INTRODUCTION

We are living in truly exciting times...

Almost every week a technological breakthrough is announced – a new kind of VR headset, a crop-spraying drone or a computer with a flexible screen. Around the world, scientists and engineers are working on revolutionary new inventions that may soon become regular fixtures of our world – driverless cars, intelligent robots, 3D printing and energy from nuclear fusion.

Modern technology develops at a startling pace. People living just thirty years ago might find today's world bewildering, with its smartphones, social media, virtual assistants, video calls and video-sharing websites.

They'd be equally amazed at how these developments have transformed our lives, making us better informed and more connected than ever before.

Today's innovators are often inspired by the futuristic visions of science fiction – worlds in which we can travel through time, conceal ourselves in an invisibility cloak, upload our minds to a computer and create artificial life.



Many of these ideas could one day emerge as real technologies. Colonies in space, super-intelligent robots and eternal life are just a few of the concepts we'll be exploring.

So what steps are scientists taking to make these dreams real, and what are the implications for humanity?

SPACE COLONIES

Today, our survival as a species depends on a single planet. But what if one day something happened to Earth – an asteroid strike, a super-volcano or a climate catastrophe – that threatened human civilisation? We could easily go the way of the dinosaurs...

That's why people have been looking to the stars for our salvation. Could we one day colonise space?

A DANGEROUS PLACE

The problem is, we aren't built to live in space:

- There's no air, food or water.
- It's a place of extreme temperatures. The Sun-facing side of the International Space Station can reach 121°C (250°F) and the shadow side a freezing -157° C (-250°F).
- Lack of gravity is bad for the bones and muscles.
- There are high levels of harmful radiation.

Any space colony would have to protect people from these dangers.

If we lived in space for a long time, our bodies would probably adapt, evolving denser bones, for example, to counter the lack of gravity.

Colonists on planets with less sunlight, like Mars, might develop larger eyes to see better.

After thousands of years, colonists might even become a new species.

CASH-TEROIDS?

Asteroids have billions of tonnes of valuable metals, such as iron, nickel, gold and platinum, so colonising space could allow humans to harvest its resources and get rich!

SUN POWER

Space colonies would have to be completely self-sufficient. The Sun could provide all the colony's heat and electric power (via solar panels) – although this would decrease the further away from the Sun the colony was.

DID YOU KNOW?

One of the earliest stories about building a community in space was *The Brick Moon* by Edward Hale in 1869, about an inhabited artificial satellite.

ANY AIR UP THERE?

The components of air – oxygen, nitrogen and carbon dioxide – can be produced from substances found in space.

Moon rock contains oxygen, which can be harvested using heat and electricity.

Air could be cleaned and recycled for colonists, perhaps by planting a forest in the colony.

COSMIC CARROTS

Food, including rice, potatoes and peas, has already been grown on space stations. Nutrients from toilet waste can be used to fertilise crops. In low gravity, roots grow in all directions, and water and nutrients float. Plant seeds need to be glued to little bags filled with soil and fertiliser so the nutrients get to the roots.

COLONIES IN ORBIT

A space colony wouldn't have to be on a planet or moon. It could be based inside an enormous space station orbiting Earth or some other body. The space station would need to rotate to create its own gravity.

In the 1970s, American physicist Gerard O'Neill proposed 'O'Neill Cylinders' – a pair of rotating cylinders, 8km (5mi) wide and 32km (20mi) long, each with an Earthlike interior large enough to support thousands of people.

By contrast, today's International Space Station is 109m (360ft) x 73m (240ft) in size, with a crew of three to six astronauts.

DID YOU KNOW?

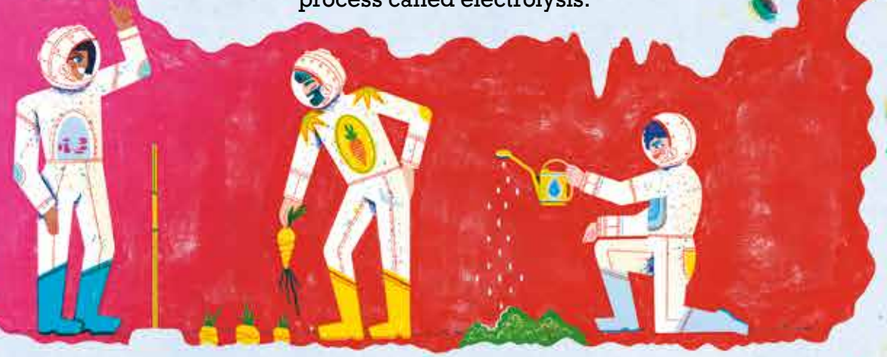
An O'Neill Cylinder space colony would be big enough inside for clouds to form.

THE MOON

A future colony on the Moon would be relatively close to Earth, making trade and communications between the two easier.

As the Moon has no atmosphere and harmful radiation, the best location for a colony would be underground, inside a lava tube (a tunnel created by the Moon's ancient rivers of volcanic lava).

Some of these lava tubes are up to 5km (3mi) wide. Water could be obtained from ice at the Moon's poles and used to generate oxygen through a process called electrolysis.



EUROPA AND TITAN

Saturn's biggest moon, Titan, has an atmosphere containing oxygen, hydrogen, nitrogen and methane – all elements necessary for life – making it perhaps the most hospitable world in our solar system for human colonisation.

DID YOU KNOW?

On Titan, gravity is so low and the atmosphere is so dense, a human could strap on a pair of wings and fly.

TITAN

EUROPA

Scientists believe that Jupiter's fourth biggest moon, Europa, has an ocean beneath its icy surface, which may even contain life.

This might be the only possible location on Europa for a human colony as the moon's surface is extremely cold, with high levels of radiation.

