and coming technologies such as malaria vaccinations and by thinking of ways to raise money to carry on the program sustainably. Penultimately, I showed how malaria is treated when compared to the flu. Finally, I compared the treatments of malaria and flu and also the price of those treatments.

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PhD Tutor's comment:
S.'s essay blew me away. His input through the tutorials was impressive and he made me question things along the way too. His essay reflects not only an improvement in his knowledge and academic writing, but also in his ability to think outside of the box and reach for the higher grades in doing so, achieving a 1st for this piece of work. I believe S. will go on to do brilliant things and it was a pleasure to teach him.

NIRS Application to a Triathlete

Year 8, Key Stage 3

E. Owen, The Macclesfield Academy, Cheshire.
Supervised by A. Imere, University of Manchester.

Introduction

Near infrared spectroscopy (NIRS) is an analytical technique that uses the near infrared area of the light spectrum which is between visible and ultra violet light (from 780nm to 2500 nm) [1].

Near infrared light was discovered by William Herschel in the eighteen hundreds, but the first industrial application began in the 1950s. Originally, NIRS was only used as an add-on to other optical devices. Later, developments in light-fibre optics and the monochromator-detector allowed NIRS to become useful in scientific research [1].

There are many industrial uses for NIRS. These include: agriculture. e.g. determining the quality of products; material science. e.g. research into the optical characteristics of nanoparticles; medical and pharmaceutical advances. e.g. brain scans; and industrial uses. e.g. getting accurate C02 consistency [1].

Since 2006, NIRS technology has become more widely used to assess changes in metabolism and oxygenation of muscles. This can be done both during and after exercise in the laboratory and in real-life sports situations. This allows athletes to see where they could improve their muscle use to increase their performance [2].

This essay will explore the design of an NIRS product that measures oxygen levels for a triathlete.

Problem

The NIRS product will be developed for a Great British triathlete, Alistair Brownlee. He is thirty years old and comes from Leeds. He is the first triathlete ever to retain two Olympic gold medals and has completed the Iron Man, a triathlon contest [3].

Alistair will benefit from measuring oxygen levels in his blood because he will know how well his muscles are working. Muscles need oxygen to complete aerobic respiration and a lack of oxygen causes anaerobic respiration, which produces lactic acid, causing muscles to fatigue [4]. Therefore, knowing his muscle oxygen levels will allow him to adjust his training to improve performance. Furthermore, Alistair could measure his readings during a triathlon, enabling him to adapt his effort both during the event and in subsequent triathlons.

A standard Olympic triathlon consists of 1.5km of swimming, 40km of cycling and 10km of running [4]. As a triathlon consists of swimming, cycling and running, any device designed for Alistair would have several specific requirements. These include being waterproof; compact; durable; lightweight; and reliable and not falling off when his wetsuit is removed.

Ideas

A common method to measure oxygen levels is through the use of pulse oximetry. Like NIRS it is non-invasive. An example device is the finger pulse oximeter, which, when in use, is attached to your finger and instantly gives an oxygen reading from your blood [5]. However, the reading is only of the oxygen level in your blood, not directly in the skeletal muscle. In addition it does not measure metabolism.

NIRS is a superior technology in the fact that it is possible to measure the oxygen saturation level in specific muscles not just in the blood and NIRS also can measure metabolism. In addition, NIRS can be placed anywhere, not just on the end of your finger.

The next important factor to consider is how the NIRS device should be attached to the triathlete design. For instance, the device could be integrated into the clothing or could be a wearable device using a strap to keep it in place. As triathletes predominantly use their legs, the near infrared light needs to be applied onto the legs. It could also be beneficial to measure oxygen in the arm.

An obvious design is to use small, sticky pads to attach the NIRS device to a leg muscle. However the stickiness would likely fail because the water would reduce stickiness when swimming. Also moisture from sweat would have a similar effect possibly resulting in the device being lost. This problem could be overcome by strapping the device onto the thigh, however, this may be uncomfortable.

The next key factor to consider is how the data will be transmitted and stored. It would be useful to send the data long range to a main processing unit which would store the data in the cloud for experts to analyse. However given that it is likely that multiple NIRS devices would be required, for example on the legs and arms: it would be inefficient for each NIRS device to send it's data remotely. Therefore, the wireless NIRS devices need to send data to a small, local computer such as a smartphone or watch. This would also allow the athlete to access the important data in real-time.

