RAFFLES INSTITUTION
YEAR 5 GENERAL PAPER
STUDENTS' INFORMATION PACKAGE

Units: Science & Technology (Terms 3 & 4, 2017)

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ASSSESSMENT
Term 3 & 4 - 1 full comprehension, 1 essay

Science & Technology

Enduring Understanding(s):
What will students understand as a result of this unit?

The nature of science:

1. Science attempts to understand, explain and predict the world we live in, through diverse methods of experimentation or observation and theory construction.
2. Like all other disciplines, science rests on assumptions, which may or may not be justifiable.
3. The relationship between science and religion, in the particular the question of their compatibility, is a subject of continued debate.

Science and society:

4. Science is a social enterprise, informed and affected by perspectives, values and interests. Scientific discovery, technological change and social change affect one another and cannot be discussed in isolation
5. In this way, technology has far-reaching effects, both positive and negative, on norms, values and quality of life.
6. The negative effects and ethical concerns revolving around scientific research as well as technological tools have resulted in calls for regulatory measures.
7. Science, like all other fields, is affected by issues of funding and concerns of profit and practicality.
8. This has an impact on issues such as accessibility to technology, ethical usage and how research is prioritised.

Essential Questions:
What are the essential questions of this unit?

1. Is science value-neutral?
2. What are the ethical responsibilities of the scientist?
3. How do consumer interest and profit motive affect the field of science?
4. What ethical issues are raised?
5. Does more advanced technology necessarily imply better lives?

Essay Questions:

Science and Ethics

1. To what extent do we need religion when science can answer most of our questions? (RI Y6 CT2 2016)
2. 'Human need, rather than profit, should always be the main concern of scientific research.' Discuss. (Camb 2016)
3. 'Human actions should be based on scientific fact, not religious faith.' How far do you agree with this statement? (Camb 2015)
4. To what extent is it desirable to place limits on scientific research? (RI Y5 Promo 2015)
5. 'We should only fund scientific research that improves our quality of life.' Discuss. (RI Y6 CT1 2015)
6. 'Unlimited scientific research is the only way to make real scientific progress.' Do you agree? (RI Y6 Prelim 2015)
7. Do you agree that exploring space should not be a priority in today's world? (Promo 2014)
8. 'Moral considerations hinder scientific progress.' Comment. (JC2 CT1 2012)
9. Should scientific research be largely driven by commercial interests? (JC1 CT 2012)
10. To what extent is it acceptable for private companies to be involved in financing scientific research? (Camb 2011)
11. Can national nuclear programmes ever be justified? (JC2 Prelim 2011)
12. Do you agree that the barriers to scientific research in the 21st century are more ideological than technological? (JC2 CT2 2011)
13. Can space research be justified nowadays? (Camb 2011)
14. 'Scientific decisions should be left to scientists.' To what extent do you agree? (JC2 Prelim 2010)
15. Do moral judgements compromise the true spirit of scientific inquiry? (JC2 CT1 2010)
16. Should Science serve only the public good and not private gain? (JC1 CT 2010)
17. 'Science cannot stop while ethics catches up.' (Elvin Stackman) What is your view? (JC1 Promo 2009)
18. Should every country have the right to carry out unlimited scientific research? (Camb 2009)
19. 'Science can and should be free from values.' Discuss. (JC1 Prelims 2007)
20. Are there any circumstances in which it would be acceptable to use animals for scientific research? (Camb 2006)
21. 'Science has lost its social and moral purpose.' To what extent do you agree? (JC2 Prelims 2006)
22. Should scientific research be dictated by ethical concerns? (JC1 Prelims 2006)
23. To what extent is the integrity of scientific research undermined by its links with big business? (JC2 CT1 2005)
24. Do moral standards impede the progress of science? (JC1 Promo 2005)
25. 'How inventions and discoveries are used is not the concern of the scientist.' Do you agree? (Camb 2004)
26. 'The end justifies the means.' How true is this statement with regard to the latest scientific developments? (JC1 Promo 2003)
27. 'Space exploration is a colossal waste of money and human lives.' Do you agree? (JC2 CT1 2003)

28. Discuss some of the moral issues facing the world of science and medicine today. (JC1 Promo 2002)
29. Should any limits be placed upon scientific developments? (Camb 1996)

Technology and Society

1. Why should we bother with remembering when technology can do it for us? (RI Y6 CT1 2016)
2. 'Science creates more problems than it seeks to solve.' Comment. (RI Y5 CT 2016)
3. 'Books serve little purpose in education as technological developments become more sophisticated.' How far do you agree? (Camb 2015)
4. Is a fear of artificial intelligence justifiable? (RI Y5 Promo 2015)
5. To what extent can technology be a solution to social problems? (RI Y6 CT1 2015)
6. Consider the view that science serves mankind better than religion. (RI Y6 Prelim 2015)
7. Are we overly dependent on digital technology? (RI Y5 CT1 2015)
8. Examine the extent to which expenditure on arms and the armed forces is justifiable in the modern world. (Camb 2014)
9. To what extent can the regulation of scientific or technological developments be justified? (Camb 2014)
10. Do you agree that the best way to combat disease is through science? (Prelim 2014)
11. Discuss how robotics contributes to the modern world. (RI Y6 CT2 2014)
12. To what extent should we limit technology's influence on sports? (RI Y6 CT2 2014)
13. 'Technological advancement has worsened the problem of poverty.' Do you agree? (RI Y5 CT 2014)
14. How far is it acceptable for technology to be used only for financial benefit? (Camb 2012)
15. Consider the view that modern technology is the only answer to world hunger. (JC2 Prelim 2012)
16. 'Technology has failed to simplify our lives.' To what extent is this true? (JC1 Promo 2012)
17. Consider the view that most work these days could, and should, be done from home. (Camb 2011)
18. Does technology facilitate crime? (JC2 CT1 2011)
19. Discuss the view that science and technology gives us hope for the future. (JC1 Promo 2011)
20. To what extent has technology had a negative impact on the skill levels of the people? (Camb 2010)
21. 'We have become a people unable to comprehend the technology we invent.' Discuss. (JC2 CT2 2010)
22. Would you agree that modern technology addresses our human desires more than our needs? (JC1 Promo 2010)
23. "Humanity is acquiring all the right technology for all the wrong reasons." Comment. (JC2 CT2 2009)
24. To what extent has technology had an impact on both privacy and security in your country? (Camb 2009)
25. Is the pursuit of nuclear technology desirable in today's world? (JC2 Prelims 2008)
26. 'In the global race to thrive, it is ultimately science and technology which will determine the winners and losers of globalisation.' Discuss. (JC2 CT2 2008)
27. Do you agree that genetic modification brings about more problems than solutions? (JC2 CT2 2007)

28. “Technology has impoverished the mind”. Comment. (JC1 CT 2007)
29. Do you agree that as technology advances, the arts get more enriched and more interesting? (JC2 CT2 2006)
30. Biotechnology provides the perfect answer to the world’s problems.’ Do you agree? (JC2 CT2 2006)
31. “Technology has made our lives busier, not better.” How far do you agree with this statement? (JC1 CT 2006)
32. Does modern technology always improve the quality of people's lives? (Camb 2006)
33. ‘The young embrace modern technology; the old feel threatened by it.’ Is this true? (Camb 2006)
34. Is man a machine? (JC1 Promo 2005)
35. Does the modern world place too much reliance on technology? (Camb 2003)
36. "Computers and mobile phones have made us all worse at talking to one another, not better!" What do you think? (Camb 2001)
37. Is a world dominated by science a dream or a nightmare for future generations? (Camb 1998)

Technology and the Environment

1. Should there be any controls over the production of energy when the need for it is so great? (Camb 2015)
2. Discuss the view that, with an increasing global need for energy, every possible source should be exploited. (Camb 2014)
3. ‘Protecting the environment is a futile pursuit.’ Discuss. (JC1 Promo 2012)
4. “Environmental concern and economic growth cannot co-exist.” Do you agree? (Camb 2011)
5. ‘The dangers of nuclear energy far outweigh its benefits.’ Discuss. (JC1 CT 2011)
6. Are concerns about the need for us to conserve our environment exaggerated? (JC1 Promo 2011)
7. Going green is a luxury only developed countries can afford.’ Comment. (JC2 CT1 2010)
8. In your opinion, is your country doing enough to protect the environment? (JC2 CT1 2009)
9. ‘Too little, too late.’ Does this describe our efforts at environmental conservation? (JC2 CT1 2008)
10. Consider which sources of energy offer the greatest potential as substitutes for fossil fuels. (JC1 Promo 2008)
11. “Air travel should be discouraged, not promoted.” To what extent do you agree? (Camb 2008)
12. Is technology the best answer to environmental destruction? (JC1 CT 2008)
13. “The environment should be saved at all costs.” Do you agree? (JC2 CT1 2007)
14. How important is it to explore alternative forms of energy? (Camb 2006)
15. Is effective farming possible without science? (Camb 2005)
16. "Air travel creates more problems than benefits." Is this a fair comment? (Camb 2002)

Bioethics and Health

1. How effectively is public health promoted and managed in your society? (Camb 2015)
2. ‘Disease is the greatest threat facing mankind today.’ To what extent do you agree with this statement? (RI Y6 Prelim 2015)

3. Consider the view that advances in gene therapy research have gone too far. (RI Y6 CT1 2014)
4. Should everyone be expected to donate suitable organs after death? (Camb 2012)
5. Discuss the extent to which it has become harder to lead healthy lives today. (JC2 CT2 2012)
6. How far should medical resources be used to extend life expectancy? (Camb 2011)
7. 'The key to good health is lifestyle rather than medicine.' How far do you agree? (Camb 2010)
8. 'One ounce of prevention is worth a pound of cure.' Discuss this statement with reference to the role of modern medicine in the world today. (JC2 CT2 2010)
9. What is wrong with organ trading? (JC2 CT2 2009)
10. Should euthanasia be legalised in Singapore? (JC2 CT1 2009)
11. Is the rise of medical tourism a good thing? (JC1 Promo 2009)
12. 'The global health threat is the most serious problem facing the world today.' Do you agree? (JC2 CT2 2008)
13. Should research into expensive medical treatments be allowed when only a few can afford them? (Camb 2007)
14. Should Singapore continue to invest billions of dollars in the biomedical industry? (JC2 CT1 2007)
15. 'Disease is not just an individual concern, but a global one.' What is your view? (Camb 2006)
16. Medical science has been so successful that people now expect too much of it.' Discuss. (Camb 2005)
17. Should medical science always seek to prolong life? (Camb 2003)
18. Does the legalising of euthanasia lead inevitably to the gas chambers? (JC2 CT2 2005)
19. "If people become ill it is largely their own fault." How far do you agree? (Camb 2002)
20. Examine the implications of cloning for the human race. (Camb 2001)
21. How far do you agree that health is the responsibility of the State, not of the individual? (Camb 2000)
22. Can the transplanting of animal organs into human beings ever be justified? (Camb 1999)
23. "A preoccupation with physical fitness is the curse of modern life." Do you agree? (Camb 1999)
24. "The first duty of a doctor has always been to preserve life." How far can this principle still be maintained? (Camb 1998)

Concerning Mathematics

1. How far has modern technology made it unnecessary for individuals to possess mathematical skills? (Camb 2016)
2. To what extent can Mathematics be considered a form of art? (RI Y6 Prelim 2015)
3. 'Mathematics is the most reliable way of understanding the world.' Discuss. (RI Y5 Promo 2015)
4. Can mathematics be seen as anything more than a useful tool in everyday life? (Camb 2010)

Reading 1: What is science? **EU1 and EU2**

Adapted extract from "Philosophy of Science: A Very Short Introduction" (2002), Dr Samir Okasha

This reading will help you:

- Identify some criteria that define science.
- Consider how valid these criteria are.
- Re-evaluate the notions you may have about how science "works".

What is science? What is it that *makes* something a science? Surely science is just the attempt to understand, explain and predict the world we live in? But is it the whole story? After all, the various religions also attempt to understand and explain the world, but religion is not usually regarded as a branch of science. Similarly, astrology and fortune-telling are attempts to predict the future, but most people would not describe these activities as science. Or consider history. Historians try to understand and explain what happened in the past, but history is usually classified as an arts subject, not a science subject.

Many people believe that the distinguishing features of science lie in the ***particular methods*** scientists use to investigate the world. This suggestion is quite plausible. For many sciences do employ distinctive methods of enquiry that are not found in non-scientific disciplines. An obvious example is the use of experiments. Not all sciences are experimental though – astronomers obviously do not do experiments on the heavens, but have to contend themselves with ***careful observation*** instead. The same is true of many social sciences. Another important feature of science is the ***construction of theories***. Scientists do not simply record the results of experiment and observation in a log book – they usually want to explain those results in terms of a general theory. It is an important problem to understand how techniques such as experimentation, observation and theory-construction have enabled scientists to unravel so many of nature's secrets.

Science vs. Pseudo-science

Karl Popper, an influential 20th century philosopher of science, thought that the fundamental feature of a scientific theory is that it should be falsifiable. To call a theory falsifiable is not to say that it is false. Rather, it means that the theory makes some ***definite predictions that are capable of being tested against experience***. If these predictions turn out to be wrong, then the theory has been falsified or disproved. So a falsifiable theory is one that we might discover to be false – it is not compatible with every possible course of experience. Popper thought that some supposedly scientific theories did not satisfy this condition and thus did not deserve to be called science at all; rather they were merely pseudo-science.

Karl Marx ("father" of modern communist ideology") claimed that in industrialised societies, capitalism would give way to socialism and ultimately to communism. But when this didn't happen, instead of admitting that Marx's theory was wrong, Marxists would invent an *ad hoc* explanation for why what happened was actually perfectly consistent with their theory. For example, they might say that the inevitable progress to communism had been temporarily slowed by the rise of the welfare state, which 'softened' the proletariat and weakened their revolutionary zeal. In this sort of way, Marx's theory could be made compatible with any possible course of events. Therefore, Marx's theory does not qualify as genuinely scientific, according to Popper's criterion.

Popper contrasted Marx's theory with Einstein's theory of gravitation, also known as general relativity. Unlike Marx's theory, Einstein's theory made ***a very definite prediction***: that light rays from distant stars would be deflected by the gravitational field of the sun. Normally this effect would be impossible to observe – except during a solar eclipse. In 1919, Sir Arthur Eddington organised two

expeditions to observe the solar eclipse of that year, one to Brazil and one to the island of Principe off the Atlantic coast of Africa. The expeditions found that the starlight was indeed deflected by the sun, by almost exactly the amount Einstein had predicted. Einstein had made a definite, precise prediction, which was ***confirmed by observations***. Had it turned out that starlight was not deflected by the sun, this would have shown that Einstein was wrong. So Einstein's theory satisfies the criterion of falsifiability.

Some regard Popper's criterion as overly simplistic. Popper criticized Marxists for explaining away data that appeared to conflict with their theories, rather than accepting that the theories had been refuted. However, this very procedure is routinely used by 'respectable' scientists and has led to important scientific discoveries. Newton's gravitational theory, for example, made predictions about the paths the planets should follow as they orbit the sun. For the most part, these predictions were borne out by observation. However, the observed orbit of Uranus consistently differed from what Newton's theory predicted. This puzzle was solved in 1846 by Adams and Leverrier, working independently. They suggested that there was another planet, as yet undiscovered, exerting an additional gravitational force on Uranus. Shortly afterwards, the planet Neptune was discovered, almost exactly where Adams and Leverrier had predicted.

Now clearly we should not criticise Adams and Leverrier's behaviour as 'unscientific'. But they did precisely what Popper criticised the Marxists for doing. They began with a theory – Newton's theory of gravity – which made an incorrect prediction about Uranus' orbit. Rather than concluding that Newton's theory must be wrong, they stuck by the theory and attempted to explain away the conflicting observations by postulating a new planet. Similarly, when capitalism showed no signs of giving way to communism, Marxists did not conclude that Marx's theory must be wrong, but stuck by the theory and tried to explain away conflicting observations in other ways.

This suggests that Popper's attempt to demarcate science from pseudo-science cannot be quite right. For the Adams/Leverrier example is by no means atypical. In general, scientists do not just abandon their theories whenever they conflict with observational data. Usually, they look for ways of eliminating conflict without giving up their theory. And it is worth remembering that virtually every theory in science conflicts with some observations – finding a theory that fits all the data perfectly is extremely difficult. Obviously, if a theory persistently conflicts with more and more data, and no plausible ways of explaining away the conflict are found, it will eventually have to be rejected. But little progress would be made if scientists simply abandoned their theories at the first sign of trouble.

The failure of Popper's criterion throws up an important question: Is it actually possible to find some common feature shared by all things we call 'science' and not shared by anything else? Popper's assumption that science has an essential nature is questionable. After all, science is a heterogeneous activity, encompassing a wide range of different disciplines and theories. It may be that they share some fixed set of features that define what it is to be a science, but it may not – in which case a simple criterion for demarcating science from pseudo-science is unlikely to be found.

Scientific Reasoning

Consider the following argument: The first five eggs in this carton were rotten. All the eggs have the same expiry date stamped on them. Therefore, the sixth egg will be rotten too. This looks like a perfectly sensible piece of reasoning. But nonetheless it is not a proof. Even if the first five eggs were indeed rotten, and even if all the eggs do have the same expiry date, this does not guarantee that the sixth egg will be rotten too. It is quite conceivable that the sixth egg will be perfectly good. It is logically possible for the premises of this inference to be true, yet the conclusion false. This kind of inference is known as inductive inference – ***moving from premises about objects we have examined to conclusions about objects we have not examined*** (in this example, eggs).

We rely on inductive reasoning throughout our lives. For example, when you turn on your computer, you are confident it will not explode in your face. Why? Because you turn on your computer every day and it has never exploded in your face up to now. The inference from 'up until now, my computer has not exploded when I turned it on' to 'my computer will not explode when I turn it on this time' is inductive. The premise of this inference does not entail the conclusion. It is logically possible that your computer will explode this time, even though it has never done so previously.

