What is cancer?

Cancer is a disease caused by mutations in the DNA of a cell, causing them to divide excessively and multiply. Cancer cells manipulate their environment (blood vessels, support structures etc) forming tumours. Cancer can spread to other parts of the body via a process called metastasis.

Stand up to cancer

Here you can find ten case studies of cutting-edge research being used to fight cancer. These have been developed by Stand Up To Cancer, in order to give you an insight into the game changing science being funded right now, which aims to kill cancer! They fund many ongoing projects, ten of which you can find out more about here!
The immune system is the defensive force of the body, protecting us from harm. White blood cells act as the front line troops, patrolling around the body hunting for threats and eliminating them.

When normal healthy cells are damaged or attacked, by a virus for example, they use special chemical signals to alert the white blood cells to the threat. One way cells do this is by gobbling viruses up, and spitting out bits of the virus on their surface. The virus proteins act like a bright flashing danger beacon allowing the immune system to seek and destroy infected cells.

Some cancer cells are super sneaky when it comes to avoiding the immune system. They have two mechanisms to avoid being destroyed.

Firstly, some cancer cells are great at camouflage, hiding from the immune system by looking like the normal cells that surround it. This means that by themselves, the white blood cells can’t always spot cancers.

Secondly, when the white blood cells do spot a cancer, the cancer cells have a trick up their sleeve to survive. They put a special molecule on their surface, which acts like a Taser, sending the white blood cells to sleep.
Our super-smart scientists are working on supercharging the immune system to take skin-cancers out for good.

They’re developing viruses that can be injected into the bloodstream of skin cancer patients. These viruses are designed to specifically hunt out and attack the tumour cells. The attack flags the disease to the immune system – sending out the danger beacon loud and clear. Cancer cells can no longer camouflage and the immune cells flood in ready to attack.

At the same time, our researchers will take our cancer’s ‘Taser’ molecule using immunotherapy drugs. These special chemicals are used to activate the body’s own defences to attack cancer cells. They work by blocking the Taser-like molecule, knocking out the cancer cells’ first-line defence mechanism. This boosts the body’s white blood cells to attack the tumour.

By hitting cancers with this double whammy, researchers hope they can effectively use the body’s own defensive force to hit cancer hard.

**DISCUSSION QUESTIONS**

1. **WHY ARE CANCER CELLS SO GOOD AT HIDING FROM THE IMMUNE SYSTEM?**

2. **THE NUMBER OF PEOPLE BEING DIAGNOSED WITH SKIN CANCER EACH YEAR IS INCREASING, WHY DO YOU THINK THAT IS?**
HOW CELLS SHOULD BEHAVE

The immune system is a highly co-ordinated defensive force of the body, protecting us from harm. White blood cells act as the front line troops, patrolling the body for threats and eliminating them.

When normal healthy cells are damaged or attacked, by a virus for example, they use special chemical signals to alert white blood cells to the threat. One way cells do this is by gobbling viruses up, and spitting out bits of the virus on their surface. The virus proteins act like a bright flashing danger beacon, alerting the immune system to the danger.

WHAT GOES WRONG IN CANCER?

Some cancer cells are super sneaky when it comes to avoiding the immune system. They have two mechanisms to avoid being destroyed.

Firstly, they stop communicating properly with neighbouring cells, and aren’t very good at telling the immune system that the cell has been damaged. Because they’ve evolved from our normal cells, cancer cells don’t ‘look’ very different, so are difficult to spot.

Some cells in the immune system can recognise cancer cells as abnormal and destroy them, but this is when the second mechanism comes into play. The immune cells flood into the tumour, but the cancer cells are ready with a special “mind control” molecule on their surface, which puts the immune cells to sleep.
A common type cancer treatment is radiotherapy, which works by aiming beams of radiation at a tumour, blasting apart the DNA inside cancer cells. As this happens, some of the cells disintegrate, shedding molecules and DNA. It appears that this may lead to a surprising effect. All of this debris becomes a bright ‘danger beacon’ – alerting our immune system to the presence of the cancer cells. Cue a mass infiltration of white blood cells into the tumour, primed to destroy the cancerous cells.

