KNOX
GRAMMAR
SCHOOL

STATE

DA VINCI DECATHLON 2021

CELEBRATING THE ACADEMIC GIFTS OF STUDENTS IN YEARS 9, 10 & 11

SCIENCE- SOLUTIONS

TEAM NUMBER _____

1	2	3	4	Total	Rank
/15	/15	/28	/14	/72	

QUESTION 1: CHEATING CHANCE (15 MARKS)

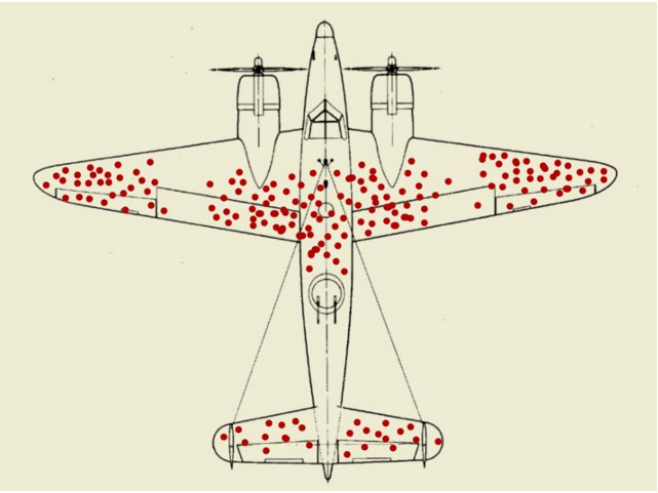
NOTE: QUESTION 1 INTRODUCES THE UNSEEN CONCEPT OF BIAS IN EXPERIMENTAL DATA. THE QUESTIONS TARGET THIS CONCEPT FROM AN EXPERIMENTAL PERSPECTIVE ALONG WITH QUESTIONS MORE FOCUSSED ON THE UNDERPINNING PSYCHOLOGY.

This first question looks at various errors in interpreting results from scientific investigations. The errors arose because scientists didn't correctly leave things 'to chance'. Instead, they added a bias to their logic which meant the results from an experiment were no longer naturally occurring.

(a) Scientists reported a theory many years ago that 'cats who fell from higher stories have fewer injuries than cats who fell from lower down'. It sounds strange but was justified using terminal velocity by suggesting cats falling from higher than six stories reach their maximum velocity during the fall, so they start to relax and prepare to land, resulting in less injury. They collected data from various vets who recorded cats that were brought to their veterinary clinic after a fall. Theorise as to why this experimental method might have been fundamentally flawed, resulting in inaccurate results. (2 marks)

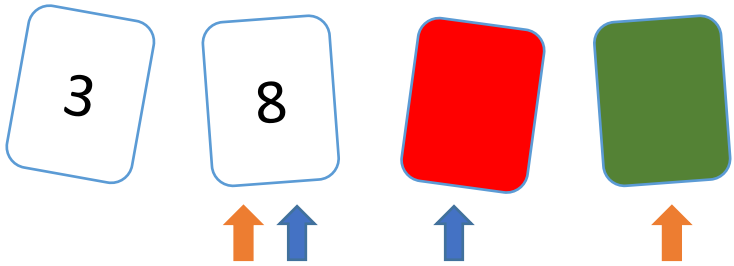
1 mark – those cats that fell from higher stories likely were not taken to vets as they did not survive, i.e. did not need emergency care.
1 mark – resultingly, the data only likely includes those few cats that did survive from a higher storey and may be a biased sample (survivorship bias). Given it is likely more dangerous from a higher storey, the fact these cats survived suggest they might be anomalies and stronger/luckier than other animals, thus potentially having less injuries than those that fall at a lower level.

(b) In World War II, planes would return from flights with many bullet holes. Below is an image representing an average of the bullet hole locations, with each red dot illustrating a bullet hole. A team of engineers hoped to improve the resilience of the plane by installing extra shielding where it is most needed. Using similar reasoning to part (a), explain where the extra shielding would be best placed to better protect the plane. Annotate the diagram to indicate these locations. (3 marks)



1 mark – where there are no bullet holes is the best location
1 mark – this is survivor bias; the planes that have returned have many bullet holes BUT that means these places are strong and the plane can withstand attack.
1 mark – Alternatively, where the bullets have not struck are likely the places where such a strike is fatal, so the plane won't return from the flight and become a part of analysis.