Do scientists use inductive reasoning too? The answer seems to be yes. Consider the genetic disease known as Down's syndrome (DS). Geneticists tell us DS sufferers have an additional chromosome – they have 47 instead of the normal 46. How do they know this? The answer, of course, is that they have examined a large number of DS sufferers and found that each has an additional chromosome. It is easy to see that the inference is inductive. The fact that the DS sufferers in the sample studied had 47 chromosomes doesn't prove that all DS sufferers do. It is possible, though unlikely, that the sample was an unrepresentative one. This example is by no means an isolated one. In effect, scientists use inductive reasoning whenever they ***move from limited data to a more general conclusion***, which they do all the time. But what justifies the faith we place in induction?

The Scottish philosopher David Hume argued that we can give no satisfactory answer. He began by noting that whenever we make inductive inferences, we seem to presuppose the ***'uniformity of nature'*** (UN). To see what Hume means by this, recall the inductive inferences above (eggs; computer; DS; even Newton's law of gravity). In each of these cases, our reasoning seems to depend on the assumption that objects we haven't examined will be similar in the relevant respects, to objects of the same sort that we have examined. That assumption is what Hume means by UN.

But how do we know that the UN assumption is actually true? Imagine how you would go about persuading someone who doesn't trust inductive reasoning. You would probably say: 'Look, inductive reasoning has worked pretty well up to now. By using induction, scientists have split the atom, landed men on the moon, invented computers, and so on.' But of course, this wouldn't convince the doubter. For to argue that induction is trustworthy because it has worked well *up to now* is to reason in an inductive way! Such an argument would carry no weight with someone who doesn't *already* trust induction. That is Hume's fundamental point.

Normally we think of science as the very paradigm of rational enquiry. We place great faith in what scientists tell us about the world. But science relies on induction, and Hume's argument seems to show that induction cannot be rationally justified. If Hume is right, the foundations on which science is built do not look quite as solid as we might have hoped.

Read / Understand / Reflect

1. In the section "Science vs. Pseudo-Science", Okasha presents a view that he disagrees with, then an argument against this view. Mark where Okasha: (i) presents the opposing view; (ii) explains the opposing view; (iii) illustrates the opposing view; (iv) makes a concession; (v) presents a counter-argument; (vi) uses illustration to develop the counter-argument; (vii) draws a conclusion.

2. According to the section "Scientific Reasoning", what assumption do we have to make in order to do science, and why? Why is it difficult to justify this assumption? What does this imply about the "rationality" of scientific thought & practice?

3. What does this article imply about the "rationality" of scientific thought and practice? How does it challenge your view of science?

Are there any claims and concepts that you need to clarify? Be proactive and ask your tutors to explain.

Essay Questions

1. Do you agree that the barriers to scientific research in the 21st century are more ideological than technological? (JC2 CT2 2011)

2. 'Scientific decisions should be left to scientists.' To what extent do you agree? (JC2 Prelim 2010)

3. Do moral judgements compromise the true spirit of scientific inquiry? (JC2 CT1 2010)

Readings 2a/2b: Science and Religion **EU1, EU3**

These readings will help you:

- See that the "incompatibility" between science and religion need not mean a zero-sum game – each can have value in our quest to comprehend our world.
- Re-evaluate the notions you may have about how science "works".

Reading 2a: Religion has nothing to do with science – and vice versa

Adapted from an article by Francisco J. Ayala (The Guardian, 28 May 2010)

Some scientists assert that valid knowledge can only come from science. They hold that religious beliefs are the remains of pre-scientific explanations of the world and amount to nothing more than superstition. On the other side, some people of faith believe that science conveys a materialistic view of the world that denies the existence of any reality outside the material world. Science, they think, is incompatible with their religious faith.

I contend that both – scientists denying religion and believers rejecting science – are wrong. Science and religious beliefs ***need not be in contradiction***. If they are properly understood, they cannot be in contradiction because science and religion concern different matters.

The scope of science

The scope of science is the world of nature: the reality that is observed, directly or indirectly, by our senses. Science advances explanations about the natural world, explanations that are accepted or rejected by observation and experiment.

Outside the world of nature, however, science has no authority, no statements to make, no business whatsoever taking one position or another. Science has nothing decisive to say about values, whether economic, aesthetic or moral; nothing to say about the meaning of life or its purpose. Science has nothing to say, either, about religious beliefs, except when these beliefs transcend the proper scope of religion and make assertions about the natural world that contradict scientific knowledge; such assertions cannot be true, in the scientific sense.

People of faith need not be troubled that science is materialistic. The materialism of science asserts its limits, not its universality. The methods and scope of science remain within the world of matter. It cannot make assertions beyond that world.

Science transcends cultural, political and religious beliefs because it has nothing to say about these subjects. That science is ***not constrained by cultural or religious differences*** is one of its great virtues. It does not transcend these differences by denying them or taking one position rather than another. It transcends cultural, political and religious convictions because these matters are none of its business.

Science cannot "disprove" religion

Still, some scientists deny that there can be valid knowledge about values or about the meaning and purpose of the world and of human life. The biologist Richard Dawkins explicitly denies design, purpose and values. In River out of Eden, he writes: "The universe that we observe has precisely the

properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind, pitiless indifference."

In a similar vein, William Provine, a historian of science, asserts that there are no absolute principles of any sort. He believes modern science directly implies that there are no inherent moral or ethical laws, no absolute guiding principles for human society.

There is a monumental contradiction in these assertions. If its commitment to naturalism does not allow science to derive values, meaning or purposes from scientific knowledge, it surely does not allow it, either, to deny their existence. In other words, science cannot disprove religion or the values and beliefs that religions embrace.

In its publication "Teaching about Evolution and the Nature of Science", the US National Academy of Sciences emphatically asserts that religion and science answer different questions about the world: "Whether there is a purpose to the universe or a purpose for human existence are not questions for science… Consequently, many people, including many scientists, hold strong religious beliefs and simultaneously accept the occurrence of evolution".

The value of science

Science as a mode of inquiry into the nature of the universe has been immensely successful and of great technological and economic consequence. The US Office of Management and Budget has estimated that 50% of all economic growth in the US since World War II can be directly attributed to scientific knowledge and technical advances.

The technology derived from scientific knowledge pervades our lives: the high-rise buildings of our cities; throughways and long-span bridges; rockets that take men and women into outer space; telephones that provide instant communication across continents; computers that perform complex calculations in millionths of a second; vaccines and drugs that keep pathogens at bay; gene therapies that replace DNA in defective cells. These and other remarkable achievements bear witness to the validity of the scientific knowledge from which they originated.

The scope of religion

People of faith should stand in awe of the wondrous achievements of science. But they should not be troubled that science may deny their religious beliefs. Nor should people of faith transgress the proper boundaries of religion by making assertions about the natural world that are contrary to scientific knowledge. Religion concerns the meaning and purpose of the world and human life, the proper relation of people to their Creator and to each other, the moral values that inspire and govern their lives.

Science, on the other hand, concerns the processes that account for the natural world: how the planets move, the composition of matter and the atmosphere, the origin and function of organisms. Religion has nothing definitive to say about these natural processes: nothing about the causes of tsunamis or earthquakes or why volcanic eruptions occur, or why there are droughts that ruin farmers' crops. The explanation of these processes belongs to science. It is a categorical mistake to seek their explanation in religious beliefs or sacred texts.

Science provides an account of how galaxies, stars and planets came about after the big bang. It has discovered how the HIV epidemic originated and how Aids spreads. ***A person of faith may interpret these events in religious terms, but they are explained by science***.

There are people of faith who see the theory of evolution and scientific cosmology as contrary to the creation narrative in Genesis. But Genesis is a book of religious revelations and of religious teachings, not a treatise on astronomy or biology.

According to Augustine, the great theologian of the early Christian church, it is a blunder to mistake the Bible for an elementary textbook of astronomy, geology, or other natural sciences. As he writes in his commentary on Genesis: "If it happens that the authority of sacred Scripture is set in opposition to clear and certain reasoning, this must mean that the person who interprets Scripture does not understand it correctly… It is a disgraceful and dangerous thing to hear a Christian, presumably giving the meaning of Holy Scripture, talking nonsense on these topics [the Earth, the heavens, the motion and orbit of the stars, the kinds of animals and shrubs]."

Successful as it is, however, ***a scientific view of the world is hopelessly incomplete***. Matters of value and meaning are outside the scope of science. Even when we have a satisfying scientific understanding of a natural object or process, we are still missing matters that may well be thought by many to be of equal or greater import. Scientific knowledge may enrich aesthetic and moral perceptions and illuminate the significance of life and the world, but these matters are outside the realm of science.

Francisco J. Ayala is a molecular biologist and evolutionary geneticist at the University of California, Irvine.

Reading 2b: Why Science does not disprove God

Adapted from an article by Amir D. Aczel (TIME, 27 April 2014)

A number of recent books and articles would have you believe that – somehow – science has now disproved the existence of God. We know so much about how the universe works, their authors claim, that God is simply unnecessary: We can explain all the workings of the universe without the need for a Creator.

And indeed, science has brought us an immense amount of understanding. The sum total of human knowledge doubles roughly every couple of years or less. In physics and cosmology, we can now claim to know what happened to our universe as early as a tiny fraction of a second after the Big Bang, something that may seem astounding. In chemistry, we understand the most complicated reactions among atoms and molecules, and in biology we know how the living cell works and have mapped out our entire genome. But does this vast knowledge base disprove the existence of some kind of pre-existent outside force that may have launched our universe on its way?

Science: Triumphs and limits

Science won major victories against entrenched religious dogma throughout the 19th century. In the 1800s, discoveries of Neanderthal remains in Belgium, Gibraltar and Germany showed that humans were not the only hominids to occupy earth, and fossils and remains of now extinct animals and plants further demonstrated that flora and fauna evolve, live for millennia and then sometimes die

off, ceding their place on the planet to better-adapted species. These discoveries lent strong support to the then emerging theory of evolution, published by Charles Darwin in 1859. And in 1851, Leon Foucault, a self-trained French physicist, proved definitively that earth rotates – rather than staying in place as the sun revolved around it – using a special pendulum whose circular motion revealed the planet's rotation. Geological discoveries made over the same century devastated the "young earth" hypothesis. We now know that earth is billions, not thousands, of years old, as some theologians had calculated based on counting generations back to the biblical Adam. All of these discoveries ***defeated literal interpretations*** of Scripture.

But has modern science, from the beginning of the 20th century, proved that there is no God, as some commentators now claim? Science is an amazing, wonderful undertaking: it teaches us about life, the world and the universe. But it has not revealed to us why the universe came into existence nor what preceded its birth in the Big Bang. Biological evolution has not brought us the slightest understanding of how the first living organisms emerged from inanimate matter on this planet and how the advanced eukaryotic cells – the highly structured building blocks of advanced life forms – ever emerged from simpler organisms. Neither does it explain one of the greatest mysteries of science: How did consciousness arise in living things? Where do symbolic thinking and self-awareness come from? What is it that allows humans to understand the mysteries of biology, physics, mathematics, engineering and medicine? And what enables us to create great works of art, music, architecture and literature? Science is ***nowhere near to explaining these deep mysteries***.

Science: "What" & "how", but not "why"

But much more important than these conundrums is the persistent question of the fine-tuning of the parameters of the universe: Why is our universe so precisely tailor-made for the emergence of life? This question has never been answered satisfactorily, and I believe that it will never find a scientific solution. For the deeper we delve into the mysteries of physics and cosmology, the more the universe appears to be intricate and incredibly complex. To explain the quantum-mechanical behaviour of even one tiny particle requires pages and pages of extremely advanced mathematics. Why are even the tiniest particles of matter so unbelievably complicated? It appears that there is a vast, hidden "wisdom," or structure, or knotty blueprint for even the most simple-looking element of nature. And the situation becomes much more daunting as we expand our view to the entire cosmos.

We know that 13.7 billion years ago, a gargantuan burst of energy, whose nature and source are completely unknown to us and not in the least understood by science, initiated the creation of our universe. Then suddenly, as if by magic, the "God particle" – the Higgs boson discovered two years ago inside CERN's powerful particle accelerator, the Large Hadron Collider – came into being and miraculously gave the universe its mass. Why did this happen? The mass constituted elementary particles – the quarks and the electron – whose weights and electrical charges had to fall within immeasurably tight bounds for what would happen next. For from within the primeval soup of elementary particles that constituted the young universe, again as if by a magic hand, all the quarks suddenly bunched in threes to form protons and neutrons, their electrical charges set precisely to the exact level needed to attract and capture the electrons, which then began to circle nuclei made of the protons and neutrons. All of the masses, charges and forces of interaction in the universe had to be in just the precisely needed amounts so that early light atoms could form. Larger ones would then be cooked in nuclear fires inside stars, giving us carbon, iron, nitrogen, oxygen and all the other

elements that are so essential for life to emerge. And eventually, the highly complicated double-helix molecule, the life-propagating DNA, would be formed.

Why did everything we need in order to exist come into being? How was all of this possible without some latent outside power to orchestrate the precise dance of elementary particles required for the creation of all the essentials of life? The great British mathematician Roger Penrose has calculated – based on only one of the hundreds of parameters of the physical universe – that the probability of the emergence of a life-giving cosmos was 1 divided by 10, raised to the power 10, and again raised to the power of 123. This is a number as close to zero as anyone has ever imagined. (The probability is much, much smaller than that of winning the Mega Millions jackpot for more days than the universe has been in existence.)

The scientific atheists have scrambled to explain this troubling mystery by suggesting the existence of a multiverse – an infinite set of universes, each with its own parameters. In some universes, the conditions are wrong for life; however, by the sheer size of this putative multiverse, there must be a universe where everything is right. But if it takes an immense power of nature to create one universe, then how much more powerful would that force have to be in order to create infinitely many universes? So the purely hypothetical multiverse does not solve the "problem" of God. The incredible fine-tuning of the universe presents the most powerful argument for the existence of an immanent creative entity we may well call God. Lacking convincing scientific evidence to the contrary, such a power may be necessary to force all the parameters we need for our existence – cosmological, physical, chemical, biological and cognitive – to be what they are.

Science and religion are two sides of the same deep human impulse to understand the world, to know our place in it, and to marvel at the wonder of life and the infinite cosmos we are surrounded by. Let's keep them that way, and not let one attempt to usurp the role of the other.

For discussion:

1. The authors claim that science and religion need not conflict for they explain different things about the world we live in. Can you think of some examples of science and religion clashing with each other? How can these "conflicts" potentially be resolved?

2. Do you think science and religion *need* each other in order to progress and advance? Why or why not?

Essay Questions

3. "Science encourages doubt; religion quells it." Comment. (RI, JC2 Prelim 2007)[1]
4. To what extent do we need religion when science can answer most of our questions? (RI Y6 CT 2 2016)
5. 'Human actions should be based on scientific fact, not religious faith.' How far do you agree with this statement? (Cambridge 2015)

[1] In analysing this question, ask yourself what this essay question assumes about the nature of science and religion. Do you agree with the assumptions made? Why or why not?

Reading 3: Patients' rights and end-of-life decisions **EU5 and 6**

Adapted from a WebmedCentral article by Brunila Bara, Jonad Bara (Dr) & Gentian Vyshka (Dr)

This reading will help you to understand that:

- The right to die raises many difficult ethical questions.
- Doctors have a duty of care which consists on diagnosing, treating and advising within reasonable means. Such treatment ordinarily aims to benefit a patient through preserving life, relieving pain and suffering, protecting against disability, and returning maximally effective functioning.

3a. The concept of "A right to die"

At the heart of liberty is the right to define one's own concept of existence, of meaning of the universe, and of the mystery of human life. As Abraham Lincoln, speaking in Baltimore in 1864 said, the understanding of rights, life and liberty is different for different people.

The right to die raises many difficult questions in medical care: What is the right to life? When life, and therefore the right to protection of life by law, begin or end? May, or must, the state protect the right to life even of a person who does not want to live any longer, against that person's own wishes? Is it acceptable to provide palliative care to a terminally ill or dying person, even if the treatment may, as a side-effect, contribute to the shortening of the patient's life? Should the patient be consulted on this? Do people have, not just a right to life and to live but also a right to die as and when they choose? Do they have the right to decide on what they consider to be a "good death"? Can they seek assistance from others to end their lives? Can the state allow the ending of life in order to end suffering, even if the person concerned cannot express his or her wishes in this respect?

The answer to such questions might be easier in cases arising by requests of mentally fit patients, who request to die for they are unable to commit suicide themselves. ***The situation is very different in cases of patients who cannot express their opinions***, such as patients in a persistent vegetative state (PVS). In such cases, the question that arises is whether they too have a right to die.

The Oxford English Dictionary defines the "right to die" as "pertaining to, expressing, or advocating the right to refuse extraordinary measures intended to prolong someone's life when they are terminally ill or comatose". Such a right includes issues of suicide, active euthanasia (the deliberate action to hasten death), passive euthanasia (allowing a person to die by refusal or withdrawal of medical intervention), assisted suicide (providing a person the means of committing suicide), and palliative care (providing comfort care which accelerates the death process).

Role of the physician

It is impossible to talk about a right to die without ***considering the acts or omissions of the physician***. It is obvious that if a family member, friend or relative helps someone die, in the comfort of their own house, they will definitely face prosecution. The situation changes in medical care. Obviously it would be easy for the state to ban any sort of assistance from doctors to help their patients to release suffering and pain, and sanction punishment by law to any doctor that would commit such actions. But then, when talking about patients that cannot commit suicide themselves, would such actions be considered as state interference on their right to put an end to their life? Is there such a right?

A person may decide to end his or her life not only actively, i.e. committing suicide, but also passively such as refusing life-saving treatment, food and water. However, even in such situations the possibility remains that another person will get involved, not to assist in suicide, but to make dying comfortable and painless. Terminally ill people or those unable to commit suicide themselves rely on their doctors to give an end to their lives.

Doctors have a ***duty of care*** which consists on diagnosing, treating and advising. These obligations are both moral and legal. Treatment ordinarily aims to benefit a patient through preserving life, relieving pain and suffering, protecting against disability, and returning maximally effective functioning. A doctor's duty of care is to ***take reasonable steps*** (as other reasonable doctors would) to save or prolong life or to act in the patient's best interests. Although in most instances doctors would prescribe the drug for the purpose of pain relief, it is arguable that at times, they may in fact do so to assist their patients to put an end to their suffering.