The final factor to consider is how the data will be used. The data needs to be analysed offline by experts so that a new training regime could be created for the athlete based on the data. However, the triathlete will want to monitor their oxygen levels during exercise so that the athlete can adapt their effort levels during the event. This could be achieved through creating a smartphone application [Fig. 1].

Fig 1: [6] An existing NIRS muscle oxygen level monitor combined with a linked smartphone application.

The device is called 'TriView' because you can view your muscle oxygen levels and metabolism in all the three sports in a triathlon (running, cycling and swimming).

To address the problem of attaching multiple devices, a trisuit (which is what most triathletes wear when completing a triathlon [7]) will be modified to contain the NIRS devices, in both the legs and arms, ensuring that it would not fall off when swimming.

As the NIRS devices are located directly on the limbs, the near infrared light does not need to travel anywhere, hence there would be no need for optical fibres. In addition, there is a small Bluetooth device inside the NIRS devices so that the data can be directly transferred to the Display Pad. As the data is not being transmitted long-distance, not much power would be consumed during this process, hence only a small battery will be required.

The NIRS device requires a light source, sending light into the tissue. This is achieved using a single-colour green LED because the single colour is easier to process. A laser would be not be used as it is potentially harmful and would use too much power.

The NIRS devices must also contain a spectrometer which would separate the scattered light [8]. In addition, a photodiode muse be included and is required to convert the light waves into electrical currents so the data can be transmitted [9].

The second main component of the TriView device is a computer comprising of a data display; a large, highly flexible screen which would be integrated into the arm of the trisuit. The computer also consists of a Bluetooth receiver (to collect data from the NIRS devices) and also a 4G transmitter[10], to transmit data to the cloud.

The computer and display would be integrated onto the trisuit to make it secure. The display will show real-time data of the oxygenation and metabolism allowing Alistair to see his readings during a triathlon enabling him to adapt as necessary during the event [Fig. 2]. The the display pad (computer and display) and NIRS devices would have to be waterproof.