But the immune system cannot escape the mind control molecule, and is sent to sleep.

Our amazing researchers are testing a new drug that blocks the mind control molecule, keeping the immune system active and on the attack. Radiotherapy is used to destroy as many cancer cells as possible, then this new drug stops the cancer cells from controlling the immune system. The white blood cells can kill the cancer cells, without being sent to sleep!

Potentially this treatment could do even more than that... white blood cells are designed to have an excellent ‘memory’. Its why people usually only get chicken pox once, your body can remember what chicken pox looks like and can fight it better a second time. If white blood cells can remember what cancer looks like, then maybe they can be primed and ready in case the same cancer comes back – providing long term immunity to cancer!

This cutting edge treatment is being tested on lung cancer patients, but could be the key to turning the tide against cancer completely.

**DISCUSSION QUESTIONS**

1. **Can you think of any potential side effects of influencing the body’s immune system to fight cancer?**

2. **Radiation blasts apart the DNA within cells. What are the potential risks with this treatment?**
Scientists and doctors use tons of cool tech in the fight against cancer. Using equipment like microscopes, scientists can zoom in on individual cells within a tissue and look inside them to see the tiny individual structures. When looking at human cells, there are many specific recognisable features used to identify the cell type. For example red blood cells have no nucleus, stomach cells have microvilli, and nerve cells have long dendrites.

But what equipment can we use when we can’t take a slice of tissue and use a microscope? Diagnosing cancers often requires looking inside the body, using a range of imaging devices, such as CT scanners, X-Rays, or MRI Scanners.

When trying to spot pre-cancers in the food pipe (oesophagus) an endoscope is used. This is a camera on a long flexible tube, and it replicates what we can see with the human eye – a bit like an image we would take on our phone.

Pre-cancer cells are abnormal cells with the potential to become cancerous, but are currently not dangerous. A great way of preventing a cancer developing is to remove pre-cancer cells before they get a chance to become more abnormal and cause havoc. Unfortunately, this is easier said than done.

The problem with trying to spot early stage cancer cells is that, to the human eye, these abnormal cells can look exactly like normal oesophagus cells. Using the current technology, it can be difficult to tell the difference between them, making it tricky to catch and remove these dodgy cells early.
HOW OUR SCIENCE IS STANDING UP TO CANCER

Scientists are upgrading the traditional endoscope with the help of some of the latest tech from the world of physics. By exploiting gadgets used in military surveillance, they’re aiming to build a revolutionary medical imaging device; a camera that will capture and analyse information we can’t yet even imagine - colours the human eye can’t see presented with holographic-style detail.

The camera processes not only more colours of light, but also the angle that the light rebounds off the tissue, hitting the lens. This could give doctors more information about the colour, and a 3D map detailing all the tiny structural details of the tissue.

Oesophageal pre-cancer cells will have no-where to hide and no way to disguise themselves. They can be found and killed in the early stages of development before they cause a problem. Saving more lives.

If this technology works, there is potential for it to be applied in other cases where cancer is hard to spot like lung and the colon.

DISCUSSION QUESTIONS

1. WHY IS IT BETTER TO CATCH CANCERS EARLY?

2. CAN YOU THINK OF ANY OTHER TECHNOLOGY THAT COULD BE USED TO HELP DOCTORS IN SURGERY?
HOW SCIENTISTS CURRENTLY VIEW CELLS

We use various imaging techniques to look inside cells and study how they work. This can only tell us so much though, as cells rely heavily on each other as part of larger tissues and organs. It’s only by working together that cells can cause massive changes like growth or movement. For this reason it is also important to study the environment a cell sits in, and the tissue it’s a part of.

This can be done by preserving the tissue in a gloopy substance called resin. The resin acts to ‘freeze’ the tissue, so scientists can make super thin clean slices for a microscope.

WHY DO WE NEED TO FIND NEW WAYS TO IMAGE CANCER?

Our scientists are constantly working on new innovative ways to stop cancer. Before they can do that, we have to understand exactly how cancer works, and how it interacts with its environment.