Should the right to die be protected?

When deciding on end-of-life cases judges are faced with some really important questions: Is there a "right to die," "a right to determine the time and manner of one's death", a "liberty to choose how to die," a right to "control of one's final days," "a right to choose a humane, dignified death," and "the liberty to shape death"? Do terminally ill persons have a right to avoid both "severe physical pain" and "the despair and distress that comes from physical deterioration and the inability to control basic bodily and mental functions"? Is a liberty interest implicated when the state blocks a person from seeking relief from severe pain or suffering?

There are two distinctive views of the right to die: the right to die as a negative right, which requires a duty of non-interference and calls for non-action from others; and the right to die as a positive right, which entails not only a duty of non-interference, but also "the duty to *help,* at least in the cases where the right-holder would not be able to do the thing without help".

In order to benefit from the existing negative right to die, one must be competent to make a decision. Further to this, the person should be physically able to carry out the act of suicide. Therefore, a person contemplating suicide should begin and end the whole process by oneself. Any sort of assistance provided either 'before the fact', 'during the process of attempt to commit suicide' or 'after the attempt' would potentially render the assistant an offender and subject to prosecution.

Some judges are in favour of protecting the right to die, assisted suicide and voluntary euthanasia, while others focus on state's interest in the protection of life. For those who support this right, it is tempting to argue that the court should recognise the right as fundamental and, under traditional fundamental rights jurisprudence, effectively stop all infringements. The problem with such an approach is that to do so would undervalue the state's legitimate interest in preserving life in all forms when a state chooses to adopt a pro-life policy. The policy that must be adopted must balance these two interests so that they may coexist to the fullest extent possible.

There is though, arguably, a ***"right to die with dignity"***, which includes as one of its core aspects a right to avoid "unnecessary and severe physical suffering". A successful claim to assisted suicide would require a showing of ***a need to avoid "severe physical pain"***, and any physical pain can be avoided with either pain control medications or "sedation which can end in a coma". Faced with the argument that assisted suicide is the only way to respond to the severe suffering of some dying patients, the courts have observed that these patients can turn to the alternative of terminal sedation. However, terminal sedation is essentially a form of euthanasia.

Many are of the opinion that withdrawal of life sustaining treatment on patients in a persistent vegetative state is also another form of euthanasia. One possible justification for distinguishing between euthanasia and withdrawal of life sustaining treatment is the distinction between acts and omissions, or between killing and letting one die. Treatment withdrawal, which indubitably involves doctors doing something, is a good example of conduct which lies on the boundary between acts and omissions, because it could easily be described as an action. It is by taking into account the ***surrounding circumstances***, and not by labelling what the doctor does as an omission, that we can ascertain whether his conduct is acceptable. The morally relevant fact is not whether what the doctor does is an omission or an action, but rather whether the background against which the decision has been taken justifies the doctor's conclusion that life, in these circumstances, should not be artificially prolonged. Certainly there are cases where refusal of treatment is motivated by the desire to avoid a continued life of suffering and other cases where it is only the treatment itself the individual seeks to avoid.

While deciding on right-to-die cases, the courts have emphasised the distinction between withdrawal of life sustaining treatment and suicide assistance. Withdrawal of life-sustaining treatment is permitted because the patient dies from the underlying disease, not from the active intervention of the physician.

Slippery slope?

Opening the door to assisted suicide for terminally ill persons could pose too great a risk of suicide for persons who are not competent, who are not terminally ill, whose desire for suicide would abate with treatment for mental depression or with validation from others of the value of their life, or who are vulnerable to influence by family members and physicians concerned with the financial and psychological burdens of caring for the patient.

The majority of individuals and countries are of the opinion that legalization of physician-assisted suicide or euthanasia would "undermine the trust that is essential to the doctor-patient relationship" because physicians would be causatives of death as well as healers of illness. A right to assisted suicide for the terminally ill inevitably leads society down the ***slippery slope to assisted suicide for patients who are not terminally ill***: Once we permit assisted suicide for some persons, there will be no reason for denying it to other persons who claim great suffering.

Even though the majority of states worldwide do not accept and ban any form of assisted suicide, when it comes to decision-making, the judges themselves are of different opinions. As a result it is very difficult to have a sharp opinion whether to accept some sort of assisted suicide or be against any such form.

3b. Albanian case law on the right to die

In Albania, the Constitution protects the right to life and health care. According to the Constitution the protection of life is an important constitutional requirement. The concepts of life and dignity are important constitutional values considered as the source of all other fundamental rights and freedoms. The individual and his life are of superior value for the state.

Regarding the individual's right to die, in Albania both forms of euthanasia and assisted suicide are banned and considered a criminal offence. The problem consists in the fact that this is not literally provided by law, but it is through the interpretation of laws that such actions are considered criminal offences.

In Albania, patients' rights are guaranteed and protected by the Constitution, The European Convention on Human Rights (as a ratified international agreement), Law 'On health care in the Republic of Albania'; Law 'On public health'; Law 'On the regulated professions in the Republic of

Albania' (the part that provides duties and obligations for the health care professionals) and The Ethical Code on Medical Deontology.

Albania's Criminal Code provides criminal acts against health due to negligence. None of these articles provides limitations on the right to die or euthanasia. It is only through the interpretation of law 'On health care in the Republic of Albania' and the Albanian Code of Ethics and Medical Deontology that euthanasia is considered as a criminal offence.

The law 'On health care in the Republic of Albania' provides that, for the safeguard of the ethical rules and medical deontology by the health care professionals, Professional Orders are created. Professional Orders' duties and activities are provided by their respective laws. Such laws provide the duty of the physicians to apply the Code of Ethics and Medical Deontology.

According to this Code, relief of suffering and pain is one of the fundamental duties of the physician towards its patient. This is particularly important while treating a dying patient. ***The physician, except treating the patient, must also offer spiritual assistance and care, in respect of patient's wishes and religious beliefs, safeguarding his dignity until the end of his life***. The physician must inform the family of the patient on his condition and try to get their cooperation in relieving the suffering of the sick.

Acceleration of the end of life or death provocation is contrary to medical ethics. If the patient is unconscious, with no hope to live, the doctor must act according to his judgment in patient's best interest. The physician must decide on the therapeutic actions he will undertake, after consulting his colleagues and patient's closest family members.

As noted, the Albanian Code of Medical Ethics and Deontology allows a margin of appreciation regarding euthanasia, stressing the importance of patient's dignity and best interest, while prohibiting any form of acceleration of end of life or provocation of death.

In the Albanian jurisprudence, there is no case of active or passive euthanasia, or of assisted suicide. However, there is an immediate need for the Parliament to regulate the activity of physicians on such cases. The state must also take necessary steps to inform not only patients on their rights on medical care, but also the physicians on their rights and duties.

Even to the questionnaire prepared by the European Health Committee, followed and assembled by the Parliamentary Assembly of the Council of Europe, which led to Recommendation 1418 (1999) 'Protection of the human rights and dignity of the terminally ill and the dying', Albania answered that there was no law on euthanasia, that the term was not included in the Albanian Criminal Code, therefore there were no sanctions against it, that the only provisions on the Albanian Criminal Code could be found on the chapter 'On offences against life and health' and that the activity of the physician was provided only in the Albanian Code of Ethics and Medical Deontology.

At present, the activities of Albanian physicians in end-of-life situations are still not regulated either by law, by decision of the executive power, or any other regulation. Other Albanian researchers have also suggested the immediate need for such legislative regulations.

The legislative reform should be coupled with a program to promote the understanding and use of procedures on end of life or terminally ill patients amongst the general public and the legal and medical professions. The patients must have greater access to information about their rights regarding medical treatment. The physicians must understand and apply not only the law but they should understand also the consequences they're faced with if they do not obey the laws in force

regarding medical care. Patient's dignity and best interest should be protected, as should patient's health and life.

Concluding remarks

The involvement of the medical profession in everyone's lives makes the understanding of the law governing the medical profession extremely important. It is certain that at some point in our lives we are forced to rely upon the medical profession. The almost certain involvement of the medical profession in achieving good health makes the laws governing the medical profession and the rights of the patients vitally important.

Obviously the right to life is fundamental in our scheme of values. Such right, considered as the centre stone of all individual rights and freedoms describes the belief that a human being has an essential right to live, particularly that a human being has the right not to be killed by another human being. Nevertheless, the interest in the preservation of human life is not itself sufficient to outweigh the interest in liberty that may justify the only possible means of preserving a dying patient's dignity and alleviating her intolerable suffering.

The right of the patient to die today should be considered in the light of the changes society is going through and of new approach towards human rights.

For discussion:

1. Should a doctor's main role be to prolong the life of his patient?
2. Should people be given the right to die?

Essay Questions

A. How far should medical resources be used to extend life expectancy? (Cambridge 2011)
B. Should euthanasia be legalised in Singapore? (JC2 CT1 2009)
C. Discuss some of the moral issues facing the world of science and medicine today. (JC1 Promo 2002)
D. "The first duty of a doctor has always been to preserve life." How far can this principle still be maintained? (Cambridge 1998)
E. Moral considerations hinder scientific progress.' Comment. (JC2 CT1 2012)
F. Should every country have the right to carry out unlimited scientific research? (Cambridge 2009)

Readings 4a/4b: Drug patents **EU6 and 7**

These readings will help you understand that:

- Pharmaceuticals are contentious because they constitute a public good which is produced by private companies. The tension lies in the right to healthcare of individual members of society versus the right to protect one's intellectual property for profit.
- Drug patents spur innovation as a result of the profit motive, yet they deny access to these drugs to the very group of people who need them the most precisely because of it.
- Drug patents may also impede the progress of scientific research as they make the development of similar drugs for common ailments a lot more profitable than investing in research into drugs for rare conditions with no existing treatments. In effect, they exacerbate the existing divide between the rich and the poor by catering to the needs of the former and neglecting the needs of the latter.

Reading 4a: Why drug patents are needed

Adapted from an article in The Economist (4 Jan 2014)

Of all the goods and services traded in the market economy, pharmaceuticals are perhaps the most contentious. Though produced by private companies, they constitute a public good, both because they can prevent epidemics and because healthy people function better as members of society than sick ones do. They ***carry a moral weight that most privately traded goods do not***, for there is a widespread belief that people have a right to health care that they do not have to other goods such as smartphones or running shoes.

Innovation accounts for most of the cost of production, so the price of drugs is much higher than their cost of manufacture, making them unaffordable to many poor people. Firms protect the intellectual property (IP) that drugs represent and sue those who try to manufacture and sell patented drugs cheaply. For all these reasons, pharmaceutical companies are widely regarded as vampires who exploit the sick and ignore the sufferings of the poor.

Such criticism reached a crescendo more than a decade ago at the peak of the HIV plague. When South Africa's government sought to legalise the import of cheap generic copies of patented AIDS drugs, pharmaceutical companies took it to court. The case earned the nickname "Big Pharma v Nelson Mandela". It was a low point for the industry, which wisely backed down. Now arguments over drugs pricing are rising again. Activists are suing to block the patenting in India of a new hepatitis C drug that has just been approved by American regulators. Other skirmishes are breaking out, in countries from Brazil to Britain.

The resurgence of conflict over drug pricing is the result not of a sudden emergency, but of ***broad, long-term changes***. Rich countries want to slash health costs. In emerging markets, people are living longer and getting rich-country diseases. This is boosting demand for drugs for cancer, diabetes and other chronic ailments. In emerging markets, governments want to expand access to treatment, but drugs already account for a large share of health-care spending – 44% and 43% in India and China respectively, compared with 12% in Britain and America. Meanwhile, a wave of innovation is

producing expensive new treatments. In 2012 American regulators approved 39 drugs, the largest number since 1996. Cancer treatment, especially, is entering a new era[2].

Blurred lines

During the peak of HIV, the arguments for compulsory licensing were strong, for drugs should be made as widely available as possible during an epidemic to prevent it from spreading. But ***compulsory licensing also discourages innovation***, and will do so increasingly as emerging markets make a bigger contribution to pharmaceutical company revenues. What is more, as such countries get more prosperous, so their elites get richer; and it is not obvious that poor Americans should subsidise drugs for rich Indians.

Today's problem is different: a steady wave of the diseases that come with age, not an out-of-control virus. It requires a tailored economic medicine. By varying their prices more – charging Americans and Britons more than Africans – firms can pep up their profits at the same time as expanding their markets, ***making both shareholders and the sick better off***. Some companies are trying this. Roche, a Swiss company, has created new brands and packaging for lower-priced drugs in India and Egypt.

But there are risks to so-called "tiered pricing". People may buy drugs in low-price countries and sell them at a profit in high-price ones. ***Finer pricing therefore needs to be helped by stronger rules*** to prevent IP from being removed by law, or undermined by illegal trade. More compulsory licensing is not in the interests of the world's sick; protection for drugs patents is.

Reading 4b: Drug patents are bad for your health – the cost of mismarketing **EU4 and EU7**

Adapted from an article by Dean Baker (The Hankyoreh, 11 May 2015)

The rationale for granting patents for new drugs is to give companies incentives to research new and better drugs. Allowing them a monopoly for a period of time allows drug companies the opportunity to recoup the cost of their investment and make a profit from their research.

This is the good story of patent protection. But as every economist knows, any act of government intervention has unintended consequences. A patent monopoly allows drug companies to sell drugs at ***prices that are far above their free market price***. This is especially true with major breakthrough drugs that can sell for prices that are several thousand percent above their free market price because of their health benefits. For example, the hepatitis C drug Sovaldi sells for $84,000 for a three-month course of treatment in the United States. A generic version is available in India for less than $1,000.

This enormous gap between the price for which a patent-protected drug can be sold and the cost of production to the manufacturer creates a ***huge incentive to promote the drug*** wherever possible. This includes pushing the drug for uses for which it has not been approved by the Food and Drug authority or other national regulatory agencies. There is also an ***incentive to conceal evidence*** that a drug may be less effective than claimed or even harmful.

[2] *Related article (The Economist, 4 Jan 2014): "Getting close and personal – Researchers and drug companies are ganging up for a new push against cancer"*

As we know, people respond to incentives. This means drug companies will act in ways that are harmful to the health of patients in order to take advantage of the huge profits available from patent monopolies. To get some idea of the costs in terms of increased mortality and morbidity, Ravi Katari and I calculated the costs[3] associated with five prominent instances in which drug companies either lost a court case or reached a settlement because they had misrepresented the safety or effectiveness of their drugs.

By our calculations, the cost of the increased mortality and morbidity associated with the improper marketing of these five drugs was $382 billion over the 14-year period from 1994 to 2008, or just over $27 billion a year (in 2014 dollars). This is roughly the same amount as the industry claims to have spent on research over this period. In other words, the harm caused by inaccurate marketing and disclosure of information for just these five drugs is comparable in value to all the research performed by the drug industry during the same period.

To be clear, the allegations in these five cases are that the companies deliberately concealed information or misrepresented research findings. This would mean that the damage was not the result of inevitable mistakes, but rather deliberate actions motived by profit.

Our calculations are very imprecise, but they suggest the ***enormous costs society may incur as a result of the perverse incentives that patent monopolies provide to drug companies***. These five drugs were selected because they were especially egregious examples, but there are dozens of other instances where evidence has been produced showing drug companies misled the public about the safety or effectiveness of their products. And the cases that have come to light can only be a subset of the instances where drug companies have withheld or misrepresented information that could reflect badly on their drugs.

Of course, this is not the only problem with patent-financed drug research. Patent monopolies provide an incentive for drug companies to develop copycat drugs rather than seek out drugs for conditions for which no treatment exists. They also encourage secrecy, which ***impedes the progress of research***. And the high drug prices that result from the monopolies create enormous complications for whoever gets stuck with bill, whether it is the patient, an insurance company, or the government.

In the case of Sovaldi, there has been much hard-wringing about whether insurance companies and the government should pay $84,000 for every person suffering from hepatitis C, or whether this cost should only be incurred for especially severe cases. There would be much less hand-wringing if the issue was paying $900 for a generic version of the drug.

There are ***alternative mechanisms for financing research***. Nobel Prize winning economist Joe Stiglitz has proposed a prize system in which the government would buy up the patents for drugs that are shown to be effective and then allow them to be sold as generics. Alternatively, we can go the route of directly financing research through the government. The United States already spends more than $30 billion a year on publicly funded biomedical research through the National Institutes of Health. If this sum was tripled, it could likely replace the funding now being supported through patent monopolies and then all new drugs could be sold at generic prices.

[3] *For the full report, go to http://www.cepr.net/documents/publications/mismarketing-drugs-2015-04.pdf*

100 Our paper suggests that patents are an extremely inefficient way to support research because of the perverse incentives they provide drug companies. It would be unfortunate if the drug companies are able to further entrench a system that has so many negative side effects.

For discussion:

- What are the arguments for and against drug patents from the passages? What examples can you find to further substantiate both sets of arguments?
- Whose interests do drug patents protect? Which rights do they override? Is this justifiable?

Application question / Research:

- Which author do you agree with more and why?
- Whose views are more applicable to the Singapore context?

Essay Questions

A. To what extent is the integrity of scientific research undermined by its links with big business? (JC2 CT1 2005)

B. Is it ever justifiable to infringe intellectual property rights? (RI 2007 Y6 CT2)

C. Should research into expensive medical treatments be allowed when only a few can afford them? (Cambridge 2009)

D. Should Science serve only the public good and not private gain? (JC1 CT 2010)

E. To what extent is it acceptable for private companies to be involved in financing scientific research? (Cambridge 2011)

F. Should scientific research be largely driven by commercial interests? (JC1 CT 2012)

Readings 5a-d: Animal Testing **EU4, EU6 and EU7**

Reading 5a: Should testing on animals be banned?

Excerpted from The Independent, 15 Aug 2012, Laura Davis

Key ideas in these readings:

- The issue with animal testing is more than a case of the ends justifying the means (utilitarianism); it also brings into contention the right of human beings to life-saving treatments and medication versus the right of animals not to be subjected to experimentation (virtue ethics).
- What constitutes necessary research in the name of science is debatable; just as what constitutes unnecessary suffering can be contentious.
- There are alternatives to animal testing, but these alternatives are not without problems.