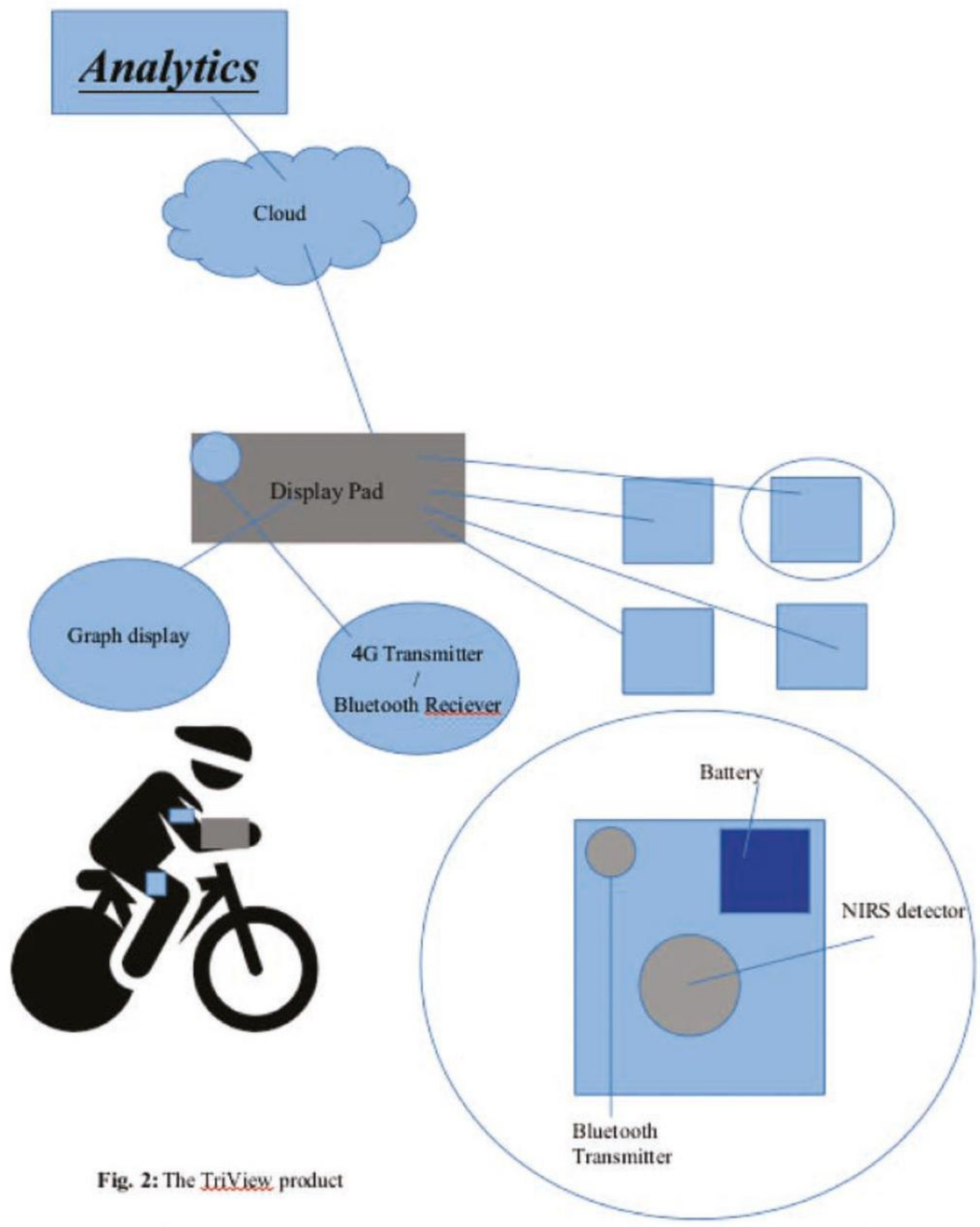

Fig. 2: The TriView product

Improve

The device could be refined in many ways. One issue is the effect of sweat on NIRS data therefore the data is less accurate for high intensity work-outs [14]. This could be improved by adding sweat collecting areas around the small devices in the trisuit. Another way to solve the problem is introducing indocyanine green dye. This has to be applied through an injection so it could be applied before training. The dye improves light scan results which could help for high intensity work-outs [15].

The device could also be improved by adapting the device for other athletes for example a skier. Although, this could be challenging as the design may not work in colder temperatures.

As power may fail, an electrical dynamo could be implemented, using the athlete's kinetic energy to power the devices or recharge the batteries [16].

Conclusion

NIRS is an analytical technique and is beginning to be applied in sports science. There are problems with measuring oxygen levels for triathletes but if these were resolved, the triathletes would be able to measure oxygen levels in their blood so they know how well their muscles are working.

There are quite a few ways the device could be made; with straps or even as a watch but as the triathletes swim, some small devices integrated into a trisuit are best. The device has been designed to be lightweight, durable, reliable and also waterproof and so should be ideally suited for a triathlete.

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PhD Tutor's comment:

It was a great pleasure to work with E. during the Brilliant Club tutorials on Illuminating the Body. In class he generously shared his ideas and contributed to develop sophisticated discussions. E.'s final assignment particularly impressed me, as the pupil showed an in-depth understanding of the subject, which went far beyond the content covered in the tutorials. He read widely around the topic and creatively manipulated the information to produce his own, original near-infrared spectroscopy system to monitor oxygen levels in athletes' muscles. I am very proud of E.'s progression throughout the programme and there are no doubts he will be an excellent undergraduate.

A machine to measure muscle oxygen levels for athletes

Year 8, Key Stage 3

M. Piperdi, Moor Park High School and Sixth Form, Preston.
Supervised by I. Salako, University of Sheffield.

Mo Farah is the UK's most successful track athlete with ten "world and Olympic gold medals" among many other achievements (BBC Sport). He became the first athlete to win three long distance doubles at successful championships. Born in Somalia, Mo Farah came to the UK at the age of eight. He now lives in Portland, Oregon (USA) with his wife and four children. The journey to his successful career began when his P.E teacher noticed his exceptional running skills. Although Farah never originally wanted to become a track runner, it was what he was good at and what he decided to pursue his career in (Mo Farah official website).

As a professional runner he needs to train hard and to be able to perform at his best, it is important that he knows the oxygen levels in his blood, in order that he can keep the oxygen levels throughout the body in balance. This would allow him to run faster for longer periods of time without getting tired therefore enabling him to win comfortably whilst remaining at the top of the leader board (Mo Farah official website). For this reason, a device to measure oxygen levels in the blood would benefit Mo Farah.