As a cancer begins to grow, it builds itself the perfect habitat to develop and thrive. Firstly, the greedy cells require a constant supply of oxygen and nutrients. To do this, they hijack nearby blood vessels, sending out signals to make new blood vessels grow deep into the tumour. The cancer also brainwashes nearby cells to make the perfect life support system. The resulting tumour environment is complex to visualise, and vital to the tumour’s survival.

In order to understand this better, scientists can grow cancer cells as miniature balls called organoids. Organoids are much closer to living tumours than cells grown in a petri dish, and allow for a better visualisation of the cancer and its environment.
HOW OUR SCIENCE IS STANDING UP TO CANCER

Traditional microscopes are designed to look at tiny cross-sections through a tumour, and present a 2D image. This can’t tell us much about the complex 3D environments and the chemical interactions going on inside organoids.

By using elements of biology and physics, scientists may be able to build new technology to peer inside at the inner workings of these 3D environments. Each type of cancer has a unique architecture which, if identified, could help steer drug development. This could result in targeted treatments, specific to tumour type.

This type of imaging doesn’t damage the organoids in the way microscope slides would. The organoids can be measured again and again, including before, during, and after as a drug is being tested. Even cooler is that they will be able to take live film - rather than a still image. So scientists can have a 3D video recording of the inner working of the tumour.

Potentially this technique could change the entire way new drugs are developed. The drugs can be tested in a more accurate way, and the treatments that show promise can reach patients sooner.

DISCUSSION QUESTIONS

1. WHY WOULD IT BE HELPFUL FOR SCIENTISTS TO SPEND MORE TIME ON BETTER IMAGING EQUIPMENT?

2. HOW COULD THIS LEAD TO NEW TREATMENTS?
Tissue and organs in the body are made up of many different cell types and molecules. The most general basic building blocks are epithelial cells, the cells that form the lining of our organs. But cell types can get super specific. Nerve cells carry electrical impulses to and from the brain, while white blood cells work as part of our immune system. There are also specialised support cells called fibroblasts which connect many cell types together.

Since individual cells are so small, larger processes like movement must involve multiple cell types. Nerve cells transmit signals from the brain for a muscle to move, blood vessels provide oxygen and energy to the muscle, and the muscle cells contract in sync. Many different cell types are used to produce a single action.

Most cancer cells can’t move and spread around the body on their own, instead they have to take over and use neighbouring cells to do their bidding. So cancer cells will corrupt nearby fibroblasts (a connective tissue cell), and turn them into cancer conspirators called cancer-associated fibroblasts (CAFs). This allows cancer cells to gain two vital abilities.

Firstly, by “stiffening up” and linking the CAFs become the perfect framework for cancer cells to build their own blood supply and provide themselves with essential nutrients. And secondly, the CAFs can form makeshift escape tunnels that expeditionary cancer cells can burrow through.

Cancer cells can even recruit blood vessels, making them grow towards the cancer cell. The manipulated cells that line the blood vessels send out special “hand hold” molecules that the cancer cells can grip onto to escape. Once a cancer has recruited fibroblasts into CAFs, and grown itself a blood supply, it can escape and spread around the body, becoming a lot harder to treat.
Instead of targeting the tumour cells, our scientists are targeting cancer’s recruits… the cancer-associated fibroblasts (CAFs) and corrupted blood vessel cells themselves.

Targeting CAFs at the same time as treating the cancer could be a great new way of weakening cancers. Existing treatments could be much more effective. Molecules that are essential to CAF function have been identified, and if the researchers can develop interfering drugs they may be able to rid the tumour cells of valuable allies.

Ridding cancer of the ability to build a blood supply and move could drastically weaken the disease. Ultimately thousands of cancers could become far more treatable than they are now.

DISCUSSION QUESTIONS

1. **Why can you only use this method at the same time as another treatment?**

2. **Why is creating a blood supply so necessary for tumours?**
HOW CELLS SHOULD BEHAVE

The genome is the instruction manual at the heart of all cells. Like a book, the genome made up of strings of letters that provide specific meanings – commonly known as DNA.

A gene is like one individual ‘sentence’ within our manual. The stretches of DNA that form these genes get read (transcribed) and made into proteins (translated). When and which protein is made is controlled by a master area of DNA - which acts like a bookmark - called a promotor. This little stretch of DNA is used as a way of identifying which genes need to spring into action.