Animal welfare charities reacted angrily to news in July that the number of animal experiments rose to a record high in Britain last year – a 40 per cent rise over the last decade.

Last month, Cardiff University defended sewing kittens' eyes shut, as means to find a cure for lazy eyes. In their statement, they said the purpose of the work and its conduct was approved by both the university's own ethical review process and the Home Office as part of the licensing process.

The 1990s saw a campaign to end cosmetics testing Europe-wide, and next year, Europe will introduce a ban on selling newly animal-tested cosmetics, for the first time excluding products that don't comply.

When it comes to scientific research, however, scientists have defended the use of experiments and said researchers were reducing the proportion of animals used per study at a time of rising funding for bio-sciences.

But should animals be used for scientific testing? Is it far removed from testing for beauty products? Or is the research required to help save human lives?

Alistair Currie: Animals are not ours to experiment on

Animals are not ours to use for experimentation. They feel pain and fear just as we do, and their overwhelming natural inclinations – like ours – are to be free and to protect their own lives, not to be locked in a small cage inside a laboratory, where they are subjected to abuse and suffering that would be illegal if they took place anywhere else. No animal should ever face being genetically engineered to develop cancer, as mice are; being intentionally paralyzed from brain damage, as monkeys are; or being force-fed pesticides and other chemicals, as dogs are.

In addition to being unethical, animal testing is fundamentally flawed because it studies the wrong species – and that is a scientific problem that can never be overcome. Approximately 90 per cent of medicines that pass tests on animals fail in people, either because they aren't safe or don't work. That's an enormous waste of money, animal lives, scientific resources and hope.

Scientific research may now finally be able to progress into the 21st century because the British public is demanding human-relevant, modern research techniques instead of obsolete and unreliable animal tests. The development of cutting-edge non-animal methodologies that can accurately predict what happens in human beings involves exciting, progressive and effective science – not to mention the fact that it is infinitely kinder to animals. Increasingly, governments, companies

and researchers themselves are recognising that the animal-testing model is broken and can never be fixed. Why conduct painful and lethal tests on the wrong species when sophisticated computer and mathematical models, human tissue and cell cultures and smarter, more focused clinical and epidemiological studies can show us more accurately what happens to human bodies with diseases?

The scientific community urgently needs to rethink its psychological dependence on cruel and unreliable animal tests and align itself with progressive thinking for a future filled with less suffering for all species.

Alistair Currie is a Policy Adviser for the People for the Ethical Treatment of Animals in the UK.

Reading 5b: Not Dr Frankensteins

Adapted from an article by Kemal Atlay (*The Guardian,* September 2016)

Media reports of scientific testing on greyhounds were written to elicit outrage but failed to reference the outcomes or ethics standards used

In 1985, at the height of the Aids epidemic, scientists in the US made a huge breakthrough in understanding this mysterious, deadly disease by isolating the Simian Immunodeficiency Virus (SIV) in captive rhesus macaques. A few years later, they successfully developed the first effective therapy against HIV/Aids, which gave researchers a foothold to continue investigating the disease.

Today, anti-retroviral therapies have advanced to such an extent that people living with HIV can easily manage the condition with a simple drug regimen and can even suppress HIV levels in the blood to undetectable levels. None of this, or countless other medical advances, would have been possible without animal-based research.

So why are we seeing so many attacks by politicians, activists and even the media on this fundamental aspect of scientific research?

Earlier this month, Crikey published an article about the use of greyhounds in a study conducted by researchers from Monash University and the Alfred Hospital. The words “grisly” and “gruesome” were thrown in to elicit a specific response: outrage and disgust.

The Age then published its own story on the same experiment that used similarly emotive language but took things a step further by heavily featuring the voices of animal rights activists. In both instances, the articles were unashamedly one-sided and demonised not just the researchers involved the study, but the use of animals in science in general. So, what exactly was the experiment in question?

The researchers were investigating how well they could preserve a heart once an organ donor had died and before transplantation occurs, with the aim of improving the success rate of heart transplants in humans. In order to test this, they anaesthetised 12 greyhounds – they were knocked unconscious to prevent any pain or suffering – before they were suffocated to induce circulatory death. The hearts were then removed and preserved for four hours using two different methods of preservation. Half of the dogs then received a heart transplant and were revived to monitor how well the heart functioned before they were promptly euthanised.

It may not sound pretty, but this is how scientific research works and how medical research in particular has advanced to such an incredible extent. Animal models have allowed scientists the study all manner of medical conditions: experiments using mice have provided crucial insights into how

Alzheimer's disease actually progresses in the human brain; Zika-infected monkeys have allowed scientists to slowly decipher how the virus works in order to develop a cure; and surgeries on dogs and cats have allowed researchers to develop and perfect life-saving procedures, like open-heart surgery and organ transplants.

The aforementioned articles did not convey the significance of the study – the researchers concluded that their findings had "potential for clinical application in DCD [donation after circulatory death] transplantation" – and make no reference to the strict ethical approval processes in place.

As a result, they made the scientists look like modern-day Dr Frankensteins performing all manner of experiments with whatever animal they can get their hands on but this couldn't be further from reality. Scientists that use animal models in their work are guided by the 3Rs principles (replacement, reduction and refinement) that make them consider the impact of their work and ensure humane treatment of animals.

On top of that, an animal ethics committee must approve all animal-based research proposals before the scientists can proceed. The Australian Code of Practice for the Care and Use of Animals for Scientific Purposes dictates that these committees must include: a vet, an animal welfare representative, an animal researcher, and an independent representative. They have the power to reject proposals, advise researchers to adjust the proposal according to the 3Rs, and even stop experiments after they've begun.

Earlier this year, neurobiologist Associate Professor James Bourne wrote an impassioned defence of his work and the scientific community in response to federal Greens senator Lee Rhiannon's moves to ban the import of non-human primates for scientific research. Bourne's work is focused on how the brain repairs itself following an injury that results in brain damage, such as heavy impact from contact sports, traffic accidents and workplace injuries. He writes:

Primates share approximately 98% identity with the human genome and many anatomical, physiological, and behavioural similarities. For this reason, primates are critical to biomedical research targeting the causes, progression, prevention, and treatment of a wide variety of diseases.

Bourne goes on to explain that even though researchers are conscious of reducing the use of animal models, often there is "no alternative approach that can replicate the vast complexity of human disorder and disease." He also stresses the importance of transparency in ethical approval processes and in the role of various bodies holding researchers to account – this ensures the public remains confident that the work being carried out by the scientific community is done so in the most efficient, ethical and humane way possible.

No one expects or wants scientists to conduct experiments on human beings to understand things like brain damage or heart transplants. Hence, animal-based research is crucial in ensuring we can still explore and investigate all manner of medical disorders and diseases without putting people's lives at risk.

For discussion:

1. The opposition to animal testing tends to centre on the unnecessary pain and suffering of the animals used for testing. Is the answer then more stringent regulation? Why or why not?
2. If animal testing is done in order to find safe and effective drugs/treatments for other animals, would it be acceptable? Why or why not?
3. How comfortable would you be (or for your loved ones) to consume a drug or undergo a medical procedure without it being tested on a live organism?

Essay Questions

1. Are there any circumstances in which it would be acceptable to use animals for scientific research? (Camb 2006)

Reading 5c. Singapore guidelines on animal testing

Adapted from the website of the Agri-Food & Veterinary Authority of Singapore

Under the Animal & Birds (Care and Use of Animals for Scientific Purposes) Rules, any research facility that uses animals for scientific purposes must obtain a licence from AVA. As part of the licensing requirements, a research facility must comply with Guidelines set forth by the National Advisory Committee for Laboratory Animal Research (NACLAR) for the proper care and use of animals for scientific purposes and allow AVA to carry out inspection of its facilities.

Overview of NACLAR

The National Advisory Committee on Laboratory Animal Research (NACLAR) was established in 2003 to develop national guidelines for the care and use of animals for scientific purposes in Singapore. The Committee comprises representatives from academia, research organizations, the AVA, as well as legal and ethical specialists.

The Three R's Principle

The NACLAR Guidelines on the Care and Use of Animals for Scientific Purposes was released in October 2004. The scope of the Guidelines covers all aspects of the care and use of animals for scientific purposes including their use in teaching, field trials, environmental studies, research, diagnosis, product testing, and the production of biological products. The aim of the NACLAR Guidelines is to promote humane and responsible care and use of animals for scientific purposes in Singapore.

In essence, the NACLAR Guidelines are based on the principles of the 3Rs:

- Replacement of animals with alternative methods;
- Reduction of the number of animals used;
- Refinement of projects and techniques used to minimise impact on animals.

The Guidelines also outline the responsibilities of institutions, investigators and persons involved in the care and use of animals for scientific purposes. All research facilities which house and use animals for scientific purposes will have to operate in accordance with the Guidelines to qualify for licensing from the AVA.

The Guidelines also describe the operational aspects pertaining to the Institutional Animal Care and Use Committee (IACUC). The IACUC is responsible for the oversight and evaluation of animal care and use programmes of an institution, and is responsible for ensuring that the care and use of animals for scientific purposes and all animal experimental procedures are in compliance with the Guidelines. Under the Guidelines, all institutions with research facilities are required to establish their own IACUC to assume this function.

The last section of the Guidelines outlines the training scope and requirements for users of animals and animal institution personnel. This includes the scope of the core curriculum and the relevant core competencies, such as special courses for animal procedures. The Guidelines require all users of animals for research to undergo appropriate training before carrying out any experiments involving animals. It will assist IACUCs in determining the scope and depth of education training programmes that will meet both institutional needs and the requirements of NACLAR.

Notes 5d. Alternatives to animal testing

Adapted from information on the websites of PETA / Speaking of Research

Experiments on animals are cruel and expensive, and they produce dangerously misleading results that are generally inapplicable to humans. With this in mind, the world's most forward-thinking scientists are developing and using methods for studying diseases and testing products that replace the use of animals and are actually relevant to human health.

These modern methods include sophisticated tests using human cells and tissues (also known as *in vitro* methods), advanced computer-modelling techniques (often referred to as *in silico* models) and studies with human volunteers. These and other non-animal methods are not hindered by species differences that make applying animal-test results to humans difficult or impossible, and they usually take less time and money to complete.

In Vitro Testing

- Harvard's Wyss Institute has created "organs-on-chips" that contain human cells grown in a pioneering method that mimics the structure and function of human organs and organ systems. The chips can be used instead of animals in disease research, drug testing and toxicity testing. They have been shown to replicate human physiology, diseases and drug responses more accurately than crude animal experiments do. Some companies, such as the HμRel Corporation, have already turned these chips into products that researchers can use in place of animals.
- A variety of cell-based tests and tissue models can be used to assess the safety of drugs, chemicals, cosmetics and consumer products. CeeTox (bought by Cyprotex) developed a method to assess the potential of a substance to cause a skin allergy in humans that incorporates MatTek's EpiDerm™ Tissue Model – a 3-dimensional, human cell–derived skin model that replicates key traits of normal human skin. It replaces the use of guinea pigs or mice, which would have been injected with a

substance or had it applied to their shaved skin to determine an allergic response. MatTek's EpiDerm™ is also being used to replace rabbits in painful, prolonged experiments that have traditionally been used to evaluate chemicals for their ability to corrode or irritate the skin.

- Researchers at the EURL ECVAM have developed five different tests that use human blood cells to detect contaminants in drugs that cause a potentially dangerous fever response when they enter the body. The non-animal methods replace the cruel use of rabbits in this painful procedure.

Shortcomings: Although the aim is to *refine* the models and *reduce* the number of animal experiments, *in vitro* testing cannot *replace* animal testing altogether. The reasons for this are fairly straightforward: A drug might work fine on a cell in a test tube, but how will it work in a body? A test tube has no blood circulatory system, no liver, no brain, and no nervous system at all. A test tube cannot feel pain or get pregnant. We just don't know whether it would work for sure until we try it on a living creature. And again, it's either animals, or us, that we have to trial the drugs on next.

Computer (*In Silico*) Modelling

- Researchers have developed a wide range of sophisticated computer models that simulate human biology and the progression of developing diseases. Studies show that these models can accurately predict the ways that new drugs will react in the human body and can replace the use of animals in exploratory research and many standard drug tests.
- Quantitative structure-activity relationships (QSAR) are computer-based techniques that can replace animal tests by making sophisticated estimates of a substance's likelihood of being hazardous, based on its similarity to existing substances and our knowledge of human biology. Companies and governments are increasingly using QSAR tools to avoid animal testing of chemicals, and PETA's affiliate in the US actively promotes and funds their use internationally.

Shortcomings:

- Computer modelling plays an important part in the research process however its capacity to replace the use of animals is limited. Before one can program a computer model to reflect an aspect of our physiology, an understanding of the physiology being modelled is needed. This knowledge tends to come through research using animals. So animals are needed before we even get to the computer.
- Most scientists do not have access to supercomputers on the scale of Blue Gene/L, which are needed to attempt more complex simulations.
- Computer simulations of organs have some use, but, unlike *in vivo* research, they are generally forced to focus on major interactions at the cost of minor ones. A simulation of a heart may appear to reproduce the movement of muscles used in pumping blood, but will likely be at the cost of minor reactions and interactions going on within an individual cell.

Research with Human Volunteers

- A method called "microdosing" can provide vital information on the safety of an experimental drug and how it is metabolised in humans prior to large-scale human trials. Volunteers are given an extremely small one-time drug dose, and sophisticated imaging techniques are used to monitor how the drug behaves in the body. Microdosing can replace certain tests on

animals and help screen out drug compounds that won't work in humans so that they won't needlessly advance to government-required animal testing.

Shortcomings: By its very nature, micro-dosing cannot predict toxicity or side effects that occur at higher 'therapeutic' doses. It is an unrealistic hope, and a false claim, that micro-dosing can replace the use of animals in scientific research wholesale. This was confirmed recently by the respected organization FRAME (Fund for the Replacement of Animals in Medical Experiments), which stated in this context: *"Animal studies will still be required".*

- Advanced brain imaging and recording techniques – such as functional magnetic resonance imaging (fMRI) – with human volunteers can be used to replace archaic experiments in which the brains of rats, cats and monkeys are damaged. These modern techniques allow the human brain to be safely studied down to the level of a single neuron (as in the case of intracranial electroencephalography), and researchers can even temporarily and reversibly induce brain disorders using transcranial magnetic stimulation.

Shortcomings:

- *Although* this 'alternative' can fulfil a useful role and help *reduce* the number of animals used, it cannot replace animal research altogether. Watching how the brain works can help us understand part of the problem, but it also occurs on the genetic and molecular level, which MRI scans cannot show us.
- MRI scans may show us a problem in the brain, but animal research is likely needed to fix the problem. We cannot alter a human brain between MRI scans in an attempt to find a cure, so we must use animals first, to ensure the methods safety.

- Instead of experimentally inducing human diseases in animals in artificial environments, epidemiological studies – the study of diseases naturally occurring within populations – can provide vital, human-based information on the risk factors and causes of diseases. These types of studies have informed us about the relationship between smoking and cancer, the mechanism of the transmission of AIDS and other infectious diseases and the identification of heart disease risk factors, allowing appropriate measures to be taken to prevent or reduce the occurrence of those diseases.

Human-Patient Simulators

- Strikingly life-like computerised human-patient simulators that breathe, bleed, convulse, talk and even "die" have been shown to teach students physiology and pharmacology better than crude exercises that involve cutting up animals. The most high-tech simulators mimic illnesses and injuries and give the appropriate biological responses to medical interventions and injections of medications.
- For more advanced medical training, systems like TraumaMan – which replicates a breathing, bleeding human torso and has realistic layers of skin, tissue, ribs and internal organs – are widely used to teach emergency surgical procedures. These systems have been shown in numerous studies to impart lifesaving skills better than courses that require students to shoot or cut into live pigs, goats or dogs.

Reading 6: Billionaires with big ideas are privatizing American science **EU3 and EU4**

By William J. Broadmarch (The New York Times, 15 March 2014)

This reading will help you:

- understand science philanthropy and its impact on scientific progress
- understand the concerns regarding science philanthropy
- understand how bureaucratic processes can slow down scientific progress
- understand the differences between the processes involved in securing government versus private funding

Last April, President Obama assembled some of the nation's most august scientific dignitaries in the East Room of the White House. Joking that his grades in physics made him a dubious candidate for "scientist in chief," he spoke of using technological innovation "to grow our economy" and unveiled "the next great American project": a $100 million initiative to probe the mysteries of the human brain.

"We can't afford to miss these opportunities while the rest of the world races ahead," Mr. Obama said. "We have to seize them. I don't want the next job-creating discoveries to happen in China or India or Germany. I want them to happen right here."

Absent from his narrative, though, was the back story, one that underscores a profound change taking place in the way science is paid for and practiced in America. American science, long a source of national power and pride, is increasingly becoming a private enterprise. From Silicon Valley to Wall Street, science philanthropy is hot, as many of the richest Americans seek to reinvent themselves as patrons of social progress through science research.

"For better or worse," said Steven A. Edwards, a policy analyst at the American Association for the Advancement of Science, "the practice of science in the 21st century is becoming shaped less by national priorities or by peer-review groups and more by the particular preferences of individuals with huge amounts of money."

This is philanthropy in the age of the new economy — financed with its outsize riches, practiced according to its individualistic, entrepreneurial creed. The donors are impatient with the deliberate, and often politicized, pace of public science, they say, and willing to take risks that government cannot or simply will not consider.

Yet that personal setting of priorities is precisely what troubles some in the science establishment. Many of the patrons, they say, are ignoring basic research — the kind that investigates the riddles of nature and has produced centuries of breakthroughs, even whole industries — for a jumble of popular, feel-good fields like environmental studies and space exploration.

Fundamentally at stake, the critics say, is ***the social contract that cultivates science for the common good***. They worry that the philanthropic billions tend to enrich elite universities at the expense of poor ones, while undermining political support for federally sponsored research and its efforts to foster a greater diversity of opportunity — geographic, economic, racial — among the nation's scientific investigators.

