

## REAL-WORLD EXAMPLE

### Algorithms used by the police and courts

In 2020 the *Harvard Gazette* reported on the use of algorithms by the US government. There were approximately 2.2 million adults in prison in the US in 2016. With increased pressure to reduce these numbers, police departments used predictive algorithms to help decide where to locate police personnel on the streets. At the same time, courtrooms were using criminal risk assessment algorithms to determine the length of prison sentences. This algorithm created a score for each defendant based on their profile and likelihood

of reoffending. However, criminals from low-income and minority communities were at risk of having higher scores because historically they came from areas with a disproportionately higher number of court cases. This led to less-favourable sentencing. In a different case, one court sentenced a man to 18 months in jail because the algorithm placed a greater weighting on his age. If he had been older, he would have had a much shorter sentence.

<https://news.harvard.edu/gazette/story/2020/10/ethical-concerns-mount-as-ai-takes-bigger-decision-making-role>

As we can see from the example, there are real concerns about how much we should rely on algorithms for making judgements. The main problem is that many algorithms make judgements based on the bias that already exists in society. Since machine learning algorithms are learning from data sets using historical data, it is not surprising that these algorithms adopted the same level of bias that was present with previous human judgements.

## ATL ACTIVITY

### Thinking

Formulate a reasoned argument to support your opinion about the use of algorithms to replace human judgements.

- Conduct wider research to find two more examples of how algorithms are being used.
- Use this research to write a paragraph about algorithms replacing human judgements.
- The paragraph should include your opinion, which should be supported by clearly written arguments with real-life examples.

## Algorithmic bias

There are two main reasons why artificial intelligence systems have built-in bias:

- 1 Human algorithm developers unknowingly introduce bias into their models.
- 2 The training data set includes biased data or is incomplete, so it is not a true representation of the population.

## REAL-WORLD EXAMPLE

### Bias in algorithms

A study published in 2020 found that the algorithm used to determine the health of a patient's kidney function used race as one of the factors. Of the 57,000 medical records reviewed in Massachusetts, one-third of the black patients would have had their disease classified as more severe if the formula used for white patients had been applied.

[www.wired.com/story/new-formula-help-black-patients-access-kidney-care](http://www.wired.com/story/new-formula-help-black-patients-access-kidney-care)

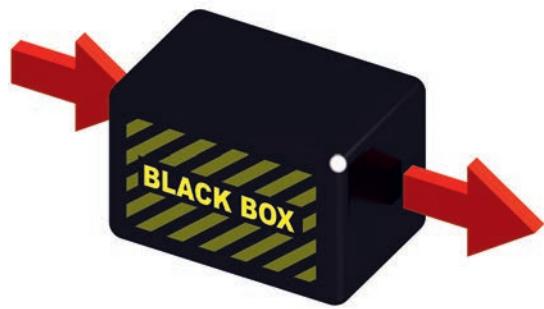
## Black box algorithms and the lack of transparency

Many of today's algorithms are often considered to be **black box algorithms**. In artificial intelligence this is when insights are made but it is not clear how the algorithm came to reach the conclusion from the data input. People are generally aware that algorithms are influencing the world they live in, yet don't know what they are or how they work.

Since artificial intelligence algorithms can learn from experience and improve over time, it is very difficult to know how they are making decisions. As artificial intelligence becomes increasingly sophisticated with developments in deep learning, programmers have less control over how artificial intelligence learning evolves. This creates issues around who is responsible when the algorithm does not perform as expected. Who is to blame? Is it the programmer or the data scientist?

With highly regulated industries such as health care and financial services, **transparency in algorithms** is important. People in these industries are held accountable for the decisions being made by artificial intelligence systems. This can be problematic, however, because:

- it is often difficult to explain how the algorithm reached its conclusion
- it is not always possible to know how the training data was selected
- the evolving nature of machine learning makes it difficult to keep up.



### ◆ Black box

**algorithm:** An algorithm that provides insight without clarity on how the conclusions were reached from the data input.

### ◆ Transparency in

**algorithms:** the ability to understand and be able to explain the inner workings of the algorithm.

### REAL-WORLD EXAMPLE

#### Black box algorithms: Object detection systems in autonomous vehicles

'Predictive inequity in object detection', an academic paper written by a group of researchers at the Georgia Institute of Technology, highlighted that the deep learning computer vision model found it difficult to detect people with dark skin. If used in autonomous vehicles, it would unlikely detect a pedestrian crossing the road if they had darker skin. Due to the nature of the black box algorithms, it made it much harder for developers to go back and correct the algorithm.

### REAL-WORLD EXAMPLE

#### Black box algorithms: Deep Patient software

In 2015, a research group trained their Deep Patient software to discover patterns hidden in hospital data to predict if a patient was likely to develop medical problems. It was particularly good at predicting psychiatric disorders, which were often difficult for human doctors to foresee. However, because of its black box nature and lack of transparency, doctors were very resistant to using it.

### Top tips

The dilemmas found in this chapter are closely linked to many of the dilemmas in artificial intelligence, robotics and autonomous technologies.

## Inquiry

In this inquiry we will focus on only two of the stages. After your initial research, use the guiding questions for each stage to help you complete the activity.

### 3.2E Algorithmic dilemmas (content) and 2.6 Systems (concepts)

**Inquiry focus:** How have the use of black box algorithms resulted in unintended consequences for a digital society?

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

- Use your research skills to find three sources to further your understanding of this question.
- Your final choice of sources must be able to help you gain a deeper understanding of this topic, provide a balance of claims and perspectives, and be embedded in the content (algorithms) and concept (systems).
- Write a short report to justify your chosen sources and their usefulness in this inquiry. Your report should include:
  - a discussion on the origin and purpose of each source, including any potential bias or limitations of using the source
  - a discussion of the main ideas being presented in each source and what features of the source were used to support the claim being made
  - a discussion on how the sources corroborate or contradict, and how it has helped you gain a deeper understanding of this question
  - a bibliography entry for each source at the end of the report.

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

How has the use of black box algorithms in one real-life scenario resulted in unintended consequences for a digital society?

Analyse the inquiry focus using the perspective of systems by answering these questions:

- Describe the components of the digital system for the selected real-world scenario that uses a black box algorithm.
- Explain how the different components of the digital system interact with each other and the people and communities using it. Use a diagram to support your explanation.
- In what ways have black box algorithms changed the human/built/natural systems that are related to the real-life example. Are they evolutionary, adaptive, transformational or radical?
- Evaluate the intended and unintended consequences of the specific use of this black box algorithm?
- How has the use of black box algorithms made it possible for developers and users to fully understand the connections between the components of the digital system?
- In your opinion, are digital systems and devices becoming too big and complex to understand?



## Activity: HL Extended Inquiry



Once you have studied Section 5.1, complete this inquiry activity.

### 3.2E Algorithmic dilemmas (content) and 5.1 Global well-being

**Inquiry focus:** How is algorithmic bias contributing to global inequality?

Research and describe the global challenge:

- Use effective research skills and identify one example where algorithmic bias is contributing to global inequality.
- Describe the challenge in detail.

Research and evaluate one intervention for this challenge:

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.



## Activity: HL Extended Inquiry



Once you have studied Section 5.2, complete this inquiry activity.

### 3.2E Algorithmic dilemmas (content) and 5.2 Governance and human rights

**Challenge:** An algorithm was developed to predict which patient would need extra medical care. The algorithm favoured white patients over black patients because they had used historic data on patient health care spending and made faulty assumptions based on the correlation between income and race.

**Inquiry focus:** To what extent is algorithmic bias reinforcing racial and ethnic discrimination?

Research and describe the global challenge:

- Use effective research skills to find out more about the global challenge of algorithmic bias and racial/ethnic discrimination.
- Describe the challenge in detail.

Research and evaluate one intervention for this challenge:

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.



## Creativity, activity, service (CAS)

### User guide for CAS

As a service for the CAS coordinator, use the knowledge gained about algorithms in this unit to develop a step-by-step guide for IB students on how to document CAS at school.

- Use your knowledge about the characteristics of an algorithm and ways of representing algorithms to analyse the system in place at your school.
- Discuss the choice of digital media to use with the CAS coordinator.
- Select suitable software to create the guide and distribute it to students.

## TOK

### Knowledge and technology

Digital technology is changing the way we know things. Is it helping or hindering our cognition? One may start to question the ethical limits that should be put in place during the process of acquiring knowledge, especially the use of algorithms by IT systems. Can the use of algorithms to predict behavioural traits ever be free from human bias?

## Reflection

Now that you have read this chapter, reflect on these questions:

- Could you explain the characteristics and different components of an algorithm?
- Compare the different ways algorithms can be represented? When is each of these ways used in real life?
- Could you explain the different types of algorithms and when they are used in a range of contexts?
- What is the relationship between data (3.1), algorithms (3.2) and artificial intelligence (3.6)?
- What are the main causes of bias in an algorithm, and what solutions are there to resolve this?
- To what extent should society allow algorithms to replace human decision-making?
- How have the dilemmas in algorithms created intentional and unintentional outcomes for society?
- How have algorithms created human rights challenges in society, and how are they becoming interventions for these challenges?
- How is bias in today's algorithms changing what we know about the world?



## Extended essay (EE)

The uses of algorithms and the dilemmas that they raise may generate some initial ideas for an extended essay topic.

## Learner profile

### Inquirers

Inquirers conduct wider research into different claims and perspectives to check for possible algorithmic bias.

# 3.3

# Computing devices

## UNDERSTANDINGS

By the end of this chapter, you should understand:

- ▶ a computer is a machine that automatically executes sets of instructions to perform specific tasks
- ▶ computers have evolved over time and are increasingly ubiquitous in the everyday life of people and communities.

The term computer is widely understood and recognizable. Ask anyone and they will direct you to the personal computer sitting on an office desk or a mobile device in your school bag. However, what makes a computer a computer? Who is using computers and for what purpose? How has this changed over time? What is coming next in computing?

## ATL ACTIVITY

### Thinking

Complete this reflection activity:

- Look around the room – identify all the different computers, whether it is the laptop you are working on or the watch you are wearing.
- Think about all the different computers that you have interacted with over the last week. List them and write one sentence for each on how it has impacted your life.
- What do you know so far about the different components inside a computer? Have you ever opened a desktop computer or a tablet? What can you see inside? How many components can you list?

## 3.3A Types of computers

**Computers** come in all shapes and sizes so, to start off this unit, we will look at the different types of computers.

### ■ Embedded computers

Embedded computers can be found everywhere. Simply put, an **embedded computer** is a combination of hardware and software designed to perform a specific task and incorporated into an electronic or mechanical system. For example, computers are embedded into household appliances such as washing machines, microwave ovens, video consoles and digital cameras. Embedded computers are designed to withstand the specific environment that they are being used in. For example, an embedded computer in a car would be durable and able to cope with the heat of the engine.

### ■ Personal computers

Computers are all around us in one form or another, come in all shapes and sizes and for a wide range of purposes. You are probably most familiar with computers that you interact with daily. For example, a **personal computer (PC)** was designed for individual use and entered the home market in the early 1980s. The desktop computer – consisting of a system unit, monitor, keyboard and

#### ◆ Computer:

A machine or device that processes data, performs calculations and conducts operations based on algorithms provided by software and hardware programs; it can input data, process it, store it and produce an output.

#### ◆ Embedded computer:

A combination of hardware and software designed to perform a specific task and incorporated into an electronic or mechanical system.

#### ◆ Personal computer (PC):

A general purpose computer designed for individual use.

mouse – was the first type of personal computer. Today, they are less common in the home but still popular in the corporate world as they are easier to customize and upgrade, and make it harder for corporate data to ‘walk out of the door’.

In January 2003, Steve Jobs announced, ‘This is going to be the year of the **notebook** for Apple.’ By July 2005, laptop sales had exceeded those of desktop computers. Although laptops were still widely used in 2010, **tablets** began to increase in popularity. High-quality tablets, such as Apple’s iPad, filled the gap between laptop and mobile phone. Although **smart/mobile devices** are the fourth device on our list, this is not based on when they were introduced but on their size. Many mobile devices have location services and use GPS, which adds additional functionality and mapping applications, however, they are limited by their lower processing power and battery life.

As **Moore’s Law** has been applied to microprocessors, RAM and storage, laptops today are almost as powerful as desktop computers, and have the additional benefits of portability and convenience.

The smallest of device that we will discuss in this chapter is the **wearable computer**. Although wearables are not new, they have been transformed over time. For example, wearable technology was popular in 1975 with the introduction of the first calculator watch – but fast-forward nearly 40 years to the launch of Google Glass in 2013, Apple Watch in 2015 and the Oculus Rift VR Headset in 2016. Today health/fitness watches are widely used both to track fitness and monitor chronic diseases such as diabetes.



◆ **Moore’s Law:** The number of transistors in a dense integrated circuit doubles every two years.

## Links

This content links to ergonomic design in 4.4B The human body.

## Top tips

There are many different types of computers and they are used in a wide range of contexts. Although these computers may look very different, remember that they often have the same basic components and perform the same basic tasks: to input, process, store and output.

## Inquiry

### 3.3A Types of computers (content) and 4.1 Cultural (contexts)

In this inquiry we will focus on the Analyse stage of the inquiry focus. Before attempting this inquiry make sure you have read Section 4.1 – Culture. Conduct research and use the guiding questions to help complete the activity.

**Inquiry Focus:** Wearable technology is making its way into the leisure industry.

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

- Research one example of smart clothing being used in the leisure industry, for example, smart yoga pants.
- Describe the technology.
- Discuss the positive and negative impacts of this technology on two stakeholders.

## EXAM PRACTICE QUESTIONS



### Paper 2

#### Source A

Analyse the following statistics which shows the trends in the use of the different types of computers to access the internet between 2019 and 2020.

	2019: 37.5 trillion visits			2020: 30.2 trillion visits		
	Desktop	Mobile	Tablet	Desktop	Mobile	Tablet
Visits	32%	63%	5%	29%	38%	3%
Bounce rate	43.11%	53.49%	46.64%	41.69%	52.11%	46.82%
Page views per visitor	3.75	2.68	3.40	3.95	2.67	3.21
Average time on site (seconds)	313.99	154.37	227.03	351.54	160.13	237.13

Source: [www.perficient.com/insights/research-hub/mobile-vs-desktop-usage](http://www.perficient.com/insights/research-hub/mobile-vs-desktop-usage)

- 1 Explain two trends in the use of desktop, mobile and tablet devices when used to access the internet. [4 marks]

### Learner profile

#### Reflective

Reflect on the way that computers have evolved in your lifetime. How do these technologies influence your day-to-day living?

### Mainframe computers and servers

When someone talks about a **mainframe** computer, it often creates visions of James Bond movies and rooms in government buildings filled floor-to-ceiling with technology. Nowadays the term mainframe computing generally refers to commercial **servers**, with the mainframe being the largest of these. Mainframes can serve thousands of users and support just as many applications and devices simultaneously.

Many medium-to-large-scale businesses use a collection of servers, each performing different functions on the network. For example, a business may have a print server, a database server, an email server, a web server and a file server. Very large collections of servers are called server farms and some data centres cover huge areas.



■ Mainframe computer, National Museum of Computing, Bletchley



■ A server room

◆ **Mainframe:** A large computer used by businesses to host databases, servers used for transactions and business applications. Mainframe computers require high-level security measures.

◆ **Server:** A large computer dedicated to managing network resources. They can use specialized server hardware or can be a regular computer with a server-specific operating system capable of managing network resources.

## ATL ACTIVITY

### Research

Conduct effective primary research by carrying out an interview with a member of the IT staff at your school.

- Before holding the interview, plan out the questions you would like to ask.
- Write at least five open-ended questions.
- Try finding out:
  - the different types of devices on the school network
  - what servers the school has and their functions
  - where the servers are hosted (for example, in the cloud or on the premises)
  - what operating systems are being used by the school servers
  - which applications are being used by the school.
- Record the interview as an audio file.
- Create a short podcast of the interview.

## REAL-WORLD EXAMPLE

### Microsoft's underwater data centre

In 2018, Microsoft launched Project Natick – a data centre 117-feet deep undersea data centre near the Orkney Islands in Scotland. Data centres positioned on the seabed benefit from the cool temperatures, which make them more energy efficient. Microsoft found that the data centre was eight times more reliable than those they had installed on land.

## Activity: HL Extended Inquiry



Once you have studied Section 5.3B, try out this inquiry.

### 3.3A Types of computers (content) and 5.3B Responsible use of resources

**Challenge:** Capgemini reported that their data centres use approximately 200-terawatt hours (TWh) every year. This is higher than the annual consumption of energy of some countries. Data centres alone contribute to approximately 0.3% of overall carbon emissions. Information and communications technology (ICT) systems create more than 2% of carbon emissions worldwide.

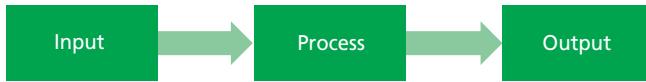
**Inquiry focus:** How are companies addressing environmental factors and sustainability when designing data centres?

Research and evaluate one intervention for this challenge:

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.
- Present your work in the form of a written report.

## 3.3B Components of a computer

All modern computers function on the same model:



- A computer system needs to be able to input data. This is done using an **input device**. Common examples of input devices include keyboards, mice, touchscreens, microphones and sensors.
- Once data has been input, it needs to be processed. This takes place within the **central processing unit (CPU)**, which is sometimes referred to as the microprocessor.
- The output is the outcome once the processing is complete. For this to happen, there must be an **output device**. Common output devices include monitors, screens, printers, speakers and LED lights.

### Hardware

If we look closer inside a computer, there are many common components, each performing a different role.

The **motherboard** is the circuit board that allows data to travel to the different components. The CPU is considered the main brains of the computer and carries out and controls the computer's instructions. Their performance can be affected by three main factors:

- **Clock speed**, measured in hertz, which represents the number of pulses the CPU clock generates per second.
- **Cache**, a small amount of memory built into the CPU; it stores data temporarily while it is being processed.
- The number of **cores** a CPU has: the more cores there are, the faster the CPU can process data; many processors have quad (four) core processors.

Data is not always immediately sent for output – often it is stored in the memory. **RAM (Random Access Memory)** is the short-term memory where data is stored temporarily while it is being processed or viewed on screen. It may be held more permanently in **secondary storage**, such as on a hard disk drive (HDD) or solid-state storage device (SSD).

Some motherboards come with built-in **sound and graphic cards**. Users who play games with high-quality graphics or use video editing software will want to take special note of these specifications and may upgrade their desktop computer with additional graphic and sound cards. The graphics processing unit (GPU) contains a circuit that will speed up the rendering of images and video, and thus free up the CPU to perform other tasks.

◆ **Central processing unit (CPU)**: The part of a computer that carries out and controls the computer's instructions.

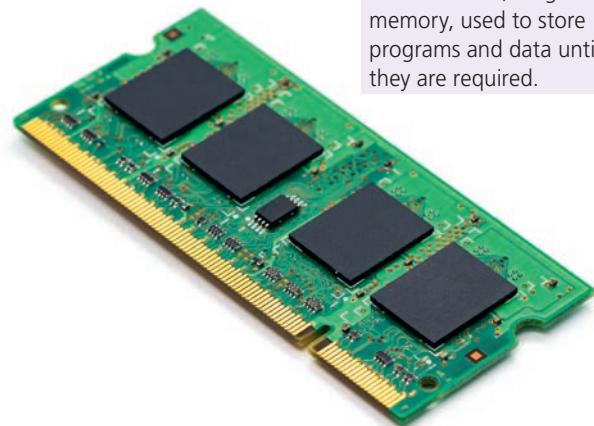
◆ **Motherboard**: A circuit board that allows data to travel to the different components in a computer.

◆ **Cache**: The small amount of memory built into the CPU that stores data while it is being processed.

◆ **RAM (Random Access Memory)**: Short-term memory where data is stored temporarily while it is being processed or viewed on screen.



■ CPU chip



■ RAM

◆ **Secondary storage**: is non-volatile, long-term memory, used to store programs and data until they are required.

**Power** is essential for any computer to work, whether the device is plugged directly into a power source or uses a battery. Personal computers have built-in power supplies. These convert AC (alternating current) to DC (direct current), which supplies the computer and its components with the right amount of voltage. Different countries use different voltages, so it is important to have the right power adapter when travelling with your computer.

Most laptops and phones use **lithium-ion batteries**, which are small containers of chemical energy. When a phone is plugged in to charge, the electricity is used to reset a chemical reaction within the battery. Lithium batteries contain a lot of power in a small size, which has made them suitable for portable devices.

### ATL ACTIVITY

#### Communication

Create a video presentation to explain the different components of a computer.

- Investigate the role that the different components (motherboard, CPU, memory, storage, graphics and sound components, power supply) have when the computer is performing a task.
- Create a video to explain what the role of each of these components is and how they work together.
- Use the video you created to explain your understanding of these technologies to one of your classmates.

### Software



Up until now we have only talked about the hardware (the different physical components) that a computer is made up of, however, these are only useful when used with software. There are different types of software including the operating system, utility software and application software.

The **operating system** is the software on a computer that manages the hardware, software and memory, as well as providing a user interface. Popular operating systems include Microsoft Windows, Linux, Apple MacOS, Google's Android OS and Apple iOS.

The **user interface** allows the user to interact with the device. This maybe via a **graphical user interface (GUI)**, which allows the user to select icons or click on links, such as those used on a tablet or phone; or it may be voice activated, such as those found in 'virtual assistants' such as Amazon's Alexa. It could also be a **haptic interface**, which allows the user to interact with a device through bodily sensations and movements. Commonly used in virtual reality, a haptic interface uses built-in sensors that send electrical signals to the computer. Once processed, it sends a signal back to the human. For example, in a virtual racing game a user may use a data glove and, while driving the car, receive vibrations similar to that experienced when driving a real car.

#### ♦ Operating system:

Software that manages the hardware, software and memory of a computer as well as providing a user interface.

♦ **User interface:** The means by which human users interact with a digital technology. The intent is to make the user's experience straightforward, intuitive, and requiring minimum effort to achieve the desired outcome.

One of the most important resources that an operating system must manage is the memory. It is responsible for moving data between RAM and virtual memory, and allows more than one application to run at the same time. Since computers have a finite amount of memory, it is important that this memory is managed efficiently. In addition to memory, the operating system must also manage the hardware. It does so by communicating with device drivers (a piece of software that informs the operating system how to communicate with the hardware).

**Utility software** is designed to perform specific useful tasks that either help to analyse, configure or maintain the computer. Utility programs may come as part of the operating system, for example, the features of the operating system that manage files, or may be installed separately, such as compression software or antivirus software.

Then there is **application software**. These are the computer programs that serve a specific purpose, such as a word processor or video editor. Think of a brand-new laptop or phone, first out of the box. It would have come with several system applications that are part of the operating system, but for the new device to be truly functional, it needs application software.

One way to classify software is through ownership and licensing. Two types are **open-source software** and **proprietary software**.

## ■ Malicious software

Not all software is written for ethical purposes. **Malicious software**, also known as malware, is software written with the specific purpose of stealing data or damaging computers/IT systems. Examples include viruses, worms, spyware, adware and ransomware. Malware appears as harmless files or links but is designed to trick users into downloading them. According to Statista.com, in 2020 there were 5.6 billion malware attacks worldwide with 678 million different types of malicious software.

### REAL-WORLD EXAMPLE

#### Malicious apps on Google Play

Google removed 200 malicious apps from their app store in September 2021. At first glance these apps looked innocent, for example 'Handy Translator Pro' or 'Rate and Pulse Tracker'. However, after downloading these apps, the users would receive multiple notifications offering prize money in return for providing their mobile number. They would then be signed up for fraudulent SMS services that charged users while earning money for the malware operators.

[www.wired.com/story/grifthorse-android-google-play-scam-campaign](http://www.wired.com/story/grifthorse-android-google-play-scam-campaign)



#### ◆ Utility software:

Software designed to perform specific useful tasks that either help to analyse, configure or maintain the computer.

#### ◆ Application software:

Software that serves a specific purpose, such as a word processor or video editor.

#### ◆ Malicious software (malware):

Software designed to steal data or damage computers/IT systems.

#### ◆ Open-source software:

is free of charge and free of copyright, allowing the source code to be modified, often by an open-source community. However, there is no guarantee that the software will be bug free or support readily available.

#### ◆ Proprietary software:

is often downloaded after paying for a license or subscription. In return for payment, users can expect updates and help from the company. Proprietary software is copyrighted which denies users access to the source code (so that it cannot be modified) and restricts the sharing of the software.

## ATL ACTIVITY

### Thinking

Analyse the software on your computer by completing the following tables.

#### Operating system

Name and version of system:		
Utilities (software to help manage the computer, e.g. maintenance utilities, security utilities)	Pre-installed with the operating system (yes/no)	Installed separately (yes/no)
e.g. Recycle Bin		
e.g. WinZip		

#### Details of application software

Type of application software	Name	Version
e.g. Word processor	Microsoft Word	V2106

## EXAM PRACTICE QUESTIONS



### Paper 1 (core)

- Identify two input devices that would be used by a gamer. [2 marks]
- Explain three components of a computer that would need to be optimized when playing a computer game. [6 marks]

## 3.3C Uses and forms of computer coding

In the last chapter you would have read about how algorithms are represented by code and how software applications are programmed. These are often called **high-level languages** because they are designed for programmers and are written in a language closer to the human language. However, this is not how computers understand code. Instead, they use low-level languages. At a hardware level, computers understand **machine code** or **assembly language** that needs to be translated into machine code.



◆ **Machine code:** Sometimes called object code, machine code is written in binary (0s and 1s) or hexadecimal instructions that the computer can respond to directly. Each type of computer has its own machine language.

◆ **Assembly language:** Used by programmers to write code for special hardware or so that a task can be performed very quickly.

It is very difficult for programmers to program in binary or assembly code, so they write in high-level languages that are then translated so that the computer can execute the code. A program called a **compiler** translates the code in the source language, for example Java, into the object code in binary and stores this in a program file. When the computer runs this program file, the operating system will open the file, read and execute the binary instructions.

### ATL ACTIVITY

#### Research

Use effective online research skills to learn more about different forms of code.

- Conduct an online search to find out more about the different forms of code: machine code, assembly code and code written in a high-level language such as Java.
- Find an image of the code used in the different languages. How are they similar and how are they different?
- Outline the advantages and disadvantages of each form of coding for the programmer.

## 3.3D Evolution of computing

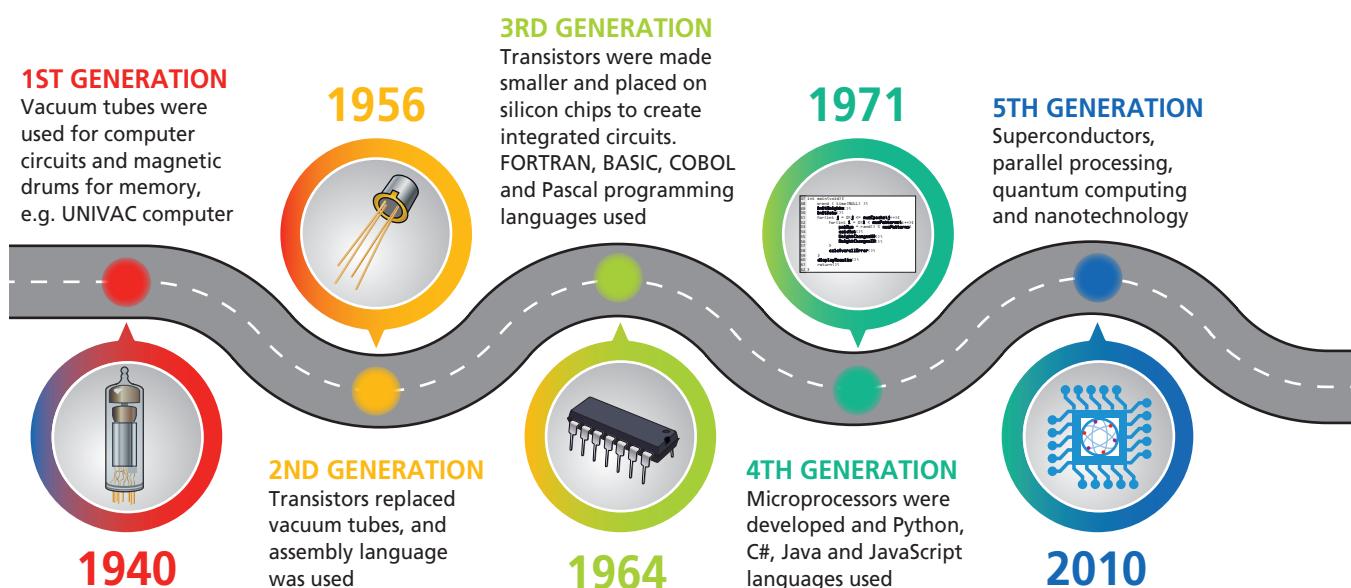
### ATL ACTIVITY

#### Thinking

Even in your lifetime you will have seen changes in digital technology. Think back as far as you can remember.

- How old were you? What digital technology can you remember?
- Is that technology still in your life today? If so, is it the same or how is it different?
- What digital technology in your life today was not available then?

The history of computing is often defined by technological breakthroughs of the time. These are then categorized into what we call generations. To date there are five generations of computing that have influenced our lives today.



## ■ First generation: Vacuum tubes (1940–46)

During this period, vacuum tubes were used for computer circuits and magnetic drums for memory, which could only perform one activity at a time. They would take days to program in machine language and would frequently malfunction due to the heat they emitted.

## ■ Second generation: Transistors (1956–63)

Transistors were developed and used to replace vacuum tubes. Transistors allowed computers to become smaller and more reliable, with the benefit of being more energy efficient. Like the first generation of computers, they used punch cards and paper tapes, and produced printouts as output. Assembly language was introduced, making it easier for programmers, and high-level languages such as COBOL and FORTRAN were being developed.