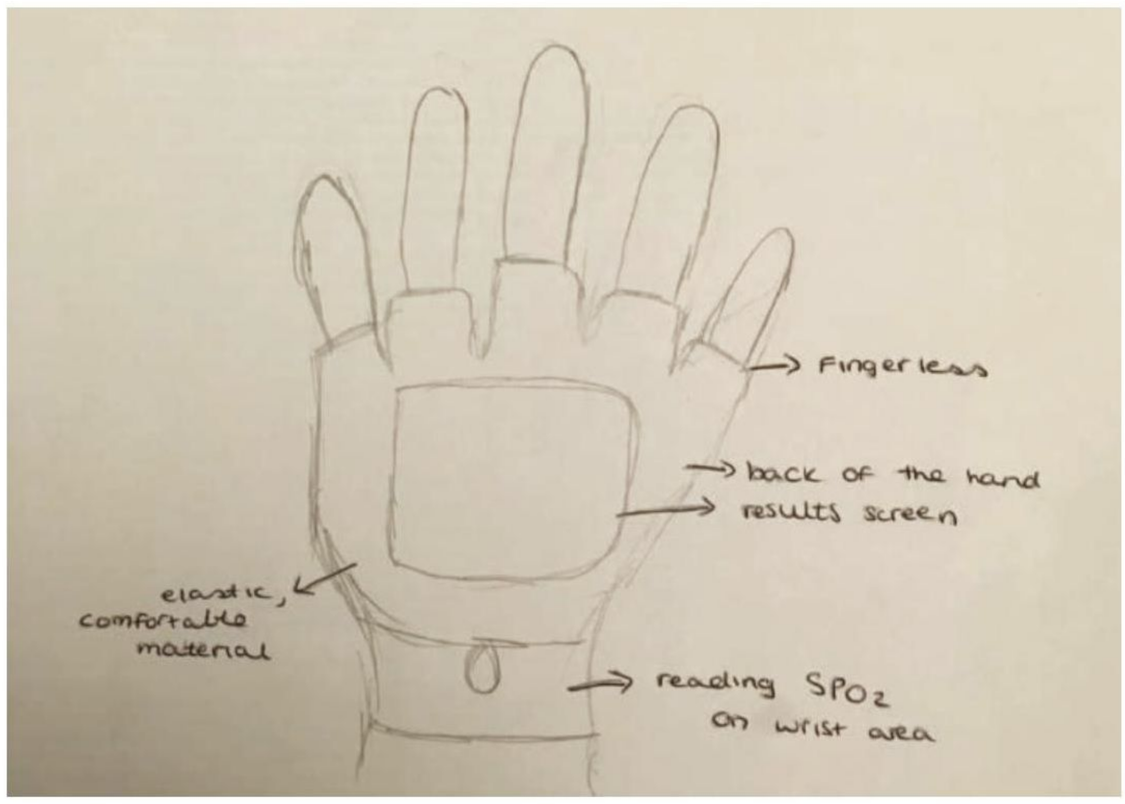
Like all sports, running has its own unique attributes therefore a particular style of device would be needed to measure oxygen levels in the blood specifically for running. The ideas that need to be considered are problems such as being able to measure the oxygen levels without altering his performance. It would be beneficial to consider where the device would be placed on his body and where it would be most effective. For this reason, it would be useful to design a device that would feel comfortable on the athlete whilst measuring oxygen levels effectively and successfully.

There are many devices currently on the market that are able to measure oxygen levels in the blood. For example, the pulse oximeter measures pulse rate and oxygen saturation in the blood, in order to maintain an effective oxygen range. In the early 1970's the creator, Takuo Aoyagi (a Japanese bioengineer), "recognised that he might be able to use the pulsating changes in the light transmission through the ear to measure arterial oxygen saturation" (Oximetry org.). Using it to monitor oxygen levels can help make adjustments to get an equalised oxygen flow. It is wireless, lightweight and easy to use. This can drastically improve the performance of an athlete.

Another device that could potentially be used is the standard oxygen monitor which is used in ICU and surgery. This device is good at "detecting low oxygen levels that arise because of low or obstructed blood flow even though the lungs are working just fine" (Stanford news). The inventor, David Benaron, designed this piece of equipment so that it can determine oxygen levels by noninvasively reading the colour of the blood (Stanford news). "Unlike the pulse oximeter, this new monitor can zero in on the amount of oxygen reaching specific areas" (Stanford news). However, because this device is normally placed on the finger it may be impractical for an athlete such as Mo Farah to wear this whilst running as it may fall off.