(c) One of the most common biases in experimentation is confirmation bias. It arises when scientists interpret new evidence as confirmation of their existing beliefs or theories. Below are 4 cards used in an experiment. The participant in the experiment is asked: "which 2 cards should you turn over to test the claim that if a card has an even number on one face, then its opposite face is red?". Two possible selections are shown below using blue and orange arrows. Explain which of the two selections would be the most correct answer and which selection is the result of confirmation bias. (4 marks)



1 mark – the orange arrows are the best option
1 mark – the blue arrows are the result of confirmation bias
1 mark – the orange is correct as the best chance you have of testing the claim is to disprove it by using an even number card and a card with a different colour.
1 mark – the blue arrows don't give you the best chance to test the claim. If the red card has an even number, you only know that card follows the theory, and similarly for the 8 card. It is still possible that the green card has an even number behind it!

(d) The table below includes descriptions of four experiments, each with a different type of bias affecting the chances of collecting 'natural' data. Your task is to (1) describe the bias that is occurring in each example and (2) suggest an improvement to the experiment that would overcome the bias. (6 marks)

A general conceptual explanation similar to that provided below is required for a mark in relation to the description. Improvements should align closely with the examples below.

EXAMPLE	DESCRIPTION OF BIAS	IMPROVEMENT
An experiment aims to test how precisely high school students can estimate Australia's population. The survey each student received had 2 questions in this order:	Anchoring bias (not necessary to name specifically). Occurs where having heard a previous value/indicator in relation to	Remove the first question.

1. Is Australia's population more than 30 million? 2. What is Australia's current population? Australia's population is 25.5 million but the average answer for question 2 was significantly greater, demonstrating the students were imprecise at estimating the population.	the question of concern, you automatically associate any future related responses to that initial anchor point. Here, since 30 million was suggested participants therefore naturally anchored their estimate to a higher number.	
A shoe company wants to maximise sales of their next product so release a survey: 'what new product would you pay for?'. The survey was sent to the people who signed up the company's subscription email list.	Selection bias (not necessary to name specifically). Here, they have limited their test sample only to their subscribers, people already likely to buy their products/are interested in their products (at least compared to the general population).	To increase sales, they should test the general population.
A holiday program wanted to test the students' satisfaction of its classes. One class provided feedback forms during the last class while a second class provided the feedback form a week after the last class. The results, shown below, show that class two was clearly more preferred. Class 1 – 78% satisfaction Class 2 – 91% satisfaction	This is recall bias (again, name not necessary). The class with immediate feedback recalls more specific episodes that were less favourable during the class, so on average reports a lower satisfaction. After one week, it is more likely that the specific episodes are less vivid and an overall impression remains, resulting in a higher satisfaction.	Both classes should have TWO feedback forms. One initially after and the second a week after. This allows for all types of feedback to be collected (specific and general perceptions) ½ mark for simply immediately after for both classes.

QUESTION 2 – STORIES OF SERENDIPITY (15 MARKS)

NOTE: QUESTION 2 IS FAIRLY OPEN-ENDED AND FOCUSES ON SCIENTIFIC THINKING. MOST PAPERS SHOULD BE ABLE TO MAKE A MEANINGFUL ATTEMPT AT THIS QUESTION AND LIKELY RECEIVE SCORES BETWEEN 12-15.

Many recognisable science developments have occurred by chance rather than purposeful experimentation. Microwave radiation, for example, was discovered after chocolate melted in a researcher's pocket. One of the greatest serendipitous discoveries is the alleged apple that fell on Newton's head.