■ UNIVAC computer from the 1940s

## ■ Third generation: Integrated circuits (1964–71)

Transistors were made smaller and placed on silicon chips (called semiconductors). These were even more efficient, reliable and faster than the previous generation, and were able to run multiple applications at the same time. This generation no longer used punch cards; instead, input devices such as a keyboard and mouse were installed with an operating system. The main programming languages of this generation were now high-level including FORTRAN, BASIC, COBOL and Pascal.

In 1965, Gordon E Moore made a statement based on what he noticed during the chip manufacturing at Intel – that the number of transistors in a dense integrated circuit would double every two years. This insight became the golden rule and Moore's Law has been driving the electronics industry until today.

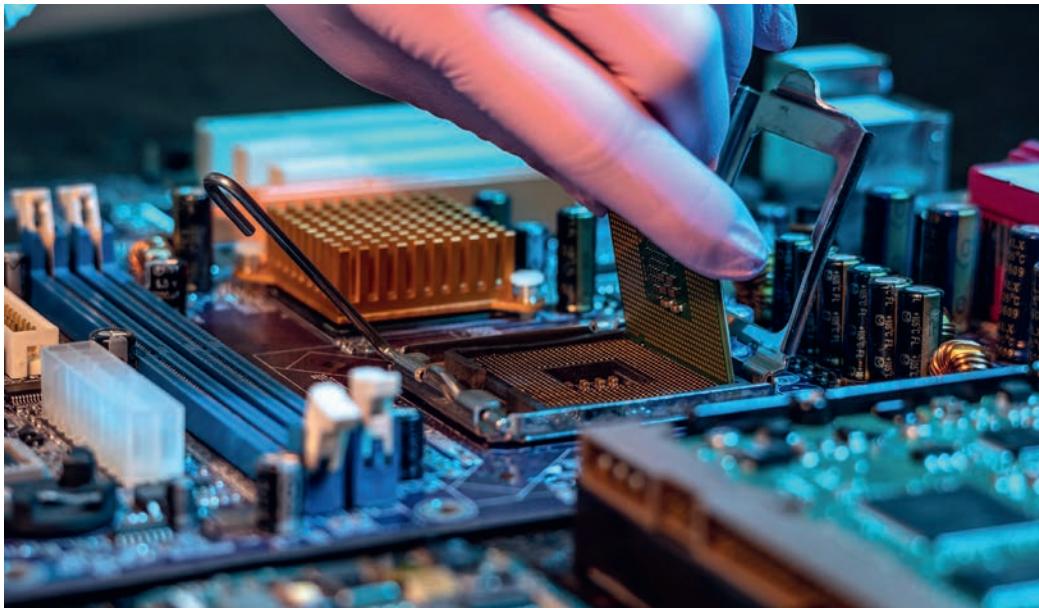
### ATL ACTIVITY

#### Communication

Conduct an oral presentation to a group of friends about Moore's Law.

- Search for a video to further explain Moore's Law.
- Make notes and then orally present your understanding of Moore's Law.
- Practice presenting without using your notes.
- Present your findings to a friend.
- Ask for feedback on how well you presented.

## ■ Fourth generation: Microprocessors (1971–2010)



The introduction of the microprocessor saw thousands of the third-generation integrated circuits built on to a single silicon chip. Compare the size of a CPU today with those in the first generation. They have even more processing power. Many of the components that we looked at earlier were introduced in this generation, for example RAM, CPU and hard disk drives. The programming languages in this generation were all high-level, including Python, C#, Java and JavaScript.

Earlier in this chapter we looked at the introduction of the personal computer as a desktop computer with a GUI – this was in the fourth generation.

## ■ Fifth generation: Artificial intelligence (2010–present)

Although many of the computers used today are similar to the fourth generation, the development of technology that has made artificial intelligence possible is considered the fifth generation. From superconductors (with millions of transistors on a microchip) and parallel processing (using two or more microprocessors to run tasks at the same time) to quantum computing and nanotechnology, computing today is still changing radically. One of the goals of this generation is for computers to use natural language as input, such as voice recognition, and for computers to learn for themselves.



## Quantum computing

Previously we talked about computers understanding binary, which consists of 1s and 0s (an on and off switch of the circuit), with each being one ‘bit’ of data. In **quantum computing**, computers use qubits, which follow the law of quantum mechanics. Instead of being on *or* off, they can be both on *and* off, or somewhere in between – this is called superposition.

Essentially quantum computing allows for uncertainty and the ability to analyse multiple options at the same time, making problem-solving much more efficient. Quantum computing is set to combat problems that would take current supercomputers hundreds of years to solve.

Quantum computing is currently being researched to make further developments in battery technology, cybersecurity, drug development, financial modelling, weather forecasting, artificial intelligence, traffic optimization and cleaner fertilizers.

### REAL-WORLD EXAMPLE

#### Daimler's electric vehicles

Quantum computing is being used by Daimler to help design the next generation of lithium-sulfur batteries. Quantum computing has a greater ability to simulate the molecules and model the dipole moment of the lithium-containing molecules. Quantum simulations can be used to run through millions of chemical reactions and help narrow down which experiments should be tested in the laboratory.

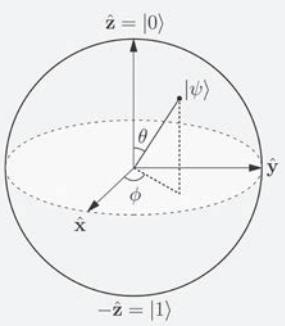
<https://group.mercedes-benz.com/magazine/technology-innovation/quantum-computing.html>

### ATL ACTIVITY

#### Research

Use effective online research skills to find other real-life uses of quantum computing.

- Using a search engine, find reliable sources to explain one other real-life use of quantum computing.
- Write a short paragraph to summarize the example
- Provide an opinion on the future impact of this digital technology from the example.



◆ **Quantum computing:** The technology that uses quantum mechanics to create powerful quantum hardware which can solve complex problems faster than existing supercomputers.

### Links

The content on quantum computing links to 4.5B Science and technology innovation.

## Inquiry



In this inquiry we will focus on only two of the stages. Ensure that you are familiar with the concept of ‘Change’ before attempting this task. After your initial research, use the guiding questions for each stage to help you complete the activity.

### 3.3D Evolution of computing (content) and 2.1 Change (concepts)

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

Change involves, understanding and evaluating people, ideas, objects and forces that shape the world: past present and future.

- Conduct some wider research and select one significant development in computers that is driving the change of computers in the present.
- Select three sources.
- Your final choice of sources must be able to help you gain a deeper understanding of this topic, provide a balance of claims and perspectives, and be embedded in the content (evolution of computing) and concept (change).
- Write a short report to justify your chosen sources and their usefulness in this inquiry. Your report should include
  - a discussion on the origin and purpose of each source, including any potential bias or limitations of using the source
  - a discussion of the main ideas being presented in each source and what features of the source were used to support the claim being made
  - a discussion on how the sources corroborate or contradict, and how it has helped you gain a deeper understanding of this question
  - a bibliography entry for each source at the end of the report.

### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

Using your research, answer the following questions:

- Why did the change take place? Was it due to needs or desires? Was it forced or optional? What were the main reasons for the change?
- When change happened, was progress made? Changes always bring a mixture of positive and negative impacts and implications – what were they at this time?
- To what extent was the change disruptive?
- Can change be predicted? Can we predict the outcomes of change? Can we force change?
- Overall has this change been beneficial?

## Activity: HL Extended Inquiry



Once you have studied Section 5.3B, try out this activity.

### 3.3D Evolution of computing (content) and 5.3B Responsible use of resources

**Challenge:** The world is relying on the global distribution of oil and gas, which are often delivered by sea. Determining the most efficient route is important to reduce the carbon emissions. It is incredibly complex, however, as there are millions of options.

Research and describe the global challenge:

- Use effective research skills and describe this challenge in more depth.

### Intervention

Research and evaluate this intervention: ExxonMobil is using IBM quantum computing to model the maritime inventory routing.

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.

## Learner profile

### Inquirers

In this unit you will have developed the skills to conduct several inquiries, whether it is the current prediction of Moore's Law or investigations into the uses of quantum computing.

## C Creativity, activity, service (CAS)

### Run a coding club at school

Research the different clubs on offer at your school for the lower years. Is there a coding club?

If so, see the club coordinator and offer to support the students and help by creating activities each week.

If there is no coding club, see how many friends would like to join and set one up. This would make an ideal CAS project. You will need to seek approval and plan and design each session. Run the club for 8 to 10 weeks, and do not forget to reflect!

## TOK

### Knowledge and technology

The evolution of computers has changed the way that IT systems collect, process and present knowledge over time. These technologies have provided tools to do the job that may have promoted the availability of knowledge or restricted it. Questions to be asked could include:

- How have the developments in computing helped people process data and information to gain knowledge?
- How is digital technology going to shape our knowledge of the sciences?

The development of computer systems has also raised ethical questions, such as:

- Should we hold people in the IT community responsible for the digital technology they create?

## E Extended essay (EE)

Studying the evolution of computing may give you some initial ideas for an extended essay topic. If it does, put some of them down on paper and convert them into a mind map or spider diagram. What questions evolve as you put down your ideas? How has further research helped refine the topic?

## R Reflection

Now that you have read this chapter, reflect on these questions:

- What type of computers are you surrounded by day to day?
- How important are the different components of a computer for effective computer processing?
- Could you investigate how computers are used in a wide range of contexts?
- How can IT companies ensure that they are sustainable and use resources responsibly during the manufacturing and distribution of computers?
- How are computers being used as interventions for sustainable development?
- What significant developments are driving change in computers (computing) today?
- How are developments in computing changing the way that we process and share knowledge?



## Links

Quantum computers use the properties of quantum physics to store data and perform calculations. This technology will be used by scientists in Physics research, and in the study of chemical reactions in Chemistry.

# 3.4

# Networks and the internet

## UNDERSTANDINGS

By the end of the chapter, you should understand that:

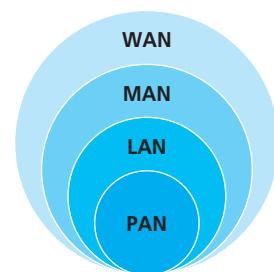
- ▶ networks connect computers, people and communities, allowing data and information to be created, accessed and shared in a distributed manner
- ▶ networks and the internet are defining features of digital society that have evolved over time
- ▶ networks and the internet involve significant opportunities and dilemmas for life in digital society.

From the minute we wake up to the time we put our phone on charge at the end of the day, our lives are being affected by networks, in particular the internet. Imagine you arrived at school and couldn't connect to the school Wi-Fi? How are you going to access the lesson resources if the school network is down? How can you upload your homework? How can you search for information that you need for an assignment? Our lives have become dependent on networks, whether it is the school network that you use to print out your work, or the internet to access online resources.

In this chapter we will look at network technologies and how they are configured to make-up the networks we use today; as well as the internet and the World Wide Web, and the services that are available to us. Is Sir Tim Berners-Lee's vision of the World Wide Web meeting his expectations? Or is the internet broken? Read on to find out more.

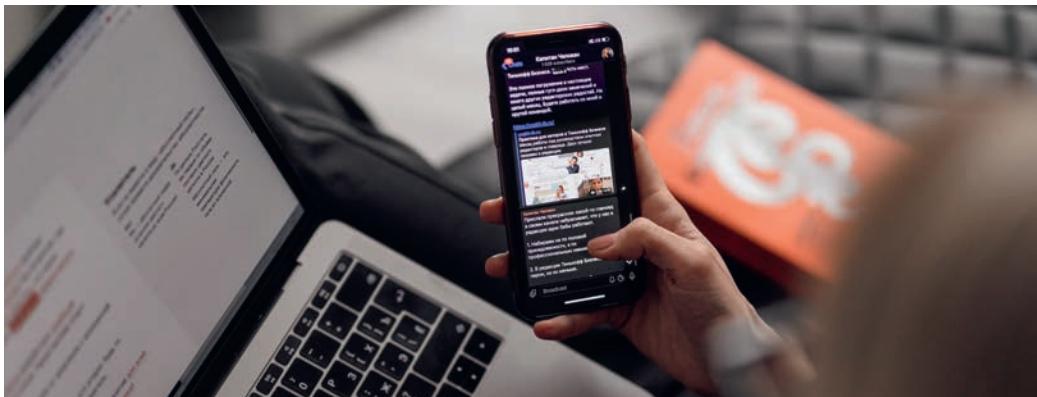
## 3.4A Types of computing networks

To understand **networks**, you need to appreciate that there are many types of networks, suitable for different purposes and situations. Types of networks can be categorized in several ways, whether it is by physical size, type of connectivity or how data is shared.



### Networks by size

- **Personal area network (PAN):** This is the smallest type of network and consists of the connected devices that are in close proximity to an individual. A typical PAN could be wirelessly connecting a phone and printer to one laptop. Another example is a health watch wirelessly syncing data to a phone.



■ A personal area network (PAN)

◆ **Network:** A series of interconnected nodes (connection points) that are able to transmit, receive and exchange data. The data may have various formats including text, sound, images and video. Examples of nodes include computers, servers and routers.

◆ **Personal area network (PAN):** The smallest type of network, consisting of the connected devices that are in close proximity to an individual.

- **Local area network (LAN)**: This is a group of computers or devices that are connected on a single site. This could be on a small scale, such as a home with two or three users, or on a larger scale, such as an office or school that may have hundreds of users. A LAN is usually set up to help the sharing of resources, whether it is giving access to a centralized store of data in an office, sharing a printer at home or sharing internet access in school.
- **Metropolitan area network (MAN)**: This is a network that covers a larger geographical area. It will include two or more computers connecting together when they are not in the same building or campus, but they are in the same city. This type of network can cover an area of between 5 and 50 km. Examples of MANs include governments that provide free Wi-Fi access to residents in a city, or municipalities that connect traffic lights or parking meters to a single network. A future use of MANs will be the road infrastructure used by autonomous vehicles.

### REAL-WORLD EXAMPLE

#### Free Wi-Fi in New York

New York City provides free Wi-Fi to all residents as well as wirelessly connecting traffic lights and parking meters.

<https://www.techtarget.com/searchnetworking/definition/metropolitan-area-network-MAN>

- **Wide area network (WAN)**: The largest of networks is spread across a wider geographical area. WANs can be a collection of LANs connected by telecommunication technologies that are available to the public or may be limited to an organization that operates nationally or internationally. Typically, a company can have offices in different cities connected by public telecommunications networks in order to share applications and centrally held resources. This eliminates the need to have a server at each location, and all offices can access the same data. To secure the public connection a virtual private network (VPN) is often used. Alternatively, the organization may lease a dedicated line from their internet service provider (ISP), which they do not have to share with any other organization in the area. The largest WAN accessible to the public is the internet – a collection of networks and networking technologies that link billions of users worldwide.

### ATL ACTIVITY

#### Thinking

Make a personal connection to this topic.

- Describe a scenario when you have used each type of network (PAN, LAN, MAN, WAN).



■ LAN in an office



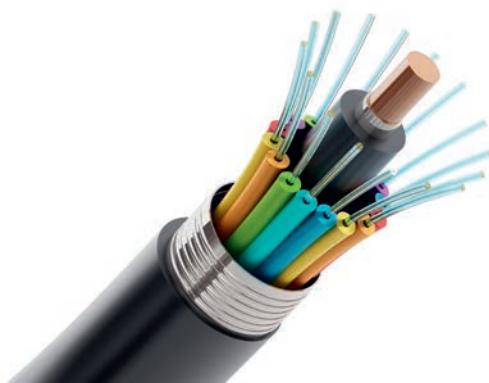
◆ **Local area network (LAN)**: A group of computers or devices that are connected on a single site.

◆ **Metropolitan area network (MAN)**: A network that covers a larger geographical area, such as a city.

◆ **Wide area network (WAN)**: A national or international network; the largest example is the internet.

## Type of connectivity

- **Wired networks:** Traditionally, networks were wired – devices were connected on the network with copper ethernet cables using an ethernet port (either integrated on to the motherboard or installed as a separate network interface card) and a router or switch. Fibre-optic cables are now being used as they offer better connectivity over greater distances and a faster speed. Wired networks are still used by many businesses and governments because they are considered to be more reliable, operate at faster speeds and are able to transfer data more securely. However, developments in wireless technology mean that many of these advantages are slowly being eroded.
- **Wireless networks:** Wi-Fi technology allows devices embedded with wireless network interface cards to connect to a wireless network using either a wireless access point or wireless router. A wireless connection uses radio signals to send data across the network. It is widely used because it is easy to set up (there is no need for cables) and it offers flexibility because devices can connect anywhere within range. A wireless network still uses cables to connect the access points to a wired backbone, however, but it allows the devices (personal computer, laptop, tablet, printer and so on) to connect wirelessly.
- **Cloud networks:** Traditional wired and wireless networks are used to connect devices together to access shared resources and data with the networking technologies all on the physical site. Cloud networks have changed this. With a cloud-based wireless network, the organization can still install access points on site, but the management of the network or the data can be hosted off-site. Configurations to the network can be made by accessing the IP (internet protocol) address of the hardware controlling the wireless network, making it easier to deploy, saving costs and allowing for scalability.



■ Fibre-optic cable



◆ **Wireless networks:**  
Use of wireless technologies to connect the different nodes to form a network.

◆ **Cloud network:**  
Incorporate some or all of the network capabilities on a public or private cloud platform.



### ATL ACTIVITY

#### Research

Use effective online research skills to investigate current networking technologies.

- Investigate which current wired and wireless technologies are being used in your home or school.
- Draw up a table to compare the speed, range of connectivity and cost of each of these.

## Sharing data

One of the main benefits of using a network is the ability to share resources and data, however, where the data is stored will depend on the type of network.

- **Client-server networks:** In this type of network, data is stored centrally on a server and access is given to the devices connected to the network (for example, a personal computer or mobile device). These devices are referred to as ‘clients’ and the server can either be hosted internally by the organization or externally in the cloud. Many organizations use this model so that organizations can prioritize IT resources that will secure and backup the data. This type of network does have disadvantages, however. Configuring and setting up a server can be costly and requires expert staff. There must be adequate bandwidth for all clients to request access to the server at the same time.

- **Peer-to-peer network (P2P):** Alternatively, a network can be configured so that there is a decentralized method of storing data. In a P2P network, each computer is equally responsible for storing and sharing data. The main advantage is that the network is not dependent on one server. It is easy to set up, but it is much harder to manage and control the security of the data. P2P networks are very popular for sharing large files over the internet; for example, some online gaming platforms (such as Blizzard Entertainment and Wargaming) use P2P networks for downloading games between users. It is also the network model used for cryptocurrency. Unfortunately, P2P technologies can be used to illegally share copyright content such as movies and music. The decentralized nature of P2P networks makes it very difficult for authorities to shut them down.

### ATL ACTIVITY

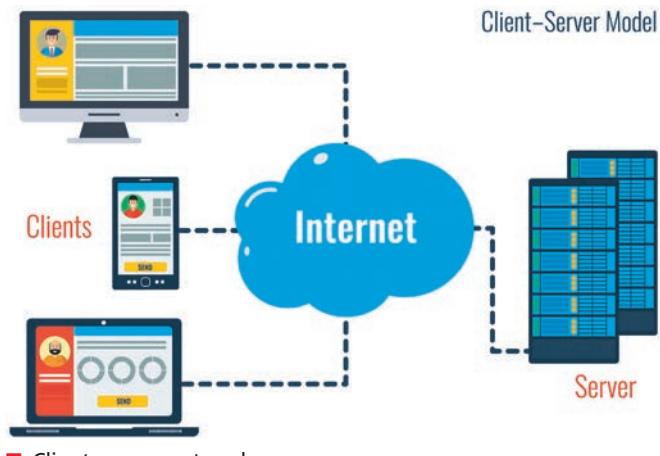
#### Thinking

Make a personal connection to this topic.

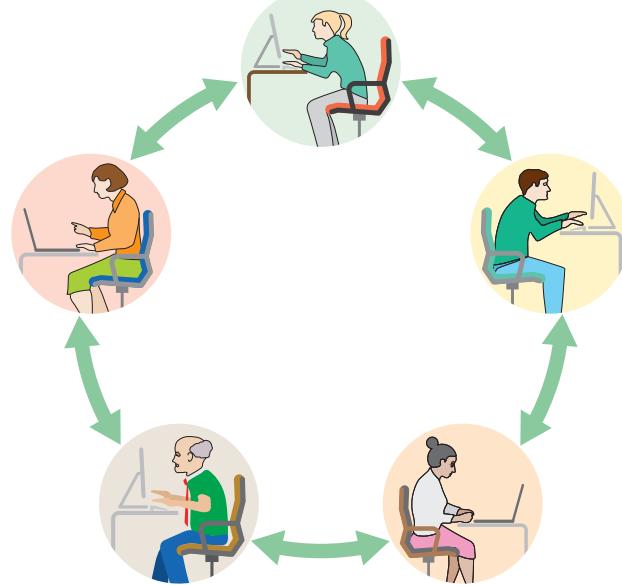
- Describe a scenario when you have used each type of network (client–server and P2P).

#### ◆ Client–server network

**network:** A type of network where data is stored centrally on a server and access is given to each device (client) connected to the network.



#### ■ Client–server network



#### ■ P2P network

#### ◆ Peer-to-peer network (P2P)

**network (P2P):** A decentralized network in which each computer is equally responsible for storing and sharing data.

**◆ Network interface card:** Device responsible for converting data into a digital signal and communicating this data to a network.

**◆ MAC address:** A unique identifier assigned to every piece of hardware.

## 3.4B Components of computing networks

Computers need specialist hardware to connect to each other on a network. As we mentioned earlier, the **client** can be a range of devices, from a personal computer to a laptop or tablet. Each of these will connect to the network provided that they have a network interface card. The **network interface card** (wired or wireless) is responsible for converting the data into a digital signal and communicating this data to the network. In a small network such as a home network, all that is needed is a router. Every piece of hardware on a network has a unique **MAC address**, which is allocated at the time of production. A MAC address is made up of 48 bits of data written in hexadecimal characters.

A **router** is networking technology that transfers data from one network to another. Its main role is to forward the data packets to their destination by the most efficient route available. A router allows you to connect to the internet from home as it forwards the data packet to the modem and then on to the ISP. A **modem** converts digital data into analogue data so that it can be transmitted over a telephone line using the telecommunications network. Many of today's ISPs offer a much faster connection using fibre optics, referred to as 'fibre to the home' (FTTH), and will install a fibre-optic router and modem to support this.

When it comes to larger networks, such as the network found in schools or an office, additional hardware is required so that the network can support the larger area. For a wireless network, **wireless access points (WAP)** are strategically placed around the building for the best coverage. This technology has a number of dedicated radio channels that the computers can connect to. Each WAP will be networked with a cable connected to either a switch or a hub – even a wireless network still has some wired components.

A **hub** is the least intelligent of the devices and will broadcast data to all of the devices on the network. This uses up a lot of bandwidth and sends unnecessary data, but it is easier to set up and can be useful when connecting only a few devices, for example, game consoles for a local multiplayer game. Instead of a hub, most local area networks use **switches**. These are more powerful and intelligent; they will forward the data packets more efficiently and give the network manager more control over how the data is shared across the network. Many larger organizations operate the **Client–server model** described earlier, which requires additional hardware – a server – which was discussed in the previous chapter.



■ Wireless internet router

◆ **Router:** A networking technology that transfers data from one network to another by the most efficient route available.

◆ **Modem:** A device that converts digital data into analogue data so that it can be transmitted over a telephone line.

◆ **Wireless access point (WAP):** A device that creates a wireless local area network to improve coverage throughout a building.

## ATL ACTIVITY

### Communication

Explain in your own words how the network components work together.

- Use a drawing program to create a diagram of your home network.
- Check that you have included each of the components identified in this chapter.
- Label all of the components and write a brief explanation of what each one does.
- Write an explanation on how the components connect together.
- Use the network diagram you created to explain to your peers how the different components on a network work together to share data.



■ Network switch and ethernet cables

## 3.4C Characteristics of computing networks

Earlier in this chapter, we discussed the different types of networks, their components and the fact that they have a common goal, which is to provide the **infrastructure** that allows people to communicate and share resources and data. It is no small feat that networking technologies allow data to travel globally using a wide range of technologies by different manufacturers. This **interoperability** can be attributed to the use of a common set of standards and network protocols.

◆ **Hub:** A networking device that broadcasts data to all devices on the network.

◆ **Switch:** A networking device that forwards data packets more efficiently than a hub.

◆ **Interoperability:** Allows different digital technologies or systems to connect and exchange data with one another without restrictions.

## Network standards and protocols

A **network protocol** is a set of agreed rules that state how to format, send and receive data. To successfully transmit data, both sides of the communication must accept and follow these protocols.

In networking, different layers are identified to handle the different parts of a communication. This layering makes it easier for standards to be put in place. As shown in the diagram, there are four layers:

- **Application layer:** this includes the set of protocols that are used by applications, for example the web browser.
- **Transport layer:** this layer sets up the communication between hosts using protocols such as UDP and TCP. The **transmission control protocol/internet protocol (TCP/IP)** states how data is exchanged by providing end-to-end communication that identifies how the data is to be broken into packets (just like sending a large mosaic by post). The IP part of the protocol defines where the data has been sent to and from, while the TCP is responsible for breaking down the data into smaller sections before sending. Instructions would be included alongside the data on how to reassemble it back to its original form.
- **Internet layer:** this layer adds the sender and recipients' IP addresses and routes the packets across a network. An **IP (internet protocol) address** is a logical numeric address that is assigned to every node on a network. Every time a device connects to a network, an IP address will be assigned to it. This is different to a MAC address: MAC addresses are fixed by the manufacturer, whereas an IP address is assigned by the dynamic host configuration protocol (DHCP). Web servers typically have a fixed IP address.
- **Physical network layer:** this includes the protocols that allow the different networking technologies to work together, for example, ethernet.

To make our life easier, we do not need to remember the IP address of every web server that we visit. Instead, we type the website address into a web browser, which consists of a domain name, for example Twitter.com. This request is then sent to a **domain name server (DNS)**, which will look up the IP address in its database of public IP addresses. Once the IP address is known, the data packet will be forwarded to that address. For example, a request to visit Twitter.com would be sent to the IP address 104.244.42.1.

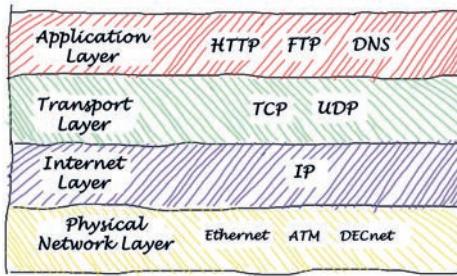
### ATL ACTIVITY

#### Thinking

Make a personal connection to this topic with this activity.

- Look up the MAC address of your computer and write it down.
- Use a route tracing utility such as TRACERT to view the path that a data packet would take from your computer to a website request.
- What IP addresses were at the start and end destination?

## Internet Protocol



#### ◆ Network protocol:

A set of agreed rules that state how to format, send and receive data.

#### ◆ Transmission control protocol/internet protocol (TCP/IP):

Protocol that defines where data is to be sent to and from (IP), and how the data is to be broken down into packets before sending (TCP).

#### ◆ IP (internet protocol) address:

A logical numeric address

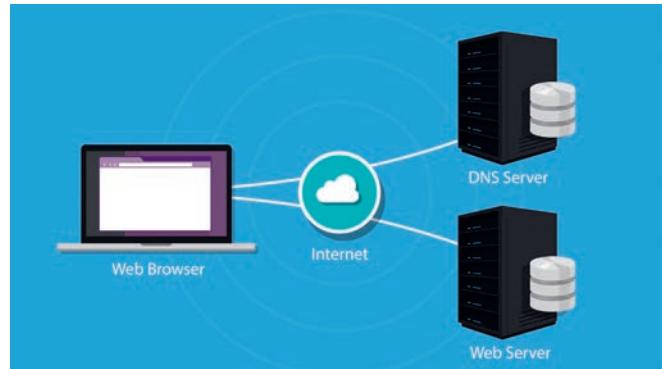
that is assigned to every

node on a network.

#### ◆ Domain name server (DNS):

A server that translates domain

names into IP addresses.



■ Domain name server (DNS)

## Network capacity

Earlier we looked at different technologies that could influence the speed that data can travel in a network. We also need to consider how much data can be transferred at any one time. Imagine you are getting ready to watch the World Cup football final using live streaming and all you see is a spinning wheel icon (this is called a throbber). How do content providers ensure that they meet the needs of the public? They must ensure that they have enough **bandwidth** to accommodate the needs of their audience. Although bandwidth and **speed** are talked about in the same conversation, they are different.

◆ **Bandwidth:** The maximum rate of data transfer at any one time, measured in hertz (Hz).

◆ **Speed:** The length of time it takes for data to be transferred, measured in megabits per second (Mbps).

### REAL-WORLD EXAMPLE

#### Live streaming football



In June and July 2021, the UEFA Euro 2020 football competition was expected to live stream to 1.9 billion viewers, be available in 229 areas with 137 broadcasting partners. There was 3500 hours of content with 36 cameras per match.

[www.svgeurope.org/blog/headlines/uefa-euro-2020-the-host-broadcast-facts-and-figures-for-the-tv-coverage-of-europes-biggest-football-show](http://www.svgeurope.org/blog/headlines/uefa-euro-2020-the-host-broadcast-facts-and-figures-for-the-tv-coverage-of-europes-biggest-football-show)

As streaming videos and music have become commonplace, so has the use of file **data compression** to make the storing and streaming of data more efficient. Compression algorithms are used to reduce the amount of space needed to represent a file. There are two main types of compression algorithms:

- lossy compression, for example JPG and MP4, which reduces the file size by permanently removing unimportant, less noticeable data from the file
- lossless compression, which reduces the file size without losing data; this means that the data can be returned back to its original size after transmission, for example, PNG and BMP.