There is also another device called the humon hex. The humon hex is wearable and is a heart rate dependant device. It uses optical lenses to non-invasively monitor oxygen levels in the muscle. "It was initially designed to be worn on the thigh as the quad is the main muscle that powers running motions", but it can also be worn on the arm (gizmag). This would make the design more practical for wearing whilst running.

Bearing in mind the products that are currently available, I propose to produce and manufacture a new and more effective device called the handy oximeter (shown in the diagram below) as it is worn on the hand as a glove. It also measures oxygen hence the name oximeter. It would be fingerless and fit comfortably on the hand. The material would be thin and stretchy, similar to lycra and not uncomfortable. On the wrist area would be the device reading the (SPO2) from arterial blood gas analysis. On the back of the hand will be a surface for a screen to show the results of the amount of oxygen there is in the blood. The fingers would be uncovered so that they can grip onto things such as a water bottle or cup during a marathon.



To make one of these devices would require a team of specialist engineers and experts who have the skills and expertise to complete the challenging task. A clinical engineer who specialises in a type of biomedical engineering primarily for implementing medical technology to optimise healthcare delivery would be useful for their medical knowledge and technological knowledge to help adjust the device and create it.

Biomedical engineers usually work in a hospital. They could assist with the kind of materials necessary because they would know what would be harmful to the skin and what wouldn't. In addition, mechanical engineers work mainly with machines and could be useful for helping build the product in a more successful way. They would be able to make sure the device would not malfunction or harm your body.

As with other medical devices, there are other challenges that the engineers may face. For example, not all runner's hands are the same size and everyone would need their own suited glove. For this reason, it may become necessary to measure every athlete's hand to size and each glove would be specially made to fit each individual athlete's hand.

Also, the engineers would need to consider that sometimes when the athlete is in training, it is very likely that they are going to sweat and some of the sweat may be on their hands. Therefore, they would need to make sure that the glove is made using waterproof materials which won't be penetrated by sweat and also that any moisture does not allow any important components to slide off or become damaged. In addition to this, the people designing the material would need to be aware of the fact that some materials can damage your skin and some athletes may have allergies to certain materials therefore, they would need to ensure that they speak to individual athletes regarding these requirements.

The engineers who are constructing the product would also need to keep in mind that the components must be small so as not to distract the athlete, and not impede the athlete's performance. However, this may mean that these parts are difficult to work with due to their size. They must also ensure that the screen cover is strong enough to withstand different temperatures since Mo Farah trains in extreme heat but also competes in many countries of the world with varying climates.

As there are challenges for track running, in a similar manner there would also be the possibility of the handy oximeter to be adapted for other sports such as tennis and swimming. This would mean making some alterations to some areas of the design. For example, being a hand-held device, the structure would completely change for tennis because the player would need to hold a tennis racket in their hand whilst playing the game. This would cause many challenges because the handy oximeter could no longer be called handy. Also, the tennis player couldn't even check the device whilst training or playing the game because it would cause a disruption to what they were doing and could distract them. This would mean that the device would have to be situated in a completely different place and one possible solution would be to alter the product so that the most important components fit within the confines of a sweat band around the wrist.

The product would have to be adapted yet again for water-based athletes such as swimmers. In this case, the engineers would need to re-evaluate the materials they would be using because all aspects of the product would have to be waterproof and withstand other things such as water pressure. This may also mean that yet again the product would need to be placed on another area of the body as the hand usually hits the water with force when swimming. A particularly good area for it to be placed would be the thigh as it has strong muscles and there is likely to be less damage to the product.

In conclusion, devices and products that measure oxygen levels in the blood that are currently available can be adapted and re-engineered to suit an athlete such as Mo Farah. I have proposed a new device called the handy oximeter to measure the oxygen levels in Mo Farah's blood which I believe will be reliable and effective. Finally, although alterations would have to be made I think that the handy oximeter would be very useful for many other athletes in very different sports to measure oxygen levels.

PhD Tutor's comment:
M. was a very attentive student in class. Although, she was shy to participate, she endeavoured to make meaningful contributions to discussions in class. Her technical write up about an oxygen measuring device is a particularly excellent piece: it was well researched, very creative (and a build-up on existing ideas), it had logically structured paragraphs and her language style was top-notch.

The climate has always been changing, so humans cannot possibly be responsible for the current climate change. Discuss.