(a) Consider the essential navigation tool: a compass. Imagine you discovered the compass by chance on one recent day after observing a few interesting phenomena. Your task is to describe the observations that you made to make this discovery and explain how these observations demonstrated the theories/scientific phenomena that explain how a compass functions. The quality of creative writing will not be assessed, rather the focus is on demonstrating an understanding of scientific principles. (3 marks)

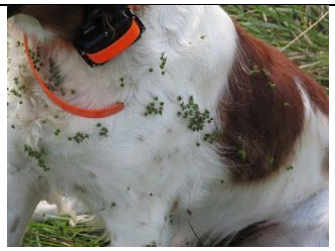
1 mark – observe a magnetised object rotate towards north.
1 mark – observe that if you place this object in a frictionless environment it will naturally rotate towards north (e.g. paperclip in water)
1 mark – justification of forming a compass using the two principles above by enclosing metal arrow in a low friction liquid that allows one to always have a point of reference towards north.
Note: this question should be marked without being too critical. It is expected that at least 80% of papers will receive 100% on this part.

(b) Most chance discovery in science resulted from observing nature. Below are various snapshots from nature. Your task is to match the list of technologies below to the correct natural source of inspiration and briefly explain what idea was borrowed from nature in each example. Note: the list contains more technologies than needed and there is no repetition of technologies in the table. (12 marks)

1 mark for each. Explanation must link an observation from nature to a feature of the technology. No ½ marks. An example is provided below, but a response does not need to mimic or include all the details in this example.

Kevlar, Space robots for external repairs on the ISS, Speedo swimsuits, Wind turbines, Bullet trains, Velcro, Multi-chimney cooling system, blu-tack.

NATURAL INSPIRATION	TECHNOLOGY	EXPLANATION
	Velcro	The burrs latch onto hair using a hooks, the same system incorporated into what we know as Velcro

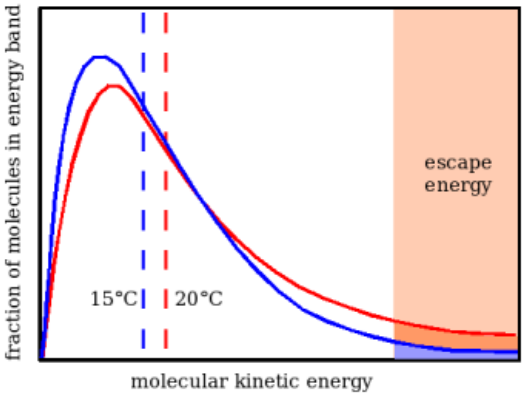
		
	ISS Space Robots	The Gecko's feet are naturally 'sticky' due to the microscopic grooves that can grip surfaces. Same principle used for robots on the slippery metal surfaces on the ISS outer shell.
	Speedo Swimsuits	Shark skin comprises of aerodynamic plates, replicated in the material design of swimsuits for speed.
	Wind Turbines	The Whale fin contains groves that reduce friction and improves the streamline of airflow.
	Bullet Train	The nose of the bird is able to enter water bodies without any disruption to the water surface, used for the aerodynamic front of the train.
	Multi-chimney cooling system	Termite mounds are often extremely cool compared to ambient temperature and this arises from a complex network of channels, like chimneys, that allow hot air to rise out of the mound.

QUESTION 3 – DRYING DILEMMA (28 MARKS)

NOTE: THIS QUESTION FOCUSES ON PRECISE SCIENTIFIC EXPERIMENTATION, THEORISING AND JUSTIFICATION. KEY PRINCIPLES AND UNDERSTANDING OF THEORY IS REQUIRED IN RESPONSES. THIS QUESTION IS EXPECTED TO BE A MORE CHALLENGING PART OF THE PAPER, PARTICULARLY FROM (A) TO (E) AND (G).

Drying clothes, for many, often seems to be a game of chance. At times, in a heated house, clothes can take days to dry, while outside they take only hours even on cooler days. The science behind drying clothes, however, is quite simple. Firstly, the liquid water needs to be converted by energy to vapour. Secondly, an air stream is needed to remove the vapour. This question will examine this process more closely followed by considering an experiment that tries to determine the optimal conditions to achieve the fastest drying process.