Historically, disease research has been particularly prone to unequal attention along racial and economic lines. A look at major initiatives suggests that the philanthropists' war on disease risks

widening that gap, as a number of the campaigns, driven by personal adversity, target illnesses that predominantly afflict white people — like cystic fibrosis, melanoma and ovarian cancer.

Initially, people like Martin A. Apple, a biochemist and former head of the Council of Scientific Society Presidents, saw the donors as superrich dabblers. Now he believes that they are helping accelerate the overall pace of science. What changed his mind, he said, was watching them persevere, year after year, in pursuit of highly ambitious goals.

"They target polio and go after it until it's done — no one else can do that," he said, referring to the global drive to eradicate the disease. "In effect, they have the power to lead where the market and the political will are insufficient."

"Today, federal funding of basic research is on the decline," the group said. "The best hope for near-term change lies with American philanthropy."

A New Template

In the traditional world of government-sponsored research, at agencies like the National Science Foundation and the National Institutes of Health, panels of experts pore over grant applications to decide which ones get financed, weighing such factors as intellectual merit and social value. At times, groups of distinguished experts weigh in on how to advance whole fields, recommending, for instance, the construction of large instruments and laboratories costing billions of dollars.

By contrast, the new science philanthropy is personal, anti-bureaucratic, inspirational.

The philanthropists' projects are as diverse as the careers that built their fortunes. George P. Mitchell, considered the father of the drilling process for oil and gas known as fracking, has given about $360 million to fields like particle physics, sustainable development and astronomy — including $35 million for the Giant Magellan Telescope, now being built by a private consortium for installation atop a mountain in Chile. The cosmos, Mr. Mitchell said in an interview before his death last year, "is too big not to have a good map."

The availability of so much well-financed ambition has created a new kind of dating game. In what is becoming a common narrative, researchers like to describe how they begged the federal science establishment for funds, were brushed aside and turned instead to the welcoming arms of philanthropists. Advancement Resources of Cedar Rapids, Iowa, did its first workshop in 2002 and has now conducted hundreds across the country, mostly to coach scientists and medical institutions in what it calls the art of donor development. "We help make their work accessible to people who do not have scientific backgrounds but do understand money," said its founder, Joe K. Golding.

Government Gloom

In November 2012, the White House issued a thick and portentous update on the health of the nation's research complex. It warned of American declines, emphasized the rise of scientific rivals abroad and called for bold policy interventions. "Without adequate support for such research," the experts wrote in their cover letter, "the United States risks losing its leadership in invention and discovery." A group of scientific societies recently surveyed 3,700 scientists and technical managers and reported that 55 percent knew of colleagues who had lost jobs or expected to lose them soon.

Some of the donors themselves worry that too much focus on private giving could diminish public support for federal science. Representative Lamar Smith would beg to disagree. Last year, after a meteor exploded over Russia and injured more than 1,200 people, Mr. Smith declared that new sensors in space were "critical to our future." Then he held a hearing to showcase a satellite-borne

telescope meant to scan the solar system for speeding rocks that could endanger the planet. Money for the venture comes from leaders of eBay, Google and Facebook, as well as anonymous private donors.

"We must better recognize what the private sector can do to aid our efforts to protect the world," Mr. Smith said.

A Focus on Disease

If the map of the world of private science has yet to be drawn, one thing is clear: Much of the money is going into campaigns for a cure.

This private war on disease has resulted in significant advances in treatment and opens up blockages that have traditionally kept basic discoveries from being turned into effective treatments — especially for rare diseases that drug companies avoid for lack of potential profit.

The first success came with cystic fibrosis, which arises when a faulty gene clogs the lungs and pancreas with a sticky mucus. People with cystic fibrosis suffer from coughing, fatigue, poor digestion and slow growth, and die relatively young.

Around 2000, a surge of wealthy donors began making large contributions to the Cystic Fibrosis Foundation. Year after year, the foundation held galas, hikes, runs and golf tournaments, eventually raising more than a quarter-billion dollars. With great skill, it used the money to establish partnerships across industry and academia, smashing through the walls that typically form around research teams.

By early 2012, the financial surge produced the first treatment for an underlying cause of cystic fibrosis. The medication thinned the deadly mucus, lessening symptoms and drastically improving quality of life.

The success begot a global rush to turn basic discoveries into treatments, a field now known as translational science. It also inspired rich donors to shower new money on disease research.

Many of their efforts are rooted deep in personal or family trauma. Sometimes, by sheer force of genetics and demographics, that impulse may risk widening historical racial inequalities in health care and disease research, disparities that decades of studies have shown to contribute to higher rates of disease and death among blacks, Hispanics and other minority groups.

Of course, the pervasiveness of most diseases means most philanthropists give comfort and medical relief across the lines of race and ethnicity. So, too, the techniques of translational science, inspired by philanthropy, are now being applied in a federal effort against sickle cell anaemia, a blood disorder that mainly strikes black people and has long been something of a research orphan.

Setting the Agenda

In the early 1980s, Leroy Hood, a biologist at the California Institute of Technology, proposed to make the first automated DNA sequencer, which he pitched to the National Institutes of Health as a way to rapidly identify the billions of hereditary units in every human cell. His grant proposals were rejected, so he turned to Sol Price, a warehouse-store magnate whose companies ultimately merged with Costco.

The breakthrough of the DNA sequencer led to the Human Genome Project — the federal effort that, at a cost of $3.8 billion, mapped all the heritable units — and, more recently, to the burgeoning field of personal genomics. Science philanthropy, Dr Hood said, "lets you push the frontiers."

Over the years, the flood of private money has also inspired something of a reversal. In gene sequencing, in translational medicine, in the Obama administration's Brain initiative and in other areas, the federal government, instead of setting the agenda, increasingly follows the private lead.

Sometimes, private donors go to the government's aid. When budget cuts threatened to shut down a giant particle accelerator on Long Island in 2006, Dr Simons, the hedge-fund investor, who lives nearby, raised $13 million to bail it out. As a result, research teams were able to keep exploring subatomic aspects of the blast that brought the universe into existence.

If the rich donors are to be believed, their financing of scientific research in the years ahead will expand greatly in size and scope. A main reason is the Giving Pledge.

In 2010, Mr. Gates, along with his wife, Melinda, and the investor Warren E. Buffett, announced the campaign. So far, roughly a fifth of America's nearly 500 billionaires have signed up, pledging to donate the majority of their fortunes to charity.

Shortly before he died, Mr. Mitchell, the telescope man, spoke of his concern that American science was already losing its competitive edge. He cited the discovery of the Higgs boson, a subatomic particle seen as imparting mass to the universe. The finding was made at a particle accelerator in Europe after tight budgets shut down a rival machine near Chicago.

"We have no excuse" for losing the lead, Mr. Mitchell said. "We need to fix it."

For discussion:

1. What, according to the author, are motivations behind the pursuit of technological innovation?
2. What is translational science? List a few examples of how science philanthropy has contributed to translational science.
3. Describe how funds are raised for science philanthropy.
4. What are several concerns regarding private funding?

Essay Question:

1. The idea that science and technology will solve our problems is a delusion. Discuss. (RI Y6 CT2, 2016)

Reading 8: What Disruptive Technology Means **EU5**

The Economist, January 2015

This reading will help you to:

- Understand what constitutes a disruptive technology
- Introduce you to some examples of disruptive technology
- Offer a glimpse of their impact

Every so often a management idea escapes from the pages of the *Harvard Business Review* and becomes part of the zeitgeist. In the 1990s it was "re-engineering". Today it is "disruptive innovation". TechCrunch, a technology-news website, holds an annual "festival of disruption". CNBC, a cable-news channel, produces an annual "disruptor list" of the most disruptive companies. Mentioning "disruptive innovation" adds a veneer of sophistication to bread-and-butter speeches about education or health care. But just what is disruptive innovation?

The theory of disruptive innovation was invented by Clayton Christensen, of Harvard Business School, in his book "The Innovator's Dilemma". Professor Christensen used the term to describe innovations that **create new markets by discovering new categories of customers**. They do this partly by harnessing **new technologies** but also by developing **new business models** and **exploiting old technologies in new ways.** He contrasted disruptive innovation with sustaining innovation, which simply improves existing products. Personal computers, for example, were disruptive innovations because they created a new mass market for computers; previously, expensive mainframe computers had been sold only to big companies and research universities.

The "innovator's dilemma" is the difficult choice an established company faces when it has to choose between holding onto an existing market by doing the same thing a bit better, or capturing new markets by embracing new technologies and adopting new business models. IBM dealt with this dilemma by launching a new business unit to make PCs, while continuing to make mainframe computers. Netflix took a more radical move, switching away from its old business model (sending out rental DVDs by post) to a new one (streaming on-demand video to its customers). Disruptive innovations usually find their first customers at the bottom of the market: as unproved, often unpolished, products, they cannot command a high price. Incumbents are often complacent, slow to recognise the threat that their inferior competitors pose. But as successive refinements improve them to the point that they start to steal customers, they may end up reshaping entire industries: classified ads (Craigslist), long distance calls (Skype), record stores (iTunes), research libraries (Google), local stores (eBay), taxis (Uber)[4] and newspapers (Twitter).

Partly because of disruptive innovation, the average job tenure for the CEO of a Fortune 500 company has halved from ten years in 2000 to less than five years today. There is good reason to think that the **pace of change will increase, as computer power increases and more things are attached to the internet, expanding its disruptive influence into new realms**. Google promises to reinvent cars as autonomous vehicles; Amazon promises to reinvent shopping (again) using drones; 3D printing could disrupt manufacturing. But perhaps the most surprising disruptive innovations will come from bottom-of-the-pyramid entrepreneurs who are inventing new ways of delivering education and health-care for a fraction of the cost of current market leaders.

[4] In a more recent article, Professor Clayton Christensen argued that Uber is not technically a form of disruptive innovation. Central to his argument is that Uber is not disruptive to taxis, did not originate in a low-end or new-market foothold and caught on with the mainstream quite rapidly in a way. More can be found in the December 2015 issue (pp 44-53) of the Harvard Business Review: *https://hbr.org/2015/12/what-is-disruptive-innovation*

For discussion:

1. Various disruptive innovations are highlighted in the above article (e.g. Craigslist, Skype, eBay). Using Christensen's definition of disruptive innovation, explain why these services are considered to be such.

2. The article predicted that "the most surprising disruptive innovations will come from…the inventing [of] new ways of delivering education and healthcare…" Why do you think accounts for his opinion, and how far do you agree?

Reading 9: How technology changes the skills we need to learn **EU4 and EU5**

Adapted from an article by Greg Satell (Forbes, 28 Sep 2013)

This reading will help you to understand that:

- While many believe that our reliance on technology make us lose certain abilities, technology can also free up our cognitive energy for other things.
- With more time and energy saved, technology can allow us to develop ourselves like honing our social skills which we have lost because of our pursuit of efficiency.

A while back, Bill Keller of *The New York Times* stirred up a hornet's nest when he wrote a column worrying that joining Facebook would have a debilitating effect on his 13 year-old daughter's intellectual faculties. Technology advocates, including me, pounced. Now there are new studies out that seem to support his argument. One shows that using search engines decreases our memory and another suggests that GPS may atrophy our brains. Discovery magazine has collected a half-dozen similar examples on its site.

I think the question itself is misplaced. Clearly, ***we use technology to do things for us that we no longer are doing for ourselves and that means certain abilities degenerate***. Yet, it also means we are ***freeing up cognitive energy*** for other things. So what's really important is not the skills we are losing but those that we need to develop.

What makes an expert?

We come into the world not knowing much. We can't speak, eat by ourselves or use even the most basic household objects. Eventually, we start picking up patterns from our environment. We start babbling phonemes (elementary units of language) and then begin to combine them into words, the words into sentences and so on.

We learn virtually everything that way – by combining low order patterns to form higher order ones. Once we are able to understand language, we can absorb the patterns of others, learning values from our parents, social norms on the playground and eventually all the other skills that make up a modern life.

Experts define themselves by learning the highest order patterns through what Anders Ericsson, calls deliberate practice. For example, a normal person can learn to hit a golf ball competently in a few lessons, but pro golfers continuously work to master even the most miniscule patterns inherent to the game.

In much the same way, surgeons spend years learning the patterns of the human body and experienced firemen become familiar with the patterns of burning buildings. An expert has internalised the patterns of his chosen field and can act without thought or deliberation, but can operate seemingly by instinct.

How machines are taking over

The fear that new technologies lessen our ability to function is nothing new. In Plato's dialogue, *The Phaedrus*, Socrates worried that writing would diminish our ability to engage in conversation. Certainly, machines have hampered our ability to do physical labour and have contributed to obesity.

What makes the new breed of machines truly different is that they are able to recognize patterns and learn in much the same way we do. Researchers at IBM taught their algorithm to translate between French and English by exposing it to proceedings of the Canadian Parliament. IBM recently sent its Watson computer to medical school.

Yet computers can absorb material much faster than we can. In *How To Create A Mind*, Ray Kurzweil estimates that the human brain can recognize 100,000 patterns. In its first year as a med student, Watson pieces 600,000 of medical evidence, two million pages of text and 1.5 million patient records. Much like in the old fable of John Henry, we are beginning to realize that even our most ardent efforts will fall short. ***Just as we can't match the strength of a locomotive or the memory of a library, even the patterns learned in a lifetime of experience pale in comparison to the abilities that our new machines are beginning to acquire***.

Why Marcus Welby was inefficient

If you find yourself unable to sleep and start surfing channels in the triple digits, you may come across some old reruns of *Marcus Welby MD*, a popular medical drama from the early '70s. It doesn't look like anything you'll see in a hospital today.

The first thing you'll notice is how much medicine has changed. You don't see Dr Welby ordering a barrage of tests or asking patients what kind of insurance they have. In fact, he spends most of his time talking and getting to know each of his patients personally. He was, by today's standards, enormously inefficient.

In the decades since, we have learned to be efficiency driven machines. We're more data focused, evidence based and rational. Mostly, we see this as an improvement. After all, a doctor who treats more patients can cure more people. However, we've lost something too and ***letting machines take over gives us the opportunity to get it back***.

As Sandy Pentland, a big data expert at MIT and one of the most cited computer scientists in the world, put it in a recent interview, "***We teach people that everything that matters happens between your ears when in fact it actually happens between people.***"

Skills for a new age of inefficiency and imprecision

The truth is that technology makes us both dumber and smarter. In our technological age, we use machines to do many things we used to do for ourselves, so it shouldn't be surprising that we're getting worse at performing certain tasks. We have been engineered by evolution to conserve our limited capacities by adapting to our environment.

We can, if we want, choose to maintain those skills by going to the gym to replace physical work or performing mental exercises on Lumosity to sharpen our mental faculties, but what should really concern us is building the skills we need for the future:

- **Social Skills:** Richard Florida argues that, as our economy is becoming more service oriented, ***we need to invest in social skills*** and points to studies that show that such investments can earn a handsome return.

- **<u>Teamwork</u>:** While computers excel at problem solving, they are ***less able to decide which problems are important to solve or what approach can best be applied***. Discovering "what is" and asking "what if" are two fundamentally different skills. As Scott Page, an economist at the University of Michigan has found in his research, complex questions are often best answered by diverse teams rather than by homogenous groups or individuals, even if the latter are more talented.

- **<u>The New Math</u>:** As I've argued before, our future won't be made as much as it will be designed and, for now at least, ***algorithms don't design themselves***. Valdis Krebs of Orgnet points out that "Universities are still stuck on teaching 20th century math for building things rather than 21st century math for understanding things" and suggests that curriculums focus less on the mathematics of engineering (i.e. calculus) and more on the mathematics of patterns (i.e. set theory, graph theory, etc.).

The power to choose

What's most important is that technology gives us more power to choose. We are no longer stuck on the farm or in the factory, but are more free than ever to pursue our own passion and purpose.

For some, that will mean greater devotion to family and community, others may want to take joy in lost arts that have long outlived their usefulness and still others may devote greater time to matters of the soul. ***As we free ourselves from the shackles of efficiency, we are more able to seek out value.***

The reality of modern life is that we are all uploading old patterns to the cloud to make room for new ones. The choices we make are our own. We're as smart as we want to be.

<u>Comprehension / Reflection</u>

1. Why do some people believe that technology has a negative impact on our skills level?
2. To what extent has technology freed up more time and energy for people in modern society?
3. The author of this article suggested that there are many skills that need to be honed in our digital world, such as social skills and problem-solving skills. Do you agree that such skills are necessary? How effective has society been in honing such skills among young people?

Reading 7: Why Robots Won't Steal Accountants' Jobs **EU5**

Lee Fook Chiew and Loke Hoe Yeong For The Straits Times 24 June 2017

This reading will help you:
- Understand how and why certain jobs will stand in the face of modern technology

It is hard to blame the students of today for feeling added angst over their future careers. They constantly read reports about the prospect of automation putting jobs at risk. We certainly do need to prepare for the future workplace, in which the impact of digital disruption will be felt deeply. But rather than dwell on the fears of robots stealing jobs, professionals such as accountants should look instead to the opportunities afforded by the latest digital developments.

The American economist Philip Auerswald underscored in his book The Coming Prosperity that in the course of history, whenever machine and tools substituted one type of human capability, new human experiences and capabilities actually emerged. This happened when humans made the transition from hunter-gatherers to farmers, and then from farming to more industrial modes of work.

Likewise, the boundaries of the accountancy profession are shifting, and the skills which it calls for are evolving. The advance of technology has freed accountants from the drudgery of menial and mundane tasks such as the manual data entry of invoices, to pursue higher-value work that may bring in higher incomes. That includes accountants harnessing technology like data analytics tools to provide more in-depth and timely financial expertise to help their business outfits navigate today's volatile business landscape.

To give a simple example, records of point-of-sale transactions can be used to project future patterns of consumer behaviour. Accountants can move from having a "hindsight view" to having more "predictive foresight". One of the possible outcomes of predictive foresight is that companies know what inventories to hold, which frees up capital and lowers costs such as rental - since less storage space is now required - and obsolescence.

Accountants in business can also use data analytics to understand and discover patterns in customer behaviours and advise businesses on the best course of action in a competitive market.