Year 8, Key Stage 3

K. Wilkinson, Hele's School, Plymouth.
Supervised by N. Ellis, University of Exeter.

Introduction

Some people, including some scientists, believe that "the climate has always been changing, so humans cannot possibly be responsible for the current climate change." The climate shows how the atmosphere is changing over a long period of time. It is the average of the weather which is the conditions in the atmosphere over a shorter period of time. The climate is changing over time (figure 1) and there are many reasons for this. For example, Earth has experienced ice ages in the past, such as the Karoo Ice Age 360 – 260 million years ago, where the climate cooled dramatically. Some people consider the climate change to be completely natural whereas others think that it is human induced and what we do every day has an impact on it. In this essay, I will be discussing different factors of climate change and weighing up and comparing both natural affects and human induced affects.

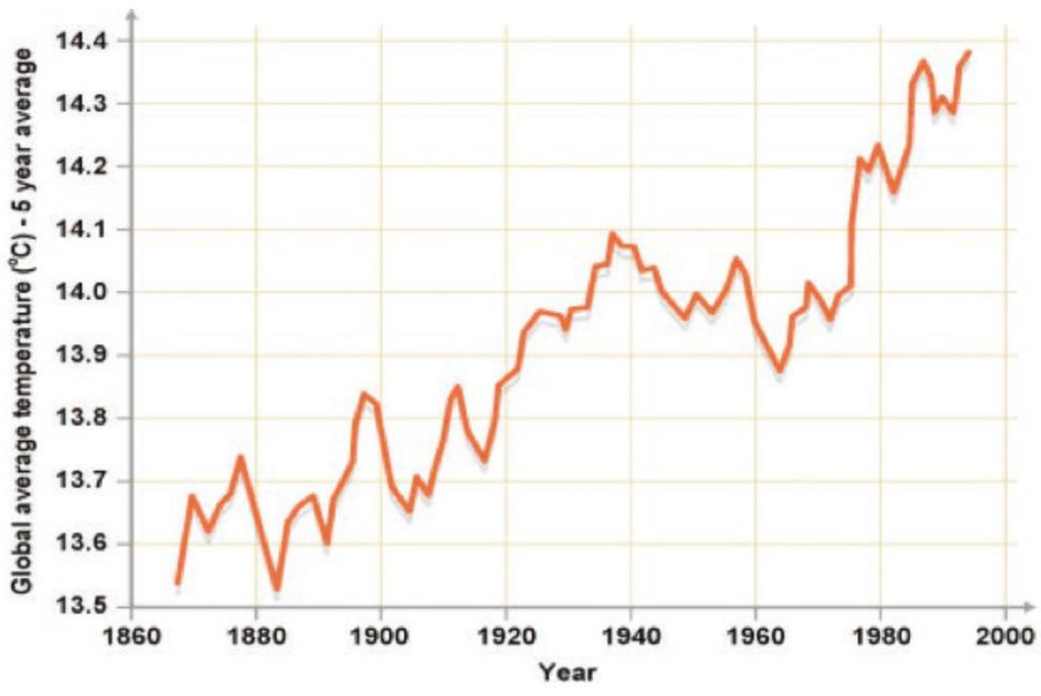


Figure 1 - This graph shows how the average global temperature has risen between 1860 and 2000.

Climate has always been changing naturally

On the one hand, some people agree with the statement "the climate has always been changing, so humans cannot possibly be responsible for the current climate change."

One way to prove this is to study the ocean currents. Due to the continents, the ocean has to travel and channel down to different places. This results in ocean currents. These currents are determined by the density and the temperature and change the speed meaning that the quantity of heat transported to different locations can vary. For example, the oceans absorb twice as much of the sun's radiation as the atmosphere or land surface (Rahmstorf, 1997) meaning that however cold or hot our climate is depends a lot on the oceans.

Another way the climate is changing naturally is the Earth's orbital changes; precession, eccentricity and obliquity (figure 3). Precession is the direction of the Earth's tilt, eccentricity is the shape of the Earth's orbit and obliquity is how much the Earth tilts. Today, we are at the point of precession where we are nearest to the sun in winter and further away during summer. This is constantly changing very small amounts over time. It changes our climate as the position of precession would be expected to cause less severe seasons—and that is what we may be experiencing now as the winters are warmer, and the summers are not markedly hotter (Purdue University,