◆ **Data compression:** Is a process that reduces the size of a file by re-encoding it to use fewer bits of storage than the original file.

### ATL ACTIVITY

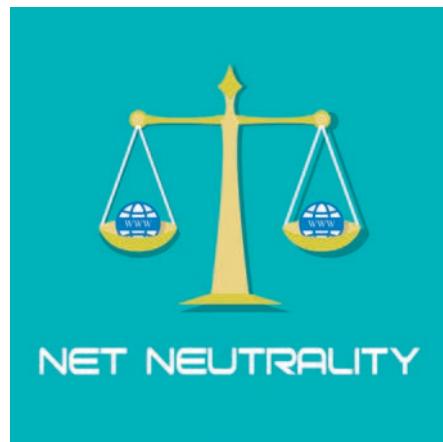
#### Communication

Explain in your own words how compression works.

- Conduct more in-depth research about compression technologies and where they are used.
- Create an infographic that includes
  - an explanation of the difference between lossy and lossless compression
  - an explanation, with an example, of how the compression algorithm works
  - real-life examples of where the different technologies are being used.

All things are not equal on a network – sometimes priority can be given to a specific website. Imagine if your school's ISP allowed free access to your school's top 10 most-visited websites. This could give the school a tremendous advantage, with students and teachers being able to access learning materials much faster. This would be an example of **net partiality**.

**Net neutrality**, on the other hand, is the notion that the internet should be free and without restriction, so that all data requests made on the internet are treated equally. So, although the earlier example shows a clear benefit to the school, it is a slippery slope when telecommunication companies start to control who has access to which websites and at what speed. This could easily lead to ISPs charging companies to have preferential treatment and users having to pay extra to view specific content. This is not the internet that Sir Tim Berners-Lee had in mind when he created it.



### ATL ACTIVITY

#### Thinking

Prepare for a debate on net neutrality. Not all country leaders have the same views on net neutrality; for example, Barack Obama was pro net neutrality while Donald Trump was against it.

- With friends, research two political leaders with opposing views on net neutrality.
- Hold a debate on the topic of net neutrality, with one group in favour and one group against.
- At the end of the debate, take a vote on which view of net neutrality you support.

◆ **Net neutrality:** The concept that all data requests on the internet should be treated equally by the internet service providers (ISPs).

### Security

As soon as we start sharing data between different users on different devices in different locations, there is going to be a risk to the security of our data which may give rise to many of the dilemmas identified later in this chapter. It is therefore of paramount importance that all measures are taken to secure data.

Networking and security professionals have a very important role in keeping networks secure from both inside and outside threats. Likewise, individuals, whether they are using a mobile device, smart fridge (IoT) or desktop computer, also need to be educated and are responsible for having a certain level of security in place.



#### Controlling access from within

Network access controls can be set up to control how users access physical resources and data. The most basic of these is **authentication** using a unique username and strong password. When access rights are being configured, the network administrator determines which files and resources will be accessible and what type of access will be given, for example, read-only access or full control.

More common now is **multi-factor authentication**, which provides greater security as multiple methods of authentication are used to verify a user's identity for a log in or transaction. Two or more independent credentials are used to identify a user. This may be physical, through the use of a token, card or text message, or something that is part of the user, for example biometric measurements such as faceprint, or something known only to the user such as a PIN or phrase.

#### Controlling access from outside threats

Three technologies that can protect a network from outside threats include firewalls, proxy servers and virtual private networks (VPNs), which we discussed earlier in this unit.

◆ **Multi-factor authentication:** The use of multiple methods of authentication to verify a user's identity.

### Links

This links to the content on biometric passports in Section 4.6B Governing bodies.

A **firewall** may be in the form of hardware (used by large organizations) or software (which can be turned on as part of the operating system) on a computer. The purpose of the firewall is to block unauthorized access to the network by inspecting packets trying to enter or leave the network. These requests are accepted or rejected depending on the set of rules defined by the firewall.

Additionally, a **proxy server** can be installed at the network's gateway for the purpose of accepting and forwarding connection requests. It uses the anonymous network ID instead of the actual IP address of the network address. It can also filter content requests from within the network and may be used to limit users from accessing certain undesirable or unproductive sites using keywords or by blacklisting web addresses.

Protecting the network gateway is one way of keeping data secure, but what if this fails? If the files are accessed, how can we ensure that they cannot be read? **Encryption** is used to help secure data on networks, whether this is encrypting data on the server storage device or encrypting the wireless connection using WPA (Wi-Fi protected access).

◆ **Firewall:** Hardware or software designed to block unauthorized access to a network by inspecting incoming and outgoing network traffic.

◆ **Proxy server:** Computer system that acts as an intermediary between the client on the network and the internet; providing an additional layer of security.

## EXAM PRACTICE QUESTIONS



### Paper 1 (core)

- 1 Identify two hardware technologies used to form a LAN. [2 marks]
- 2 Describe two characteristics of a network. [4 marks]
- 3 Explain three measures that a network administrator should take to increase the performance of the network. [6 marks]

## Inquiry

In this activity we will focus on the Explore stage of inquiry. Before attempting this task, re-read Section 2.6 systems.

### 3.4 Networks and the internet (content) and 2.6 Systems (concepts)

**Inquiry focus:** To what extent are humans involved in the effectiveness of a computer network?

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

- Select three sources that have different claims and perspectives on this topic.
- Evaluate and justify your choice of sources for this inquiry focus. Your report should include
  - a discussion on the origin and purpose of each source, including any potential bias or limitations of using the source
  - a discussion of the main ideas being presented in each source and what features of the source were used to support the claim being made
  - a discussion on how the sources corroborate or contradict, and how it has helped you gain a deeper understanding of this question
  - a bibliography entry for each source at the end of the report.

## Inquiry

### 3.4 Networks and the internet (content) and 4.5A Learning and education (contexts)

**Inquiry focus:** How have the developments of networks in schools impacted the design and delivery of formal education?

#### Evaluate

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

- Conduct wider research for the inquiry focus to obtain the perspective of both the student and teacher.
- Create a spider diagram for each stakeholder showing the positive and negative impacts.

#### Analyse

Evaluate impacts and implications for relevant people and communities

- Is your evaluation based on your analysis?
- Does your evaluation focus on the impacts and implications for people and communities?
- Is your evaluation effective, sustained and well-supported by evidence?

- Write a detailed conclusion based on the notes made in the analysis stage to address the initial inquiry focus.

## 3.4D Computing network providers and services

Earlier in this section we talked about the different hardware and software that make up the internet, and the protocols for global interoperability. However, gaining access to global resources requires one other element: registration to a mobile service provider (MSP) or an internet service provider (ISP).



A **mobile service provider (MSP)**, also known as mobile carrier or mobile phone operator, is a company that offers cellular connection to mobile phone subscribers. An MSP purchases a license to transmit radio signals over a specific range within a particular frequency band, such as 1800 to 2100 MHz, which is used to provide high data speeds. These mobile phone networks are referred to as 4G or 5G networks (the G standing for ‘generation’). Mobile phone customers use this service to make phone calls, send and receive text messages, and use their data to browse the web.

Users now have the choice to make calls directly using their mobile phone network or using **VoIP (voice over internet protocol)**. With a regular mobile phone call, a user can call a landline or another mobile phone and audio data is transferred wirelessly from cell tower to cell tower. With VoIP, audio data is transformed into digital packets that are sent via the internet between any two devices. Popular examples include Skype, WhatsApp and Facebook Messenger.

An **internet service provider (ISP)** refers to a company that provides internet access to its customers, making it possible for subscribers to use online services such as browsing the ‘web’, online shopping, file sharing and video conferencing. They also provide other services such as email, domain registrations and web hosting.

◆ **Mobile service provider (MSP)**: A company that offers cellular connection to mobile phone subscribers.

◆ **VoIP (voice over internet protocol)**: Allows users to make voice calls using a broadband Internet connection instead of an analogue phone line.

◆ **Internet service provider (ISP)**: A company that provides internet access and other related services to its customers.

## Inquiry

### 3.4 Networks and the internet and (content) and 2.3 Identity (concepts)

**Inquiry focus:** What is the relationship between network and network services and our identity?

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

#### Evaluate

Evaluate impacts and implications for relevant people and communities

- Is your evaluation based on your analysis?
- Does your evaluation focus on the impacts and implications for people and communities?
- Is your evaluation effective, sustained and well-supported by evidence?

- Use secondary research to support your findings.
- Analyse and evaluate the use of networks (use two specific examples) and their relationship with our identity using the following questions:
  - How are networks used to help construct one’s identity?
  - How are identities on these networks different from those in the real world?
  - Why there might be a difference?
  - To what extent do different aspects of one’s identity appear on these networks?
  - How has one’s identity on these networks changed over time?
  - How can networks be used to hide or distort one’s identity?
  - Evaluate the potential harm and benefits that arise from the use of networks to develop one’s identity.

## ATL ACTIVITY

### Communication

Create a promotional elevator pitch to present to your peers.

- Compare the packages of two local mobile service providers and two internet service providers.
- Make a list of what services they offer.
- Analyse and make a decision as to which one offers the best deal.
- Create an elevator pitch to a friend to persuade them to switch mobile phone providers.

## 3.4E The World Wide Web



In everyday language, you and your friends might talk about going on the ‘net’ or searching the ‘web’, and we might use these terms interchangeably, so how are they different? Simply put, the **internet** is the network of computers and networking technologies that we talked about earlier. A computer can connect to the internet through a router and connect with a web server to access resources or services. The **World Wide Web (WWW)**, on the other hand, is the collection of websites and web services that are hosted on these web servers and identified by their URL (uniform resource locator), for example <https://example.com>, and accessed through a web browser.

The three main technologies that have allowed for the interoperability between all of the technologies on the internet are URL, HTTP and HTML.

- A **URL** is the unique address of each resource on the web, which could be the address of a web page or the file hosted by a web server.
- From the application layer (mentioned earlier in this chapter), **HTTP (hypertext transfer protocol)** or **HTTPS (secure hypertext transfer protocol)** determines how web resources are transmitted between the web browser and the web server. The more secure HTTPS is now a requirement of many web browsers, which has forced web-hosting companies to add security certificates to their web servers so that when users transfer sensitive data it is encrypted.
- **HTML (hyper text markup language)** is the format of web pages that allows documents to be displayed as web pages as well as web pages to be linked together.

◆ **Internet:** The global collection of networks and networking technologies that link billions of users worldwide.

◆ **World Wide Web (WWW):** The websites and web services that are hosted on web servers and identified by their URL (uniform resource locator).

## 3.4F Evolution of the internet and the web

### ■ The early days of the internet (1969–2000)

The internet started earlier than the World Wide Web. The first computer network was in 1965 when a computer at the University of California, Los Angeles, was used to send a message to a computer at Stanford University. Although the first attempt caused a system crash, the second attempt was more successful and led to the creation of the ARPANET (Advanced Research Projects Agency Network) in 1969. This network was expanded to include up to 30 academic, military and research institutions, connecting them from different locations including Hawaii, Norway and the UK. It saw the introduction of the TCP/IP protocol and was operational until 1990.

As the internet grew from 2000 nodes to 30,000, it became very apparent that it needed to be easier to use. The solution was found by Sir Tim Berners-Lee with the invention of the **WWW** in 1989. His proposal was for the information being shared to be structured and linked in a new way that made it quicker and easier to access. Alongside these protocols, the web browser was introduced, which made the WWW more accessible.

In 1993 there were only 130 websites, which grew to 100,000 by 1996.

With the exponentially growing internet and WWW, the **World Wide Web Consortium (W3C)** was formed in 1994 to promote its evolution and ensure interoperability. At the time of writing, Sir Tim Berners-Lee is the director of W3C. His main aim is to coordinate the developments of both web technology and standards. W3C uses processes that promote the development of these standards based on the agreement of a wide range of members who work for organizations all over the world.

## The expansion of the web (2000–20)

As the web continued to grow and become a mainstream digital technology, it was still very much in the hands of the elite few that knew how to program in HTML. Websites were considered static and did not change frequently, because every change of content or formatting required a programmer. This version of the web was called Web 1.0.

By the year 2000, new technologies and protocols had been developed that changed this, and Web 2.0 was born. Web 2.0, also known as the ‘social web’, enabled users to generate their own content without needing to be coding experts. In this era, web developers would use XML and RSS to format and structure websites, allowing users to add their own content. This also allowed for more dynamic content as it was separated from the formatting. This period also saw the introduction of social media platforms, blogging, podcasting, social bookmarking and tagging, many of which are still popular today.

## Web 3.0: the semantic web (2020–present)

Web 2.0 was mainly about innovating the user experience. In Web 3.0 the focus shifted to the back end, with the promise of being more intelligent. One development is the focus on generating a greater understanding of the meaning of the words being used when creating, sharing and searching content. A second feature of this generation is the utilization of artificial intelligence and natural language processing. Websites can now display interactive 3D graphics and the market for the internet of things (IoT) is growing.

## The internet of things (IoT)

The **internet of things (IoT)** refers to all of the devices that are connected to the internet. Nowadays billions of devices are ubiquitously connecting and sharing data across the internet, and these are not just phones and laptops – it includes smart appliances and autonomous vehicles, and items as small as a smart lightbulb or as large as a jet engine.



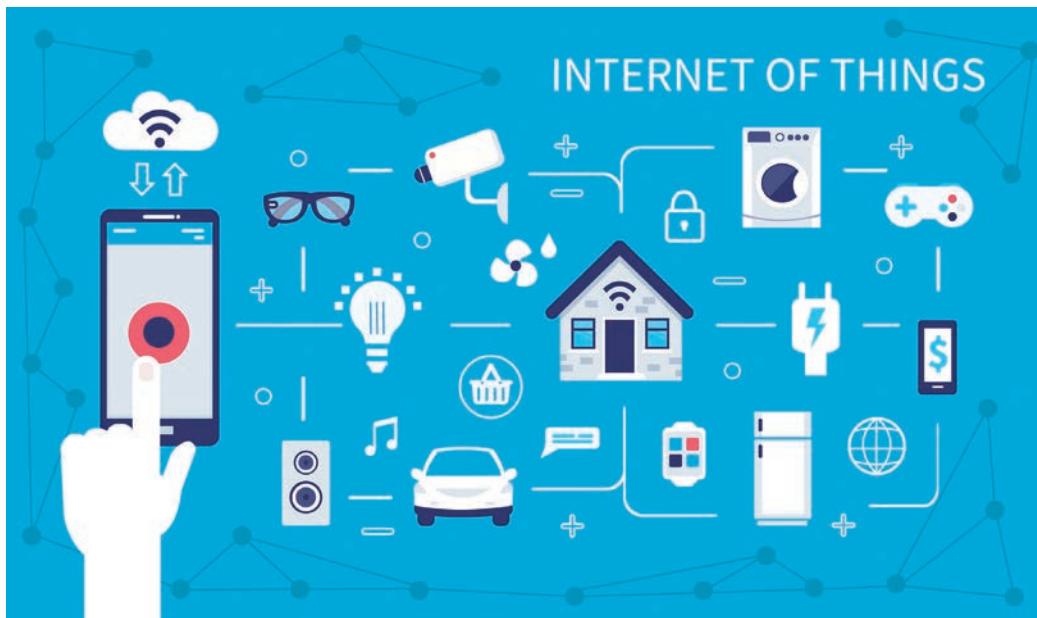
Sir Tim Berners-Lee



### Links

This section links to Chapter 3.7.

◆ **Internet of things (IoT)**: Internet-connected devices that collect and share data.



IoT devices use sensors to collect data and communicate with each other over a network, often with the aim of providing assistance or increasing efficiency. In the home, individuals are investing in smart home technologies to increase efficiency, become more energy efficient or to control household appliances for greater convenience. For example, smart lightbulbs can be controlled with a phone, and smart door locks can let delivery drivers drop off packages.

While the IoT promises to make our homes and environment smarter, privacy and security remain real concerns that need to be addressed.

## Inquiry

### 3.4F Evolution of the internet and the web (content) and 4.1B Home, leisure and tourism (contexts)

**Inquiry focus:** How is the introduction of smart home technologies having an impact on families and their friends?

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

- Conduct a survey among your family and friends to find out their opinions on the growth of smart home technologies.
- Develop your survey to find out which technologies they use, the positive experiences that they have had, and any concerns that they have regarding these technologies.
- Evaluate the effectiveness of your primary research.



## Inquiry

### 3.4F Evolution of the internet and the web (content) and 2.1 Change (concepts)

**Inquiry focus:** Evaluate one technological development of Web 2.0 or Web 3.0 using the concept of change.

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

#### Evaluate

Evaluate impacts and implications for relevant people and communities

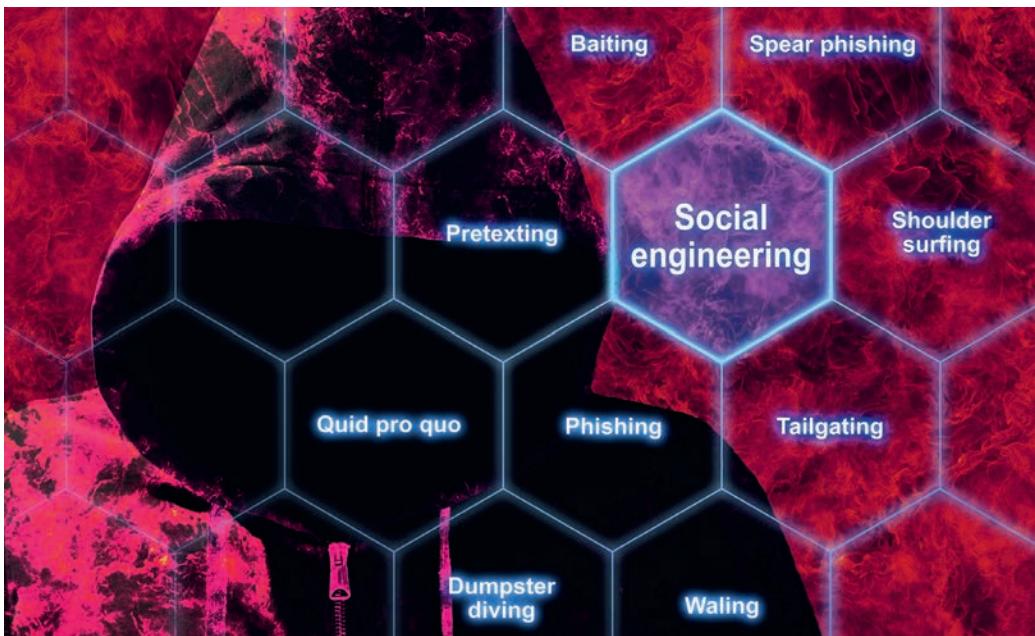
- Is your evaluation based on your analysis?
- Does your evaluation focus on the impacts and implications for people and communities?
- Is your evaluation effective, sustained and well-supported by evidence?

Select one Web 2.0/3.0 technology and use secondary research to answer the following questions:

- Why did this change take place? Was it due to needs or desires? Was it forced or optional? Was it due to something being new?
- When the change happened, was progress made?
- Discuss the positive and negative impacts and implications due to the change of this technology.
- To what extent was this change disruptive?
- Was this change predicted? Was it possible to predict the outcomes of this change?
- To what extent was this change beneficial at a personal, local and global level?

## 3.4G Internet dilemmas

### Understanding the risks to data



Networks at home or in the workplace must be secure. Users must take measures to protect their hardware and data from loss, damage and misuse, yet at the same time enable staff to carry out their jobs, which often involves the sharing of data or computer hardware. To keep a network secure it is important to understand the types of threats that may be encountered. Many of these are external to the network, and have increased exponentially due to the ease with which devices can be connected through the internet.

Specific risks include:

- **Spamming** refers to the sending of unsolicited emails, mainly for the purpose of advertising. With advances in email filtering, many spam emails are filtered out before they reach your inbox. According Statista.com, in March 2021 45% of email traffic was spam.
- **Hacking** can be defined as unauthorized access to a computer or network and can be accomplished in many ways. Hackers use a range of tools to gain access to their intended target, including:
  - **Social engineering** – tricking a user into sharing their username and password with a fraudster. For example, hackers have been known to impersonate IT staff, claim that they are conducting routine maintenance and make requests for credentials from the customers. With these details, hackers will have instant access to these accounts.

◆ **Spamming:** Sending unsolicited emails, mainly for the purpose of advertising.

◆ **Hacking:** Unauthorized access to a computer or network.

◆ **Social engineering:** In internet security, this means to manipulate a user into sharing confidential or personal information with a fraudster.

◆ **Phishing:** A type of social engineering that involves sending fraudulent emails designed to trick users into revealing sensitive information.

## REAL-WORLD EXAMPLE

### Phishing at Google and Facebook

Between 2013 and 2015, Lithuanian national Evaldas Rimasauskas set up a fake company pretending to be a computer manufacturer that worked with Google and Facebook.

**Phishing** emails were sent to Google and Facebook employees that included invoices for goods and services that were fake. None the wiser, the employees processed the invoices and the money was paid to a fraudulent bank account. He cheated these companies out of US\$100 million before being caught.

[www.tessian.com/blog/examples-of-social-engineering-attacks](http://www.tessian.com/blog/examples-of-social-engineering-attacks)

- **Hacking a website or penetrating a network** includes gaining access to the back-end database of user information, or redirecting users to a different website.
- **Exploiting a security flaw** – if a network does not have adequate malware and virus protection, or a firewall, hackers can take advantage of this to gain access to company servers.

## REAL-WORLD EXAMPLE

### Log4J attack

In December 2021, the BBC reported that a security flaw in the Java code 'Log4shell' had made many corporate networks running online services vulnerable to hackers. It gained public attention after it was found to affect some sites hosting Minecraft and was rated a serious vulnerability as Apache Software Foundation issued a fix to solve the problem.

[www.bbc.com/news/technology-59638308](http://www.bbc.com/news/technology-59638308)

◆ **Virus:** A type of malicious software comprised of small pieces of code, often attached to legitimate programs or emails.

## REAL-WORLD EXAMPLE

### Bangladesh Bank Hack

In 2016, the North Korean Lazarus group attacked Bangladesh's national bank with the aim of stealing US\$1 billion. The elaborate plan consisted of a range of techniques including the social engineering of staff to gain access to the network through an email in which the hacker presented himself as a potential intern. The email included his CV as an attachment, which contained a virus. Once in the bank's system, the hackers patiently analysed the network, moving from computer to computer until they had access to the printer, which was used as a paper backup of all bank transactions. Once the printer was taken out of action, the hackers made steps to transfer the money out of the bank into their own bank accounts.

[www.bbc.com/news/stories-57520169](http://www.bbc.com/news/stories-57520169)

- **Ransomware** is malware that infects a computer and effectively locks the user out of their own device and demands a payment to unlock it. Ransomware is typically activated by clicking on an email attachment, hidden in a software download, or through visiting a malicious website or link.

◆ **Ransomware:**  
Malware that infects a computer and effectively locks the user out of their own device and demands a payment to unlock it.



## REAL-WORLD EXAMPLE

### WannaCry Ransomware, May 2017

One of the most infamous of attacks was the WannaCry ransomware which spread globally and affected 230,000 computers, with users being held hostage until a ransom was paid in Bitcoin. The ransomware took advantage of a vulnerability in the Windows operating system, and although Microsoft had released a security patch, many organizations had not updated their computers. One-third of British hospitals were affected, resulting in the postponement of many life-saving operations. This ransomware is estimated to have caused US\$4 billion in losses across the world.

[www.kaspersky.com/resource-center/threats/ransomware-wannacry](http://www.kaspersky.com/resource-center/threats/ransomware-wannacry)

- **Distributed denial of service (DDOS)** happens when a network of computers has been installed with malware designed to target a web server. When a hacker wishes to attack, they instruct their army of infected computers (bots) to make a connection to the target web server at the same time. The web server cannot cope with this spike in demand, which effectively prevents other users from being able to access the website.

◆ **Distributed denial of service (DDOS) attacks:** Overwhelming a site or service so that it is not available to its intended users.

## REAL-WORLD EXAMPLE

### DDOS at Amazon

Amazon web services were under attack in February 2020, which meant that many businesses using its hosting services lost revenue and reputation due to the unavailability of their site at this time.

<https://securityboulevard.com/2020/09/top-five-most-infamous-ddos-attacks/>

## REAL-WORLD EXAMPLE

### The Meris Botnet

In 2021, the security division of Rostelecom, the largest provider of digital services in Russia, took down part of the Meris Botnet, one of the largest available to cyber criminals, which consisted of 250,000 infected devices.

[www.wired.com/story/security-roundup-even-cia-nsa-use-ad-blockers](https://www.wired.com/story/security-roundup-even-cia-nsa-use-ad-blockers)

## ATL ACTIVITY

### Research

Use effective online research skills and use correct citation and referencing.

- Conduct research on each type of attack (social engineering, hacking, virus, DDOS and ransomware).
- Create a short report that includes:
  - one real-life example for each type of attack
  - a short description of the scenario
  - a brief discussion of the impact of the attack on the victims
  - a summary of the consequences for the individuals/group who carried out the attack.

◆ **Anonymity:** The use of digital technology to conceal a person's true identity.

◆ **Internet trolls:** People who leave intentionally provocative or offensive messages online in order to get attention, cause trouble or upset someone.

## Consequences of the risks to data

Chapter 3.1 Data and data analysis addressed the concerns of privacy, which has led to other issues due to the widespread use of networks and the internet.

**Anonymity** is the most extreme form of privacy, to the extent that a user's name and identity are concealed when using applications and online services. Being anonymous online allows users to have the confidence to express themselves freely without fear of retribution. While this can make the internet a safe place to seek information and share opinions, it has also increased the confidence of those with malicious intent, such as cyberbullies and **internet trolls**. There are two types of trolls:

- people that target influencers with a large social media following – their aim is for their hateful messages to reach as wide an audience as possible
- people that just enjoy causing harm to others – the more one responds, the more hateful messages they send.

Trolling can cause significant harm and stress to those being affected, including disrupted sleep, low self-esteem and self-harm.



## REAL-WORLD EXAMPLE

### Online harassment

Recent studies estimated that every one in three Australians have experienced some form of online harassment, and that it had cost the government A\$3.7 billion (approximately US\$2.6 billion) in 2019 in health costs and lost income.

<https://theconversation.com/new-research-shows-trolls-dont-just-enjoy-hurting-others-they-also-feel-good-about-themselves-145931>

Anonymity can help users to maintain their privacy as well as protect them from cybercrimes such as **identity theft**. Identity theft is when someone steals your personal information to commit fraud. Such information can be used to impersonate you when applying for bank cards, medical services or other financial benefits.

## REAL-WORLD EXAMPLE

### Identity theft

In 2020, identity theft cost Americans US\$56 billion with over 49 million consumers being victims.

The most common ways for identity theft to occur included access to personal information through a data breach or by scammers emailing or calling to ask for your information by pretending to be from a government agency or a popular retailer.

[www.cnbc.com/2021/03/23/consumers-lost-56-billion-dollars-to-identity-fraud-last-year.html](https://www.cnbc.com/2021/03/23/consumers-lost-56-billion-dollars-to-identity-fraud-last-year.html)



With the ever-increasing number of websites requesting users to sign up, there is no surprise that our personal information ends up in many web servers on the internet. But what happens when we stop using these services? What happens to our data? Is it still being kept securely? These are the sorts of questions we should be asking.

With many countries tightening up their data protection regulations, **the right to be forgotten** is now being enforced by governments. For example, the GDPR governs how data is being protected in Europe and states that citizens have the right to request to have their data erased from an organization should the right circumstances apply. These include:

- the personal data is no longer needed by the organization
- the individual's consent has been withdrawn
- there is no longer a legitimate reason to keep the data, or data was obtained unlawfully
- the individual objects to having their data used for direct marketing purposes.

◆ **Identity theft:** When someone steals your personal information with the intention of committing fraud. They may use your information to apply for a credit card or gain access to medical services.

## Top tips

There are many similarities between the dilemmas in this chapter and those found in Chapter 3.1 Data and data analysis.

## ATL ACTIVITY

### Thinking

Look for a personal connection to one of the internet dilemmas and reflect on each question:

- Which internet dilemmas have you or someone you know been affected by?
- How did you manage it?
- What advice would you give to someone going through the same experience?

## Inquiry

### 3.4G Internet dilemmas (content) and 4.2C Goods, services and currencies (contexts)

Using the inquiry process presented in Section 1.4, complete a full inquiry, including all stages of this process. Research and investigate one internet dilemma and the impact it has had on e-commerce. Select how you will communicate your findings.

## Activity: HL Extended Inquiry



### 3.4E The World Wide Web (content) and 5.1A Local and global inequalities (contexts)

#### Challenge

During the second wave of COVID-19 in India, the country was faced with a huge challenge: there was no efficient way to match up available oxygen tanks with patients.

#### Intervention

Listen to this Digital Human podcast from 21 June 2021:

[www.bbc.co.uk/programmes/m000x6pq](http://www.bbc.co.uk/programmes/m000x6pq)

Social media was used to send out 'SOS tweets' during the second wave of COVID-19 in India. The communications platform was used to help source oxygen needed for friends and family, empowering ordinary people to participate in the relief work.

Research and evaluate this intervention using the HL extended inquiry framework.

- How was social media being used as an intervention to solve the problem of a shortage of oxygen in India?

Make a recommendation for steps for future action.

Present your work in the form of a written report.

## Deeper thinking

### Surveillance



Simply put, surveillance is the close monitoring of a person or group of people. However, there is an ever-increasing range of technologies that can be used in surveillance, both directly or indirectly. Obvious surveillance technologies include CCTV (closed circuit television) or network cameras. Strategically placed inside and outside of buildings, at traffic junctions and on highways, video footage is being captured 24-7. As these technologies are being combined with facial recognition and artificial intelligence technologies, privacy concerns are rising.

According to a 2020 study by Comparitech, 16 out of the top 20 most surveilled cities are in China based on the number of cameras per 1000 people. The cities outside of China in the top 20 were London, Indore, Hyderabad and Delhi.