In time to come, accountants may be involved in the design of the systems and machines that take over some accounting tasks. Auditors will need to be trained to audit the reliability, rigour and accuracy of these systems and machines.

At the end of the day, it is no longer just about what profession one belongs to, but what skills one possesses. The impact of digital disruption will be keenly felt in all professions and jobs.

VALUE OF HUMAN PROFESSIONALS

What then is the value of human professionals? Take medicine as an example. Most people, we would hazard a guess, would prefer not to have a robot replace their doctor. That is not in any way to belittle the tremendous progress in artificial intelligence research in the medical industry. With the possibility of voluminous medical research knowledge being fed into a machine, a robot can realistically diagnose a patient much more accurately than a human doctor can.

Rather than robots replacing medical or accounting professionals, the latter need to work hand in hand with robots, to continue raising the value of work within their profession. However, a patient's interface with a human professional is important for a number of reasons. The human doctor

provides person-to-person psychological care that includes empathy and the soliciting of patients' concerns to enable the best diagnosis. A robot's "clinical" approach could solicit a different set of concerns and issues from the patient compared with a human doctor's "softer" approach.

Furthermore, Professor Richard Lilford, the University of Warwick's Chair in Public Health, highlighted the importance of human intuition where "you've got to act in medicine before you've got any certainty and that sort of thing the doctor will have to do". He concluded that a computer "may become a second opinion, or perhaps even a first opinion, but the doctor will still make the final call".

Then there are the issues of ethics, in medicine as in other professions, including accountancy. In a joint report released last year on "The Future of Professional Learning and Entrepreneurship" by the Institute of Singapore Chartered Accountants (ISCA) and the Institute of Chartered Accountants in England and Wales (ICAEW), born out of conversations with a range of professionals, there was unanimous consensus that the real value of the accounting profession lies in its members' integrity and ethics. Some participants were of the view that clients would have more trust in audit opinions issued by a human auditor as compared with a robot.

So, rather than robots replacing medical or accounting professionals, the latter need to work hand in hand with robots to continue raising the value of work within their profession.

According to a study of over 2,000 work activities in more than 800 occupations by the McKinsey Global Institute released this year, the easiest jobs to automate are those involving predictable physical activities such as assembly line work in manufacturing. The next easiest jobs to automate include data collection and processing activities.

At the other end of the spectrum, the hardest activities to automate are those that involve managing and developing people or require deep expertise in decision-making and planning. Rather than being a monolithic role, the accountancy profession similarly covers a spectrum of activities from routine ones such as data entry to analysis and judgment. Routine activities can be and already are being automated with accounting software like Xero and QuickBooks. The implication of this would be job losses especially for accountants doing mainly routine accounting work, unless they can move on to higher value roles.

When the accountant analyses, applies judgment and then explains the issues relating to quality financial management to his clients or employers, he is actually assuming a role akin to an educator - an activity which the McKinsey study identified as among the most highly resistant to automation in the foreseeable future.

The accountancy profession involves more than bookkeeping roles today. The core competencies and skills of an accountant provide a strong foundation to go into many other high-growth fields of specialisation and trades, and even as entrepreneurs. The use of analytics, as discussed earlier, is but one example of how the accounting professional can work hand in hand with technology to raise the value of their work in the near term.

There is little reason to believe that the accounting profession will die out as a result of technological disruption. The profession has not only survived but also transformed itself since the onset of the digital revolution, and will continue to do so. There are also bountiful opportunities in the region. Businesses in the ASEAN region will need accountants and finance professionals to support their growth, and most emerging markets are short of these professionals. Singapore accountants are well equipped to take on these roles.

For discussion:

- Having read the above, in your opinion, which other professions do you consider possibly more resistant to automation and why?

- Do you think the overall anxiety surrounding automation's potential displacement of workers is justified? What are the implications of this on education and governmental policy-making?

Essay Questions:

1. Does modern technology always improve the quality of people's lives? (Cambridge 2006)

2. 'The young embrace technology, the old are threatened by it.' Is this true? (Cambridge 2006)

3. Does the modern work place too much reliance on technology? (Cambridge 2003)

4. Should we be concerned that machines are replacing us at the workplace? (RI Y5 CT 2017)

Reading 10: The politics of outer space **EU3, EU4 and EU7**

Adapted excerpts from an interview with Dr Jill Stuart, London School of Economics, August 2014

This reading will help you to:

- Understand the changing use of outer space
- Identify the major players vying for supremacy in developing commercial space activities
- Understand the military sub-text that underlines a lot of activities in outer space
- Review the arguments for and against manned and unmanned space exploration
- Consider whether space tourism is really viable in our lifetime

Forty five years after the Moon landing, outer space still holds a fascination for the world, associated with prestige, political and military power.

Why is it so important for countries to have a presence in space?

Manned space exploration gives countries power and prestige. There are only three countries in the world that have successfully managed to put humans into space – the US, Russia and China. It indicates you have a very strong economy; that you are technologically advanced, very ambitious and have political backing within your country. There's also a military subtext because if you can launch a benign military satellite into outer space, you can launch an intercontinental ballistic missile by changing the payload that's on top of that rocket. Finally, there is a nationalistic element to manned exploration that I think incentivises governments to invest in it.

It is 45 years since the US won the space race and put the first man on the Moon. What was the significance of that at the time?

The American moon landing was a political victory in the context of the Cold War. There was the bi-polar space race going on between the United States and the Soviet Union and the Moon was the unspoken prize. However, the Soviets continued to invest money into space stations and after the Moon landing they launched Mir which became a very prestigious space station. There were also six further Apollo landings resulting in 12 American astronauts walking on the Moon before they ended manned missions in 1972.

Who is leading the space race today?

By most accounts the United States is still the world leader in space for a variety of reasons: they have, by far and away, the largest civilian space budget, not to mention a sizeable military budget. They also have a very robust commercial space sector and are the leading shareholders in the international space station. However, the United States space program has weakened in recent years. They no longer have the ability to put astronauts into space since they retired the space shuttle and they now rely on the Russians in order to get to the international space station. They are hoping that commercial companies that have government backing from NASA will soon be able to bridge that gap for them.

Which other countries apart from the US and Russia, are major players in space?

Countries such as China, Japan, India and the United Arab Emirates are now investing a lot of time and money into manned and unmanned space programs. In addition you have countries, including the UK and within Europe, that have healthy, developing commercial space activities - either the ability to build and launch their own satellites into space, or the budget to buy satellites and have them placed into orbits so that they are building up their own space infrastructure. Politically, having a presence in outer space still carries a lot of prestige, but there's also practical reason for being there, both in the civilian and military sphere, and also for commercial reasons.

Should we be concerned about the unchecked development of anti-satellite weapons?

The use of anti-satellite weapons is of concern, partly because of the issue of debris. When China shot down one of its own satellites with an anti-satellite weapon, first of all that sent a political message that they were capable of doing so; but these weapons also create a dangerous scenario known as the Kessler Effect. When satellites break up they cause a cascade of debris, with a greater likelihood of further collisions with other satellites.

Should we be focusing more on the practical uses of space rather than human spaceflight? Is unmanned exploration where we will reap more of the benefits?

Whether or not we should continue to invest money in manned exploration versus unmanned projects is hugely controversial. In support of manned space exploration, people say that there are things that humans can simply do that robots can't. If we ever get to the surface of Mars you would need humans in order to complete certain tasks. There's also a sentimental, romantic value to putting humans in space. On the other hand, manned exploration is much more expensive and more dangerous and those funds can be reallocated to robotic missions that can achieve a lot more for the same amount of money. To a degree, some of the really practical uses of outer space - for example satellites for telecommunications - are being filled by the commercial sectors so it is not something that governments have to continue to invest in.

What is the current status regarding who governs outer space and what treaties are involved?

The international community first started talking about space governance in the 1950s when it became apparent that we were going to be able to place satellites into earth orbit. There was this question of who governs space, who owns it, how are we going to politically organise this or should we just leave it anarchic?

In 1967 the Outer Space Treaty established that outer space would be neutral territory and that no sovereign state could lay claim to celestial bodies. That treaty was followed by four others, from 1967 up until 1979. Those cover such scenarios as objects crashing in space, or from space, and who is liable for that; what happens to astronauts if they crash land on earth; and also the establishment of a registration regime so that anything placed in outer space has to be registered with a launching country. The last treaty was with regard to the Moon and sought to deal with some of the bigger issues surrounding its governance, mining and ownership. It was the only one of the five that was not widely ratified so was considered a failure.

Since 1979 we have backed away from having these big multinational treaties and moved more towards smaller memorandums of understanding between countries. Through this we are starting to pick apart the more difficult and contemporary issues in outer space politics relating to debris, satellite registration where there are increasingly crowded orbits, ownership over the Moon and celestial bodies, and mining.

What are the issues surrounding the Moon that are yet to be resolved?

There's a lot of renewed interest in going back to the Moon because it is seen as potentially a launch pad and stopping off point on to other planets such as Mars. It has resources such as Helium 2 that could be used as fuel for furthering rocket missions and other resources that might be able to be brought back to Earth.

This does raise legal and ethical questions about what we want the future of the Moon to be. Do we want countries to be able to mine it? Are we okay with companies mining it? As it stands right now it is considered under the Outer Space Treaty to be neutral territory and technically, no country may lay sovereign claim to it.

Is space tourism really viable or is it just a big pipe dream and a large waste of money?

First of all, it is worth remembering that space tourism is not new. The international space station has been taking tourists since the 1990s. These were people who paid in the region of $10 million to go up for a week or so with the Russians who are partners of the International Space Station. What's interesting about companies such as Virgin Galactic is that as they lower the price and also shorten the amount of time in space, you are potentially opening up space tourism to a larger market - still a very elite market given the prices we are talking about, but a larger market. They have had a lot of delays but I do think eventually that it will start to happen. There's going to be a lot of safety, environmental and legal issues to overcome beforehand.

<u>For discussion</u>:

1. According to the author, what are several benefits of space research and exploration?

2. The author states that since the early five space treaties, there has been a drought in global agreements on outer space. Based on the space activities described in this article, provide reasons for why we need new and improved space treaties, laws, regulations and standards. You may refer to the article, "Global Space Governance Can Fuel New Business and Innovations" by Joseph N. Pelton and Ram Jakhu (Space News, 2014)[5] as background reading.

<u>Essay questions</u>:

1. Do you agree that exploring space should not be a priority in today's world? (RI 2014Promo)
2. Can space research be justified nowadays? (Cambridge 2011)

[5] *Accessible at http://spacenews.com/41014global-space-governance-can-fuel-new-business-and-innovations/*

Reading 11: Why India Is Investing in Space **EU4, EU7**

Adapted from article by Kate Greene (17 March 2017. Source: http://www.slate.com)

This reading will help you to:

- Understand a nation's political, national and military motivations for pursuing space research.
- Appreciate the issues of how developing countries like India can has sound political and economic reasons to invest in space research and contribute to the international community.

In February, India broke a record. The Indian Space Research Organisation launched a whopping 104 satellites into orbit, besting the previous record—37 satellites on a Russian rocket in 2014. The deployment was a "remarkable feat" and proud moment for the space community and the entire nation, said Prime Minister Narendra Modi in a tweet. "India salutes our scientists."

The large number of satellites was possible because all but one of the satellites were nanosats weighing less than 10 kg (about 20 pounds). The majority were from the United States, two were from India, and there was one each from Kazakhstan, Israel, the Netherlands, Switzerland, and the United Arab Emirates. The only non-nano sat was from ISRO, designed for imagining and mapping applications. It was the heavyweight at more than 1,500 pounds.

Still, the feat was nontrivial. Engineers had to calculate precise trajectories and carefully choreograph the satellites unfurling. There were no crashes. Mission accomplished.

This wasn't the first time ISRO won international headlines for its savvy engineering. Back in 2014, the organization placed a spacecraft called Mars Orbiter Mission in orbit around the red planet. India was the fourth country to do this—after the United States, Russia (first as the Soviet Union), and the European Space Agency—and the only country to do so on its first try. What's more, the mission, which was more of a technology demonstration than a scientific investigation, was comparably cheap: reportedly only $73 million. (Modi noted that MOM cost less to make than the movie Gravity, though not exactly a balanced comparison.) In contrast, NASA's most recent Mars orbiter, MAVEN, loaded with cutting-edge scientific instruments and launched in 2013, cost $671 million.

These days, ISRO seems to be everywhere. The Indian government continues to boost its budget year over year. The organization is planning an orbiter-lander-rover mission back to the moon (its first was an orbiter in 2008) and another satellite mission to Mars. It's also considering an orbiter to Venus to study the planet's hot and cloudy atmosphere. All this amid an increasingly busy launch schedule for its reliable polar satellite launch vehicle rocket, the one that pushed those 104 sats into orbit. In 2008, ISRO launched only two PSLVs; in 2016, it launched six. The organization is targeting 12 to 18 launches a year by 2020 to put ever more satellites around Earth for imaging and communication purposes. And so it seems that India's space program, which was formed in 1969, is suddenly heating up. Why?

If you pay attention to international politics, you might suspect one reason is the recent rise in Indian nationalism. Modi, who has been in office since 2014, campaigned on a platform similar to U.S. President Donald Trump's, claiming that India's previous leaders had failed the nation and that he was the only one who could fix it. He makes policy decisions suddenly and drastically, all the while stoking Hindu nationalist sentiments.

But attributing recent ISRO successes to new nationalism doesn't ring true to Jaganath Sankaran at the Center for International and Security Studies at the University of Maryland. Yes, Sankaran agrees that "people are looking for things to celebrate and satellites are a proxy for national pride." But, he

adds, space has always been important to India. In 1947, after 200 years of imperialism, the nation was eager to become self-sufficient and develop its own technologies, Sankaran says, including satellites and rocketry. ISRO's current status and list of accomplishments has been decades in the making—it's not something that arose within the past few years.

In the early days, the goals of ISRO were significantly different from those of the United States and the Soviet Union, which were focused on human space exploration. Instead, India was keen to develop its satellite capabilities for mapping and surveying crops and damage from natural disasters and erosion, for instance. It also used satellite communication to bring telemedicine and telecommunication to remote rural areas.

ISRO's founder, Vikram Sarabhai, said as much when arguing that a developing nation like India would need space: "We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or other planets or manned space-flight," he said, "but we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."

Another reason to be skeptical that new nationalism is behind the rise, says Sankaran, is that the modern space community in India is heavily technocratic. That is, the scientists and engineers tend to call the shots when it comes to program objectives, he says. And unlike NASA, which has some of its big-budget goals set by the U.S. president, ISRO has a more bottom-up approach to larger initiatives. "It's not the prime minister's prerogative to say build a space station," says Sankaran. "If the [space] labs don't like it, they can say no."

One possible reason ISRO seems to be on the up and up could come from the growing market for space in general. A 2015 report from the Space Foundation estimated the global space economy to be worth $323 billion. In particular, small, inexpensive satellites, like the ones ISRO launched in February, are becoming more popular. Silicon Valley startups like Planet, Vector Space, Spire Global, Capella Space, and others are trying out new technologies and applications. Their systems of choice are small cuboid satellites that are loaded with electronics, imaging and guidance systems, and even their own thrusters for applications that often involve imaging and mapping. What's more, other companies, including Facebook, are paying tens of millions to hundreds of millions of dollars to develop and launch larger satellites to supply internet access to remote regions throughout the world.

Globally, there are a number of rocket options for sending commercial satellites into space. ISRO, for its part, offers a relative bargain. One reason it's cheaper to launch with ISRO than many others is that Indian labor, from the scientists and engineers to technicians and support staff, is less expensive than in the U.S. and Europe, says Sankaran.

And when it comes to more complex planetary missions, ISRO also saves money with its organizational efficiency, according to Susmita Mohanty, co-founder and board member of Earth2Orbit, a company that advises international clients on launching with ISRO in addition to offering data analytics for satellite data. "After the budget for the Mars mission was approved, the team at ISRO put together the spacecraft and launched it in just 14 months," she wrote in an email interview. "No other space agency in the world can pull off a planetary space mission in such a compressed timeframe." This is possible because ISRO can, Mohanty says, "collapse [organizational] hierarchies and get the team together to accomplish the task in record time."

Still, there might be another reason for ISRO's rise, suggests Sankaran: the explosion of media coverage. Historically, ISRO's culture has been dictated by scientists who steered clear of the spotlight. It's taken decades for the media relations side of ISRO to catch up.

Media coverage will likely continue as more ISRO missions are approved by parliament. These days, India even has human space flight on its agenda. The organization has tested experimental designs for a crew capsule twice, Mohanty notes, with one launch and recovery in 2007 and another in 2014. And last year, the space program flew a scaled-down version of a space shuttle used to test the technology for an eventual, full-sized orbital space plane. "These technology demonstrations prove that ISRO is laying the foundation for human mission in the near future," she says.

Current satellite applications range from TV broadcasting, telecommunication, and homeland security to urban planning, real estate, land management, just to name a few, says Mohanty. "Having a fleet of Earth observation, communication and navigation satellites for a subcontinent like India is a necessity," she says, "not a luxury."

For discussion:

1. Why is investing in space for India more than just about nationalism?
2. India has been doing space research for many years but why is it only gaining attention recently?
3. Poor countries are often criticized for channelling state money towards space programmes instead of development programmes. How is it justified in India's case?

Reading 12: Drones among us **EU5, EU6, EU7**

Adapted from "The unknown future of drone technology" (Donna N. Peeples, 21 May 2015, Pulse)

This reading will help to you will learn about:

- How drones are used for retail and civilian purposes
- The guidelines for using drones
- The benefits and problems of drone technology

In 2013, Amazon CEO Jeff Bezos announced to the world that the online retailer would begin to develop a "drone-to-door" delivery service for its loyal customers. Dubbed "Amazon Prime Air", the system would deliver packages directly to your doorstep in just 30 minutes after an order is placed, setting a new and higher bar for "fast delivery".

However, after a variety of issues and concerns were addressed by increasing regulations added by the Federal Aviation Administration (FAA) to approve Amazon's drones, the dream of flight seemed grounded. It appeared Bezos' announcement would never get off the ground. But after two years of waiting for the FAA, Amazon will finally get to test these drones on U.S. soil – or, should I say U.S. air? – this April, bringing customers one step closer to having their Tide detergent refilled by a delivery drone.