MARS

Mars has no atmosphere, so colonists would have to live inside artificial habitats with their own life-support systems.

Frequent dust storms may require satellites to beam solar energy wirelessly to the Martian surface.

Caves near the volcano Arsia Mons or lava tubes might be good sites for a base.

Some scientists believe Mars could be 'terraformed' by gradually changing its atmosphere and climate to make it hospitable to human life.

SUPER-INTELLIGENT MACHINES

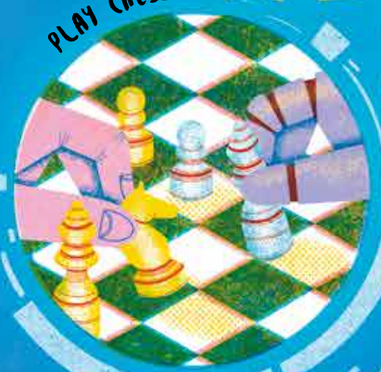
Perhaps the most popular character in all of science fiction is the intelligent robot. Audiences are happy to accept thinking, feeling movie robots, but will it ever be possible to build a machine with humanlike intelligence?

Until recently, this idea seemed like a fantasy. But huge progress in artificial intelligence (AI) has meant that, today, AI programmes are used to diagnose diseases, compose music, translate languages and recognise faces.











ROBOT BUDDIES

Robots' lack of consciousness hasn't stopped them being used as companions. 'Pepper', released in 2015, is programmed to recognise faces, read basic human emotions and talk to its human friends.

Humans are naturally sociable and can often feel lonely, so it's very likely that robots will continue to be used in this way to provide friendship.

In some ways, AI programmes are far more advanced than humans. They can perform millions of calculations a second and can beat humans at games such as chess.

Yet we shouldn't get too excited. So far, no machine has ever fallen in love, or appreciated a beautiful sunset. Machines don't know that they exist. In other words, they aren't conscious like humans.



DID YOU KNOW?

One of the biggest problems for driverless cars is the weather. Snow, for example, can confuse machine vision and make it harder to identify other objects.

COMPUTER-CONTROLLED CARS

Sometimes, it's their very lack of humanity that makes machines useful to us. They don't get angry, tired or lose concentration, making them ideal drivers. Driverless vehicles are linked to AI programmes that can see, hear, think and make decisions.

In the future, driverless cars will be connected to the road network and traffic signals, as well as each other, enabling them to decide on the best and safest routes.

CAN COMPUTERS SEE?

Machines can be brilliant in some areas and struggle in others. Most people find it easy to identify an apple in a tree or read an angry expression because humans have spent millions of years using their eyes to find food and evade danger. However, computers can have trouble working out where an object ends and a background begins.

COMPUTER EYE

HUMAN EYE

Yet, thanks to their increasing power and ability to learn from their mistakes, computers are getting much better at analysing visual data. This allows them to do things humans can't, such as reconstruct a scene from different angles, restore damaged or blurry images and estimate the speed of an object in a video.

CAN MACHINES THINK AND FEEL?

So computers can display friendship, drive cars and recognise objects. But will they ever become truly conscious? Could a self-driving car one day decide to deviate from its programmed route and go its own way?

Some scientists believe that consciousness isn't necessarily unique to humans. It happens because our brains work in a certain way, and there's nothing to stop it from happening in an artificial brain too.

The problem is we don't yet know how human consciousness happens. Once we've cracked that, machine consciousness might be just a short step away.

But even if machine consciousness isn't possible, as long as they *appear* conscious to us – by laughing at our jokes or telling us about their 'thoughts' and 'memories' – it'll be much like talking to a person...

SUPER AI

What does seem likely is machine super-intelligence – the emergence of machines that are far superior to even the brightest humans.

These machines would have perfect memories, an internet-sized brain and be able to do hundreds of activities at once.

They could even connect with each other to create one all-knowing super-mind. A machine with intelligence on this scale could pose a threat to the human race.

A ROBOT REVOLUTION

Already, robots and AI systems are replacing humans in all sorts of jobs, including manual labour, translation, legal and financial research and even some kinds of journalism.

But could a super-intelligent machine one day take over the world? It's possible – once it can outthink us and take actions we can't foresee or guard against.

If a super-machine decided that humans posed a risk to itself or to its resources, it may even decide to dispose of us...

CATASTRO-PHONE

It's possible that an AI takeover could happen by accident. If a machine was programmed to, say, make as many smartphones as possible, it might decide to take over the planet so that it could use all its resources to make phones.

It could decide to kill or imprison all humans to stop them shutting it down, or use the Earth's resources to make different things.

As machines get smarter, it becomes ever more important for us to embed safeguards in their programming so they don't end up harming us.

HOW COULD IT HAPPEN?

Why not just unplug the machine before it takes over? An artificial super-intelligence could get around this by spreading itself through our computer systems like a virus.

TIME TRAVEL

We are all time travellers, heading into the future at a rate of exactly one hour per hour. It doesn't feel like time travel because we're doing it together. Usually by time travel, we mean someone's personal time getting out of step with this process.

So, if we travelled faster than one hour per hour, we'd reach the future before anyone else; travelling slower than that speed would take us to the past.

PAST AND FUTURE

So, do the past and future actually exist, and are they places we could visit? We know from photos and our memories that the past exists.

As for the future, scientists disagree on whether it's fixed like the past or constantly being formed due to our actions.

If it's fluid, then what would we be visiting? Just one of many possible futures? If it's fixed, we'd have no power to change it.

TIME TRICKERY

If you went back in time, you could prevent your mother and father from meeting, meaning that you were never born. But if you were never born, who went back in time to prevent them from meeting? This is called a paradox – an absurd or contradictory idea.