(a) Temperature can be defined as the average energy of molecular motion. Within a shirt, for example, that is at a temperature of 15 °C there will be a number of different molecules of different energy, but the average of these will produce the temperature of 15 °C. At one particular temperature, we can map the percentage (fraction) of molecules at each energy level (energy band) as shown below. Explain why in the sketch below the red curve represents the shirt at 20 °C while the blue line represents the shirt at 15 °C. (3 marks)



1 mark – the energy profile in red has more molecules in higher energy bands and less in lower energy bands than the blue curve
1 mark – As a result, the average of all the energies in red curve will be greater than the blue curve
1 mark – the averages are indicated by the dotted lines.

(b) Molecules with a high enough energy, indicated in our sketch above as the percentage of molecules in the 'escape energy' shaded area, have enough energy to escape from

the liquid water surface. Identify two forces that require a high energy for the molecule to break in order to escape the liquid water surface. (2 marks)

1 mark - tension at the water's surface **(generally surface tension)**
1 mark - Intermolecular forces between the water molecules inside the water mass (H bonding specifically)
Other forces may be possible, use discretion. Only intermolecular forces and surface tension are required or similar descriptions of the forces. No additional marks for technical responses such as H Bonding.

(c) Once molecules escape, the remaining molecules re-distribute their energy and consequently reach a lower temperature, indicated by the blue curve in the sketch above. By considering the liquid phase molecular model, explain how molecules can 're-distribute their energy'. (2 marks)

1 mark – in a liquid molecules are closely packed and moving rapidly
1 mark – when a molecule collides with another, it will affect both of the collided molecules' energy

(d) On the sketch in (a) the lower temperature distribution (blue line) has a far lower proportion of high energy molecules in the escape energy area than the red line. Predict what this means for the rate of evaporation. (1 mark)

1 mark – It will be slower

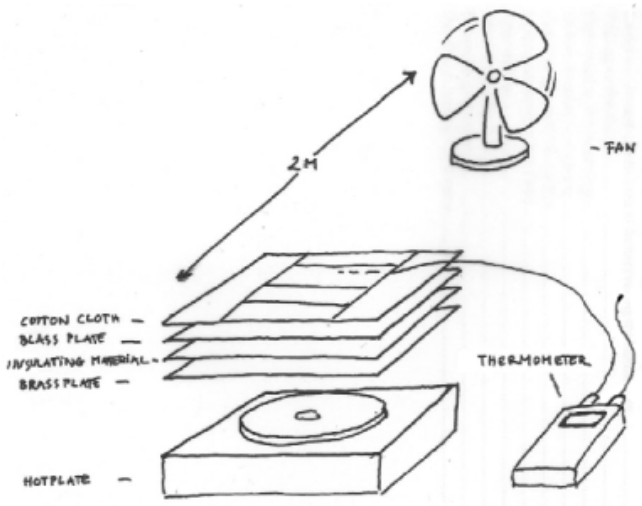
(e) In the drying of clothes, the process in (b) to (d) repeats indefinitely, causing the shirts' temperature to vary until an equilibrium is reached. Explain what allows the process to repeat and predict what causes the process to reach an equilibrium. Will the equilibrium temperature be equal to, higher or lower than the ambient temperature surrounding the clothes (which are pegged to a non-conductive drying stand)? (4 marks)

1 mark – the material can absorb heat from the surroundings, reaching a higher blue line energy distribution and allowing the process to repeat.
2 marks – at some point the energy lost due to evaporation is exactly compensated by the heat from the surroundings (1 mark), so an equilibrium temperature is reached (1 mark).

1 mark – it will be lower than the surrounding given the balancing of the external temp with the internal heat/energy loss of evaporation.

(f) An experiment was designed to test whether heat, air or both are ideal for drying clothes. A description of the setup is below, using a cotton cloth to represent a piece of clothing. All clothing has a constant moisture content even when dry, about 9% for cotton. If this internally bound water is lost then cotton fibres will shrink and if misaligned during the process, the cloth will be permanently warped or shrunk. Ideal drying, therefore, is limited to drying the clothes without removing the 'dry' moisture content.