Although the entire human genome is present in every cell. Not all of it is read by all of the cells. In fact, the type of cell is determined by which genes inside the cell are active and producing proteins.

For example, a stomach cell holds the instructions to be any cell in the body, but it only reads and uses the instructions to be a stomach cell. These instructions determine the shape and actions of the cell, and although the cells can “squidge” and move a little, most cells stay the same shape their whole lives.

WHAT GOES WRONG IN CANCER?

Cancer cells are often very faulty and stop functioning like normal cells do. This is because of mistakes that occur within normal cell DNA – such as the letters getting jumbled, whole chunks being deleted, or different bits fusing together in the wrong order - which leads to uncontrolled growth and division of faulty cells.

These errors are known as mutations, and certain mutations can give cancer cell a surprising quality - the ability to change shape and spread to new locations. Once a cancer has begun to spread, it becomes harder to treat, radiotherapy and surgery might not be able to remove all the cancer, making them less effective.
Researchers have pinpointed particular genes that are behind the cells' shape-changing power. If any of these genes become faulty, then the shape-changing power could be activated at the wrong time. This enables cancer cells to shape-shift and spread.

Once a cancer has recruited fibroblasts into CAFs, and grown itself a blood supply, it can escape and spread around the body, becoming a lot harder to treat.

**HOW OUR SCIENCE IS STANDING UP TO CANCER**

Our scientists are focusing in on the shape shifting genes to try and stop cancer from being able to move.

Specifically they are working on molecules that act as tiny ‘freeze rays’, blocking and interfering with genes inside the cell. This could work by molecules attaching to DNA so that it can’t be read, or by blocking molecules involved in the shape changes. However it happens, the aim is to freeze cancer cells so they will be stuck in one place unable to spread.

Without the ability to change shape and move around the body, the cancer cells could be far more vulnerable to current treatments. This means doctors may be able to remove the entire cancer in one try.

**DISCUSSION QUESTIONS**

1. **THE PROCESS OF USING DNA TO MAKE A PROTEIN IS COMPLICATED. WHERE ELSE IN THIS PATHWAY COULD SCIENTISTS INTERFERE AND HOW?**

2. **WHY DOES THE MOBILITY OF CANCER CELLS CAUSE SUCH A PROBLEM TO DOCTORS?**
HOW CELLS SHOULD BEHAVE

When looking at human cells, there are many specific recognisable features used to identify the cells. For example, red blood cells have no nucleus, stomach cells have microvilli, and nerve cells have long dendrites.

Some cells, like red and white blood cells, are made to move around. But many normal healthy tissue cells have a fixed unchanging shape, structure and location in the body. They stay still and use chemical signals to communicate over long distances rather than moving themselves. This keeps organs together and in sync to maintain the function of our body.

WHAT GOES WRONG IN CANCER?

Cancer cells are often very faulty and stop functioning in ways normal cells do. Changes occur in normal cell DNA which leads to uncontrolled growth and division. The letters get jumbled, whole chunks of DNA are deleted, or different bits of DNA fuse together in the wrong order.

These errors are known as mutations, and certain mutations can give cancer cell a surprising quality - the ability to change shape and spread to new locations. The cancer cells either invade nearby tissues, or detach entirely, using the blood stream to reach far off places in the body. Once a cancer has begun to spread, it is harder for radiotherapy and surgery to remove all the cancer, making them less effective.

Yet, there’s an in-between stage, a point after the tumour is contained at one location, and before the mass spread of cancer cells. A handful of small cancer ‘outposts’ develop. The cancer cells cannot yet migrate far and wide, and need this first stepping stone to begin their advance.
Radiotherapy works by aiming beams of radiation at tumours, blasting apart the DNA inside cancer cells. Although the doctors aim the beam as accurately as possible, some healthy cells always get caught in the crossfire, which can lead to unpleasant side effects. For most people these aren’t too severe though, and radiotherapy has helped rid millions of people of cancer.

But when the cancer is present in many sites around the body, the risks start to outweigh the gains. So we need to find better ways to deliver the cancer blasting beams.

