferred into the ACC (and waves). • There is no land stopping or significantly slowing the ACC. Underwater features such as the Macquarie Ridge and the Drake Passage slow the ACC in those areas only. • The ACC is cold because of its southerly latitude which results in a low sun angle which doesn't warm the water up. • The persistent westerlies will cause evaporation of the surface of the ocean, further cooling it. **Global importance of the ACC:** • The ACC mixes all the oceans of the world layer by layer. The ACC also helps spread and direct the very dense deep water of the THC into the Pacific, Atlantic and Indian oceans via the Deep Western Boundary currents. Any changes in density or flow rate of the ACC will also signal a change in the THC. For example, warming of the deeper layers would slow convection and consequently the speed of the THC affecting the world's climate because heat wouldn't be distributed as effectively. **Research importance and challenges (these must relate to the global importance of the ACC):** • The baseline data on density and flow rate, measured by the Macquarie Ridge moorings, can be used to determine any weakening, strengthening or density changes of the ACC over time. This data can be compared with data from similar moorings in the Drake Passage. The expectation would be that any changes measured at the Macquarie Ridge, would be also found in the Drake Passage. • This data will show overall trends in speed and density (of each layer) of the ACC because all the oceans are mixed in the ACC. The instruments are spread out along the moorings so that the density of each distinct layer can be measured. • It is important for the research to be done over a long enough period to detect any trends. This is a challenge because the area the ocean covers is so vast and the water takes a long time to circulate. Also, changes to the ACC / THC will take a long time to become obvious and will happen many decades in the future. Changes in the data now could signal future changes, such as a slow-down in the THC.	Very little understanding of question with very little development of ideas. Resource booklet copied only.	Shows some understanding of question with only some development of ideas. Some synthesis and integration of the processes.	Good understanding of question with good development of ideas. Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication. • Must have a proper sense of scale.

• Research on density (salinity / temperature) will show any significant changes to the ACC such as density changes in the different layers. Such changes would affect the thermohaline current (THC). For example, warming of the deeper layers would slow down the THC affecting the world's climate because convection would slow down and heat wouldn't be distributed as effectively. • Macquarie Ridge is close to New Zealand and it is relatively easy for researchers to reach. Part of the ACC continues northwards around Zealandia / New Zealand continental shelf and so knowledge of any changes to the ACC flow or density in this area is also important for New Zealanders. • The earthquakes in the Macquarie Ridge area are strong, shallow and relatively frequent. These will cause severe shaking which could move the moorings. The shaking could also cause underwater landslides / avalanches and the loosening of any sediment that has been deposited on the mountain slopes or in the gaps, which may move / smother / damage the moorings and their equipment. • The earthquakes occur in clusters, which will weaken the sides of the mountains / sediment even more than just one event, so increasing the likelihood of underwater avalanches. • Underwater landslides or sediment collapse could cause tsumanis which could further damage the moorings and research vessels. Also, convergence of the Pacific plate with the Australian plate would cause uplift, which could cause tsunamis. • The acoustic release could be triggered or damaged by sediment / landslides / tsunamis, making the moorings unable to be retrieved.				