Some forms of surveillance may not be as obvious and may be a direct or indirect result of using an IT system or service. These include:

#### ■ **Government monitoring of communications:**

In some countries, governments monitor internet use and communication technologies. Although it is often used for national security, it can result in the monitoring of ordinary citizens.

#### ■ **Drones:** These have multiple uses but one common use is to capture aerial video footage. Drones can be controlled remotely and are a very effective way to monitor an area.

#### ■ **Wearable cameras:** Whether it is a policeman's body camera or a skateboarder's GoPro, cameras may be capturing where you are and what you are doing without your knowledge or consent.

#### ■ **Location services:** Enabling location services on mobile phones improves app performance and allows users access to the full features of the app, however, the app is also collecting your location in real time.

#### ■ **Smart home technologies:** Intelligent devices, which are increasingly used in the home, need to monitor their environment to perform their function efficiently, which includes those who are at home.

#### ■ **Trace and track apps:** With nationwide restrictions being imposed due to COVID-19, users in many countries have had no choice but to adopt trace and track apps in return for being able to visit places outside of their home.



## Inquiry

### 3.1I Data dilemmas (content) and 4.6D Laws, regulations and policies (context)

#### Determine inquiry focus

Formulate an inquiry question, find real-world example(s) and connect them to the 3Cs

- Is your question concise, thought-provoking and worth considering from different perspectives?
- Does your question support discoveries that move beyond recall, description and summary?
- Are the course concepts, content and contexts that you have identified connected to your inquiry question?

- Conduct research into one of digital technology that is being used for surveillance, for example police body cameras or drones, and the laws regulating its use.
- From your initial research, find one real-life example.
- Using the steps above, create a statement for the inquiry focus.
- Justify your choice of inquiry focus.



## Knowledge and technology

The evolution of networking technologies and the internet has given people access to a tremendous amount of knowledge. But how do we know how much of this knowledge is true? In today's world, are we able to use terms such as 'fact' and 'truth'? How is the internet changing what it means to 'know' something? This could raise ethical questions such as:

- What role have networks had in exacerbating unequal access to knowledge?
- Alternatively, networks have given rise to questions related to perspectives such as:
- How are the different communities created by digital technology changing the communities of knowers?



## Extended essay (EE)

Network technologies, the evolution of the internet and network dilemmas may give rise to some interesting topics for an extended essay. Perhaps you could look at one of these technologies with one of the concepts, such as combining the evolution of the internet with the concept of expression, for example: To what extent are social media platforms influencing our identity?

## Learner profile

### Principled

In this unit you will be researching technologies that are impacting many lives. Are you a principled internet user? How can you ensure that your own use of the internet respects others around you?



## Reflection



Now that you have read this chapter, reflect on these questions:

- How are networks impacting your day-to-day life?
- How do the different networking technologies work together?
- How do the network protocols support the interoperability required for a global network?
- Could you identify the types of networks used in a range of contexts?
- Could you match suitable security solutions to the different security threats on a network?
- To what extent do the concerns from the internet dilemmas outweigh the benefits from using networks?
- Through the lens of change, how has the internet evolved?
- How can networks be used as interventions for global inequalities?
- How instrumental are networks in influencing how we know things?

# 3.5

# Media

## UNDERSTANDINGS

By the end of the chapter, you should understand that:

- digital media are defined by the convergence of computing, communication and content
- digital media are created and distributed through multiple channels and platforms
- digital media are associated with significant opportunities and dilemmas in digital society.

The world has been exposed to media for a very long time, whether it was the hand-drawn images found in printed newspapers archived in libraries or the paintings found in art galleries. So, when we talk about the media, what do we mean?

**Media** can be referred to as any communication channel that serves as a medium to enable information to reach a large group of people.

There are several types of media, including print media, which consists of published newspapers, magazines and books; mass media, such as the news channels on TV and radio; and **digital media**, which is the information consumed online.

Anytime you access a website or app, you will be either consuming or creating media. As both computing (3.3D) and the World Wide Web (3.4F) have evolved over time, so has digital media. In this chapter we will investigate the different types of media in more detail and the new dilemmas that have emerged due to their prolific availability.

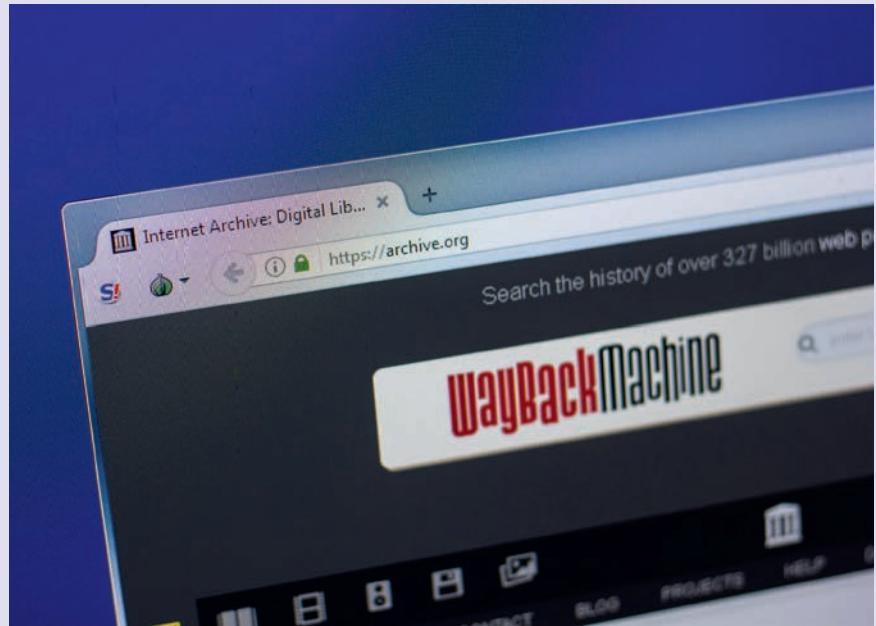
◆ **Digital media:** Video, audio, images and other content that is created, encoded and stored before sharing to the user(s). Encoding is the process of converting the media into a computer-readable format.

## ATL ACTIVITY

### Thinking

Make a personal connection to this topic by inspecting your favourite websites and how they have changed over time.

- Navigate to the 'Internet Archive WayBackMachine' – <https://web.archive.org> – and type in the URL of a website.
- Select the year it was created and then compare this to a recent date.
- Reflect on how the website was different back then, compared to now.
- Reflect on how the use of media has changed? Why do you think this took place?



## 3.5A Types of digital media

### ATL ACTIVITY

#### Thinking

Reflect on how digital media has influenced your day.

- Did you check your phone to find out what your friends have been doing on social media?
- Did you listen to a music app on the way to school?
- How did digital media provide you with information you needed for the day?
- How else have you been a consumer of media?
- Have you been a creator of media?

### Media and Web 1.0

Digital technology may have changed the speed and volume of media; but digital media still fulfils the same basic roles in society that it has always done, which is to entertain, educate and be a channel for public discussion. In the early days of the World Wide Web, web pages contained text and images and, as bandwidth increased, so did the ability to host video, animations and audio recordings.

### Media and Web 2.0

The introduction of Web 2.0 technologies, such as blogs, podcasts, wikis and social media, were instrumental in increasing the volume of user-generated content, which has changed the way that the public receives both local and global news.

### REAL-WORLD EXAMPLE

#### News from social media

In 2010, CNN reported that 75% of those surveyed were getting their news from email or social media platforms such as Facebook and Twitter. Traditional media companies were experiencing massive changes to their industry and were required to adapt in order to stay on trend and in business. By 2014, the terms, **trending** and **hashtag** were commonplace and, in 2015, the industry was producing more content targeted at social media such as **live video streaming**.

YouTube launched in 2005 and, at the time of writing, had over 2 billion monthly users and was the platform of choice for many internet influencers.

[www.forbes.com/sites/petersuciu/2019/10/11/more-americans-are-getting-their-news-from-social-media/?sh=283112063e17](http://www.forbes.com/sites/petersuciu/2019/10/11/more-americans-are-getting-their-news-from-social-media/?sh=283112063e17)

◆ **Trending:** A topic that experiences a sudden surge in popularity on social media platforms for a limited period of time.

◆ **Hashtag:** A word or phrase preceded by the symbol # to classify or categorize the accompanying text.

### Links

The rise of social media links to social media addiction in Section 3.5D Digital media dilemmas and Section 4.4C Mental health.

## REAL-WORLD EXAMPLE

### The first viral meme

The first viral **meme** was an animation of a baby dancing the cha-cha, designed by graphic designer Michael Girard in 1996. The animation was originally created to demonstrate the capabilities of software but, once shared, was converted into a gif and spread via communication technologies such as email.

With the widespread use of social media, it has become easier for memes to gain popularity and go viral. Memes have developed over time from political or cultural topics to anything that is funny and relatable, with more cultural references and sarcastic life observations.

## ATL ACTIVITY

### Social

Make a personal connection and find your favourite meme.

- Search for one of your favourite memes.
- Show it to a friend.
- Discuss why it is your favourite meme.
- Describe the genre of the meme and explain what message it is trying to show.

◆ **Meme:** An image, video, piece of text – typically humorous in nature – that is copied and spread rapidly by internet users, often with slight variations.

## Media and Web 3.0

Developments in artificial intelligence have influenced the media industry, from content creation to the consumer experience.

### Content creation



Advancements in artificial intelligence, cloud computing and graphics technology have led to a rapid development in techniques that manipulate images, audio and video.

Artificial intelligence-generated synthetic media is referred to as a **deepfake**. Deepfakes consist of synthetic (*fake*) media created using *deep learning*.

Many of these new tools are readily available online and are being used to manipulate media, whether it is superimposing one person's face on to another (face-swapping) or manipulating a voice to change the audio and lip movement at the same time (lip-syncing).

## Links

The content on memes links to Section 4.1A Arts, entertainment and popular culture.

◆ **Deepfake:** Synthetic media created with the use of deep learning/artificial intelligence.

Face-swapping technology was made popular in 2014 by Snapchat with the use of filters. The face-detecting lens technology was fun to use and entertaining, allowing people to share selfies with a choice of accessories, for example cat ears.

While the innocent use of deepfakes can be entertaining, more sinister uses of deepfakes have contributed to **fake news**. They can be used to damage reputations, fabricate evidence and defraud the public.

◆ **Fake news:** False or misleading information presented as news.

### REAL-WORLD EXAMPLE

#### Positive use of artificial intelligence for content creation

In 2021, Duran Duran created a music video for their song 'INVISIBLE' using artificial intelligence. The band teamed up with Nested Minds to generate the video. The artificial intelligence (called Huxley) used the lyrics, pictures, music and other information provided by the band to create the video using deep learning.

[www.itv.com/news/2021-05-19/duran-duran-how-the-band-made-a-new-music-video-untouched-by-human-hands](http://www.itv.com/news/2021-05-19/duran-duran-how-the-band-made-a-new-music-video-untouched-by-human-hands)

### REAL-WORLD EXAMPLE

#### Negative use of deepfakes

In March 2019, a UK-based energy firm was tricked into transferring around £200,000 (approximately US\$260,000) to a Hungarian bank account. An individual had used deepfake audio technology to impersonate the voice of the firm's CEO to authorize the payment.

### REAL-WORLD EXAMPLE

#### Deepfakes for educational purposes

In 2018, Buzzfeed worked together with the actor Jordan Peele to create a deepfake video of the former US president Barack Obama. The aim of this video was to raise awareness about the potential harm of deepfakes and the role that these realistic-looking videos could have in spreading fake news.

[www.trendmicro.com/vinfo/ph/security/news/cybercrime-and-digital-threats/exploiting-ai-how-cybercriminals-misuse-abuse-ai-and-ml](http://www.trendmicro.com/vinfo/ph/security/news/cybercrime-and-digital-threats/exploiting-ai-how-cybercriminals-misuse-abuse-ai-and-ml)

### ATL ACTIVITY

#### Thinking

Formulate a reasoned argument to support your opinion after completing this task.

- Research what free deepfake apps and software are available online.
- Select one to try out.
- Make a short deepfake video.
- Share this with a friend and see their response.
- Discuss how you created the video with your friend, including which aspects were easy and which were difficult.
- Ask your friend their opinion on your deepfake, for example, how realistic it was, or how obvious it was that it was fake.
- Form your own opinion about the use of deepfakes and potential concerns based on the outcomes of this task.

## Artificial intelligence and the consumer's media experience

Artificial intelligence can be used by media companies to predict demand and adjust their media production, accordingly. Used alongside content recommendations (such as Netflix recommendations), media companies can offer a more personalized experience.

However, one challenge for the media industry is how to effectively manage the data needed to train the artificial intelligence algorithm so that it can be more reliable. To improve the user experience, the media industry needs to collect data about the audience, such as their choice of device, when they watch and the routines they have, as well as what they are watching (content data).

## Electronic games



■ E-sport arena

Social media is not the only digital technology that has changed over time – the **electronic games** industry has also developed. The development of internet-enabled gaming consoles and personal computers has enabled more social aspects to video gaming and opened up gaming to new audiences. For example, senior citizens can now play bowling games in their retirement homes, and busy parents can play games on their phone while waiting for their children to finish after-school activities.

Previously, computer gamers did not make enough money from playing video games to make a career out of it, but this has slowly changed. Platforms such as YouTube and Twitch have allowed gaming influencers to grow their fanbase and tournaments now offer large cash prizes. E-sports (electronic sports) have been gathering momentum since 2000, with a variety of types of tournaments, from first-person shooter events (for example, Call of Duty), to multiplayer games (Dota 2) and fighter events (Mortal Kombat). In 2019, US\$100 million was made available for the Fortnite World Cup.

Like all sports, in order to succeed a player must select a game, develop their skills, find a community to practice with and climb the ladder. The window of opportunity for professional gamers is a small one, with the average age being 24 to 27. However, today many professional teams are turning to data analytics and machine learning to optimize their chances of success.

## ATL ACTIVITY

### Research

The health industry is investigating the use of recommendation systems to help design effective health messages for the public. Research this topic in more depth.

- Search for sources using the digital resources provided by your school library.
- Find at least three articles on this topic.
- Discuss your findings with a friend.
- What is the potential benefit to society from using recommendation engines for this purpose?

## Links

The content on gaming links to Section 4.1B Home, leisure and tourism.

## Inquiry

### 3.5A Types of digital media (content) and 2.4 Power (concepts)

#### Determine inquiry focus

Formulate an inquiry question, find real-world example(s) and connect them to the 3Cs

- Is your question concise, thought-provoking and worth considering from different perspectives?
- Does your question support discoveries that move beyond recall, description and summary?
- Are the course concepts, content and contexts that you have identified connected to your inquiry question?

- Conduct initial research on how the different types of media are contributing to the unequal distribution of power.
- From your initial research, find one real-world example.
- Use the steps above to create a statement for the inquiry focus.
- Justify your choice of inquiry focus.

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

#### Evaluate

Evaluate impacts and implications for relevant people and communities

- Is your evaluation based on your analysis?
- Does your evaluation focus on the impacts and implications for people and communities?
- Is your evaluation effective, sustained and well-supported by evidence?

Conduct research for the real-world example chosen, and analyse and evaluate of the use of digital media and power:

- What form does power have through the use of the media and its platform?
- Has the media and its platform been used to constrain power?
- To what extent has the use of the media and its platform impacted the balance of power on a personal, local and global level?
- Evaluate the use of the media and its platform. Does it have too much power? Is it possible to limit this power?

## Inquiry

### 3.5A Types of digital media (content) and 4.6A Political processes (contexts)

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

- Conduct secondary research into the uses of digital media for one real world example of a political movement or activism.

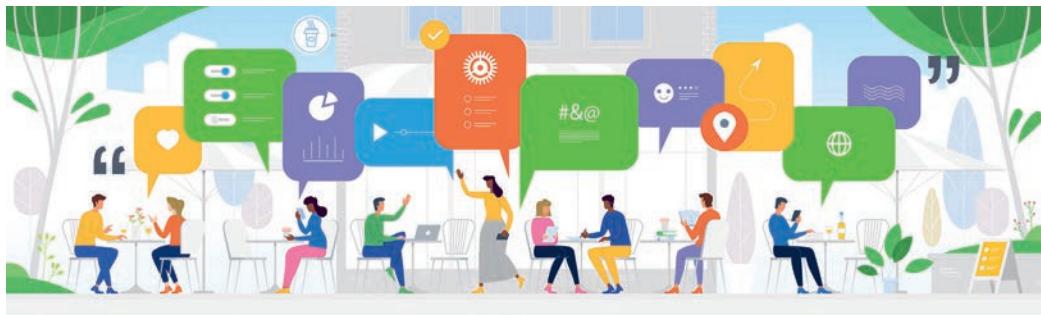
## Reflect

Reflect on new ideas and understandings, and discuss future developments

- Does your conclusion include a reflection based on new ideas and understandings that are a result of the analysis and evaluation?
- Does your conclusion include a discussion of possible new trends and future developments?
- Does your conclusion answer the inquiry question?

- Consider emerging trends and future developments of the use of digital media in this context.

## 3.5B Characteristics of digital media



Digital media generally serves the same purpose as traditional media, which is to entertain, educate and provide a forum for expression. However, digital media does have some unique characteristics:

- **Rapid sharing:** Compared to the past, it is now easy to share any kind of content, whether it is uploading a video to YouTube or reposting a Tweet.
- **Efficient storage:** Developments in storage technologies mean that huge amounts of data can be stored in one place. Mobile phones with cloud computing can store all data while people are using social media.
- **Interactivity:** Traditional media used to be ‘one way’ – audiences could receive the media but were not able to respond or interact. With interactive media in web design, media now has the potential to be more engaging for consumers and to motivate them to revisit web pages, post comments and make recommendations to friends.
- **Non-linear content or hypertextual:** In contrast to traditional media, which was linear, the use of hyperlinks on web pages allows people to click and visit pages in any order. This gives them the option to navigate media how they want to, not how a media company has decided they should.
- **Global networks:** Digital media has allowed people to interact more globally, which means that they can pool resources together more easily and have access to a wider range of sources of information than before.
- **Virtual:** Digital media allows people to communicate virtually through a wide range of technologies. They can now communicate very differently compared to how they used to face-to-face, which gives individuals more choices on how they present themselves.
- **Convergence of digital media:** People are frequently communicating using more than one form of digital media at a time. People no longer just call someone using voice – they can include voice and live video. When messaging, people do not just write in text – they can include a voice message, an emoji or an image. All of these demonstrate the convergence of media.

## EXAM PRACTICE QUESTIONS



### Paper 1 (core)

- 1 Identify two types of digital media. [2 marks]
- 2 Explain three characteristics of digital media that have contributed to the growth in consumption of digital media. [6 marks]
- 3 Using the concept 'expression', discuss how digital media is changing the way history is being recorded. [8 marks]

## 3.5C Immersive digital media

Earlier we discussed the fact that digital media allows for user interactivity. Go one step further and digital media becomes an immersive experience for people in a virtual life, based on simulations.

**Virtual reality (VR)** is a simulation that provides a completely immersive environment for the user. This is typically used with virtual reality headsets, from the cheaper option of using a phone in a cardboard mask to more expensive custom-made virtual reality goggles.

Virtual reality involves programming 3D objects to perform actions depending on how the user interacts with them. This involves the use of spatial computing. Spatial computing is when physical actions are used as inputs to receive outputs in a 3D space. This could be in three degrees of freedom (3DoF) such as a 360° video, or six degrees of freedom (6DoF), which allows a user to move backwards and forwards in a virtual space.

As businesses are looking for a competitive advantage, they are turning to virtual reality for a variety of uses:

- **Employee safety training:** Oil companies BP and ExxonMobil use virtual reality to train their employees in everyday work scenarios, such as emergency procedures. This allows employees to make mistakes in a controlled environment without causing themselves any harm.
- **Sales and marketing presentations:** Virtual reality allows sales teams to let potential customers experience products by interacting with them in an immersive environment. Zimmer Biomet, a dental technology provider, has created a virtual dental lab that lets dentists experience how the new technologies impact routine dental procedures.
- **Design decisions:** Virtual reality can be used to see the effects of various design decisions, allowing decision-makers to visualise different options before making their final choice.
- **Virtual workspaces:** Companies are investing in virtual office experiences to provide an office-like experience for employees working from home. Companies anticipate that this type of environment will provide a space for more casual work discussions, which may promote problem-solving and creative solutions.



◆ **Virtual reality (VR):**  
A simulation that provides a completely immersive environment for the user.

### ATL ACTIVITY

#### Self-management

Make a personal connection with this topic by exploring virtual reality videos on YouTube.

- Using a phone and a cardboard mask, such as Google Cardboard, search for virtual reality videos on YouTube.
- Watch several videos of different genres.
- Reflect on how this experience makes you feel.
- Did you feel immersed in the environment?
- What advantages and disadvantages do you think there are from using this type of digital technology?
- How many degrees of freedom did you experience?



### ■ Augmented reality

**Augmented reality (AR)** is when digital content is overlaid on to a real-world experience; it is commonly used with mobile devices, for example, the filter in Snapchat. Before taking a photo, individuals can see themselves (the real world) and then select from a range of digital items to enhance the picture.

Many industries are adopting augmented reality:

- The manufacturing, mining and maritime industries are using augmented reality as part of the inspection process of machinery for remote support to minimize interruptions to operations.
- In education, augmented reality is being used to allow teachers to present real situations through 3D modelling and providing a fun and engaging way to learn.

**Mixed reality (MR)** is the blending of the real world and the digital world to create a new experience.

Sometimes the simulation of a real-world system is called a **digital twin**. This technology is used by industries that are looking for ways to visualize, analyse, maintain and control their valuable assets. The dynamic nature of digital twins offers professionals more tools and information than static 3D data models.

◆ **Augmented reality (AR)**: Digital content overlaid on to a real-world experience.

## ATL ACTIVITY

### Research

Use effective research skills to find augmented reality apps.

- Search online for the top 10 augmented reality apps.
- Download one and try it out.
- Reflect on these questions:
  - What was your experience like?
  - What was the main purpose of the app?
  - Did the augmented reality aspect of the app enhance your experience?
  - Were there any disadvantages to this experience?

◆ **Mixed reality (MR)**: Blending the real world and digital world to create new experiences.

## REAL-WORLD EXAMPLE

### Royal Dutch Shell's digital twin initiative

Shell has created digital twins of their oil rigs that are out at sea. These detailed structural simulations of the oil rigs, developed using big data analytics and artificial intelligence, incorporate sensors to collect real-time data. The digital twins are being used to help manage the oil rigs, improve the safety of the workers and develop predictive maintenance by providing real-time data that they can act on.

<https://internetofbusiness.com/shell-digital-twin-oil-gas>



Virtual, augmented and mixed reality are already being used in a wide range of industries today. In the automotive industry, potential buyers can try out different options before choosing their car specifications; doctors can train in virtual 3D environments before performing surgery on real humans; and tourists can take virtual tours before finalizing their bookings.

So, why are businesses choosing this digital technology? From personal experiences it is possible to see how virtual reality is both engaging and entertaining. This is particularly useful when encouraging consumers to buy a product. Being able to visualize what it would look like, or how one can interact with it, can help consumers make up their minds.

It can also provide a cheaper and safer way of training. Immersive experiences can have a genuine physiological effect on their users, which is important in training. Training for doctors and military staff needs to be as close to reality as possible, so that their bodies are prepared for what is to come when they operate in the real world.

## Inquiry

### 3.5C Immersive digital media (content) and 4.5A Learning and education (contexts)

**Inquiry focus:** How are augmented reality and virtual reality being used by companies to support training?

#### Communicate

##### Presentation

- Is your presentation organized in a logical manner and is the media used to communicate effectively?
- Does your presentation lead towards answering the inquiry question?
- Does your presentation include findings, emerging trends, future developments and further insights?

A range of augmented and virtual reality technologies are being used in education today to enhance teaching and learning. You are a salesman for one of these technologies and have been asked to set up an exhibition to promote it. Your job is to persuade teachers to buy/use it.

Select one augmented/virtual reality technology for one subject and set up a display to include:

- a demonstration of the technology being used – in real life or via a video clip
- a description of the app, including its features and price.

You should also:

- discuss the impacts this technology will have on the students' learning
- discuss the impact that this technology will have on teachers
- cite your sources and include a bibliography.

Remember to be persuasive yet honest. If there are any disadvantages, include them, but also possible solutions.

## Inquiry

### 3.5C Immersive digital media (content) and 2.2 Expression (concepts)

**Inquiry focus:** What different kinds of stories are possible through the immersive digital world?

<b>Analyse</b>	Analyse impacts and implications for relevant people and communities <ul style="list-style-type: none"><li>● Is your inquiry question supported by additional questions to consider for analysis and evaluation?</li><li>● Does your analysis focus on the impacts and implications for people and communities?</li><li>● Is your analysis effective, sustained and well-supported by evidence?</li></ul>
<b>Evaluate</b>	Evaluate impacts and implications for relevant people and communities <ul style="list-style-type: none"><li>● Is your evaluation based on your analysis?</li><li>● Does your evaluation focus on the impacts and implications for people and communities?</li><li>● Is your evaluation effective, sustained and well-supported by evidence?</li></ul>

Explore sources to be able to effectively address the inquiry focus.

Investigate the different types of stories that are possible with an immersive digital world and select 'one or two' real-world examples.

Analyse and evaluate the effectiveness of this form of media in storytelling by answering the questions:

- What different kinds of stories are possible through the use augmented/virtual/mixed reality?
- What type of change has been brought about by the use of augmented/virtual/mixed reality in storytelling? Was it evolutionary, adaptive, transformational or radical?
- What are the positive and negative impacts of using augmented/virtual/mixed reality for storytelling?
- Should these stories be censored or controlled?
- If so, who should control these stories, and how, for example governments creating laws on censorship?
- How does this inquiry focus relate to the concepts of power, values and ethics?

## Activity: HL Extended Inquiry



### 3.5C Immersive digital media (content) and 5.1C The future of work

**Challenge:** Once you have studied Section 5.1C, research and describe the global challenge.

- Use effective research skills to identify one global challenge related to a current employment issue that is impacting global well-being that has virtual reality or augmented reality as an intervention.
- Describe the challenge in detail.

Research and evaluate one intervention using augmented/virtual reality for this challenge.

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.

## Links

Content on augmented reality links to Section 4.4B The human body.

## 3.5D Digital media dilemmas

Developments in the media industry have come with many advantages:

- Digital media has made news, information and entertainment more readily available and almost instant.
- Much of the online content is free or of minimal cost.
- Digital media is now widely more accessible around the world.

However, it has also introduced many new issues and dilemmas, which will be discussed briefly here.

### Media addiction and other psychological concerns

For many individuals, the consumption and creation of content on social media is a source of entertainment and a way of connecting with friends. However, there are more and more reports in the news of addiction and other well-being related concerns.

Social media addiction is an example of behavioural addiction. It is an uncontrollable urge to use social media for extended periods of time. Using social media can influence the way the brain functions. When using social media, individuals experience dopamine hits, which makes them feel rewarded temporarily. This might be due to the number of likes from a post or the fun content they have interacted with. However, due to the short-term nature of a dopamine hit, the brain ‘encourages’ individuals to stay on social media in order to get more dopamine, and so the addiction begins.

So, although moderate use of social media is unlikely to be harmful, the overuse of social media can lead to:

- low self-esteem
- anxiety and depression
- disrupted sleep patterns, especially if used before bedtime
- a fear of missing out (FOMO)
- decreased physical activity and engagement in real-life activities.

### Impact on journalism

Digital media has contributed to the breaking down of cultural barriers, which has allowed people to have more control over the media they consume: they can now see, experience and understand more, as well as interact with the content.

The characteristics of digital media discussed in Section 3.5B are transforming journalism.

Traditional forms of journalism have now shifted to online, real-time reporting, multimedia content, access to global information and the personalization of news, which has challenged the monopoly previously held by the mass media.

Today's journalists must develop new skills – in addition to writing and reporting, they also need technical and digital literacy skills. Journalists are expected to complete their articles with shorter deadlines and for more than one type of media. It has always been important for journalists to get their story out first but, in the rush to break news stories online, there is a higher chance that the information has not been checked adequately to stop the flow of **misinformation**.

#### ◆ Misinformation:

False or inaccurate information that is mistakenly or inadvertently created or spread; the intent is not to deceive.



Web 2.0 technologies have enabled users to generate their own content and share it with ease. Social media has become an essential tool for journalists as they can write breaking news stories and post within seconds to their thousands of followers. Social media has the additional advantage that journalists can allow readers to get to know them on a personal level through their profile and online conversations. The ability to allow journalists to create their own 'brand' can bring about loyalty in their followers.

However, the same digital technology has enabled many amateur journalists who have not undergone the same training and who are not under the same editorial control. Fake news and 'alternative facts' damage the reputation of journalists and make it harder for people to determine what is true and what isn't. One potential solution is the formation of a peer-review network, whereby journalists review and fact check each other's work.

### REAL-WORLD EXAMPLE

#### QAnon

QAnon is an American conspiracy theory movement centred around an anonymous individual called Q who made unsubstantiated claims allegedly from within the US government administration. In 2017, Q posted a series of messages (Q drops) on the website 4chan, claiming to have security clearance (Q clearance). Since then, thousands of followers have been using social media to share the conspiracy theories and coordinate abusive messages on the perceived enemies, including politicians, celebrities and journalists, who they believe are covering up the stories. Social media companies have taken down many of the Q-supporting accounts, but there are still millions of believers online.

[www.bbc.com/news/53498434](http://www.bbc.com/news/53498434)



■ QAnon Rally in London

## Media authenticity

Technological developments in the creation and distribution of media are making it increasingly more difficult to check the authenticity of the media. Social media sites have become a one-stop shop for entertainment and a way to keep up to date with friends and the news.