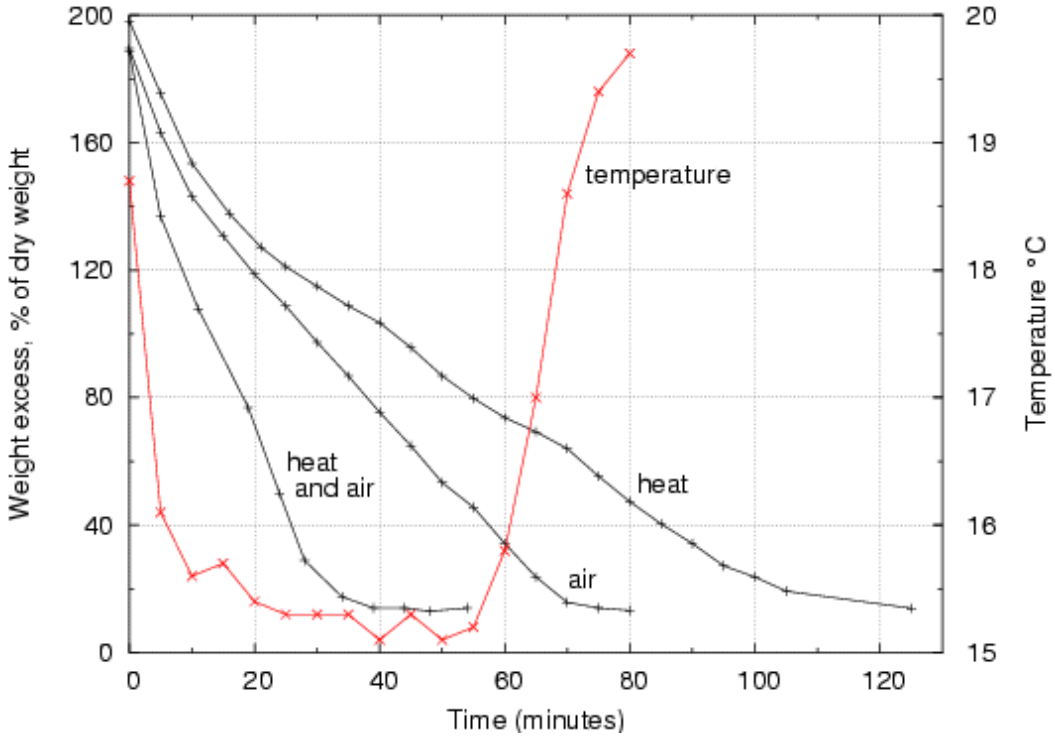
A wet cotton cloth is placed on a metal surface designed to spread the heat flow from the underlying, smaller, laboratory hotplate. The weighed portion of cloth is surrounded by a guard ring of cotton cloth which is also soaked at the beginning of each experimental run. The surface temperature of the cloth is measured by a fine thermocouple woven into the cloth. The heat flow from the hot plate is adjusted manually to hold the temperature exactly at ambient.



Complete the table below outlining key characteristics of the experiment. (6 marks)

AIM	1 mark – to determine the effect of heat and air flow on the drying rate of cotton cloth (or similar). ½ mark for a vague but relevant aim (e.g. determine the best way to dry clothes)
HYPOTHESIS	1 mark – an objective and logical prediction. E.g. If heat and air flow are used together the cloth will dry the fastest. ½ mark – a general prediction but relevant. E.g. Clothes will dry faster with heat.
INDEPENDENT VARIABLE	1 mark - Drying conditions (heat, air flow or both). Note they can use the word ventilation or similar synonym rather than 'air flow'
DEPENDENT VARIABLE	1 mark - The weight excess of the cloth (or weight compared to its dry state) (as a percentage)
4 CONTROLLED VARIABLES	½ mark for each. Could include, but not limited to: ambient temperature, type of cloth, source of heat, rate/distance of ventilation source.