THREE

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
Well labelled, accurate diagrams are considered as evidence. *Recognition will not be given for simple interpretations of data and photos from the resource booklet.* *Valid comparisons need to be made between the albedo of exoplanets and known planets or moons to explain a point.* *It is expected that the application of knowledge and the implications will be balanced in a Scholarship or Outstanding answer.* *General statements about suitability of the exoplanet for life must be qualified using more specific information e.g. evidence for water vapour may mean the presence of a water cycle and the recycling of minerals, both of which are needed for life.* **Applications and implications** • Exoplanets are a vast distance away so whole / average albedos are more relevant because it is not possible to get a detailed view of any surface features. • Albedo won't definitively identify surface features; other information is needed from instruments such as spectrometers which determine key elements making up a planet surface / atmosphere. • The distance of the exoplanet from its star may assist the interpretation of its albedo e.g. - if the planet has a high albedo but is close to its star it is more likely to have thick cloud; if it is further away it is likely to have an icy surface. • If there is evidence of an atmosphere then the exoplanet must be a certain size to retain one. Also, volcanism may have helped form / retain an atmosphere • An exoplanet with a high albedo may: - have an icy surface like Enceladus, which is shiny and smooth. Geysers and water that comes out of cracks in the icy crust will be continuously renewing the surface, which means that the icy surface stays clean resulting in a very high albedo. Tidal flexing, especially if the exoplanet is close to its star, would provide the heat needed maintain a liquid ocean under an ice sheet and to cause geysers and cracks in the ice through which water could seep up to the surface and then freeze. Tidal flexing may also cause volcanism on the ocean floor - be covered in thick, dense reflective cloud like Venus; such clouds could indicate past or present volcanism. The dense clouds of Venus reflect visible light rather than absorbing it - have a surface made of relatively smooth and therefore highly reflective	Very little understanding of question with very little development of ideas. Resource booklet copied only.	Shows some understanding of question with only some development of ideas. Some synthesis and integration of the processes.	Good understanding of question with good development of ideas. Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context. Both the applications of knowledge and implications are discussed.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication. • A balance between the application of knowledge and the implications is fully discussed.

types of rock (like parts of the Moon which are made from pale anorthosite rock) over a large part of its surface. The smoother the rock, the more light is reflected rather than scattered.

- An exoplanet with a lower albedo may have:
  - a surface that is made up of darker rocks such as basalt e.g. dark parts of Moon, and represent early volcanism or asteroid impact
  - a rough surface such as seen on Hyperion, which scatters light rather than reflecting it. Such roughness could be from rubble which may have been caused by e.g. bombardment from meteorites, volcanic tephra or erosion. Outgassing from the centre of the planet may also cause a rough surface.
  - surfaces covered in (carbon-rich) sooty deposits (Iapetus) which may have come from external or internal sources (oozed from planet’s interior) or are dirty (from debris from various origins) or erosion.
  - lots of liquid water on its surface; this may mean a water cycle which would distribute heat. Possible erosion from liquid water would enable the cycling of minerals

- An exoplanet’s albedo may be change over short or long-time periods in a regular or irregular fashion. This can mean:

  Shorter time periods
  - a planet with an irregular shape
  - a planet with a chaotic rotation
  - a planet that isn’t round like Hyperion
  - a surface that varies like on Iapetus
  - the different angles of the exoplanet’s starlight on large bodies of liquid / water.

  Longer time periods:
  - activity on the exoplanet that changes the surface, such as volcanism
  - seasonal changes
  - elliptical orbits of the exoplanet around its star
  - a tidally locked planet with dramatic variation in its surface’s albedo, like Iapetus. As the planet rotates the albedo will vary in a regular way.

Examples of scholarship answers.

- A high albedo suggesting a planet covered in fresh ice may indicate that the surface is being continuously renewed due to water coming to the surface and being frozen, as observed on the surface of Enceladus. The water must be coming from somewhere, especially if the exoplanet is outside the Goldilocks

zone. If such an exoplanet experiences tidal flexing this will provide a heat source and suggest an under-ice ocean and possible sea floor volcanism. Volcanism would provide heat and nutrients, and the ocean liquid water, which may mean primitive life could evolve / exist in the ocean. • An atmosphere may indicate water vapour and possible liquid water, and perhaps an active water cycle. This could result in the distribution of heat and water around such a planet. Also, if there was land, an active water cycle would result in erosion which would result in the recycling of matter for landscape destruction / building and for possible life. • Sooty surface material or rubbly rock, for example, may indicate volcanic activity and / or active erosion resulting in actively renewing surfaces. This results in the distribution of heat and the recycling of material. Volcanic activity may be the result of active tectonics, the presence of deep sources of magma or tidal flexing.				