Despite the U.S. government dragging behind on these approvals, for retail and civilian use, sales for drones aren't expected to slow down anytime soon. Companies like Teal Group, an aerospace research firm, estimates that sales of both military and civilian drones will total over $89 billion by 2023.

Other big companies, such as State Farm and AIG, are also getting into the drone business. In fact, State Farm is the first insurance company in the United States to receive regulatory approval to test drones for commercial use. With ***drones popping up in so many different industries***, it makes me wonder, what impact drones will have on companies' customer experience – good and bad.

The Good

State Farm plans on changing the insurance industry for the better, utilizing drones to aid in natural disaster relief. For instance, instead of State Farm spending the money (and time) to ship hundreds of claims adjusters out to natural disaster sites to assess damages, they will send only a handful of agents equipped with a drone partner to more efficiently survey damaged property.

Jason Wolf, a property defence attorney and shareholder at the Florida based firm, Koch Parafinczuck & Wolf stated in an interview to ClaimsJournal.com,

"I envision a time when, after a catastrophe, an adjuster pulls up to a neighborhood and opens the trunk of his car and presses a few buttons on his tablet device and the drone does an immediate survey of everything and streams it all right to his tablet device, and he knows exactly where to go first and what's most significant within minutes. Costing very little money, the insurance company has a sense of everything that needs to be done in a very short about of time."

Imagine all the headaches this could mitigate for customers and employees after the chaos caused by unfortunate losses created by natural disasters. As such, claims assessment aided by a drone will yield quick turnarounds and an even quicker payout to the insured.

There is also the use of drones for the collection of data by third parties. Imagine that Ford is looking to target advertisements for a new truck to areas where the road conditions would demand the use

of four-wheel drive. Ford hires an agency to send out drones to specific cities where they are looking to advertise.

This drone will collect data on road conditions and take images of cars on the road to make sure majority of drivers are in trucks, and will then report back on economic conditions. Ford doesn't want to be advertising where citizens can't or won't pay for their product.

In a world becoming more drone-centric, these types of background checks and data collections via Unmanned Aircraft System (UAS) will become increasingly more frequent. While there is a huge interest in drones and their future, there are those who have their concerns about how invasive drones can and will get down the road.

The Bad

Technology is, not surprisingly, changing fast. For example, in order for drones to reach the too-invasive level, they must first be regulated. However, the government review process is 120 days before a decision is made, and by that point Amazon says the technology of the drone they submitted for regulation is now outdated and therefore must be updated, then resubmitted to the FAA for regulation, starting the 120-day review process all over again.

The other concern of the FAA is air traffic. Coming down with a few regulations on drone flight, the FAA is requiring that drone controllers have sight of the drone at all times and that they must operate under 400 feet.

BGlobal aerospace, defence, information and services company, Exelis, Inc., was featured in an article on Engadget recently, discussing its development of an air traffic control system for drones. Nearly ready for testing at the FAA approved drone-testing sites, the low-altitude monitoring system would keep tabs on compact aircrafts flying at or under the mandated 400 feet.

It'll be interesting to see how industry giants, such as Amazon, overcome these obstacles to create a non-invasive customer experience with drone technology.

Once regulated, the next issue is over ***invasion of civilian privacy***. Private and civil liberties advocates have raised doubts about the legitimacy of facial recognition cameras, thermal imaging cameras, open Wi-Fi sniffers, license plate scanners and other sensors commonly used by drones in the civilian sphere.

Civilian uses of drones for hobby are already causing issues, most notably at the White House, but across the country as well. The LA Times reported last June that while LA Kings hockey fans were celebrating their Stanley Cup victory, a group noticed a drone flying over their heads filming the scene.

Angry at the invasion of privacy, the crowd knocked the drone out of the sky using a t-shirt and then smashed it to bits with a skateboard. In Los Angeles, flying a drone in public is not illegal, but LAPD Cmdr. Andrew Smith commented that, "it was kind of an eye-opener for us, that this something we really need to pay attention to." While the Kings fans reactions may seem a little over the top, the general population seems to feel the same way when they see a drone overhead.

With ***no official laws on the books*** regarding the use of domestic drones, the right to privacy becomes a large topic of concern for many citizens. The American Civil Liberties Union states on their website, "Congress has ordered the Federal Aviation Administration to change airspace rules to make it much easier for police nationwide to use domestic drones, but the law does not include badly needed privacy protections."

It will be interesting to see how industries positively promote drone use to their customers, without them seeing it as a threat to privacy. After all, the customer may not always be right, but they are always the customer.

With that being said, however, it's not just about protecting civilians from drones, but it's ***also protecting these drones from enemies***. The threat of a cyber-attack of a drone is always looming. "Cyberattacks on your PC — they can steal information and they can steal money, but they don't cause physical damage, whereas cyber-attacks in a UAV or a car can cause physical damage and we really don't want to open that can of worms," said Kathleen Fisher, the previous program manager of the DARPA project in a statement to NextGov.com

The Pentagon is currently working on developing code that will protect a Boeing Little Bird unmanned aircraft from being cyber hacked. Defence industry programmers are rewriting software to safeguard the computer onboard the helicopter drone and aim to have the project completed by 2017.

The Future

These issues aside, it's exciting to think about what drone technology will bring to companies and their customers – and to people everywhere. Let's face it, if we think we have seen the complete potential of what customer experience has to offer, then, well, we're being naive. The new drone technology ***will reinvent customer experience once again***. And the best part? We all get to see how in unfolds.

The future seems endless for the drone industry. Whether you feel they are an invasion of privacy, or they will begin to make our lives easier and aid society in ways that haven't even been thought of yet, drones aren't going anywhere any time soon. If you need to put it in perspective, a White Paper featured on Cognizant.com notes that 40,000 drones are expected to deploy in 2015, this is a number that will continue to increase each year. This industry is ready for take-off.

That means, if you haven't come face-to-face with a drone yet, don't worry, you will.

For discussion:

1. According to the passage, what are the *benefits and problems* of using drones for retail and civilian purposes?

2. The reading tells us that facial recognition cameras, thermal imaging cameras, open Wi-Fi sniffers, license plate scanners and other sensors are commonly used by drones in the civilian sphere. *Do you think that the convenience that drones can bring to consumers and corporations is worth the potential threat to personal privacy?*

3. "Congress has ordered the Federal Aviation Administration to change airspace rules to make it much easier for police nationwide to use domestic drones, but the law does not include badly needed privacy protections." *Given people's angry response at the invasion of privacy mentioned in the passage, what recommendations do you propose to protect people's privacy so that drones can be used by the police to enhance public safety?*

Readings 13(a)/13(b): Drones in Warfare **EU4, EU5**

These readings present contrasting views about:

- The efficacy of drones in achieving battlefield objectives
- The extent of civilian casualties resulting from drone warfare
- The impact such warfare has on drone operators

13(a) Drones: Actually the Most Humane Form of Warfare Ever

By Michael W. Lewis, 21 Aug 2013, The Atlantic [adapted]

Mark Bowden's description[6] of the drone operator's reaction to performing a specific mission – one of shock and uncertainty – clearly undermines the widely circulated but exceptionally irresponsible criticism that drones have created a "Playstation mentality" among their operators. An additional fact that that has been understood for several years now (although not widely reported) is that drone operators suffer from PTSD[7]-like symptoms at rates similar to – and sometimes greater than – those experienced by combat forces on the ground. It turns out that even from 8,000 miles away, taking human life and graphically observing your handiwork is nothing like playing a video game.

His descriptions and takeaways on most aspects of the drone program are consistent with my own experience in military aviation and the information I have gathered from human rights organisations, drone operators, military lawyers, senior military, and CIA personnel who have run the drone programmes, as well as from senior military policy advisors who were involved in changing the way drones are used.

Like any other weapons system, drones have caused civilian casualties. But they also have the potential to dramatically reduce civilian casualties in armed conflicts, and particularly in counterinsurgencies. Their ability to follow targets for days or weeks accomplishes two things that contribute to saving the lives of innocents: First, it confirms that the target is engaged in the behaviour that put them on the target list, reducing the likelihood of striking someone based on faulty intelligence. Second, by establishing a "pattern of life" for the intended target, it allows operators to predict when the target will be sufficiently isolated to allow a strike that is unlikely to harm civilians.

Another, less obvious, feature that reduces civilian casualties is that drones are controlled remotely, so the decision to employ a weapon can be reviewed in real time by lawyers, intelligence analysts, and senior commanders without any concern (in most cases) that a hesitation to act may cost lives. Even more importantly, the operators themselves are not concerned for their own safety, eliminating the possibility that the combination of tension,

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[6] *"The killing machines: How to think about drones", Sep 2013, The Atlantic Global Issue (https://www.theatlantic.com/magazine/archive/2013/09/the-killing-machines-how-to-think-about-drones/309434/ 10/32)*

2. [7] *Post-Traumatic Stress Disorder: a mental disorder develops in some people who have experienced a shocking, scary, or dangerous event*

an unexpected occurrence, and a concern for personal safety leads to weapons being fired when they should not be. This potential of drones to vastly reduce civilian casualties was not fully realised at first, but it has been dramatically attained in the past few years.

In 2007, the U.S. Army and Marine Corps began disseminating a new Counterinsurgency (COIN) Manual that emphasised the need for soldiers to be involved in nation-building and bolstering local civil-society institutions, in addition to defeating insurgents militarily. Part of implementing this strategy involved minimising civilian casualties. When Gen. Stanley McChrystal took command of ISAF (International Security Assistance Force) in Afghanistan in 2009, he emphasised the need to continue reducing civilian casualties in all phases of operations. He assigned teams of civilians and military officers to conduct root-cause analysis of every civilian casualty and tasked them with developing protocols to eliminate such deaths.

These teams produced a number of recommendations for drones. One of the most significant was switching the preferred method of targeting from compounds to vehicles. While targeting compounds improved the likelihood that the right individual was being targeted, it also greatly increased the chances that members of the target's family and the families of his bodyguards and close associates would be harmed. Although vehicle strikes ran a greater risk of target misidentification, increasing surveillance and pattern-of-life analysis mitigated that risk. Because it is easier to determine who is in a vehicle than to keep track of everyone who enters and leaves a compound, vehicle strikes reduced the likelihood that family members and friends would be collateral damage. Also, because vehicle strikes can be conducted on isolated roads, the likelihood of other civilian bystanders being harmed was minimised.

How do we know that this has succeeded? Bowden mentions studies done by several independent organisations that have assessed civilian casualties caused by drones in Pakistan. One well-respected source, UK-based The Bureau of Investigative Journalism (TBIJ) has consistently produced the highest estimates of civilian casualties for drone strikes. According to TBIJ, between January 2012 and July 2013, there were approximately 65 drone strikes in Pakistan, which they estimate to have killed a minimum of 308 people. Yet, of these casualties, even TBIJ estimates that only 4 were civilians. This would amount to a civilian casualty rate of less than 1.5 percent, meaning that only 1 in 65 casualties caused by drones over that 19-month period was a civilian. This speaks to drones effective discrimination between civilian and military targets that no other weapons system can possibly match.

Another indication that drones cause fewer civilian casualties than traditional warfare was provided by Hamid Karzai in 2011. The US was employing all types of units in Afghanistan, ground troops, airstrikes, artillery and drones. But the source of friction with the Afghan government was not drones but rather Special Forces night raids. Karzai proclaimed that he would withhold further cooperation until his government was given greater control over night raids. Drones did not cause him or the Afghan people any appreciable concern.

Michael W. Lewis flew fighters for the Navy in the early 1990s. He now teaches international law at Ohio Northern University School of Law.

13(b) Our Drone War Burnout **EU5, EU6, EU8**

By Pratap Chatterjee, 14 July 2015, The New York Times

A man bleeds profusely from a leg shattered by a missile. He drags himself slowly across a field until he dies in the dirt. These images from Heather Linebaugh's dreams play back endlessly, even in her waking hours. Cian Westmoreland dreams of dozens of children staring at the sky in terror. And Brandon Bryant writes poems about soldiers dying in a sea of blood, their bodies imagined in the grainy infrared imagery of military operations.

I interviewed all three young Air Force veterans in order to gain a greater understanding of the costs of the White House's secretive drone operations. As public support for foreign wars has fallen, following years-long occupations of Afghanistan and Iraq, the Obama administration has favoured this form of remote-control warfare. In the president's first five years in office, the CIA made 330 drone strikes in Pakistan alone, compared with 51 strikes in four years of George W. Bush's presidency.

The rationale for weaponized drones was twofold. The powerful technology of high-quality video streamed in real time via satellite promised the capability to kill enemy combatants with pinpoint accuracy. At the same time, operations could be conducted in air-conditioned comfort in locations like the Nevada desert, keeping American personnel out of harm's way.

Neither assumption was correct.

The issue of drones' civilian body count is well documented. The CIA, in classified submissions to Congress, claims civilian death rates "typically in the single digits" per year, according to Senator Dianne Feinstein in 2013, who then chaired the Senate Intelligence Committee.

Independent sources differ sharply from the official account. In 646 probable drone strikes in Pakistan, Somalia and Yemen recorded by the Bureau of Investigative Journalism, as many as 1,128 civilians, including 225 children, were killed – 22 percent of deaths. The New America Foundation's estimates are lower, but suggest a civilian death rate of about 10 percent.

The drone wars are also taking a toll at home. Air Force psychological studies have found widespread stress among pilots, analysts and operators. "What we see are elevated rates of emotional exhaustion and distress," said Dr Wayne Chappelle at the School of Aerospace Medicine at Wright-Patterson Air Force Base in Ohio.

The Air Force recently announced that only about 180 drone pilots graduate from training each year, while some 240 of the 1,260 pilots currently working expected not to continue once their six-year contracts expire. Soon after the Government Accountability Office discovered that only about one-third of drone pilots in a sample had completed their full training before being pressed into service, the Pentagon reluctantly cut back on combat air patrols until it could find more pilots.

Pilots are only part of the story. As many as 180 people, from military lawyers and

commanders to private contractors from Raytheon and Northrop Grumman, are required to maintain each patrol of three to four Predator or Reaper drones around the clock. Many technicians who review footage and other data are employed soon after high school, with less than a year of training.

None of the veterans mentioned earlier ever came close to an actual battlefield. Mr Westmoreland worked at a military base in Kandahar, Afghanistan, where he helped set up a relay system to beam aerial footage to Al Udeid Air Base in Qatar. Mr Bryant managed cameras on a Predator drone from Nellis Air Force Base, Nevada. Ms Linebaugh's job was analysing video feeds at Beale Air Force Base in California.

Yet they all attest to the stress and psychological impacts of their work. Working up to 12 hours a day, sometimes six days a week, analysts watch their targets up close for months on end. They often witness their subjects' final moments. In follow-up surveillance, they may even view their funerals.

"Watching targets go about their daily lives may inspire empathy," said Julie Carpenter, a research fellow at California Polytechnic State University who has studied human-technology interactions in the military. The Air Force is providing psychological support for drone personnel, but this interim solution seems unlikely to be adequate.

"We can say we see children and we think you shouldn't do it. But it isn't up to us," one former analyst, who asked to remain anonymous, told me. "We are completely outranked, and at the very bottom of the food chain."

Stories of the psychological trauma suffered by lower-ranked Air Force personnel are starting to emerge. Veterans like Mr Bryant, Ms Linebaugh and Mr Westmoreland have attested in documentaries and the media to deep-seated flaws they've observed in drone warfare.

We need far greater transparency about the targeted killing operations. From the glimpses we have seen, we know there have been tragic failures. In 2011, a transcript of a drone strike, obtained under the Freedom of Information Act by The Los Angeles Times, revealed widespread confusion among imagery analysts in Florida, pilots in Nevada and the missile operators on Kiowa helicopters in Afghanistan, resulting in the killing of some two dozen innocent civilians with no terrorist connections.

In 1971, in the wake of the My Lai Vietnam massacre, Vietnam Veterans Against the War held a series of hearings in Detroit called the Winter Soldier Investigation. The purpose was not to scapegoat anyone, but to gather testimony on military policies and war crimes from those who experienced the atrocity first-hand.

We need a similar forum today. For a full accounting of the impact of America's drone wars, at home and abroad, our representatives in Congress must hear directly from the veterans.

Pratap Chatterjee is the executive director of CorpWatch, an investigative journalism group, and the co-author of the forthcoming graphic novel "Verax".

For discussion:

1. What evidence does Lewis provide to support his view that drones are a "humane" form of warfare? How do Chatterjee's assertions challenge Lewis' evidence?
2. Personal accounts are cited in both articles: (a) Why do you think the writers do this? (b) Which writer uses this rhetorical strategy more successful? Justify your opinion.
3. The use of drones is said to change the future of war. Should a "PlayStation mentality to killing" be allowed? *What new responsibilities* do armchair soldiers have concerning the use of drones? *What intellectual tools* should soldiers be equipped with to handle this newfound responsibility? You may wish to refer to John Kaag's article "Drones, Ethics and the Armchair Soldier"[8] for some background information on this.

Essay questions:

1. 'Technology provides assurance in a world fraught with uncertainty and insecurity.' Do you agree? (VJC Prelim 2012)
2. Consider the view that man has more moral issues to deal with as science advances. (PJC JC2 MYE 2012)

[8] *Accessible at: http://opinionator.blogs.nytimes.com/2013/03/17/drones-ethics-and-the-armchair-soldier/?_r=0*

Subtopic
Mathematics

Enduring Understanding

1. Mathematics, as a 'science of rigorous proof', provides those who are seeking for knowledge with a sense of certainty.
2. While mathematical knowledge is derived logically by proving and deriving theorems, mathematicians consider some proofs to be more beautiful than others.
3. More practically, mathematics has been seen as useful to society and will continue to stay relevant despite our advancement and progress.