(g) The results of the experiment are shown below. Each black trend line resembles a different test – one with only heat (to ambient temperature, 20 °C), another with only air flow and a final test with heat (to ambient temperature) and air flow. The data indicates over time the weight excess of the cloth (where 0% is the original unwetted cloth). The red trend line indicates the surface temperature of the cloth over time.



(i) Rank the three tests in terms of drying rate (slowest to fastest). Theorise the reason for these results using the principles developed throughout this question (4 marks)

- 1 mark: slowest to fastest = heat, air, heat and water

- 1 mark: heat and air is the fastest as it combines the energy to quickly evaporate the water and the flow to remove the vapour from the cloth
- 1 mark: the heat is the slowest likely because while energy can produce vapour without a flow it is difficult to move the vapour out of the material
- 1 mark: in contrast, only ventilation is better than only heat as **air flow still has energy** which can be used to create vapour, while also allowing for molecular movement.

(ii) The air flow only test exhibits a near constant rate of loss until around 70 minutes when there is a significant reduction until 80 minutes. This is unusual given that from 70-80 minutes temperature has increased almost 4 °C. Predict what is occurring at each stage to produce (i) the constant rate and then (ii) the reduced rate after 70 minutes. (3 marks)

- In the constant rate of loss the water is being removed at the equilibrium process described in (a) and involves removing free water between the material fibres (1 mark)
- If the cloth heats up towards ambient temperature then it means there is a decreasing flow of energy, i.e. less energy is being lost to the surrounds (1 mark)
- A possible explanation for this is that the material is now slowly releasing internally bound water which requires more energy per molecule (1 mark)

(iii) The heat and air flow combined test exhibits a similar plateau from around 26 minutes, but in this case the temperature does not rise. Why might this be a concern and what test could be conducted to measure this concern? (3 marks)

As in part (ii), this section of the test concerns removing internally bounded water

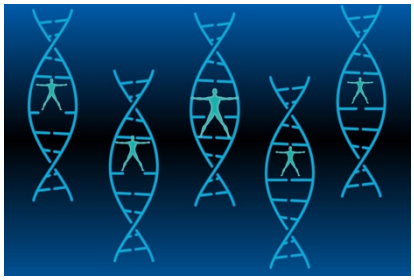
Here, however, the temperature does not increase but **decreases** temporarily (1 mark).

This indicates further removal if the internally bound water leading to over-drying (1 mark)

To test this theory, the size of the cloth could be measured to determine if any shrinking/warping occurred. (1 mark – only one suggestion required)

QUESTION 4 – THE MEANING OF LIFE – 42? (14 MARKS)

NOTE: THIS QUESTION IS MORE OPEN-ENDED AND REQUIRES SOPHISTICATED SCIENTIFIC REASONING IN THE BROADER CONTEXT OF SOCIETY. IT SHOULD BE USED WHERE NEEDED TO DIFFERENTIATE PAPERS OF EQUAL POINT SCORE, ESPECIALLY PART (D).



If you've seen *Jurassic Park* then you might recall Dr Ian Malcolm forewarning: "*Your scientists were so preoccupied with whether or not they could, they didn't stop to think if they should*." This section will ask you to consider this question in relation to a rapidly developing field of science that is removing chance from our lifespans: life-expectancy prediction and anti-ageing technologies.

Household DNA testing kits are now readily available, allowing users to determine their chances of developing certain illnesses or the likelihood that a particular treatment will be effective for them. More recent research by scientists attempts to go one step further and predict your life expectancy.