A study by George Pearson from Ohio State University found that when people use the same source for both news and entertainment, they pay less attention to the source of the content, making it more difficult for them to evaluate sources and therefore are more vulnerable to fake news.

Broadly speaking, fake news is deliberately made up with the intent to disinform and is usually political or criminal in nature. One of the main goals is for articles to go viral so that creators can make money or promote a political agenda.

### REAL-WORLD EXAMPLE

#### Fake news spreads faster than real news

An MIT researcher investigated how and why stories spread differently through social media using data from 126,000 stories that had been tweeted by 3 million people from 2006 to 2017. The study concluded that fake news spreads faster on social media than real news, mainly because false news stimulates emotions, such as surprise, fear and disgust, while real news is met with sadness, joy, anticipation and trust. The study was considered particularly important at the time as it was established that fake news had distorted the 2016 US presidential election.

[www.theguardian.com/commentisfree/2018/mar/19/fake-news-social-media-twitter-mit-journalism](http://www.theguardian.com/commentisfree/2018/mar/19/fake-news-social-media-twitter-mit-journalism)

Deepfake technology, such as lip-syncing and face swapping, were introduced earlier in this unit. A 2019 report by start-up company Deeptrace found 7964 deepfake videos online and predicted this will increase in the future, largely due to the fact that the tools are widely available and easy to use. It is still currently possible to notice if a video is fake but, as technology improves, it will become harder to distinguish between real and fake. It does not require much imagination to see the potential harm that deepfakes can have on journalism.

### ATL ACTIVITY

#### Research

Satirical news sites such as the *Onion* contain a range of fake stories with the intention of entertaining their readers by mocking people's habits and stereotypes.

- Find three stories online, two of which are fake news and one that is real news.
- Present them to your friends to see if they can guess which one is real.
- Explain the dangers of fake news to your friends.



Fake news!

### Top tips

Can you distinguish between misinformation and **disinformation**? How are they different? Make sure you have revised these key terms so that you can use them correctly in your exam answers.

♦ **Disinformation:** False information that is deliberately created and spread with the intent of influencing public opinion or obscuring the truth.

## ■ Ownership of media

The evolution of the internet has made it easier than ever to share and distribute digital media. With the right social media presence, artists can instantly reach out to millions of viewers and listeners to get their work known. But this can come at a price, forcing artists to rethink their business models if they wish to survive. As an IB student, you should be aware of academic honesty when it comes to citing sources and using someone else's **intellectual property**.

Intellectual property is the outcome of thought or intellectual effort. It gives protection to creators of new inventions, designs, brand names and other original creations. Legal rights, such as patents, trademarks and **copyright**, give the creator the rights over their work and can protect them from unauthorized use of their work for a specified period of time. The aim of intellectual property is to reward the creativity of the owners of the work and encourage inventors to share their innovations.

Copyright refers to literary and artistic works including books, music, paintings, films and computer programs, which may also be digital. It is important that all consumers of digital media and creators of digital media are aware of the copyright laws operating in their country because unauthorized use is a criminal offence and is considered theft.

Copyright laws outline the rights of users to be able to use, modify or distribute the work included in this category. To use copyrighted work, one must first identify the owner of the work and then obtain permission to use it. This can be a time-consuming process and ultimately restricts creativity. There are two circumstances in which work can be used without gaining permission, however.

This includes work in the **public domain** (work that is available to the public and not subject to copyright) and **fair use** (which can include using the work for study or research, commentary or criticism). Should there be a dispute over whether the use of copyrighted work comes under 'fair use', the following would be considered:

- Is it being used to create something new, or is it just straight-forward copying?
- Will it impact the market value of the original work?
- How much of the original work is being used?

### REAL-WORLD EXAMPLE

#### Blurred lines

Robin Thicke, Pharrell Williams, and TI's song 'Blurred lines' was released in 2013. After five years in court, however, it was ruled that it infringed the copyright (was too similar to) of Marvin Gaye's 1977 song 'Got to give it up'. Thicke and Williams had to pay a fine of over US\$5 million to the Gaye estate.

[www.rollingstone.com/pro/features/music-copyright-lawsuits-chilling-effect-935310](http://www.rollingstone.com/pro/features/music-copyright-lawsuits-chilling-effect-935310)

### ATL ACTIVITY

#### Research

Use effective online research skills to:

- Research the copyright laws in your country. Write a brief summary of the laws.
- Research the meaning of 'public domain'. What type of works can be found in the public domain?
- Research fair use and outline some examples that are usually considered to be fair use, such as news reporting.
- Find one example in your local news where copyright has been infringed. Write a summary of the scenario and details of the fine awarded.
- Use the bullets above to plan a quiz for your friends.
- Use online quiz tools to create a self-marking quiz.
- Test out the quiz and then share it with your friends.

#### ◆ Intellectual property

**property:** The outcome of thought or intellectual effort, for example a new invention or an original design. It also refers to the legal protection of that work.

#### ◆ Copyright

**protection** for the creators of literary and artistic works including books, music, paintings, films and computer programs, which may also be digital.



■ Copyright

As we said earlier, obtaining permission can be time-consuming, for both the person wanting to use the work and the owner of the work. A solution can be found in **copyleft** licensing.

Copyleft is when owners of work will allow others to use their copyrighted property freely under specific conditions. For example, copyleft software allows users to copy, modify and share their code provided that the source code remains open and publicly available. The aim of this type of licensing is to help build communities so that they can collaborate to improve the creative works.

An example of copyleft licensing is **creative commons licensing**. Creative commons can be used by anyone and helps to standardize the way that copyright permissions are granted to others who wish to use their work.

CC BY is the least restrictive and allows others to distribute, remix, adapt and build on work as long as they credit the original creator.

CC BY NC ND (non-commercial and no derivatives) is the most restrictive. This only allows others to download and share the work as long as the owner is credited. It cannot be changed or used commercially.

## ATL ACTIVITY

### Social

Work in a small group to complete this task.

- Research the different types of creative commons licensing in more depth.
- Create a set of cards that includes images of the different licences, an explanation of the licences and scenarios for each one.
- Write up the rules of the game.
- Print out the cards and invite your friends to play.

◆ **Copyleft:** When owners of original work allow others to use their copyrighted property freely under specific conditions.



■ Copyleft



■ CC BY creative commons licence



■ CC BY NC ND creative commons licence

## Links

This content links 4.1A Arts, entertainment and popular culture.

## EXAM PRACTICE QUESTIONS



### Paper 1 (core)

- 1 Identify two works of art that are covered by copyright. [2 marks]
- 2 Explain two limitations of copyright laws. [6 marks]
- 3 The evolution of the internet and computing has made it easier for people to illegally copy and distribute works of art. Discuss the impact this is having on the music industry. [8 marks]

### Paper 1 (HL extended)

- 4 Evaluate one **intervention** used in the music industry to advocate for better conditions for new music artists. [12 marks]

## Censorship and control of media

The protocols and standards used by the internet have supported the global sharing of digital media. However, not everyone has access to the same digital media, with many governments employing sophisticated digital censorship for reasons in four main categories:

- 1 Political content:** Content that is of a political nature may be blocked by governments when the opinions of minority groups conflict with that of the government.



### REAL-WORLD EXAMPLE

#### Cambodia

In July 2018, Cambodia blocked several independent news sites two days before a general election.

[www.reuters.com/article/us-cambodia-election-censorship/cambodia-blocks-some-independent-news-media-sites-rights-group-idUSKBN1KH29Q](http://www.reuters.com/article/us-cambodia-election-censorship/cambodia-blocks-some-independent-news-media-sites-rights-group-idUSKBN1KH29Q)

- 2 Social content:** Content that is socially sensitive or perceived to be offensive is often blocked by governments to protect their citizens from exposure to undesirable media. This can include content related to sexuality, gambling, alcohol and illegal drugs.

### REAL-WORLD EXAMPLE

#### Uganda

In July 2018, Ugandan communication regulators directed internet service providers to block access to pornographic websites.

<https://qz.com/africa/1340505/uganda-is-making-isps-block-pornography-from-its-citizens>

- 3 Conflict and security:** Content that is related to conflicts, militant groups and border conflicts may be blocked so that local citizens do not contribute to the conflict in question.

### REAL-WORLD EXAMPLE

#### Sri Lanka

Following a series of bombings in 2019, Sri Lanka shut down access to social media to prevent the spread of misinformation in an attempt to reduce the acts of further violence that followed.

[www.theguardian.com/world/2019/apr/21/social-media-shut-down-in-sri-lanka-in-bid-to-stem-misinformation](http://www.theguardian.com/world/2019/apr/21/social-media-shut-down-in-sri-lanka-in-bid-to-stem-misinformation)

- 4 Internet tools:** Some countries may monitor communications within a country, looking for keywords in conversations in emails or messages, or internet searches.

## ATL ACTIVITY

### Research

Practice effective online searching skills on digital censorship.

- Research the different reasons for digital censorship. Find an example of each of the above and include which country and what sort of media is censored.
- Find one recent article in the news in which the internet has been 'switched off' or monitored during times of conflict or security. Discuss with your friend how this action may have impacted the country at the time.

## Learner profile

### Open-minded

Be open to the perspectives, values and traditions of others when you are researching and discussing the use of content filtering.

## Digital media preservation



The evolution of computing and the internet has brought on the development of digital media formats and storage. Such changes have led to **obsolescence** of both storage media and data formats.

Take, for example, home video footage recorded in the 1990s using a video camera and stored on a magnetic tape. Once recorded, it would have been played back by connecting the video camera to the television. As years went by, the camera has become obsolete, and so the family would have had to upgrade to a new camera. Faced with the issue of how to view the footage stored on the tapes, the family would have used a company to convert them to a DVD format, so that it could be played on a DVD player. Fast forward another ten years and the family disposes of the DVD player and now the footage needs to be transferred to another storage device, and so the story continues.

Also, It is not just the hardware that becomes obsolete over time, but as digital technology evolves, so do the file formats being used and the software required to read the files. So, what is the solution to this never-ending story of obsolescence?

Digital preservation is essential for modern history and includes practices to ensure that information is safe from media failure and hardware/software obsolescence in the future. To preserve data, it must be transferred onto fresh media. In the case of obsolete software, emulators are used to simulate the old software so that the data can be retrieved. For example, when computers simulate an older operating system, they can then run the older software, open the file and save it in a new format.

## Activity: HL Extended Inquiry



### Learner profile

#### Principled

Use your honesty and integrity to reflect on the dilemmas created by the evolution of the digital media.

#### 5.2A Conflict, peace and digital media

**Challenge:** Digital media is being used around the world to spread misinformation and spread propaganda. Select one example of real world conflict and research how media has been used in a negative way.

**Intervention:** Research and develop your understanding of one intervention that could be used to address this challenge.

Evaluate the intervention and make recommendations for future action.

## TOK

### Knowledge and technology

Developments in digital media, and the software that is used to create digital media, provide different methods and tools to support the acquisition of knowledge.

- How has increased access to digital media impacted what we know and how we know?
- How does the choice of digital media change the way that knowledge is produced, shared and understood?

## Creativity, activity, service (CAS)

### Copyright and academic honesty awareness campaign

Using a range of digital media, create an awareness campaign for students new to the IB Diploma course about copyright and compliance with academic honesty.

## Extended essay (EE)

The evolution of digital media and how it is being used may give rise to some interesting topics for an extended essay.

Perhaps you could look at one of these technologies with one of the contexts as a focus for the essay. The technologies used for augmented reality could be investigated in a context such as e-commerce, for example: How is augmented reality impacting the shopping experience in a market of your choice (computer games, clothing, furnishings, and so on)?

Document the process of converting your initial ideas into a research question.

## Links

Links to DP Business management, The use of digital media in marketing.

## Reflection



Now that you have read this chapter, reflect on these questions:

- Which types of media do you consume or create on a daily basis?
- To what extent has media changed in your lifetime?
- How is digital media different from traditional media?
- In which contexts are the different media formats having an impact?
- How can media be used as an intervention to improve global well-being?
- To what extent are the dilemmas in the use of media impacting individuals and society?
- Discuss the relationship between media and power?
- How is the media influencing the way that we know things?

# 3.6

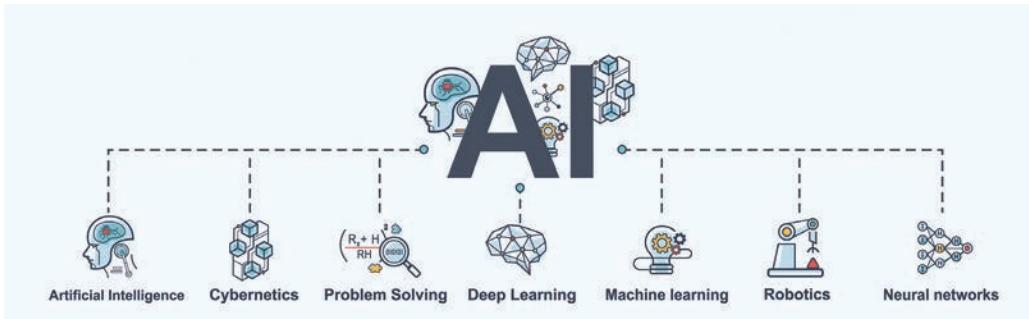
# Artificial intelligence

## UNDERSTANDINGS

By the end of the chapter, you should understand:

- ▶ artificial intelligence (AI) involves agents, devices or systems that adapt to perform tasks (or appear to do so) that once required the cognitive and creative processes of human beings
- ▶ there are several types of existing, emerging or proposed AI; these categories frequently overlap or are contested
- ▶ AI has evolved over time and introduces significant opportunities and dilemmas in digital society.

We have entered a fifth generation in computing, artificial intelligence (AI). Although stemming from science fiction and the earlier work of Alan Turing, a mathematician and cryptographer, artificial intelligence is emerging and becoming more prevalent in today's news headlines. As well as beating humans in games such as the AlphaGo challenge, it is becoming ubiquitous in our everyday lives. In this chapter we will investigate the technologies being developed in artificial intelligence, where they are being implemented and the dilemmas that are arising from their use.



## ATL ACTIVITY

### Thinking

Reflect on the following questions before starting this chapter:

- What is easy for a human to do but not a computer?
- What is easier for a computer to do than a human?
- What is meant by the term 'human intelligence'?
- What is meant by the term 'artificial intelligence'?

## 3.6A Types of AI

When looking up the word 'intelligence', one will be presented with a wide range of terms including abstract reasoning, mental representation, problem-solving, decision-making, emotional knowledge, creativity and adaptation.

Given the complexity of our brains and the way that we think, it is no surprise that it is difficult to develop artificial intelligence. It comes with other inherent problems, as well, for example:

- most people cannot describe how they do things
- there is a difference between the way a human brain is structured and human capabilities compared to that of a computer
- the best way for a machine is often different to that of a human.

How can we determine whether a computer system has true intelligence? In 1950, Alan Turing wrote an academic paper titled 'Computing machinery and intelligence', from which he developed a test of artificial intelligence called the Turing Test. Based on a party game called 'The Imitation Game', an interrogator is on one side of a screen and asks questions to different players on the other side of the screen. One of the players would be a computer (chatbot). The game would continue with the interrogator chatting (with typed text) for up to five minutes. If the interrogator mistakes the computer for a human more than 30% of the time, then the computer has passed the artificial intelligence test.

The Turing Test was used on early chatbots, such as ELIZA in the 1960s, but it took over 60 years before a chatbot passed the test. The Loebner Prize, an artificial intelligence competition, was held annually with the aim of evaluating the status of conversational machines aspiring to pass the Turing Test. In 2012, a chatbot posing as a 13-year-old Ukrainian boy (named Eugene Goostman) convinced the interrogator that it was human. This was controversial, however, as it was considered that the chatbot had tricked the humans by behaving like a teenager.

Although the Turing Test can only test natural language processing; it is still popular because it provides a simple test that can be applied to a complex situation. You can read more about the history of the test here: [www.thinkautomation.com/bots-and-ai/the-history-of-the-turing-test](http://www.thinkautomation.com/bots-and-ai/the-history-of-the-turing-test).

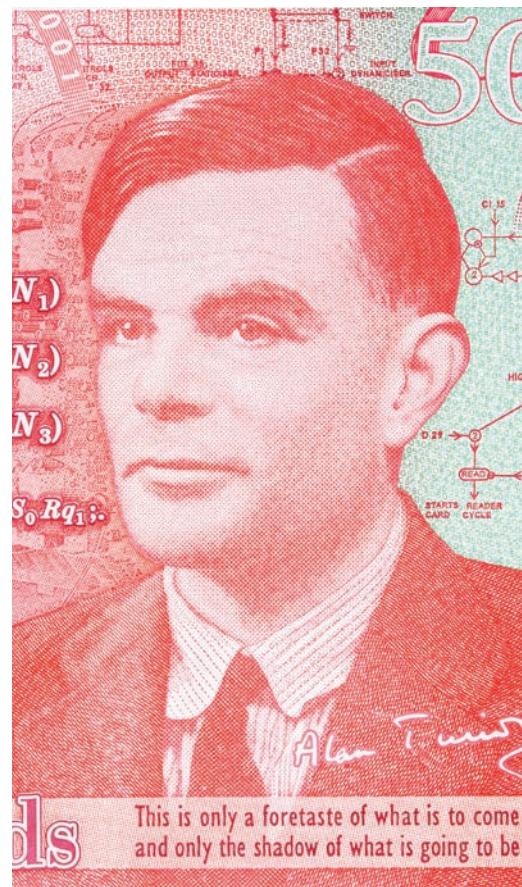
CAPTCHA (Completely Automated Public Turing Test to tell Computers and Humans Apart) is a form of modern-day Turing Test. CAPTCHA questions are frequently used when registering on a new website. It was created so that a user can prove at the time of registration to the website that they are human and not a bot.

## ATL ACTIVITY

### Thinking

Hold a discussion about the development of CAPTCHA.

- Research and collate a selection of CAPTCHA images to show how they have changed over time.
- Hold a group discussion about how CAPTCHA has evolved.
- Discuss possible reasons why CAPTCHA has changed.
- Use your knowledge of machine learning to support this discussion.



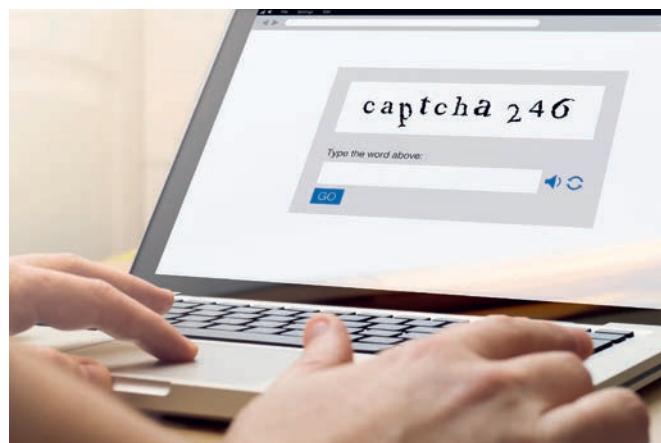
■ Alan Turing

## ATL ACTIVITY

### Social

Complete this activity with a group of friends.

- Research for an unplugged activity to recreate the Turing Test.
- Download the activity, follow the instructions to set it up, and play.



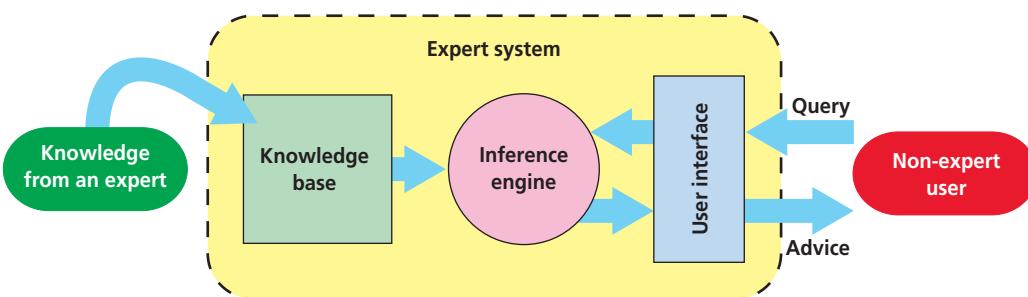
■ CAPTCHA

It is important to recognize that there are different types of artificial intelligence. The artificial intelligence that we encounter day to day is referred to as **weak or narrow AI**. It is called weak because it only has a limited function or can only perform a specific task. Take, for example, the artificial intelligence in Netflix – it can only perform one task, which is to recommend what we watch next. Other examples of weak artificial intelligence include chess programs, Google searching, Siri and Alexa, self-driving vehicles, recommendation engines and facial recognition. Many weak artificial intelligence systems are changing the world we live in as they can complete tasks much quicker than humans and can discover patterns in big data.

In certain domains, artificial intelligence can perform tasks better than humans. This is known as **domain-specific AI**. Examples include artificial intelligence that can detect cancer better than human doctors, and artificial intelligence such AlphaGo, developed by DeepMind to beat the world champion at the board game Go. However, this is not enough to be classed as **strong AI**, also known as **full AI** or **artificial general intelligence (AGI)**. Strong artificial intelligence will be when machines get to the point that they can develop consciousness and make decisions better than humans. Additionally, strong artificial intelligence will be able to demonstrate self-awareness and emotions, and have full human cognitive abilities.

Once strong artificial intelligence is achieved, the next milestone will be **super AI**, which is when machines surpass human intelligence. When artificial intelligence gets to this point, there are concerns (such as those found in science fiction) that machines will overthrow the human race. In technology, **singularity** describes the hypothetical future where AI becomes so advanced that it is superior to human intelligence. Nanotechnology is perceived as one of the key technologies that will make this a reality.

In artificial intelligence, an **expert system** is a computer system that acts like a human expert in a specific subject area. Expert systems are often used to advise non-experts when a human expert is not available.



#### Components of an expert system

An expert system has three main components: the user interface, inference engine and the knowledge base.

- The **knowledge base** represents facts and rules and is created by a knowledge engineer who collects the information provided by human experts.
- The **inference engine** uses programmed rules to interpret and evaluate the facts in the knowledge base. Logic is applied in the inference engine using if/then statements, Boolean logic and fuzzy logic. To provide a solution or answer, the inference engine uses forward or backward chaining.
- The user interface (see definition on page 97) is the part of the system that allows a non-expert to ask questions of the expert system and receive advice.

An expert system is an example of domain-specific AI and is frequently used in medical or car diagnosis, petroleum engineering, financial advising and identifying unknown items.

◆ **Weak/narrow AI:** Artificial intelligence that has a limited function or can only perform a specific task.

◆ **Domain-specific AI:** Artificial intelligence that perform tasks better than humans in certain domains.

◆ **Strong AI:** Artificial intelligence that can develop consciousness and make decisions better than humans.

◆ **Super AI:** Artificial intelligence that surpasses human intelligence.

◆ **Singularity:** The hypothetical future where artificial intelligence becomes so advanced that it is superior to human intelligence.

◆ **Expert system:** A computer system that acts like a human expert in a specific subject area.

◆ **Knowledge base:** Facts and rules in an expert system.

◆ **Inference engine:** The part of an expert systems that uses programmed rules to interpret and evaluate the facts in the knowledge base.

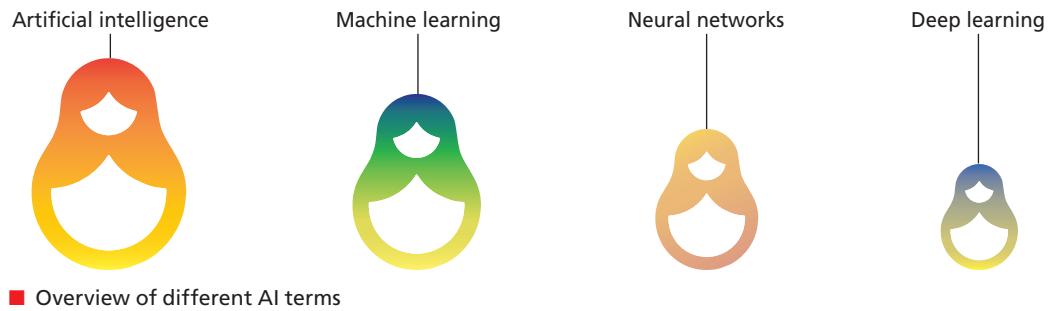
## ATL ACTIVITY

### Self-management

Become an independent learner and try something new.

- Search online for a web-based expert system, for example medical system checkers, car diagnostics or plant recognition.
- Interact with the different online expert systems that you have found.
- Reflect on how this experience is different from a human expert.
- Reflect on the pros and cons of using such a system.

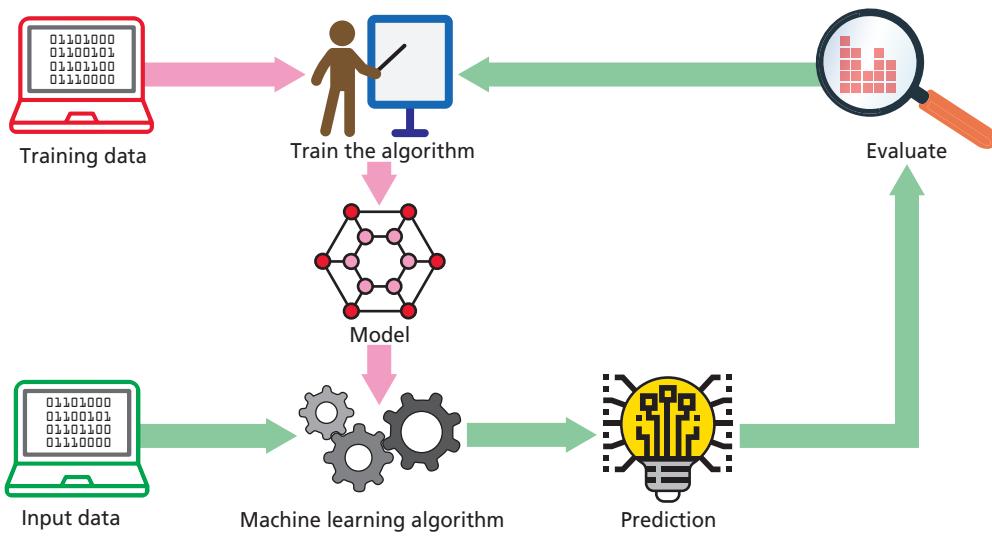
So far you have been learning about artificial intelligence, but how is this different to machine learning, neural networks and deep learning? Neural networks are then the backbone of deep learning. Over the next two sections, we will be discussing each of these in more detail.



## 3.6B Types and uses of machine learning

Before discussing the different types of machine learning, let's briefly look at the key elements of machine learning.

- It needs a set of good data (often called training data).
- It uses algorithms (based on a computer model) to look at the data and understand it.
- Data is input into the algorithm to make a prediction.
- The prediction is then evaluated and, if inaccurate, this data is fed back into the system to update the model/algorithm.



## ATL ACTIVITY

### Thinking

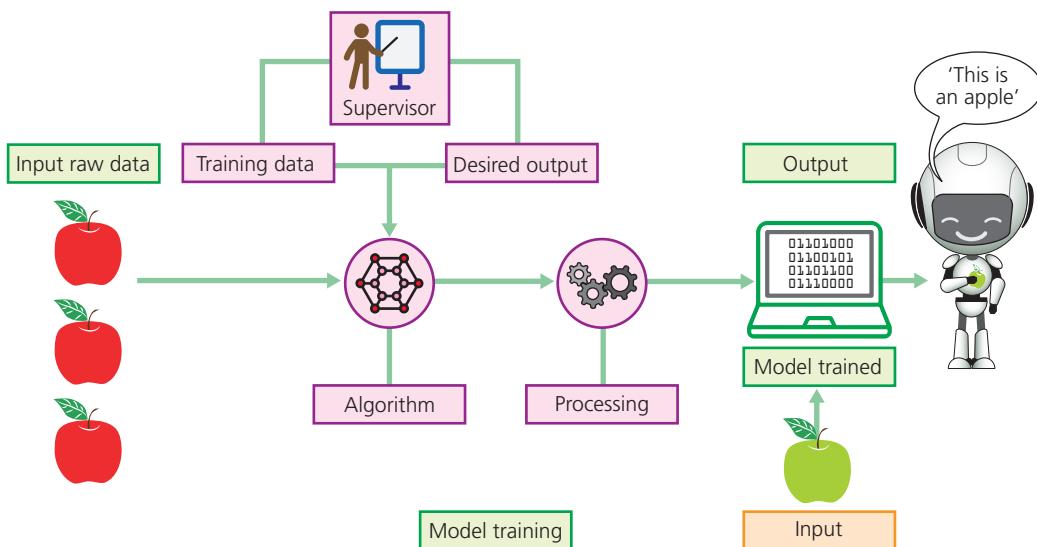
Become an independent learner and teach yourself something new.

- Search online for a web-based tool in machine learning modelling, for example Google's 'Teachable Machine'.
- Try creating different data sets and teach the model to recognize simple tasks.

## Types of machine learning

### Supervised learning

Supervised learning is the simplest form of machine learning, with algorithms learning by example. The training data consists of a set of inputs, each paired with a set of correct outputs. During the training process, the algorithm will search for patterns in the data that correlate to the desired output. Once the system has been trained, it will be fed new, unseen inputs and determine which label to give the new input. It is considered ‘supervised’ because the system is trained with known outputs and the algorithm is adjusted until it can produce the correct output for unseen inputs.



#### Supervised learning

Supervised learning can have different algorithms for different purposes. A **classification algorithm** will take input data and assign it to a category that is based on the training data. A **regression algorithm** is different in that it is used for predictions and looks at the relationship between variables. This algorithm is commonly used to make predictions, such as sales or test scores, based on the analysis of the data set.

Applications that use supervised learning include spam filters, fraud detection and handwriting character recognition.

### REAL-WORLD EXAMPLE

#### Supervised learning

In June 2020, the UK government published a report with recommendations to help fight the increase in online misinformation. The report concluded that many online platforms were using black box algorithms to select which content their users were shown. The investigation found that Google was using supervised learning.