Essential Questions

1. What is mathematical knowledge?
2. How does mathematics impact human society and our way of thinking?

Reading 14: Mathematics – Certainty and reliability **EU1**

Adapted excerpt from "Theory of Knowledge" by Richard van de Lagemaat

This reading will help you to understand that:

- Mathematics is useful as it provides a sense of certainty to people; it is a prerequisite to a career in the sciences and it allows us to prove an idea beyond a shadow of a doubt in most cases.
- While mathematics may be seen as a body of knowledge that possesses some element of certainty, newfound knowledge can prove older axioms irrelevant (as with Riemannian geometry).
- Some problems with mathematics include the fact that it is operating at an overly abstract level and thus, it has no meaning in the real world.

Mathematics is a subject that seems to charm and alarm people in equal measure. If someone asks you, 'What are you most certain of in the world?' you might reply, '2+2=4'. Surely no one can doubt that! ***Mathematics seems to be an island of certainty in a vast ocean of doubt***.

At the most general level, we might characterize mathematics as the ***search for abstract patterns***. And such patterns turn up everywhere. When you think about it, there is something extraordinary about that fact that, for anything you care to name, if you take two of that thing and add two more of that thing you end up with four of that thing. Similarly, if you take any circle – no matter how big or small – and divide its circumference by its diameter, you always end up with the same number – pi (roughly 3.14).

The fact that there seems to be an underlying order in things might explain why ***mathematics not only seems to give us certainty, but is also of enormous practical value***. At the beginning of the scientific revolution, Galileo (1564-1642) said that the book of nature is written in the language of mathematics. If anything, mathematics is even more important that it was in the seventeenth century, and mathematical literacy is a ***prerequisite for a successful career in almost any branch of science***.

The certainty and usefulness of mathematics may help to explain its enduring appeal. The mathematician and philosopher Bertrand Russell (1872 – 1970) recalled how he began studying geometry at the age of eleven: 'This was one of the great events of my life, as dazzling as first love. I had not imagined that there was anything so delicious in the world.' Russell's description would be greeted with blank incomprehension in some quarters. For many people, words such as 'love' and 'delicious' simply do not go with the words 'mathematics'. Mathematics may give some a reassuring feeling of certainty, but ***others find it threatening precisely because it leaves us with no place to hide***. If you make mistake in a maths problem you can be shown to be wrong. You can't say it's 'an interesting interpretation', or 'an original way of looking at it', or 'it all depends on what you mean by…' You're just wrong!

Mathematical thinking also requires a kind of selective attention to things; for you have to ***ignore context and operate at a purely abstract level***. While some people find the resulting abstraction fascinating, ***others can find little meaning in them***. The very success of mathematics has sometimes bred a kind of 'imperialism' which says that if you can't express something in mathematical symbols then it has no intellectual value.

A good definition of mathematic is 'the science of ***rigorous proof***'. Although some earlier cultures developed a 'cookbook mathematics' of useful recipes for solving practical problems, the idea of mathematics as the science of proof dates back only as far as the Greeks. The most famous of the

Greek mathematicians was Euclid who lived in Alexandria, Egypt, around 300 BCE. He was the first person to organize geometry into a rigorous body of knowledge, and his ideas have had an enduring influence on civilization. The model of reasoning developed by Euclid is known as a formal system and it has three elements: axioms, deductive reasoning and theorems. When you reason formally, you begin with axioms, use deductive reasoning, and derive theorems. That latter can then be used as a basis for reasoning further and deriving more complex theorems.

Axioms

The axioms of a system are its starting points or basic assumptions. At least until the nineteenth century, the axioms of mathematics were considered to be ***self-evident truths*** which provided firm foundations for mathematical knowledge. If you tried to prove an axiom, you would get caught in an ***infinite regress*** – endless chain of reasoning – proving A in terms of B, and B in terms of C and so on forever. We have to start somewhere, and there is surely no better place than with what seems to be obvious.

There are four traditional requirements for a set of axioms. They should be consistent, independent, simple and fruitful.

Starting with a few basic definitions – such as a point is that which has no part, and a line has length but no breadth – Euclid postulated the following axioms:

1. It shall be possible to draw a straight line joining any two points.
2. A finite straight line may be extended without limit in either direction.
3. It shall be possible to draw a circle with a given centre and through a given point.
4. All right angles are equal to one another.
5. There is just one straight line through a given point which is parallel to a given line.

Deductive reasoning

1. All human beings are mortal.
2. Socrates is a human being.
3. Therefore Socrates is mortal.

(1) and (2) are premises and (3) is the conclusion of the argument; and if (1) and (2) are true, then (3) is necessarily true. In mathematics, axioms are like premises, and theorems are like conclusions.

Theorems

Using his five axioms and deductive reasoning, Euclid derived various theorems, such as:

a. Lines perpendicular to the same line are parallel.
b. Two straight lines do not enclose an area.
c. The sum of the angles of a triangle is 180 degrees.
d. The angles on a straight line add up to 180 degrees.

Such simple theorems can then be used to construct more complex proofs.

Euclidean geometry was for many centuries seen as a model of knowledge because it seemed to be a both certain and informative. There was, however, one small problem. The certainty of geometry was supposed to be guaranteed by the fact that one began with self-evident axioms and used deductive reason to derive theorems. However, one of Euclid's axioms, the axiom of parallels – which says that there is just one straight line through a given point which is parallel to a given line – struck people as being ***less self-evident*** than the other axioms. This doubt may have arisen from the fact that parallel lines are by definition lines that never meet even if you extend them to infinity – but who is to say what happens at infinity? Since mathematicians wished to get rid of all possible

doubt, they expended a great deal of energy over the centuries in trying to demonstrate that the axiom of parallels was in fact a theorem. But no one succeeded in doing this.

Then in the nineteenth century, a mathematician called Georg Friedrich Bernard Riemann (1822 – 1866) came up with the clever idea of replacing some of Euclid's axioms with their contraries. Most people thought that if you based a system of geometry on non-Euclidean axioms, the system would lead to a contradiction and so collapse. This would then show that Euclid's axioms were in fact the only possible ones. However, to people's amazement, no contradictions turned up in Riemann's system.

Riemann's axioms differed from Euclid's as follows:

A. Two points may determine more than one line (instead of axiom 1).
B. All lines are finite in length but endless – i.e. circles (instead of axiom 2).
C. There are no parallel lines (instead of axiom 5).

Among the theorems that can be deduced from these axioms are:

1. All perpendiculars to a straight line meet at one point.
2. Two straight lines enclose an area.
3. The sum of the angles of any triangle is greater than 180 degrees.

These theorems sound pretty strange. How can perpendiculars possibly meet a point, or two straight lines enclose an area, or the angles of a triangle sum to more than 180 degrees? Fortunately, we can give intuitive sense to Riemannian geometry by imagining that space is like the surface of a sphere. Since we live on the surface of a sphere (more or less), this should not be too difficult to do!

The key to making sense of Riemann's system is to think about what a straight line will look like on the surface of sphere. What is a straight line? The shortest distance between two points! Now, on the surface of a sphere, it can be shown that the shortest distance between two points is always an arc of a circle whose centre is the centre of the sphere. Such 'great circles' include not only all lines of longitude, but an endless number of other circles. What this means is that, in Riemannian geometry, a straight line will appear curved when it is represented on a two-dimensional map. To illustrate this point, look at any airline flight map. Although the flight paths look curved, since airless are in the business of making money, you can be sure that in reality they always take the shortest route to their destination.

In sum, although mathematics cannot give us absolute certainty, it continues to play a key role in a wide variety of subjects ranging from physics to economics, and there is something surprising and mysterious about its extraordinary usefulness. Nevertheless, it is important to keep in mind that we ***cannot capture everything*** in the abstract map of mathematics and, despite its value, there is no reason to believe that it is the only, or always the best, tool for making sense of reality.

For discussion:

1. To what extent is a study of mathematics beneficial to people?
2. To what extent do you think governments should fund 'useless' research in pure mathematics?
3. What role do statistics play in History and the social sciences?

Reading 15: Why Mathematics is Beautiful and Why It Matters **EU2**

Adapted from an article by David H. Bailey & Jonathan M. Borwein (Huffington Post, 18 Feb 2014)

This reading will help you to understand that:

- The beauty and elegance of mathematics is derived from the following reasons: its ability to derive simplicity from complexity, its ability to express ideas showing our mastery over reality etc.
- Such a form of 'art' is, however, often seen as inaccessible.
- Given that basing mathematical education on utility and importance has not worked very wel, perhaps introducing the aesthetic in mathematics is needed.

Scientists through the ages have noted, often with some astonishment, not only the remarkable success of mathematics in describing the natural world, but also the fact that the best mathematical formulations are usually those that are the most beautiful. And almost all research mathematicians pepper their description of important mathematical work with terms like "unexpected", "elegance", "simplicity" and "beauty".

Some selected opinions

British mathematician G. H. Hardy (1877-1947) expressed in his autobiographical book *A Mathematician's Apology* what most working mathematicians experience: "*Beauty is the first test; there is no permanent place in the world for ugly mathematics*".

Mathematician-turned-philosopher Bertrand Russell (1872-1970) added that "[m]athematics, rightly viewed, possesses not only truth, but supreme beauty – a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show".

Henri Poincaré (1854-1912), often described as a "polymath," wrote, in his essay "Mathematical Creation", that ignoring this subjective experience "*would be to forget the feeling of mathematical beauty, of the harmony of numbers and forms, of geometric elegance. This is a true aesthetic feeling that all real mathematicians know, and surely it belongs to emotional sensibility*".

While a very few applied mathematicians view such ideas as a waste of time, the mathematics community is almost unanimous in agreeing with Poincare.

Physicists are just as impressed by the beauty of mathematics, and by its efficacy in formulating the laws of physics, as are mathematicians. Mathematical physicist, Hermann Weyl (1885-1955) declared, "*My work always tried to unite the truth with the beautiful, but when I had to choose one or the other, I usually chose the beautiful".* This was fully reflected in his own career, when he first attempted to reconcile electromagnetism with relativity.

His work was initially rejected (by Einstein and others), because it was thought to conflict with experimental results, but the subsequent formulation of quantum mechanics led to a renewed

acceptance of Weyl's work. In other words, the "beauty" of Weyl's work anticipated its final acceptance, well before the full scientific facts were known.

Nobel physicist Paul Dirac (1902-1984), shown below and described by Niels Bohr as the strangest man, made his most impressive discoveries or predictions, such as that of the positron, largely from demanding elegant, simple mathematical descriptions. He further elaborated on mathematical beauty in physics in these terms: "[The success of mathematical reasoning in physics] must be ascribed to some mathematical quality in Nature, a quality which the casual observer of Nature would not suspect, but which nevertheless plays an important role in Nature's scheme".

What makes the theory of relativity so acceptable to physicists in spite of its going against the principle of simplicity is its great mathematical beauty. This is a quality which cannot be defined, any more than beauty in art can be defined, but which people who study mathematics usually have no difficulty in appreciating. The theory of relativity introduced mathematical beauty to an unprecedented extent into the description of Nature.

Why is this so?

In February 2014, a team of British researchers, including two neurobiologists, a physicist and a mathematician, published a ground-breaking study[9] in *Frontiers in Human Neuroscience* on the human experience of mathematical beauty.

These researchers employed functional magnetic resonance imaging (fMRI) to display the activity of brains of 16 mathematicians, at a postgraduate or postdoctoral level, as they viewed formulas that they had previously judged as beautiful, so-so or ugly. The results of this analysis showed that beautiful formulas stimulated activity in same field, namely field A1 of the medial orbito-frontal cortex (mOFC), as other researchers have identified as the seat of experience of beauty from other sources.

This is an entirely satisfactory result. It gives an experimental validation of the mathematicians' intuition that they are experiencing the same qualitative states (qualia) as are experienced in other modalities from architecture and sculpture, to poetry and music.

So what exactly is the source of mathematical beauty? All aesthetic responses seem in part to come from ***identifying simplicity in complexity, pattern in chaos, structure in stasis***. In the arts, "beauty" can be accounted for, at least in part, by well-understood harmonies, distributions of colours or other factors.

But what about mathematics? Aesthetic responses, as Santayana in *The Sense of Beauty* (1896) has argued, require a certain distance:

> "When we have before us a fine map, in which the line of the coast, now rocky, now sandy, is clearly indicated, together with the winding of the rivers, the elevations of the land, and the distribution of the population, we have the simultaneous suggestion of so many facts, ***the sense of mastery over so much reality***, that we gaze at it with delight, and ***need no practical***

[9] *This study is summarised in a BBC Science report http://www.bbc.com/news/science-environment-26151062*

motive to keep us studying it, perhaps for hours altogether. A map is not naturally thought of as an aesthetic object... And yet, let the tints of it be a little subtle, let the lines be a little delicate, and the masses of the land and sea somewhat balanced, and we really have a beautiful thing; a thing the charm of which consists almost entirely in its meaning, but which nevertheless pleases us in the same way as a picture or a graphic symbol might please. Give the symbol a little intrinsic worth of form, line and colour, and it attracts like a magnet all the values of things it is known to symbolize. ***It becomes beautiful in its expressiveness***".

This captures the aesthetic in mathematics: ***balancing form and content, syntax and semantics, utility and autonomy***.

Why it matters

As *The Economist* puts it, in a fine essay on the changing notion of mathematical proof, "Proof and Beauty" (2005): "Why should the non-mathematician care about things of this nature? The foremost reason is that mathematics is beautiful, even if it is, sadly, ***more inaccessible than other forms of art***. The second is that it is useful, and that its utility depends in part on its certainty, and that that certainty cannot come without a notion of proof".

Some argue that mathematical principles are experienced as "beautiful" because they ***point directly to the fundamental structure of the universe***. Physicist Max Tegmark argues further that the reason that mathematics works so well, and so elegantly, in physics is because the universe (or, more properly, the multiverse) is, ultimately, just mathematics – mathematical structures and the relations that connect them constitute the ultimate irreducible "stuff" of which our world is made.

Few researchers are willing to go as far as Tegmark. But the widely sensed experiences of mathematical beauty, and the astonishing applicability of sophisticated mathematics in the natural world, still beg to be fully understood.

Understood or not, tapping the aesthetic component of mathematics is a crucial and neglected component of mathematical education. ***Given that basing mathematical education on utility and importance has not worked very well, perhaps introducing the aesthetic is past overdue***.

For discussion:

1. The author implies that introducing the beauty of mathematics in education is important. Do you agree?

2. Mathematics lacks the capacity for creativity. Do you agree?

Reading 16: Mathematics and Its Impact on Society **EU3**

Adapted from Richard Elwes's Maths in 100 key breakthroughs

This reading will help you to understand that:
1. Mathematics has made a huge impact on our human civilisation.
2. The need for mathematics is becoming ever greater with new developments in science emerging from the 20th and 21st centuries.

Mathematics is a timeless subject. While historians study the peculiarities of place and era, and artistic tastes vary from culture to culture and person-to-person, no matter whether you are an ancient Babylonian Shepherd or a 21st-century computer programmer, 1+1 is always equal to 2. The same can be said of many branches of science, of course. After all, human anatomy has changed little within the last few thousand years and gravity is nearly the same at every point on the surface of the Earth. Yet the fixedness of mathematical truths runs even deeper. If extraterrestrial life exists, its biology will surely differ from that on Earth. We can even imagine other universes in which the laws of physics are fundamentally different, yet internally consistent. But it is harder to conceive of a world where 1+1 equal 3. Mathematics is not only true, but seems inevitably, necessarily true.

Of course, our ancestors did not emerge from the primeval swamp with a mastery of numbers. Discoveries are made at certain historical junctures; new techniques are invented by specific people. This is even true for the starting point of the whole subject: counting. That ability, too, emerged at a particular stage in our evolutionary history.

So how does mathematics progress? The stereotypical picture is of a solitary scholar whose outrageous genius concocts some dramatic discovery out of the blue. But this caricature overlooks the collaborative and incremental nature of the subject. As even the notoriously self-absorbed Isaac Newton admitted, 'If I have seen further it is by standing on the shoulders of Giants.'

Many of the breakthroughs in mathematics do indeed involve the hard work and insight of a few dazzling individuals. Even so, very few emerged fully formed from nowhere but instead built on the ideas off earlier thinkers. I believe it is better to see every development as a milestone on a longer road.

There have been several periods when mathematics has flourished: the Pythagorean cult of ancient Greece imbued the subject with a mystical importance. The Indian School of astronomy laid the foundation for the numerical system we know today. The Arabic translators of the house of Wisdom gathered the world's mathematical knowledge into one supreme collection. The European enlightenment opened up new avenues of research and led to a panoply of practical applications. All of these have claims to be golden ages of mathematics. But so too does the era in which we currently live.

The expansion of schools and universities around the world, the invention of the computer and the subsequent growth of the Internet have all played a role in revolutionising the subject's culture. Today's mathematicians are armed with sophisticated tools for research, as well as for teaching and disseminating their work. What is more, the subject is now truly global, and the mathematical

community larger than ever, allowing people with common interests to communicate and collaborate more efficiently than ever before.

At the same time, the need for mathematics is becoming ever greater with the development of relativity and quantum theory in the early 20th century, our understanding of the physical universe reached a point where fluency in the language of advanced mathematics became an essential prerequisite to prove the deeper levels of reality. The same is true in other walks of life with so much data gathered by businesses and governments, experts in probability, statistics and risk are constantly in high demand. Another burgeoning industry is computer science, a subject which emerged from Alan Turing and others' work in mathematical logic in the early 20th century. The deepest questions here are still mathematical in nature: ultimately, what are computers capable of achieving? And what will they never do?

So, the golden age of mathematics is today. My predictions are: ever more aspects of science and society will be illuminated by mathematics, as more and more nominally 'pure' branches of the subject find unexpected practical applications, further blurring the boundaries between mathematics, physics, computer science and other areas of enquiry. Meanwhile, a stack of problems previously judged impossibly hard will quickly be proved by techniques as yet undreamt of. Yet, through all this progress, an embarrassing number of easy to state, seemingly obvious conjectures will still defy all attempts at solution, luring in new generations of thinkers to grapple with them.

For discussion:

1. Do you think our society has benefited from the study of mathematics?

2. Has our society placed too much faith in this area of knowledge?

Essay questions:

1. Can mathematics be seen as anything more than a useful tool in everyday life? (Cambridge 2010)

2. How far has modern technology made it unnecessary for individuals to possess mathematical skills? (Cambridge 2016)