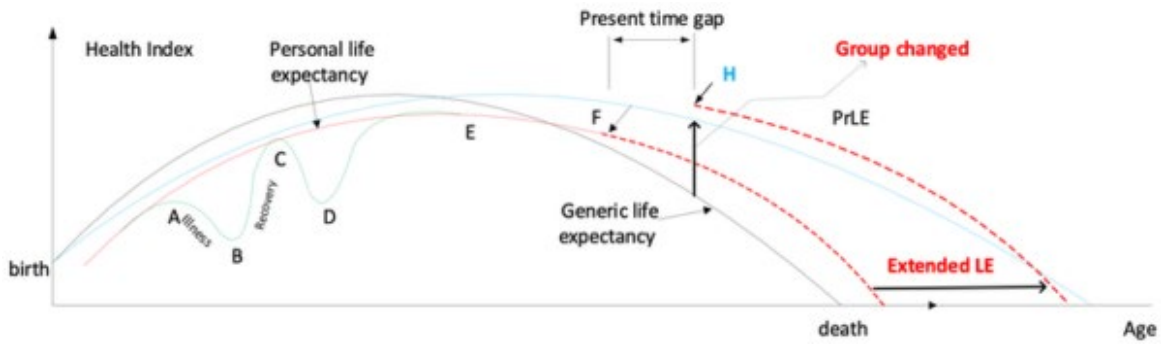
Using deep learning, artificial intelligence and predictive analytics, data scientists have been able to accurately calculate an individual's lifespan using a sophisticated system that considers a breadth of environmental, geographic, genetic and lifestyle factors.

Below is a recent article considering such technology that could remove an element of chance from the question of how long one could live. **Using the information below, and your own ideas, your task is to consider the implications of such life altering science to reach an evaluation as to whether it should be permitted as a technology for society**. To reach your conclusion, complete the short-answer responses below the article.

Much like existing tools that predict cancer survival rates, in the coming years we may see apps attempting to analyse data to predict life expectancy. However, they will not be able to provide a "death date", or even a year of death.

Human behaviour and activities are so unpredictable, it's almost impossible to measure, classify and predict lifespan. A personal life expectancy, even a carefully calculated one, would only provide a "natural life expectancy" based on generic data optimised with personal data. The key to accuracy would be the quality and quantity of data available. Much of this would be taken directly from the user, including gender, age, weight, height and ethnicity.

Access to real-time sensor data through fitness trackers and smart watches could also monitor activity levels, heart rate and blood pressure. This could then be coupled with lifestyle information such as occupation, socioeconomic status, exercise, diet and family medical history. All of the above could be used to classify an individual into a generic group to calculate life expectancy. This result would then be refined over time through the analysis of personal data, updating a user's life expectancy and letting them monitor it.



This figure shows how an individual's life expectancy might change between two points in time (F and H) following a lifestyle improvement, such as weight loss.

https://theconversation.com/dont-die-wondering-apps-may-soon-be-able-to-predict-your-life-expectancy-but-do-you-want-to-know-129068 (CC)

(a) Explain five benefits that arise from life-expectancy prediction. Each benefit must affect a different area (e.g. health, business, insurance, government, economics) and be explained (i.e. identify the feature of prediction that is beneficial and then justify why it is beneficial with reference to an area). (5 marks)

1 mark per benefit – ½ mark for the identification and ½ mark for the justification. No marks for a second benefit in the same area. E.g.:
- People are more aware of their health, so they might make improvements and be motivated to live more healthily
- Insurance companies could provide individualised services so that the more cautions/healthy individuals receive lower premiums
- Governments could use the data to allocate resources more accurately, such as giving Centrelink payment/social welfare assistance to those who need it
- Hospitals and health care could be better organised to ensure priorities and overall increase life expectancy
- The economy may be more efficient if individuals focus resources on what is needed to be healthy and maximise their output/work.

(b) Identify five risks associated with using such technology. (5 marks)

1 mark per risk. Could include:
- People being distressed – mental health issues
- Insurance companies discriminate against more at risk groups
- Pharmaceutical companies could co-ordinate targeted medical campaigns based on people's life expectancy
- The Government could choose to tax people different

- Social segregation based on those likely to live vs not

(c) By balancing the risks and benefits, along with considering which groups (e.g. individuals, government, business) would be most affected, evaluate how life-expectancy predictions should be used, if at all, in the future. If you believe it should be used in some way, explain whether this is unrestricted use or what possible limits you would apply. (4 marks)

4 marks – evaluation stated (1 mark) with detail/nuance as to the conclusion (e.g. a type of regulation or particular circumstances when the technology is allowed) (1 mark). The evaluation is justified with balancing risks (1 mark) and comparing groups (1 mark)