Human content evaluators were used to creating good-quality training sets for the machine learning system. They were given guidelines on how to rate content and were asked to use their own judgement to rate the quality,

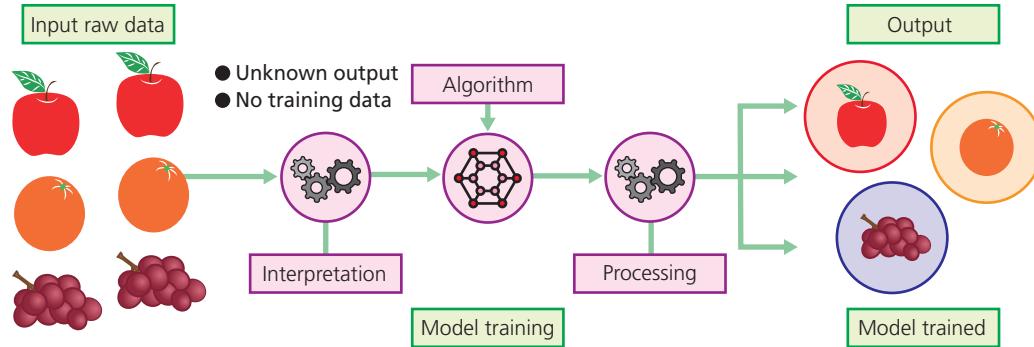
reputation and usefulness of web pages. The investigation found that rather than editing the code of the algorithms, evaluators were manually rating sites and search rankings for the training sets as a way of influencing the algorithm.

Google's algorithm is relied on by millions of users when searching for information. It uses a combination of human judgement and constant modifying of the algorithm coding (it was reported that Google modified its algorithm 3200 times in 2018).

[www.fastcompany.com/90663621/vint-cerf-google-misinformation?](http://www.fastcompany.com/90663621/vint-cerf-google-misinformation?)

## Unsupervised learning

Unsupervised learning is used to find underlying patterns in data. It uses data sets that do not have any labels but instead uses the data's features. The goal of unsupervised learning is to analyse data to find hidden patterns that cannot be noticed by a human observer. The algorithms use cluster analysis, which looks for ways to group the data.

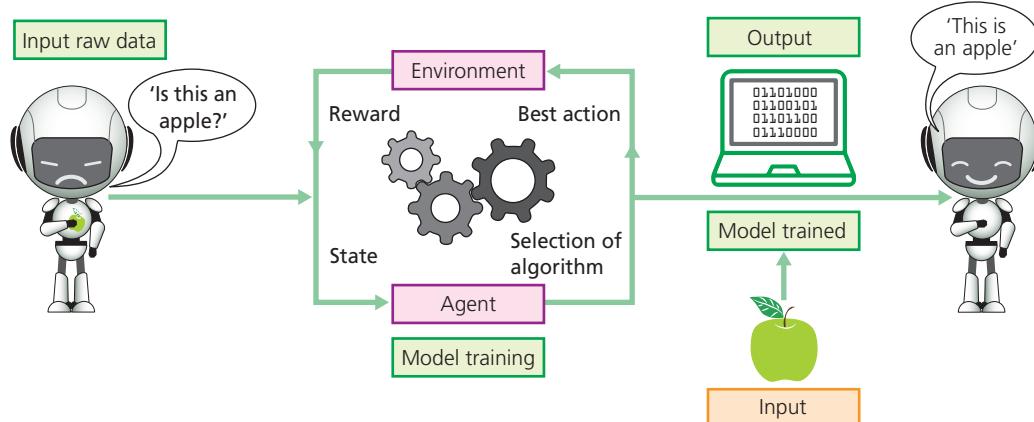


### ■ Unsupervised learning

Applications that use unsupervised learning include social networking analysis and market segmentation.

## Reinforced learning

This type of machine learning is based on rewarding positive behaviour. The algorithm is trained by rewarding the system if it performs correctly and gives a penalty if it performs incorrectly. The software agent makes decisions to maximize its reward and keep adapting to the environment. This form of machine learning requires a lot of data, which is why some of the first applications were based on how readily available the data was.



### ■ Reinforced learning

Applications that use reinforced learning include autonomous vehicles, predictive maintenance, games and robotics.

## ATL ACTIVITY

### Research

Use research skills to further your knowledge on the different types of machine learning.

- Use effective online search skills and digital resources from the school library to find out more about machine learning.
- Find one real-life example for each type of machine learning.
- Write a report to include:
  - an explanation on how machine learning is being used in this context
  - a discussion on the impact the machine learning is having in this context.
- Correctly cite the sources used and create a bibliography at the end of the report.

### Deep learning

Deep learning is a type of machine learning that is used for more complex problems. It does not require structured data, but instead uses artificial neural networks. A neural network that consists of more than three layers is considered to be a deep-learning algorithm. We will look at neural networks in the next section.

Applications of deep learning include facial recognition, image recognition, natural language processing and speech recognition.

### Pattern recognition

Pattern recognition uses machine learning algorithms to recognize patterns; these can be either observed physical patterns or mathematical patterns. Pattern recognition is used for many different purposes.

### Data analytics

Data analytics is used in stock market forecasting and audience research. In stock market forecasting, pattern recognition is used to analyse the changing values in the stock exchange in order to make predictions. Audience research, such as Google Analytics, uses pattern recognition to analyse user data for market segmentation.

### Natural language processing

Natural language processing uses machine learning to teach a computer to understand human language. It has multiple uses today including:

- text analysis, which is used to convert unstructured data into structured data ready for analysis;  
examples include analysing surveys or customer call notes
- plagiarism detection, which is used to analyse text and compare to sources on the web, for example, Turnitin
- text generation for chatbots, such as customer service chatbots on websites
- text translation, which uses text analysis, word substitution and sentiment analysis to recreate messages in different languages, for example, Google Translate
- text correction, used in grammar correcting apps, for example, Grammarly.

### Image recognition

Image recognition is used to understand what is in a picture so that it can describe the picture and the image can become more searchable. Two uses of image recognition include:

- image search – Google's image search uses both pattern recognition and meta data in its search algorithms

- facial recognition – recognizing someone from using their faceprint is used in numerous applications, for example, to unlock a phone or spot someone in a crowd.



■ Facial recognition for identification

### Voice and sound recognition

Voice and sound recognition works by analysing patterns of sound that can be converted into text and applied to natural language processing. This can be used in:

- AI assistants, so that users can interact using voice commands
- speech-to-text and text-to-speech translation, which allow users to convert spoken words into text on the screen and vice versa; one example is the use of automatic caption creation on video websites such as YouTube.

### Sentiment analysis

Sentiment analysis can interpret someone's mood or intent using pattern recognition. This is commonly used in audience research or customer relationship platforms to gain more information about a customer's response to a product or service.

#### REAL-WORLD EXAMPLE

##### Sentiment analysis at KFC

The fast-food chain Kentucky Fried Chicken (KFC) used sentiment analysis to monitor their brand and manage their reputation. They used this analysis to review the success of different aspects of their marketing campaign, for example the use of RoboCop in their advertisements. Sentiment analysis was used to make decisions about the campaign based on insights from posts and comments made by consumers reacting to the campaign on social media.

<https://theappsolutions.com/blog/development/sentiment-analysis-for-business/>

#### ATL ACTIVITY

##### Research

Use research skills to further your knowledge on deep learning.

- Use effective online search skills and digital resources from the school library to find out more about the applications of deep learning.
- Find one real-life example for facial recognition, image recognition, natural language processing and speech recognition.
- Write a report to include:
  - an explanation on how it is being used in the real-life example
  - a discussion on the impact it is having in this context.
- Correctly cite the sources used and create a bibliography at the end of the report.



## Activity: HL Extended Inquiry



### 3.6 Artificial intelligence (content) and 5.1B Changing populations

**Challenge:** The UK government has the challenge of an aging population.

Investigate the challenge in more depth.

- Who is being impacted by this challenge?
- To what extent is an aging population a problem for the UK government?

**Intervention:** A three-month trial to monitor elderly people in one region of the UK was initiated in August 2021. Sensors were installed in the homes of elderly people and were used to monitor their movement, temperature and the use of appliances. The system, powered by artificial intelligence, was able to monitor the behaviour of elderly people and determine if a potential health problem needed human attention.

Research and evaluate this intervention using the HL extended inquiry framework.

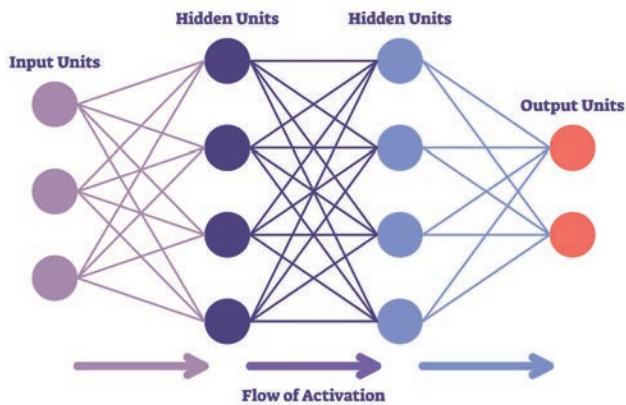
Make a recommendation for steps for future action.

Present your work in the form of a written report.

## 3.6C Uses of artificial neural networks

Neural networks are systems with interconnected nodes that work in a similar way to the neurons in the human brain. Nodes are activated when there is sufficient input, which in turn provides input for the next series of nodes, and so on (depending on how many levels there are) until it produces an output. The connections between these artificial neurons act in a similar manner to real synapses, enabling signals to be transmitted from one node to another. The signals move from one hidden layer to another, being processed on the way as they travel from the first input to the last output layer. When given input stimulus, the neurons run mathematical calculations to figure out if there is enough information to pass the information on to the next neuron. For example, data inputs received are added up and, if the sum is more than a certain threshold value, the neuron ‘fires’ and activates the neurons it is connected to.

### AI Neural Networks



■ A simple neural network with three input neurons and two outputs

### Description of steps

- Data is fed into a neural network through the input layer, which communicates with hidden layers.
- Processing takes place in the hidden layers through a system of weighted connections.
- Nodes in the hidden layer combine data from the input layer with a set of coefficients and assign appropriate weights to inputs.
- These input-weight products are then summed up.
- The sum is passed through a node’s activation function, which determines the extent that a signal must progress further through the network to affect the final output.
- Finally, the hidden layers link to the output layer, where the outputs are retrieved.

The key advantages of neural networks are:

- 1 They can learn and model non-linear and complex relationships. This is really important as many scenarios in real life are non-linear.
- 2 They can generalise and infer relationships from unseen data.
- 3 They do not impose a restriction on the input variable.

Neural networks and deep learning are currently used in image processing and forecasting.

### REAL-WORLD EXAMPLE

#### GitHub

The GitHub coding program uses a model called Codex, which uses a large artificial neural network to predict text and computer code. It uses billions of lines of code stored on GitHub to learn how to write code, not all of which is bug free.

[www.wired.com/story/ai-write-code-like-humans-bugs](http://www.wired.com/story/ai-write-code-like-humans-bugs)

### EXAM PRACTICE QUESTIONS

#### Paper 1 (core)

- 1 Identify two types of artificial intelligence. [2 marks]
- 2 Describe two uses of machine learning. [4 marks]
- 3 Distinguish between two types of machine learning. [6 marks]
- 4 For one context of your choice, to what extent has artificial intelligence been making a positive impact? [8 marks]

## Activity: HL Extended Inquiry

### 3.6B Types and uses of machine learning, 3.6C Uses of artificial neural networks (content) and 5.3C Managing pollution and waste

Once you have studied Section 5.3C, try this inquiry activity.

**Challenge:** Research and describe the global challenge.

- Use effective research skills to identify one global challenge related to the management of pollution and waste.
- Describe the challenge in detail.

**Intervention:** Research and evaluate one intervention for this challenge.

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.

## 3.6D Evolution of AI

Artificial intelligence features strongly in the imagination of many famous science fiction writers, who offer a futuristic look at our lives to come. One of the most violent depictions of an AI-dominated world was *I have no mouth and I must scream*, written by Harlan Ellison in 1967 in which artificial intelligence killed all but five of the human race.

Ellison was one of the first writers to understand that a machine with consciousness and emotions (a sentient machine) would face the same horrors as a sentient human.

But how has artificial intelligence moved from science fiction to reality?

Although the fifth generation in computing is said to have started in 2010, the roots of artificial intelligence started much earlier than this. In the period between the 1940s and 1960s, there was a strong desire to bring together the functionality of machines and organic beings. Research into artificial intelligence officially began in 1956 at the Dartmouth Conference, which aimed to unify research in **cybernetics**, automation and complex processing, thus allowing machines to 'think'. Key researchers include Norbert Wiener, a pioneer in cybernetics, John McCarthy, Marvin Minsky and Claude Shannon. In the 1950s Alan Turing was credited with being one of the first people to come up with the idea that machines could think. We talked about him earlier in this unit. While the technology remained promising, the popularity of artificial intelligence developments has had its peaks and troughs. An **AI winter** is a period in which funding and interest in research and development of artificial intelligence is reduced. The first AI winter occurred between 1974 and 1980. Researchers at the time had made promises about artificial intelligence developments that did not materialize. Consequently, many agencies cut their funding.

The next peak in artificial intelligence was the development of **expert systems**. They were considered a move in the right direction and focused on very specific problems. The first expert system, named Dendral, was developed to analyse chemical compounds by Edward Feigenbaum and Joshua Lederberg at Stanford University in 1965. Expert systems became very popular in the 1980s. They attracted funding from technology companies and the government. However, the market for expert systems collapsed and brought with it a second AI winter.

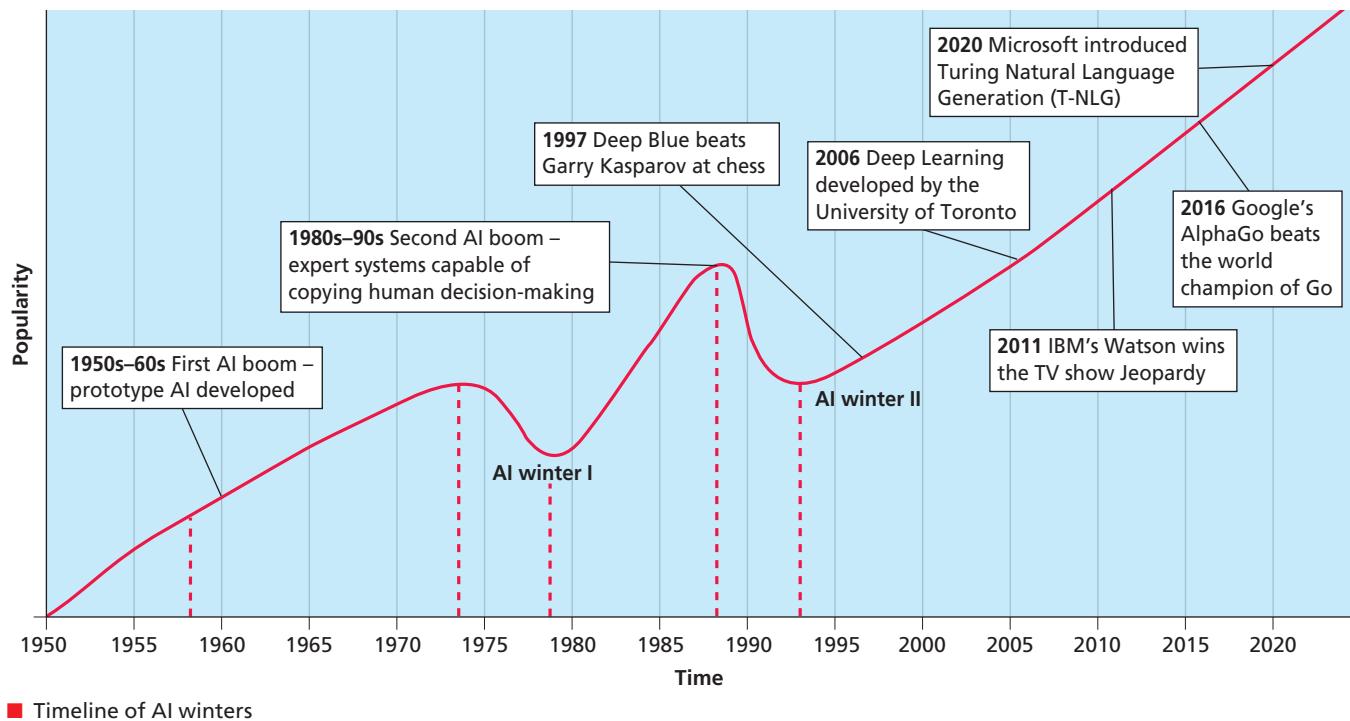
In technology, as artificial intelligence has evolved, so has the concern for the future of civilization. Two key thinkers of the time predicted a future where technology growth would be out of control and be irreversible, with the boundary between humanity and computers being removed. This concept and the term **singularity** were popularised by Vernor Vinge in 1993. Ray Kurzweil published his book *The singularity is near* in 2005, in which he predicted that singularity would be achieved by the year 2045 using super-human artificial intelligence.

There was another boom in the late 2000s and early 2010s, this time with the advances in machine learning and deep learning. Two factors can explain the new boom in this area. The first was the availability and access to massive amounts of data (big data) and the second was the developments in computer graphic cards and microprocessors, making the increased processing capabilities needed for artificial intelligence possible. These developments became the focus of many large tech companies and triggered an **AI summer**.

With AI summers leading to an increase in artificial intelligence development, the public have become concerned about what artificial intelligence might mean for future jobs. Alongside the predictions of singularity came the concern that many human jobs would be replaced by artificial intelligence. This has been seen in the manufacturing industry, with many robot-driven factories. However, Ken Goldberg, a roboticist at the University of California, Berkeley, believes that instead of artificial intelligence and robots replacing all jobs in the future, they will instead be developed to work alongside people. He called this **multiplicity**.

◆ **Cybernetics:** The study of communication and control in both living things and machines, especially automatic control systems such as the human nervous system, and mechanical-electrical communication systems.

◆ **Multiplicity:** A future in which artificial intelligence and robots are developed to work alongside people, rather than to replace them.



■ Timeline of AI winters

## EXAM PRACTICE QUESTIONS



### Paper 2

#### Source A: Article View on Artificial General Intelligence is overhyped

At the start of the 2010s, one of the world leaders in AI, DeepMind, referred to artificial general intelligence (AGI) being developed at some point in the future. Deep Mind believes that machines possessing AGI would be just as smart as humans across the board.

However, AI researchers (who wish to remain anonymous) say that statements like these were overhyped by certain companies and believe that society is entering a period where they are especially sceptical about AGI, and that we are about to enter another AI winter. The AI researchers state that 'there is a general feeling of plateau' and that 'AI is entering a new phase [in which] the public perception of AI is increasingly dark: the public believes AI is a sinister technology.'

When the reporters requested a response to the claim, DeepMind took a more optimistic view of AI's potential, suggesting that as yet 'we're only just scratching the surface of what might be possible'. While AGI isn't going to be created any time soon, machines have learned how to master complex activities such as:

- playing the board game Go
- identifying human faces, plant and animals
- translating text into practically every language
- driving cars.

*Adapted from [www.bbc.com/news/technology-51064369](http://www.bbc.com/news/technology-51064369)*

### Source B

Find a current article written by AI researchers on the 'Success of Artificial General Intelligence'.

- 1 a **Identify** two characteristics of an 'AI winter'. [2 marks]
- b **Explain** the difference between artificial general intelligence (AGI) and domain-specific AI. [4 marks]
- c Use the source above, your additional source and your knowledge of the uses of AI to, **compare** the claims and perspectives made by the artificial intelligence researchers and the companies creating artificial intelligence solutions, and the impacts that artificial intelligence will have on society. [6 marks]
- d With reference to the two sources and your knowledge of artificial intelligence, **discuss** whether **changes** in artificial intelligence have been incremental or radical. [12 marks]

### Top tips

When working on Paper 2 there will always be more than one source to analyse. Practice gathering sources with different perspectives so that you can read similar or opposing viewpoints.

## Inquiry

### 3.6D Evolution of AI (content) and 2.1 Change (concepts)

Research how past events, patterns or trends in artificial intelligence will help forecast the future developments in artificial intelligence.

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

Use your research skills to find three sources to further your understanding of this inquiry.

Your final choice of sources must be able to help you gain a deeper understanding of this topic, provide a balance of claims and perspective, and be embedded in the content (artificial intelligence) and concept (change).

Write a short report to justify your chosen sources and their usefulness in this inquiry. Your report should include:

- a discussion on the origin and purpose of each source, including any potential bias or limitations of using the source
- a discussion of the main ideas being presented in each source and what features of the source were used to support the claim being made
- a discussion on how the sources corroborate or contradict, and how it has helped you gain a deeper understanding of this question
- a bibliography entry for each source at the end of the report.

## 3.6E AI dilemmas

Earlier in this unit we discussed the different algorithms and uses of artificial intelligence, and how they have evolved. The development of artificial intelligence is important for many reasons. Firstly, it allows for the **automation of the discovery of data** and can automate certain computerized tasks more reliably and without getting tired. For example, when detecting fraudulent transactions, artificial intelligence can operate 24-7 and send alerts for human intervention. Artificial intelligence can also **add intelligence to existing products**, such as our home appliances or security intelligence in the workplace.

Since artificial intelligence is **adapting through learning** and can **analyse data** more deeply, it can be more reliable in classifying and making predictions. Developments in deep learning have made artificial intelligence systems more accurate and are consequently being widely used in the medical field, for example analysing MRIs for cancer.

Data is now more important than ever before. With the right data and sophisticated artificial intelligence, more and more answers are being provided. However, the design and use of artificial intelligence is creating a number of global dilemmas.

### Fairness and bias

One limitation of artificial intelligence is that it learns from the data sets that are fed into the system. This means that any inaccuracies in the data will be reflected in the results. This has been particularly evident with systems designed on biased data sets or algorithms. It is the role of artificial intelligence designers and developers to minimize algorithmic bias through research and data collection that represents the whole population.

#### REAL-WORLD EXAMPLE

##### Twitter

In May 2021, a study of 10,000 images found bias in what Twitter's photo crop algorithm chose to highlight. The algorithm was more reliable in selecting lighter-skinned faces compared to those with darker skin. Twitter has stopped using the tool on its mobile app following the discovery.

[www.wired.com/story/twitter-photo-crop-algorithm-favors-white-faces-women](http://www.wired.com/story/twitter-photo-crop-algorithm-favors-white-faces-women)



## Accountability in design and use

In the development of artificial intelligence, developers are responsible for the designs, developments, outcomes and impact that the system has on the world. This becomes increasingly difficult when one considers the range of uses and different types of artificial intelligence that are being developed.

When discussing accountability, several questions should be asked:

- 1 How does accountability change if the end-user has more influence over an artificial intelligence system?

### REAL-WORLD EXAMPLE

#### Tay

Microsoft's AI chatbot Tay made inappropriate statements on Twitter and was taken offline after only 16 hours. Tay was programmed to imitate the language of 18–24-year-old millennials and to talk and engage with people, learning from the users' conversations. However, the users purposefully provoked Tay with inappropriate discussions, which Tay then repeated.

[www.analyticsinsight.net/famous-ai-gone-wrong-examples-in-the-real-world-we-need-to-know](http://www.analyticsinsight.net/famous-ai-gone-wrong-examples-in-the-real-world-we-need-to-know)

- 2 How does accountability change if the artificial intelligence is being used to support decision-making or make decisions on its own?

### REAL-WORLD EXAMPLE

#### Uber's autonomous vehicles

Uber's real-world testing of autonomous cars in San Francisco in 2016 reported that the autonomous vehicle had made the decision to not stop at six red traffic lights when being tested. The testing included the use of vehicle sensors, networked mapping software and a driver in case the autonomous vehicle went out of control. This example shows how it is difficult to determine who is accountable when technology goes wrong. At the time of testing, Uber reported that it was the fault of the driver.

[www.analyticsinsight.net/famous-ai-gone-wrong-examples-in-the-real-world-we-need-to-know](http://www.analyticsinsight.net/famous-ai-gone-wrong-examples-in-the-real-world-we-need-to-know)

[www.ibm.com/design/ai/ethics/accountability](http://www.ibm.com/design/ai/ethics/accountability)



### ATL ACTIVITY

#### Thinking

In a group, conduct some wider research on the topic of accountability in the design and use of artificial intelligence. Hold a discussion to address each question.

- 1 How does accountability change if the end-user has more influence over an artificial intelligence system?
- 2 How does accountability change if the artificial intelligence is being used to support decision-making or make decisions on its own?

## ■ Transparency in design and use

Artificial intelligence should be designed so that humans can understand its decision-making process easily. The solution to this is **transparency**. As artificial intelligence's capabilities increase, so does the impact it has on society. Consequently, it should be possible to explain its decision-making to people clearly, and for people to see how its conclusions and recommendations have been formed. This is essential if developers want end-users to trust the systems. People should be aware that they are interacting with an artificial intelligence system at all times, even if the designers would like a flawless experience.

However, as deep learning algorithms evolve over time, it is very possible that developers will not be able to explain the 'black box' nature of the artificial intelligence system. Unlike traditional programs, developers cannot just examine the code to test it for bugs to make them more reliable or to see the decision-making process clearly. As users of artificial intelligence technology, if it is not performing as expected we would want to know why.

There are four main problems:

- 1 Unexplainable algorithms:** When artificial intelligence is drawing a conclusion, whether during classification or regression, there is no visible understanding of how it was reached.
- 2 Lack of visibility in training data sets:** It is not always clear where the training data has come from, whether it has been cleaned, or even if it is accessible.
- 3 Lack of visibility in methods of data selection:** Even if developers were given access to training data, this could be petabytes of data. However, they may not know which aspects of the data was actually used. For transparency, one would want to know how the training data was used.
- 4 Poor management of model versioning:** As models are continuously developed, it is sometimes difficult to keep track of which version is being used.

As society strives for greater transparency, it can come with its weaknesses as well. If people can understand how an artificial intelligence is reaching its decisions, it poses two threats:

- it is easier for hackers to try to work around the system
- it is easier for competitors to steal the artificial intelligence algorithms.

### REAL-WORLD EXAMPLE

#### Apple's credit card service

In November 2019, the US financial regulator set up an investigation into claims that Apple's credit card service was offering different credit limits to men and women. The cause of this discrimination was unclear but it was speculated that it was due to biased data sets or a lack of transparency in how the algorithms were determining what the final credit limit should be.

[www.bbc.com/news/business-50365609](http://www.bbc.com/news/business-50365609)



### ATL ACTIVITY

#### Thinking

Prepare for a debate about the transparency of artificial intelligence algorithms.

- Divide your group of friends into two: one side are pro-transparency, the other against.
- Research in more depth about the transparency of artificial intelligence.
- Conduct the debate.
- At the end of the debate, as a group take a vote on whether artificial intelligence should be more transparent.

## ■ AI's carbon footprint

The University of Massachusetts Amherst completed a research paper that estimated that the carbon emissions when training a neural network are the same as that of a car. Factors that influence the carbon footprint include:

- the algorithm and its training time
- the processing unit
- the energy efficiency of the data centre
- the type of energy used in the data centres.

CodeCarbon, an open-source project, is being developed to estimate the carbon footprint of computing. The aim of the project is to help data scientists make more environmentally friendly decisions.

## ■ Uneven and underdeveloped laws, regulations and governance

The rapid pace of artificial intelligence adoption has created a strain on existing regulations, with laws struggling to keep up. In the early 2020s, Cognilytica released a report based on an investigation into the actions taken by countries around the world. It concluded that many countries were not rushing into developing laws and regulations on artificial intelligence, instead they were waiting to see how the technology was being used before they came up with a meaningful law. Another area researched was the level of discussion regarding the restrictions of lethal autonomous weapons systems (LAWS). At the time of the report, only one country, Belgium, had passed legislation on this, with 13 countries engaged in discussions.

In the meantime, this leaves the technology companies in a dilemma, because without the laws, their technology may not be legal to operate. For example, for autonomous vehicles to be allowed on the roads, laws must be written to permit them. In this report, only 24 countries had laws allowing for the operation of autonomous vehicles.

Another aspect of artificial intelligence that is gaining regulatory attention is user data rights. Since developments in artificial intelligence require large data sets to train with, it is no surprise that these data sets may include data from people, collected by the IT systems they have signed up for. This makes it all the more important that organizations comply with data protection laws.

### ATL ACTIVITY

#### Research

Conduct effective online research on artificial intelligence legislation.

- Research existing artificial intelligence legislation in two countries (where you live and one other country).
- Focus on legislation in one of these artificial intelligence technologies:
  - facial recognition
  - autonomous vehicles
  - conversational artificial intelligence, such as chatbots
  - LAWS.
- Compare and contrast the legislation between each country.
- Suggest reasons for any differences.

## ■ Automation and displacement of humans in multiple contexts and roles

Alongside the rapid development of artificial intelligence comes concern about how the widespread use of artificial intelligence will impact employment. Will it replace jobs, will it support existing jobs, or will it create new jobs?

One limitation of artificial intelligence is that it is only capable of narrow tasks or intelligence; humans possess a more generalized intelligence that will continue to be important.

The World Economic Forum concluded that advances in artificial intelligence could potentially replace a large proportion of jobs. Artificial intelligence used to automate tasks is predicted to replace 75 million jobs by 2025. In 2020, 2.7 million industrial robots were found in manufacturing, completing heavy-duty work or completing tasks with high precision. Food preparation was another area where jobs have been lost to **automation**, as well as construction and driving jobs.

The most vulnerable group of people likely to lose jobs to artificial intelligence are those with lower-level qualifications. More-educated employees will be required to adapt to the technological changes or will be in senior management roles that still require human judgement.

The same World Economic Forum report predicted that artificial intelligence will also create 133 million new jobs. Jobs in sectors such as health, education, scientific and technical services will be least affected, and employment opportunities will be based on what artificial intelligence and robots are not capable of. Jobs that require care and understanding, for example caring for elderly people, will still be in demand, especially in countries with an aging population.

◆ **Automation:**  
The increased use of technology in a process, which reduces the need for human involvement.

### REAL-WORLD EXAMPLE

#### Alibaba's FlyZoo Hotel

Developed by Alibaba, a 290-room hotel in Hangzhou, China, promises to be the hotel of the future. It utilizes many technologies that have already been established in other hotels, including self-service kiosks for checking in, artificial intelligence-driven apps to allow travellers to book their stay, and facial recognition to gain access to rooms and elevators. Each room has a voice-activated smart assistant that can help the guests customize their room temperature, lighting and entertainment, and robots can deliver room service or perform other concierge services.

The main aim of this level of automation is to provide a better service for guests, reduce staffing costs and free up employed staff to give a more individualized service.

<https://hoteltechnologynews.com/2019/03/flyzoo-hotel-the-hotel-of-the-future-or-just-more-technology-hype>

### ATL ACTIVITY

#### Research

Look for personal relevance in this research activity.

- Research the industry that you are planning to have a career in.
- How is artificial intelligence being used in this industry?
- What jobs are being replaced by artificial intelligence?
- What jobs have been created by artificial intelligence?

## Inquiry

### 3.6E AI dilemmas (content) and 4.4A Medicine and health (contexts)

<b>Analyse</b>	Analyse impacts and implications for relevant people and communities <ul style="list-style-type: none"><li>● Is your inquiry question supported by additional questions to consider for analysis and evaluation?</li><li>● Does your analysis focus on the impacts and implications for people and communities?</li><li>● Is your analysis effective, sustained and well-supported by evidence?</li></ul>
<b>Evaluate</b>	Evaluate impacts and implications for relevant people and communities <ul style="list-style-type: none"><li>● Is your evaluation based on your analysis?</li><li>● Does your evaluation focus on the impacts and implications for people and communities?</li><li>● Is your evaluation effective, sustained and well-supported by evidence?</li></ul>

Select one artificial intelligence dilemma and research how it is impacting either the delivery of medical diagnostics, medical research, or monitoring of health and well-being.

- Discuss how the artificial intelligence is causing the dilemma.
- Discuss the impact this dilemma is having on two stakeholders, for example patients and health care workers.
- Evaluate the significance of the dilemma.

<b>Communicate</b>	<p>Presentation</p> <ul style="list-style-type: none"><li>● Is your presentation organized in a logical manner and is the media used to communicate effectively?</li><li>● Does your presentation lead towards answering the inquiry question?</li><li>● Does your presentation include findings, emerging trends, future developments and further insights?</li></ul>
<ul style="list-style-type: none"><li>■ Present your findings in a multimedia presentation.</li></ul>	

## Activity: HL Extended Inquiry



### 3.6 Artificial intelligence (content) and 5.1C The future of work

Once you have studied Section 5.1C, try this inquiry activity.

**Challenge:** Research and describe the global challenge.

- Use effective research skills to identify one global challenge regarding the future of work.
- Describe the challenge in detail.

**Intervention:** Research and evaluate one intervention for this challenge.

- Research and evaluate this intervention using the HL extended inquiry framework.
- Make a recommendation for steps for future action.

Present your work in the form of a written report.

## TOK

### Knowledge and technology

Developments in artificial intelligence raise many questions about knowledge.

- What do the developments in artificial intelligence mean for knowledge?
- Should we redefine our human concept of knowledge because of developments in artificial intelligence?

The kind of knowledge produced by technology empowered by artificial intelligence is not always ethical. Because this field of technology is relatively new, with varying legislation in different countries, there is potential for unethical uses to arise. As we saw in this chapter, claims made by artificial intelligence systems to be able to determine a person's behaviour using facial recognition could potentially lead to discrimination. So, how can one ethically define the limits of progress in knowledge that has been created by an artificial intelligence system?

### Extended essay (EE)

The evolution of artificial intelligence, its uses and its intended and unintended consequences may give rise to some interesting topics for an extended essay.

One possible focus for the essay could be how a specific artificial intelligence technology is impacting a particular context, such as human knowledge and the design and delivery of formal education.

### Creativity, activity, service (CAS)

#### Complete an online AI course

Teach yourself more about artificial intelligence by completing an online course. This may be an introductory course that will teach more theory related to artificial intelligence, or a technical course to develop skills in creating artificial intelligence. Before starting, conduct some initial research into which online platforms provide IT courses. Perhaps your school is already registered with one that can be used, or see what free courses are available.

Select the platform and the course to register for. Work through the required activities and don't forget to document the journey for CAS.

### Reflection

Now that you have read this chapter, reflect on these questions:

- What type of artificial intelligence are you surrounded by day to day?
- Are traditional tests for artificial intelligence effective for the current developments in artificial intelligence?
- How are machine learning and neural networks making IT systems more intelligent?
- In which contexts is artificial intelligence having a significant impact?
- To what extent should expert systems be used to replace or support human experts?
- Is it possible to develop artificial intelligence algorithms without bias?
- Should limits be imposed on the development of artificial intelligence?
- To what extent is current artificial intelligence legislation a barrier for artificial intelligence development and adoption?
- How can analysing past trends in AI winters and summers help predict the future of artificial intelligence?
- How is artificial intelligence being used as an intervention to solve global environmental and employment issues?
- How is artificial intelligence changing how we know things?



### Learner profile

#### Inquirer

Develop skills in inquiry to research the topics in this unit in more depth, for example the artificial intelligence legislation where you live, the use of artificial intelligence in the world around you, and the dilemmas that artificial intelligence is creating.

# 3.7

# Robotics and autonomous technologies

## UNDERSTANDINGS

By the end of the chapter, you should understand that:

- ▶ robots and autonomous technologies demonstrate a capacity to sense, think and/or act with some degree of independence
- ▶ robots and autonomous technologies have evolved over time and are increasingly ubiquitous, pervasive and woven into the everyday lives of people and communities
- ▶ robots and autonomous technologies introduce significant opportunities and dilemmas in digital society.

**Robot** – a word that was first introduced to society in a science fiction play in 1921 – is now a reality and becoming more prevalent in our lives. Robots have transformed manufacturing by increasing efficiency, safety and accuracy, but at the cost of replacing jobs on the production line. Robot designers are now turning their attention to the development of service and social robots, aimed at working alongside humans. In this chapter we will investigate different types of robots and autonomous technologies and where they are being used, alongside the dilemmas that these developments have brought about.

◆ **Robot:** A programmable machine that can complete a set task with little or no human intervention.

## 3.7A Types of robots and autonomous technologies

It is important to establish what we mean by the term ‘robot’. Essentially a robot is a programmable machine that can complete a set task with little or no human intervention.

It has taken decades to develop the robots that are integrated into today’s society. Later in this chapter we will discuss how they have evolved over time but, to get started, it is important to look at the wide range of robots that are in use today. Robots have evolved over time in two distinct categories: robots used in manufacturing, and robots designed for human interaction. In this section we will also look at other autonomous technologies, in particular autonomous vehicles and drones.

### Industrial robots

The demand for robots in manufacturing has been one of the driving forces in robotics from the 1960s to the present day. Robots used in manufacturing complete tasks such as drilling, painting, welding, assembly and material handling. Industrial robots are different from those used for professional service robots based on their purpose. Industrial robots completing tasks in manufacturing have replaced many human workers on the production line, while service robots often perform tasks by assisting workers or customers, for example, in agriculture or the construction industry.

Advances in robotics used in manufacturing are ongoing with organizations always looking for greater efficiency and accuracy on their production lines.

## REAL-WORLD EXAMPLE

### Automation in car production

In 2014, Great Wall Motors, a Chinese automotive manufacturer, increased automation in their plant with robots collaborating on different parts of the production line. For example, one robot would position the panel while a second robot would do the welding.

According to the American Society of Mechanical Engineers, the Taiwanese electronics company Foxconn announced plans to increase automation by 30% in their Chinese plants by 2020, which would ultimately replace 60,000 jobs.

[www.asme.org/topics-resources/content/top-5-robot-jobs-manufacturing](http://www.asme.org/topics-resources/content/top-5-robot-jobs-manufacturing)



### Service robots

**Service robots** have been developed to assist humans in completing tasks that are less desirable, such as dull, dirty or dangerous jobs. This category of robot may be for domestic or professional use and is growing in demand because it frees up humans to do other things, which could include more challenging tasks or allowing individuals to have more leisure time.

**Personal service robots** used in the home include robots that can vacuum, clean the pool, mow the lawn and even robotized wheelchairs for elderly people. These robots can be programmed to complete the task and work autonomously. For example, robot vacuum cleaners are becoming more common in homes: they are affordable, can vacuum your house while you are out and have features such as self-emptying bins.



■ Robot vacuum

◆ **Service robots:**

Robots developed to assist humans in completing tasks that are less desirable, such as dull, dirty or dangerous jobs.

## Virtual personal assistants

**Virtual personal assistants**, such as Google Home, Amazon Echo or Apple HomePod, are voice-controlled helpers mainly found in smart speakers or mobile phones. Once connected to the home network, a user can use voice commands to prompt different activities, such as providing a weather update, setting a timer or reading out the latest news.

◆ **Virtual personal assistant:** Voice-controlled helpers mainly found in smart speakers or mobile phones.

### REAL-WORLD EXAMPLE

#### Virtual assistants

In 2018, Hampshire County Council, UK, trialled the use of virtual assistants to support elderly people and people with disabilities. Users with limited mobility benefited from being able to use the voice-activated devices to complete tasks such as turning on smart home devices, searching for information and activating entertainment, which then allowed carers to focus on other tasks in the home.

[www.bbc.com/news/av/uk-politics-43869120](https://www.bbc.com/news/av/uk-politics-43869120)

A **professional service robot**, on the other hand, is for commercial use. These service robots may clean public places (windows and floors), make deliveries, complete inspections for maintenance and even assist in surgery. There are a wide range of professional service robots in operation today – too many to list in this book. Most professional service robots are semi-autonomous or fully autonomous, they have some mobility and can interact with people, and can be found in the retail, hospitality and health care industries. Others may be used in more challenging environments, such as space, defence or agriculture.

◆ **Professional service robot:** Semi-autonomous or fully autonomous robots developed to assist humans in commercial settings.

Safety is an important consideration for companies when introducing robots because they can handle dangerous jobs or jobs that are repetitive and unpleasant for people. Another benefit of service robots is that they can work efficiently, accurately and with very little downtime.

### REAL-WORLD EXAMPLE

#### Flippy 2, the grill chef robot

In 2017, Tech Crunch reported on Flippy, a 'grill chef' robot that was introduced in an American fast-food chain, CaliBurger, to overcome the staffing problem experienced by the chain of restaurants. Preparing foods over a hot grill all day long is an unpleasant, repetitive task, making it ideal for a service robot. The next generation, Flippy 2, is integrated with the kitchen ticket system and uses sensors and machine learning to fry foods to perfection.

<https://techcrunch.com/tag/flippy/>, <https://misorobotics.com/flippy-2/>



## Social robots

Social robots differ from service robots because they have a different purpose. Where service robots are used for dirty, unpleasant jobs, social robots are designed to interact and communicate with humans in a socially acceptable manner. Social robots are increasing in demand in the workplace, for example, customer service robots or home companion robots for elderly people. Social robots can be programmed to perform many routine tasks, but they may lack empathy or emotion and do not always respond appropriately to unknown situations. Such limitations raise dilemmas, especially if these types of robots become fully autonomous.

### REAL-WORLD EXAMPLE

#### Jibo

Jibo, a social robot for the home with a face like a cartoon, no legs and curvy body, was designed to provide friendship and companionship. It uses facial and voice recognition. It was designed to be a voice assistant and can answer questions, read the news and provide weather updates along with being compatible with many smart home devices.

<https://medicalfuturist.com/the-top-12-social-companion-robots>

### EXAM PRACTICE QUESTIONS



#### Paper 1 (core)

- 1 Identify two examples of autonomous technologies. [2 marks]
- 2 Outline one use a social robot may have in a health care environment. [2 marks]
- 3 Distinguish between social robots and service robots. [4 marks]
- 4 With reference to a real-world example, discuss whether social robots should be used as 'companion robots' for elderly people. [8 marks]

### REAL-WORLD EXAMPLE

#### Aerobot

Aerobot is a robot assistant at Istanbul Sabiha Gökçen International Airport. It communicates in more than 20 international languages and uses AI technology to profile approaching passengers in order to customise conversations. Aerobot also reminds passengers about airport health policies, reads barcodes, answers flight inquiries, and guides passengers to their boarding gates.

[www.malaysiaairports.com.my/media-centre/news/social-robots-introduced-part-airports-40-initiative](http://www.malaysiaairports.com.my/media-centre/news/social-robots-introduced-part-airports-40-initiative)

## ATL ACTIVITY

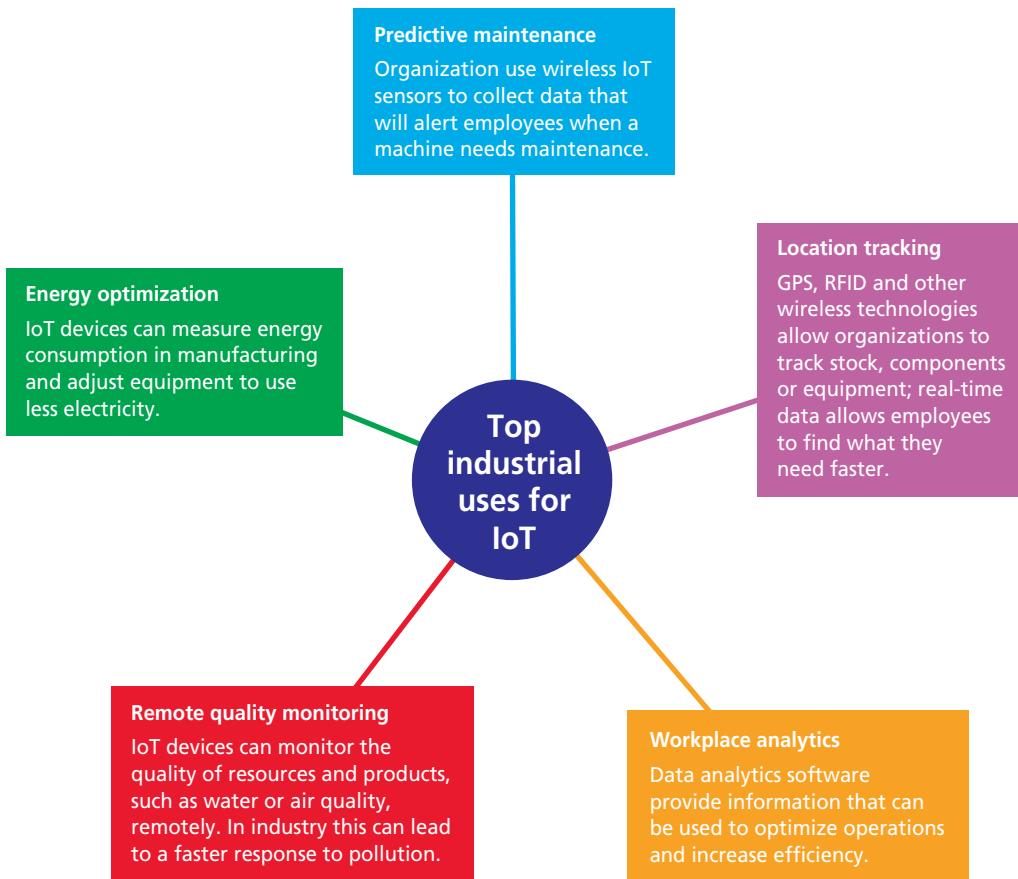
### Research

Research the use of service robots in a context of your choice.

- Select one of the contexts from 4.1 Cultural to 4.7 Social.
- Research service robots in this context using the digital resources provided by the school library and effective online search skills.
- Design a poster to communicate your findings to your parents.
- Your poster should include details about several robots being used in this context.
- For each robot include:
  - a title, image, and description of the task the robot performs
  - an outline of the impact this robot is having on the user
  - a statement to support why you selected this robot
  - a prediction of the future of the robot, for example, will it still be in use in the next 10 years or will it become obsolete?

## Internet of things (IoT)

Earlier forms of IoT used by businesses included RFID (radio-frequency identification) tags to track the location of assets or deliveries. Now, businesses can add sensors to their components to collect even more data that can be analysed to increase the efficiency of their production lines or services. In industry these autonomous technologies are also having similar benefits to those found in the home (see Chapter 3.4) but on a much larger scale.



■ Top five industrial uses for IoT

## ATL ACTIVITY

### Research

Research the growth of IoT in different markets.

- Use the internet to research statistics about IoT adoption.
- Identify the trends of adoption in one of the following segments: utilities, security, manufacturing, transportation and retail.
- Present your findings in a suitable chart.

## Links

This content links to Section 4.3C Cities, infrastructures and built environments.

## Autonomous vehicles (AV)

Many of today's traditional car manufacturers are in a race to dominate the autonomous or semi-autonomous car industry in the face of increased competition from technology companies such as Waymo or AutoZ. An **autonomous vehicle** has the ability to operate without human intervention and can drive itself.

You may have experienced autonomous vehicles at the airport, transporting you from one terminal to another, or in a city with driverless taxis. There are different levels of autonomy as categorized by the Society of Automotive Engineers (SAE). Levels 0 to 3 include low levels of autonomy designed to augment a driver. Levels 4 and 5 do not require a driver.

### Different levels of autonomy

- **Level 0:** A traditional car with zero automation. It may include cruise control, which can be turned on for long distances, or warning signs, for example when reversing or warnings for blind spots.
- **Level 1:** Driver assistance – provides features such as adaptive cruise control, which keeps the vehicle a safe distance from the vehicle in front, and lane keep assistance, to prevent the vehicle from veering out of its lane. Many newer models of cars include these features.
- **Level 2:** Partial automation – assists drivers by controlling steering and speed. It is similar to autopilot but requires the driver to have their hands on the wheel, ready to take back control should they be needed.

## REAL-WORLD EXAMPLE

### Mercedes-Benz' self-parking car

The Active Parking Assist system PARKTRONIC uses a range of sensors to determine if a car can fit into a parking spot and automatically steer the car while the human controls the brakes and gears.

[www.waltersmercedesbenzofriverside.com/what-is-park-assist-in-corona-ca](http://www.waltersmercedesbenzofriverside.com/what-is-park-assist-in-corona-ca)

- **Level 3:** Conditional automation – vehicles that can drive themselves but only under certain conditions. The driver does not need to have their hands on the wheel but must be seated in the driver's seat. For example, the car could drive automatically in a traffic jam.
- **Level 4:** High automation – vehicles that can drive themselves without human interaction and are available on public roads subject to a country's regulation. Vehicles of Level 4 or 5 do not require a steering wheel or pedals, as there is no human driver. Trialled uses of Level 4 autonomous vehicles include driverless taxis and public transport services, where vehicles can be programmed to travel between two geographical points. However, Level 4 vehicles will only operate if certain conditions are met; for example, they may only function under certain weather conditions.

## REAL-WORLD EXAMPLE



### Singapore's driverless taxis

In August 2016 Singapore became the first country to trial a driverless taxi on public roads using a Mitsubishi i-MiEV electric vehicle. The service was limited to 10 people who were able to use a smartphone app to call the taxi to one of 12 locations in Singapore. The service was limited to non-peak hours and was planned to be rolled out to the public in 2018.

To what extent are driverless taxis used now in Singapore?

[www.straitstimes.com/singapore/transport/worlds-first-driverless-taxi-trial-kicks-off-in-singapore](http://www.straitstimes.com/singapore/transport/worlds-first-driverless-taxi-trial-kicks-off-in-singapore)

- **Level 5:** Full automation is the highest level of automation, has no restrictions and, to date, has yet to be achieved. It is intended to be fully responsive to the road conditions and other vehicles on the road, so will not be restricted by the weather and can travel to any geographical location.

The prospect of widespread use of autonomous vehicles promises benefits such as fewer traffic accidents, reduced traffic congestion and energy savings.

Although many car manufacturers are striving to develop the technology for Level 4 and 5 automation, there are many obstacles to overcome, including:

- 1 **Sensors:** Autonomous vehicles use a wide range of sensors to 'see' the environment around them and feed this data back to the control system. Bad weather, heavy traffic and road signs with graffiti provide a challenge for these vehicles.
- 2 **Machine learning:** Is being used by autonomous vehicles to detect and classify objects within the path of the car. The system then uses this information to decide how to act, for example, brake or swerve to avoid the obstacle. At the time of writing, industry agreement on standards for training and testing the artificial intelligence is a challenge.
- 3 **Deep learning:** As autonomous cars are continuously learning on the road; the industry must determine how to ensure that the vehicle continues to be safe as it learns.
- 4 **Regulations and standards:** Governments need to work with manufacturers to develop the regulations and standards required to allow autonomous vehicles to operate on public roads. Governments also need to consider international standards so that autonomous vehicles can operate across borders.
- 5 **Social acceptability:** There have been several high-profile accidents involving autonomous vehicles in the news. Trust needs to be built up in the community in order for them to become more socially acceptable.

## ATL ACTIVITY

### Thinking

Conduct wider research and discuss these questions with your peers.

- What will the future of our world look like if we achieve Level 5 automation?
- Will there be any unintended consequences?
- How will autonomous vehicles change car ownership?
- How will the demand for space in our cities change?

## Inquiry

### 3.7A Types of robots and autonomous technologies (content) and 2.5 Space (concepts)

**Inquiry focus:** How will developments in autonomous vehicles affect the future use of space within urban areas?

#### Explore

Explore and collect information from relevant sources

- Do these other sources provide claims and perspectives that will be useful in the inquiry?
- Have you gathered a range of content from secondary and primary research and investigations?
- Can you provide clear justification for three main sources for their usefulness in the inquiry?

Use your research skills to find three sources to further your understanding of this question.

Your final choice of sources must be able to help you gain a deeper understanding of this topic, provide a balance of claims and perspective, and be embedded in the content (autonomous technologies) and concept (space).

Write a short report to justify your chosen sources and their usefulness in this inquiry. Your report should include:

- a discussion on the origin and purpose of each source, including any potential bias or limitations of using the source
- a discussion of the main ideas being presented in each source and what features of the source were used to support the claim being made
- a discussion on how the sources corroborate or contradict, and how it has helped you gain a deeper understanding of this question
- a bibliography entry for each source at the end of the report.

#### Analyse

Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

Analyse the inquiry focus by answering the following questions about spaces and the use of autonomous vehicles using your research.

- How is information transferred between digital objects, autonomous vehicles and the road infrastructure in a digital society?
- How is this different from the non-autonomous vehicles being used on the roads?
- How will the use of autonomous vehicles change the use of space in urban areas?
- How will autonomous vehicles affect how people experience specific spaces and locations?
- Spaces usually have laws connected to them – how is this changing with the use of autonomous vehicles?

## EXAM PRACTICE QUESTIONS



Paper 2

Source A



■ Sensors used in autonomous vehicles

- 1 Define the term 'autonomous vehicle'. [2 marks]
- 2 Explain how sensors would be used by autonomous vehicles to avoid obstacles in the road. [4 marks]

### Drones

A **drone**, also known as an unmanned aerial vehicle (UAV), is a flying robot that can either be remote controlled or autonomous. In the past, drones were commonly associated with the military and had three main purposes: they were used for anti-aircraft practice, to gather data from the sensors attached, or used with weapons to make military attacks. Nowadays drones have both commercial and private uses, with businesses using drones for delivery, surveillance, search and rescue operations, and personal use to capture video footage.

◆ **Drone:** A remote controlled or autonomous flying robot.

Drones have two main functions: flight and navigation. For flight, the drone needs to be lightweight, include propellers and have enough power to last the duration of the journey. For navigation, built-in systems such as GPS are used so that they can communicate their exact location to the user. Fully automated drones require a wide range of sensors to be able to function, as well as hosting sensors for data collection.

### REAL-WORLD EXAMPLE

#### Commercial use of drones

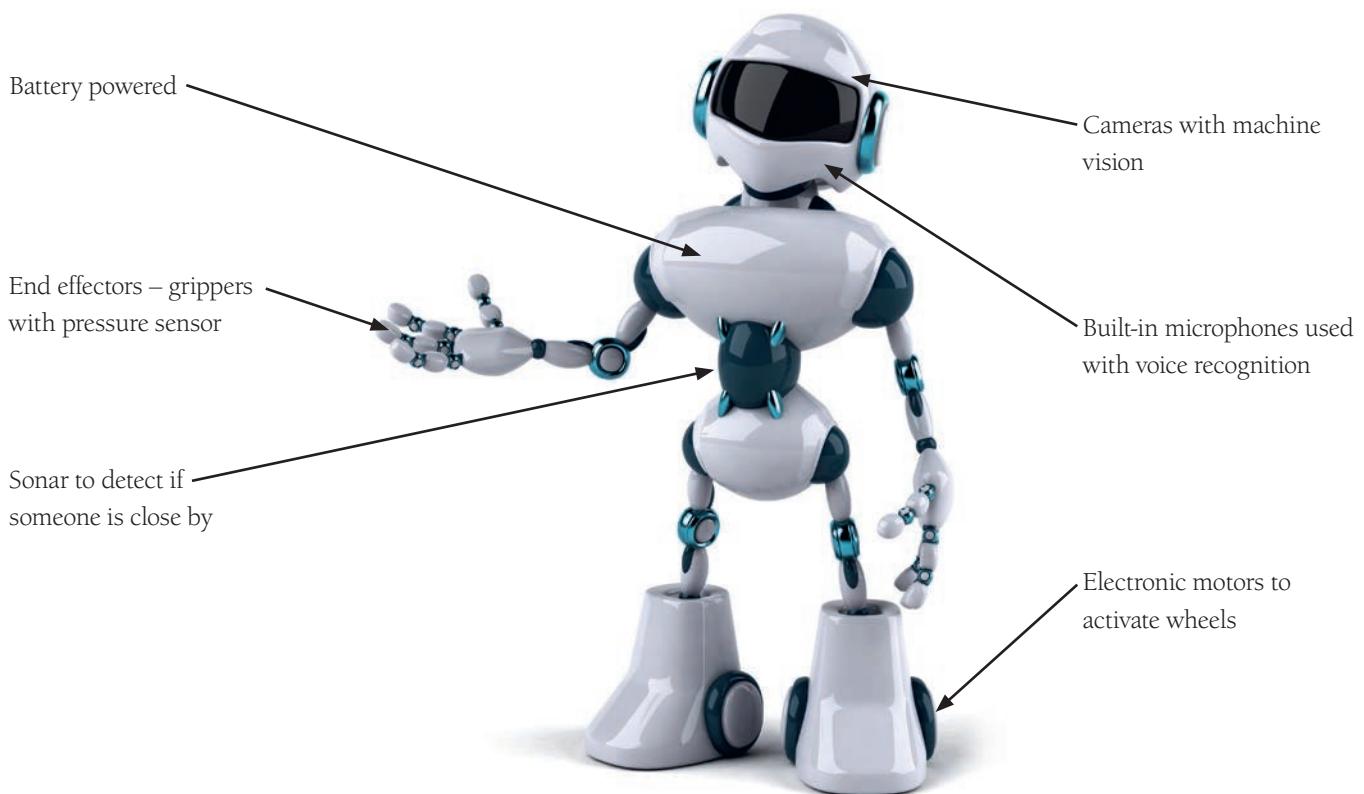
Drones may be used for making deliveries to remote locations, completing everyday tasks such as fertilizing crops, or monitoring traffic. In Ghana, a company called Zipline uses drones to deliver medical supplies to approximately 2000 medical centres.



[www.freightwaves.com/news/six-drone-delivery-use-cases-and-lessons-for-companies-to-use](http://www.freightwaves.com/news/six-drone-delivery-use-cases-and-lessons-for-companies-to-use)

## 3.7B Characteristics of robots and autonomous technologies

We have already looked at the amazing array of robots being used today. Developments in artificial intelligence mean that data collected by sensors is better perceived and understood by robots, while improvements in agility and mobility have allowed them to move more fluidly around their physical environment.



#### ■ Characteristics of a robot

## ■ Sensory inputs for spatial, environmental and operational awareness

With the help of a number of technologies, robots are able to perceive their environment in a similar way to which humans perceive the world with their five senses:

- **Vision:** Firstly, a robot needs to see its surroundings; in the same way that people use their eyes, robots use **digital cameras** to capture images within range. Two cameras (stereo vision) are needed for image recognition, which allows the robot to have depth perception. However, understanding what a camera can see is more complex, so other technologies are used to help perceive the environment.

**Light sensors** can be used to detect changes in light levels and inform the robot if it is night or day so that it can perform different functions accordingly. Simpler robots can use **infrared** or **ultrasound sensors** to ‘see’ objects. Essentially, the robot emits beams of infrared light or sound signals to determine how far away an object is based on how long it takes for the signal to bounce back. **GPS satellite navigation** can inform a robot of its exact geographical location in a physical space.

More sophisticated robots, such as autonomous vehicles, use other sensors to detect their environment, including **lidar** (light detection and ranging), **sonar** (sound navigation and ranging) and **radar** (radio detection and ranging). Like the infrared sensor earlier, they measure the time it takes for the light, sound or radio waves to bounce off an object. Lidar can measure the shape and contour of the ground, including the height of objects; sonar can measure the depth of water; and radar can detect moving objects and map the shape of the environment.

- **Hearing:** Robots can use a microphone to collect sounds, which are then converted into electrical signals used for processing. Combined with voice recognition (discussed in the previous chapter), the robot can ‘understand’ what is being said.

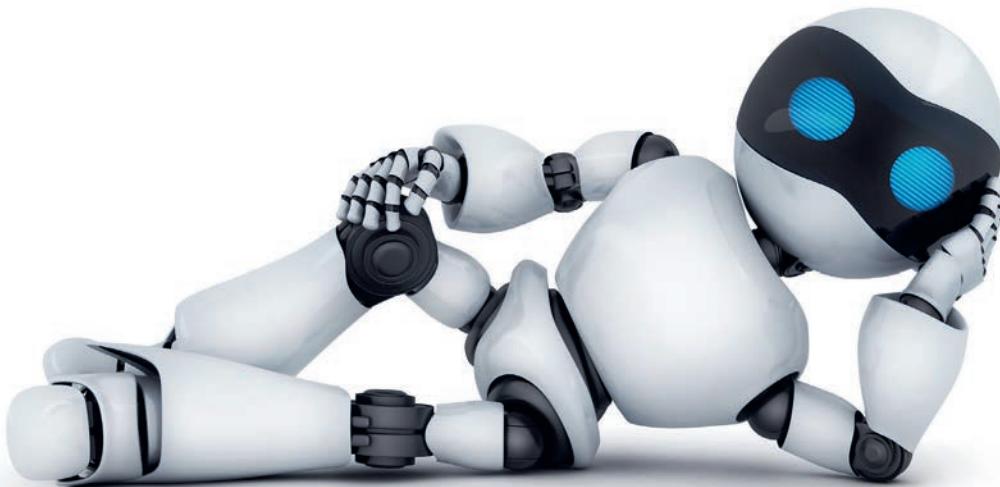
- **Smell and taste:** For a robot to be able to smell, it needs the right kind of **chemical sensor**, which collects data, converts into an electrical signal and uses pattern recognition to identify the origin of the smell. Likewise, taste also requires appropriate chemical sensors; for example, a food-tasting robot may use a pH sensor.
- **Touch:** Depending on the type of end effector, **pressure sensors or resistive touch sensors** are used to determine how strong a hold a robot has on an object so that it does not drop it or break it. Alternatively, a **capacitive touch sensor** can be used where the robot detects an object, including the human touch, that conducts electricity. Temperature sensors can also be built into robots; a robot may be required to perform a certain function when a particular temperature is reached, for example, a firefighting robot may navigate to the hottest part of a room.

## ■ The ability to logically reason with inputs, often using machine vision and/or machine learning

The robot's computerized control system is used for decision-making and will take the data collected by the sensors, process it and send a command to the actuators and end effectors. The robots that we talked about earlier would have varying degrees of artificial intelligence. Robots with basic artificial intelligence can be used to **solve problems in limited domains**. For example, a robot will collect data through its sensors, compare this data to its stored data, run through possible scenarios and select the optimum action. Simple robots on a production line may use this level of artificial intelligence, for example an inspection robot could determine if a particular product was within the approved limits.

More recent robots use machine learning to learn within a limited capacity. For example, developing a robot that can walk like ASIMO (see next section) demonstrates how the robot's skills in walking have been developed. Machine learning is being used to make robots intelligent and, ultimately, more useful. For example, let us review some of the developments we discussed in the last chapter. Supervised learning could be used by the most basic of industrial robots, such as a robot on a production line that needs to select different part types – it would be able to do so with the parts that it was trained with. Alternatively, reinforcement learning enables robots to learn, improve and adapt to their environment, as happens in autonomous vehicles. **Machine vision** has made great progress due to deep learning. It has improved depth and image recognition, which makes robots even more useful on a production line as they can work with greater accuracy.

## ■ The ability to interact and move in physical environments



Almost all robots have some parts that can move. This may be moving parts in a robotic arm on a production line, or motorized wheels that allow a service robot to roam around a hotel lobby. All moving parts will use an **actuator**, which may include an electric motor, a hydraulic system (driven by incompressible fluid) or a pneumatic system (driven by compressed gas). Each of these actuators needs power to operate. A mobile robot, for example, would use a battery, while a static robot would be powered by the main electricity supply.

While actuators will control the ‘joints’ of the robot, a peripheral device is usually attached to make these actuators useful. These devices are called **end effectors**. End effectors are either mechanical or electromechanical and can be used to grip objects and attach tools or sensors.

- **Grippers:** The most common of end effectors allow robots to pick up and manipulate objects. This is particularly useful on an assembly line.
- **Process tools:** These are tools for completing a specific task, for example tools for welding, spray painting and drilling.
- **Sensors:** We talked about sensors earlier; they are especially useful for applications such as robot inspections.

## The demonstration of some degree of autonomy

Strictly speaking, robots that are remotely controlled by humans are not actually robots. The level of autonomy defines how independently the robot can operate without a controller.

**Semi-autonomous robots** are robots that have some level of intelligence. They will be able to react to certain conditions without needing to be directed all the time. For example, a basic robotic vacuum can work autonomously with sensors that will stop the vacuum from hitting objects in its path and sensors to detect the level of debris. However, it is only semi-autonomous because, if you want to change its settings, it requires human interaction.

**Fully autonomous robots** operate independently, can accomplish more complex tasks and are generally more mobile. Currently they may be restricted to one working environment, for example a factory floor or shopping mall but, as digital technology advances, they will become more adaptable and more autonomous.

### ATL ACTIVITY

#### Research

Research and produce an infographic about social robots.

- Select one of the contexts from 4.1 Cultural to 4.7 Social.
- Research using digital resources from the school library and effective online search skills.
- Select one social robot.
- Design an infographic to explain how this robot works.
- Your infographic should include:
  - an image of the robot
  - an explanation of how the robots ‘sees’, ‘hears’ and ‘touches’
  - an explanation of how it processes the data
  - an explanation of its ability to move in and interact with its environment.
- Publish the infographic and request feedback from your peers.

◆ **Actuator:** A device that moves or controls some form of mechanism.

◆ **End effector:** A mechanical or electromechanical peripheral device that can be used to grip objects and attach tools or sensors.

## EXAM PRACTICE QUESTIONS



### Paper 1 (core)

- 1 Identify two characteristics of a robot. [2 marks]
- 2 Explain three different ways a robot can perceive its environment. [6 marks]

### Top tips

It is important to know the relationship between artificial intelligence and robots. For example, if you were to read about robot journalists online, are they referring to physical robots that are writing news articles or are they talking about artificial intelligence algorithms. Revise your definition of a robot to answer this question.

## 3.7C Evolution of robots and autonomous technologies

### ■ Early forms of robots and autonomous technology

The history of robots and autonomous vehicles is intertwined with developments in science, technology and artificial intelligence. There have been numerous developments in robots and autonomous technologies over time – too many to write about – so only a selection of important milestones are given here.

The idea of robots goes as far back as 1500BC with Egyptian water clocks using human figurines to strike the bell, or the period of around 400BC when Greek mathematician Archytas built a steam-powered mechanical bird.

Fast forward to the twentieth century and, in 1948, William Grey Walter created two autonomous robots, Elmer and Elsie. Both were shaped like tortoises and used three wheels for mobility. They could navigate themselves to a recharging station when needed.

In 1958, Charles Rosen led a research team at the Stanford Research Institute in developing a robot called ‘Shakey’. Shakey could wheel around the room, observe the scene with its television ‘eyes’, move across unfamiliar surroundings and make simple responses to its environment.

### ■ Robots in science fiction and philosophy

Before modern robots came to be in existence, they were found in science fiction stories. Czech writer Karel Čapek introduced the term ‘robot’ in his 1921 play *Rossum’s Universal Robots*, which was the first time that the word robot was formally used. The play was based on a man who created a robot but who was then killed by it – a common theme in many science fiction novels and movies.

In 1941, science fiction writer Isaac Asimov, wrote the three laws of robotics:

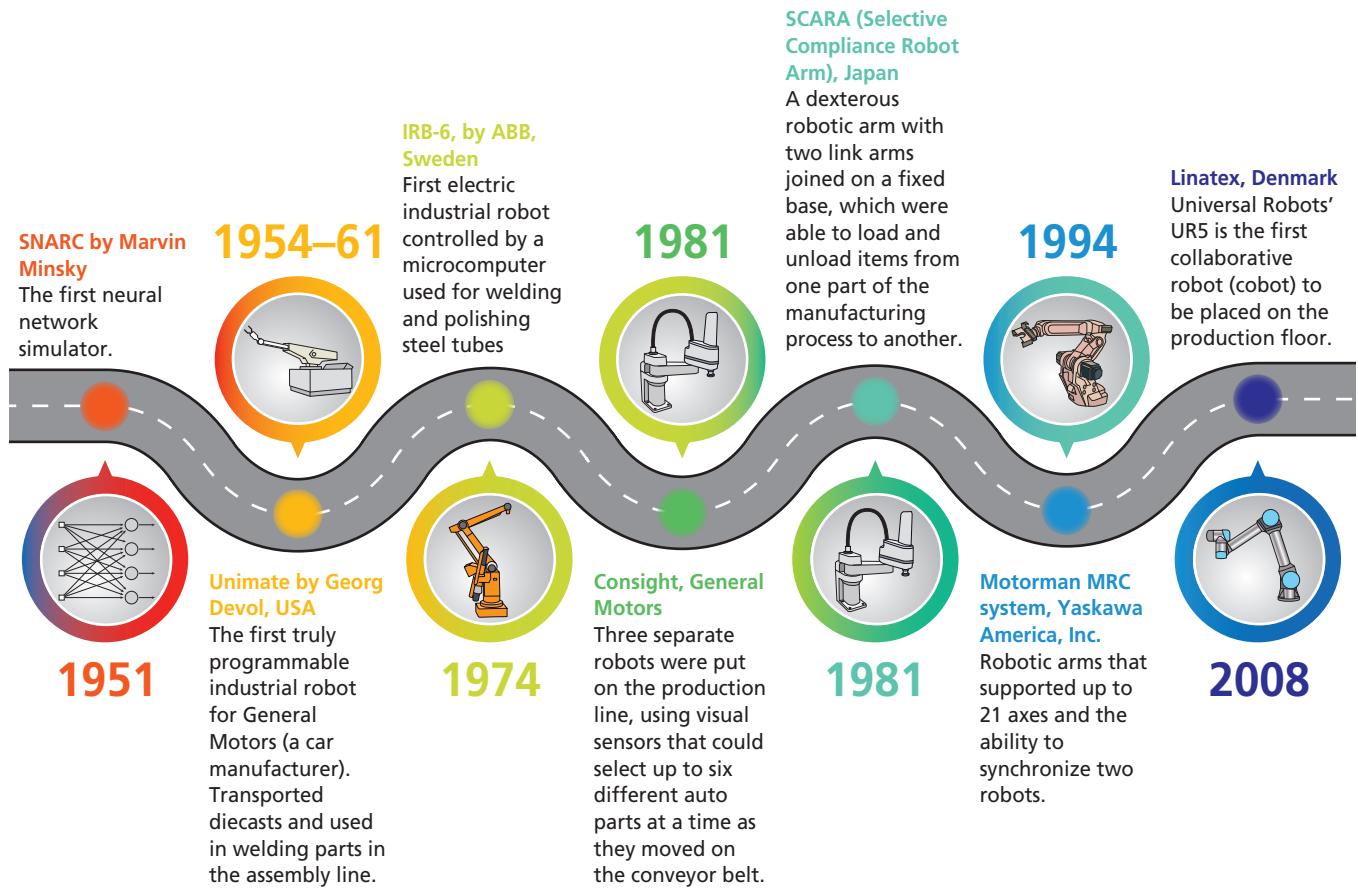
- 1 A robot must not injure a human being.
- 2 A robot must obey orders given by human beings, except if it conflicts with Law 1.
- 3 A robot must protect its own existence as long as it does not conflict with Laws 1 and 2.

The writer wrote numerous short stories about robots during the 1940s and 1950s. Later on, a ‘zeroth’ law was added:

- 0 A robot may not injure a human being or, through inaction, allow a human being to come to harm, unless this would violate a higher order law.

## ■ Robots designed for industry and manufacturing

Industry was a good place to start in the development of robotics as there was an obvious purpose – they were able to perform repetitive tasks and were capable of lifting heavy objects, making them ideal on a production line.



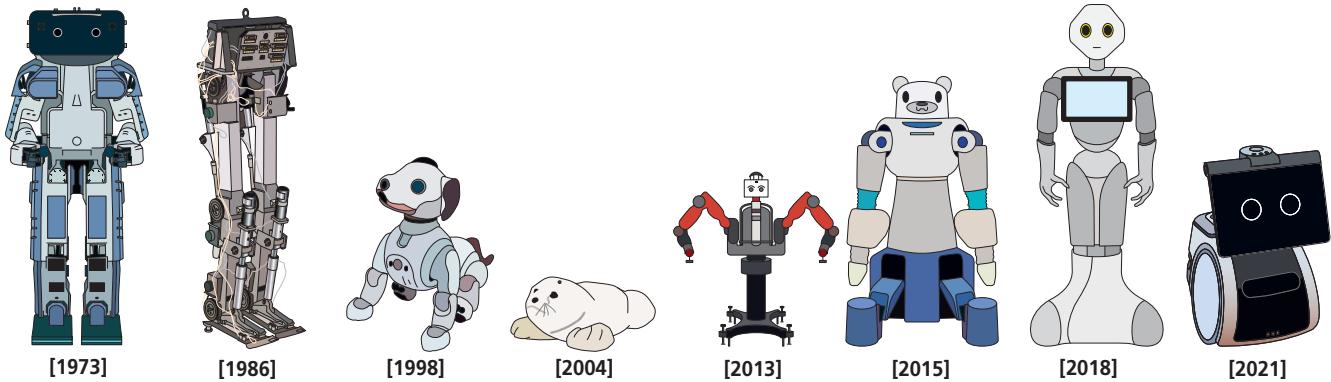
### ■ The development of robots

As developments in robots in industry have improved over time, they have been able to move faster, carry heavier loads, ‘see’ better, and handle more decisions. It is commonplace to see a robot assembly line in manufacturing today.

## ■ Robots designed to interact with humans

Many robotics researchers were developing more lifelike robots, called humanoids, and robot pets.

<b>Wabot-1,</b> Waseda University, Japan First humanoid robot with machine intelligence that could walk, grip and carry objects, 'see' by measuring distances and communicate in Japanese.	<b>ASIMO</b> (Advanced Step in Innovative Mobility) <b>Honda</b> A robot that could run, walk and climb stairs, kick a ball, sing and respond to voice commands	<b>AIBO</b> Sony, Japan Robot pet that imitated dog-like behaviour. It used actuators for life-like movement in its head, neck and tail, and sensors to enable touch and sight.	<b>PARO</b> , National Institute of Advanced Industrial Science & Technology, Japan A therapeutic robotic baby seal used to reduce stress for patients.	<b>Baxter</b> by Rethink Robotics, Germany First humanoid industrial robot developed for general use.	<b>Robear,</b> RIKEN-SRK Collaboration Center for Human-Interact ive Robot Research and Sumitomo Riko Co. A giant bear robot used as a hospital aid.	<b>Pepper,</b> Softbank Group, Japan Child-size robot that can dance, make jokes and navigate	<b>Astro, Amazon</b> Lab126, USA A home assistant robot referred to as Alexa on Wheels, which combines robotics, AI, home monitoring and cloud services.
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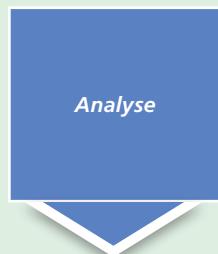


■ Robot evolution

## Inquiry

3.7C Evolution of robots and autonomous technologies (content) and  
4.4B The human body (contexts)

**Inquiry focus:** How are developments in robots being used to augment human abilities?



Analyse impacts and implications for relevant people and communities

- Is your inquiry question supported by additional questions to consider for analysis and evaluation?
- Does your analysis focus on the impacts and implications for people and communities?
- Is your analysis effective, sustained and well-supported by evidence?

- Conduct research into one digital technology that is being used to improve quality of life, for example exoskeletons designed for war veterans, robot prosthetics or digital technology implants.
- Analyse the impact that this digital technology is having on the user.

## ■ Machine consciousness, cognitive robotics and robot rights

While weak artificial intelligence would have played a role in earlier robots designed to interact with humans, it is assumed that these robots did not have consciousness and could only simulate intelligence. For a robot to have machine consciousness, it requires the development of strong artificial intelligence.

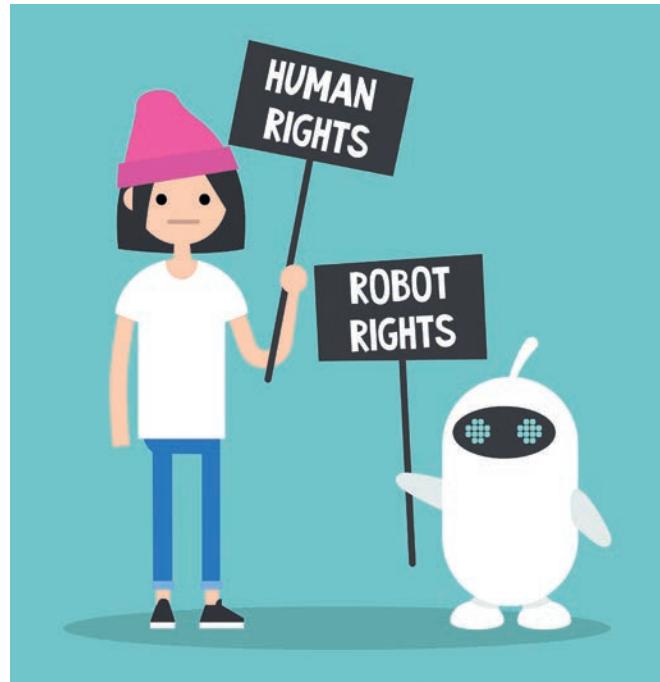
Cognitive robotics is an emerging field aimed at designing robots with human-like intelligence. The goal is to create robots that can perceive their environment, plan what they will do and deal with the uncertainty of the real world by continuous learning. An important aspect of cognitive robotics is the development of predictive capabilities and the ability to view the world from different perspectives.

### REAL-WORLD EXAMPLE

#### Sophia

Sophia was a robot celebrity in 2016 thanks to her human-like features. The use of artificial intelligence, visual data processing and facial recognition enabled her to imitate human gestures and facial expressions; she could answer questions on predefined topics using speech-to-text technology and was designed to learn. Originally designed to help elderly people in care homes, Sophia became a celebrity when she was granted citizenship by Saudi Arabia. She became the first non-human to have a nationality. Although this was considered a publicity stunt at the time, it did raise some important questions. Should robots be granted rights?

<https://delta2020.com/blog/224-rise-of-the-robots-should-we-give-robots-rights>



As robots become more sophisticated with developments in artificial intelligence, the rights of robots are becoming a matter of serious policy debate. Although present-day robots may not yet have high-level cognitive abilities, what will happen when they do? How prepared are we? Most claims for rights (human or animal) are centred around the question of consciousness. Although it is hard to define consciousness, we know that it exists because we experience it. We are entitled to rights because we can feel pain or pleasure. Rights were introduced to protect us from anything that causes us pain and, as humans, we have been programmed to learn if something is fair or unfair.

### ATL ACTIVITY

#### Thinking

Hold a discussion on the issue and questions regarding robot rights.

- If a robot became self-aware, would it deserve rights?
- Can robots feel pain or pleasure? What if they were programmed to do so?
- What if robots were programmed to recognize justice over injustice?
- What if robots develop these traits through deep learning?
- Do robots deserve rights?
- What happens if machines become conscious?

## Inquiry

3.7C Evolution of robots and autonomous technologies (content) and  
2.7 Values and ethics (concepts)

**Inquiry topic:** Is it possible to program values and ethics into a robot?

Complete all inquiry stages to address the focus question.

When analysing and evaluating the focus question, use the following questions:

- Do the designers of robots have an ethical obligation to their users?
- What happens when different ethical frameworks are applied to the issues of using robots in digital society?
- Can developers program values and ethics into robots that make decisions?
- Who decides what ethical framework robots should use?
- Does responsibility carry accountability as well?

Select the most suitable format to communicate your inquiry.

## Top tips

Visit Section 1.4 to refresh yourself on all of the stages of the inquiry process.

## 3.7D Robots and autonomous technology dilemmas

Alongside the advances in artificial intelligence, parallel developments in robotics have had positive impacts on society. For example, robotic solutions are being developed to help people with disabilities, and manufacturing efficiency has increased. However, with benefits, come challenges and some unintended consequences. One such challenge is the uncanny valley.

### ■ Anthropomorphism and the uncanny valley

Human-like characteristics are frequently given to animals in movies, for example Paddington Bear and Winnie the Pooh, as well as non-human beings such as robots. This is called **anthropomorphism**.

Let's look at two examples of robots: Pepper, with his adorable expressions, and Sophia, the lifelike robot that has been given residency in Saudi Arabia, and her uncannily lifelike expressions.

◆ **Anthropomorphism:**  
Attributing human characteristics to non-human entities.

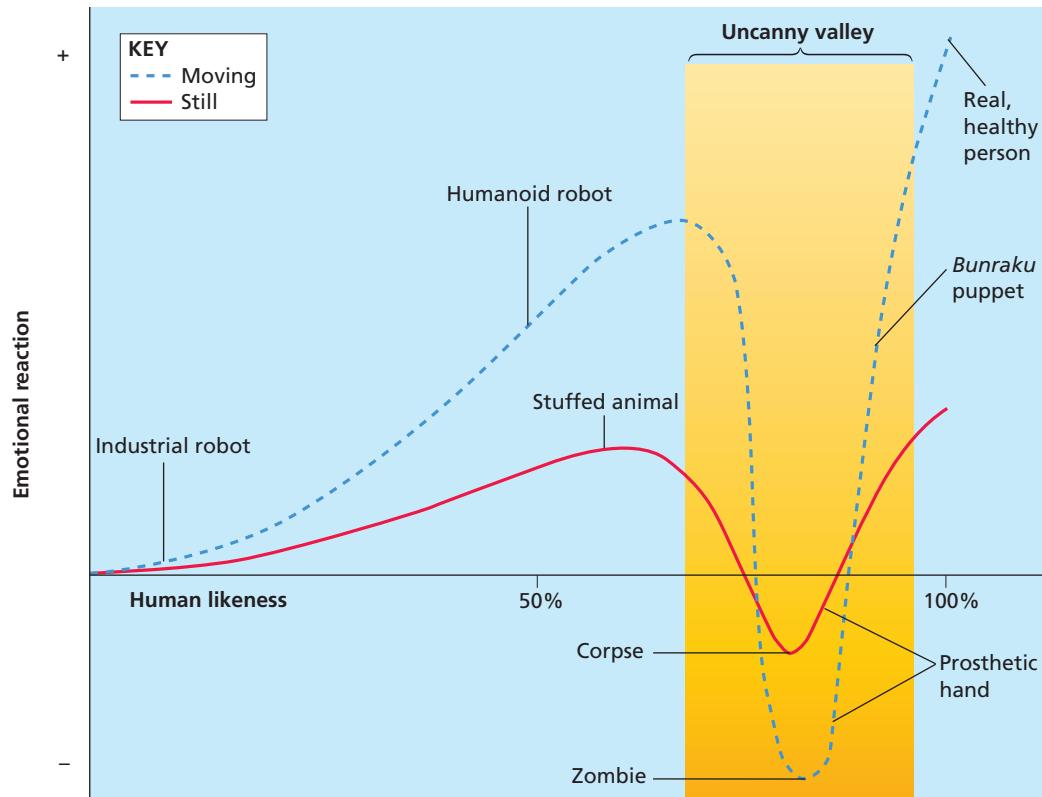


■ Pepper



■ Sophia

The term **uncanny valley** describes the phenomenon of the eerie, unsettling feeling that people get when they interact with lifelike humanoid robots or lifelike computer-generated characters. The concept was introduced by Masahiro Mori in 1970, a professor at the Tokyo Institute of Technology. He observed that robots become more appealing as they become more human-like, but only up to a certain point. This point is called the uncanny valley. After this, there is a sense of unease and a negative reaction.



■ Masahiro Mori's 'uncanny valley'

This creates a dilemma for robot designers that design machines to operate in the human world that push the boundaries of biology, cognitive science and engineering. On one hand, the more lifelike a robot is, the more they are accepted in certain situations – for example, autistic children respond better to more lifelike robots, and they are more effective in training situations. On the other hand, if they are too lifelike, they will be less accepted by society.

### ATL ACTIVITY

#### Thinking

Conduct a survey to investigate the uncanny valley.

- Create a survey that includes images of a range of robots, from non-lifelike to lifelike.
- Ask people to rate how appealing they find them and how creepy they are.
- Ask as many people as you can to complete the survey.
- Analyse the results.
- Write a conclusion to determine whether the results support the uncanny valley theory.

## Complexity of human and environmental interactions

One of the main aims of robotic research is to create robots that can work effectively alongside humans, either doing the tasks that they do not want to do because they are too unpleasant or dangerous, or to augment human abilities. However, developing a robot to work alongside unpredictable humans in environments that are constantly changing is extremely challenging.

**Cobots** (robots designed to work alongside humans and augment their capabilities) are currently being developed to work cohesively with humans. For example, a cobot needs to understand human emotions, language and behaviour. Developing robots that can respond to human emotions may be considered a more desirable end goal, as these cobots will end up in the workplace or shop floor and will ultimately be more accepted if they can make eye contact, smile or behave in a more human-like way.

The aim may not be to develop an emotional robot, however, but one that can develop an emotional attachment from the human to the robot. In the 1990s, Cynthia Breazeal developed an 'emotional robot' called Kismet. Although the robot itself did not have emotional intelligence, it did provoke authentic emotional reactions in humans.

Similarly, developing a robot to interact with the environment is also challenging. Something as simple for humans as walking has required intense focus from developers to be able to mimic both animal and human's mobility across different terrain. Developments in machine learning and robot vision technologies are being used to overcome the challenge of navigating along a path with obstacles. Even if a robot is trained in a particular environment, the slightest alteration, such as a fallen tree or ice on the road, requires the robot to relearn and adapt to the environment. There will always be new situations for which a robot has not been prepared. Robots need to develop further to be able to operate in environments that are not already mapped out or that are unfamiliar to the robot. For example, there have already been cases in the news of accidents caused by autonomous vehicles.

◆ **Cobots:** Robots designed to work alongside humans and augment their capabilities.

### REAL-WORLD EXAMPLE

#### Autonomous vehicles

In 2018, Elaine Herzberg was killed by an autonomous car in Tempe, Arizona, as she wheeled her bicycle across the road. Dashcam footage revealed that the car's safety driver was not paying attention to the road at the time, and therefore did not take over the steering wheel to prevent the accident.

[www.bbc.com/news/technology-54175359](http://www.bbc.com/news/technology-54175359)

### ATL ACTIVITY

#### Thinking

Prepare for a debate on emotional robots.

- Conduct wider research into the development of emotional robots.
- Divide the group into two: one group will support the idea that robots need to be designed to be emotional, while the other group will support the idea that robots need to be designed so that humans have emotional responses to them.
- Conduct the debate and, at the end of the session, take a vote.

## Uneven and underdeveloped laws, regulations and governance

Minimizing privacy and security risks is a challenge not only for robot developers but for governments too. For example, the data used to train robots could be misused, ultimately causing the robot to malfunction, or the robot could be hacked for malicious purposes, putting not only personal data at risk but also the human lives interacting with the robot. There are always questions about how much we can depend on robots. There are also discussions about the ownership of data, for example who owns the data – the end-user, the robot manufacturer or the robot developer? Creating guidelines and legislation related to the use of robots is essential.

If we refer back to Asimov in the 1940s, his three laws (plus Law 0) have stood the test of time and are still used as guiding principles. However, with significant developments in technology, should new laws be considered?

One issue is that robots today are far more varied than envisioned by Asimov. Therefore, one must ask, should there be a level of complexity before the rules apply? Is there an agreed definition of what a robot is before the law can be applied?

Secondly, applying the laws as a blanket approach to all types of robots may be difficult. For example, military robots could be deployed on the battlefield and ultimately save the lives of civilians and soldiers alike, yet not comply with the first law (not allowing a human to come to harm). Laws on drones and autonomous vehicles may be developed by different authorities compared to robots used in manufacturing. Therefore, the laws may need to be adapted according to the context they are being used in.

## ATL ACTIVITY

### Thinking

Research each of these principles in more detail and hold a discussion about each one.

According to Professor Frank Pasquale, an expert on the law of artificial intelligence, four more principles should be introduced:

- 1 Artificial intelligence should complement professionals, not replace them. This is particularly important where a task requires judgement or decisions that are better done by humans
- 2 Artificial intelligence and robotics should not counterfeit humanity. For example, devices should not be developed to mimic human emotions.
- 3 Robotic systems should not intensify arms races. Developments in smart robotic weapons could easily spiral out of control and turn into an arms race.
- 4 Robotic systems must always indicate the identity of their creator, controller and owner. Greater levels of transparency and accountability are important, and necessary to deter illegal activities using robots.

Governments with advanced developments in robotics are prioritizing developments in legislation. For example, Asimov's laws inspired the South Korean government to work on the Robot Ethics Charter in 2007, with the intention of writing an ethical guide on the development and use of robots. This charter was designed to mitigate the problems associated with an aging population and the growth of service and social robots.

In 2016, the UK published a set of standards to guide the ethical design and application of robots. Although not legally binding, the aim of the publication was to make recommendations and raise awareness of the ethical issues associated with the use of robots and any potential negative impacts.

The EU funded a project to develop RoboLaw, which concluded in 2014. The outcome of the project was guidelines on the regulation of robotics. In 2017, the European Parliament launched a draft report urging governments to start discussing the issues related to the development of robots.

For robots to operate legally in the real world, robot designers need to comply with each country's regulations. If something should go wrong while being used, existing legislation would be applied in a court of law, with judges using the laws to make the final decision in a trial. For example, robot applications are considered to be products, and are therefore covered under laws such as the European Product Liability Directive or the US Restatement of Torts, Third. While this might be OK for a rogue robot vacuum cleaner that damages a carpet, the outcome may be more controversial in the case of autonomous vehicles and robot prostheses.