Our scientists want to get super specific. They want to target cancer outposts with highly accurate bursts of radiotherapy. Scientists will use a more precise form of radiotherapy called stereotactic body radiotherapy (or SBRT for short). Basically 3D scanning technology is used to accurately map the location of the tumour, and then aim weaker beams of radiation at it from thousands of different angles. This means the tumour becomes the centre of a radiation hotspot, minimising harm to nearby organs.

By using SBRT, they’ll be able to target several tumours ‘outposts’ in rapid succession, hopefully hitting the cancers before they spread further.

**DISCUSSION QUESTIONS**

1. **WHY IS IT DIFFICULT TO REMOVE ALL THE CANCER ONCE IT HAS SPREAD?**

2. **DOCTORS USE X-RAYS AND MRIS TO LOCATE THE TUMOUR BEFORE STARTING RADIOThERAPy OFTEN A COUPLE OF WEEKS LATER. WHY IS THIS POTENTIALLY PROBLEMATIC?**
**DNA** is like a manual at the heart of all cells, and it holds all the instructions necessary to make a human being. Just like a book, DNA is made up of strings of letters that provide specific meanings. Individual sentences – or genes – can be read (transcribed) and then used to make proteins (translated). Not only does DNA code for proteins, it also tells the body when certain proteins should be made, and when they should be switched off. The proteins themselves can have super specific roles to play within the cell. For instance, a messenger protein scurries around relaying important information, an enzyme acts as a biological catalyst, or a structural protein acts as one of the building blocks of the cell.

Proteins can’t just be made at any time. In fact, the protein-production line is tightly controlled and very specific to cell, tissue, and even whole body function.

**Cancer** can cause the genetic instructions in the cell get muddled up, producing rogue molecules that rampage around inside the cells, making them go haywire. This is what happens in a type of cancer called **acute promyelocytic leukaemia (APL)**. This is a blood cancer characterised by not enough mature red and white blood cells, and too many immature white blood cells.

But luckily, APL has a major weakness! These cancer cells are hypersensitive to arsenic. The medieval poison causes the cancer cells to break down the rogue molecules driving the cancer, devouring themselves from the inside. Without this vital molecule, the cancer cells quickly falter and die.

Thanks in part to this arsenic treatment almost 8 out of 10 patients with APL make a full recovery.
HOW OUR SCIENCE IS STANDING UP TO CANCER

Our scientists are now studying the mechanisms involved in arsenic-inspired self-cannibalisation. If they can learn how it works, it may be possible to trigger the same process in other cancer types.

Firstly, the way arsenic works within the context of APL must be studied. How exactly does it spark the cancer cells to degrade the rogue-proteins? Then other cancer types can be investigated to see if there is a way of activating the same mechanism in them. By understanding this, scientists hope they can use arsenic to cause other types of cancer cells to digest themselves.

This could lead to a whole new way of treating many cancers... making a cure out of a poison.

DISCUSSION QUESTIONS

1. WHY DO YOU THINK TOO MANY WHITE BLOOD CELLS AND NOT ENOUGH RED BLOOD CELLS WOULD BE A PROBLEM?

2. PROTEINS PLAY VITAL ROLES WITHIN THE CELL. CAN YOU THINK OF ANY OTHER PROTEINS THAT WOULD CAUSE PROBLEMS IF THEY DISAPPEARED?
HOW THE PANCREAS SHOULD BEHAVE

This research project deals specifically with the pancreas.

The pancreas is a key organ in the digestive system. Located behind the stomach, the pancreas produces an alkaline liquid containing many different enzymes vital to digestion. The liquid both helps break down food, and neutralises stomach acid, as intestinal enzymes prefer alkaline conditions. By controlling the hormone insulin, the pancreas also monitors and alters blood sugar levels. It’s vital to our survival that this organ works well.

If any of our organs get wounded in some way, the body has a very specific response. Tissue cells will divide and multiply to bridge the gap, often creating new blood supplies as they go. These mechanisms of ‘wound repair’ are essential for keeping us alive day-to-day.

WHAT GOES WRONG IN CANCER?

Cancer is a disease of cells, and happens when the instruction manual inside our cells - DNA - gets damaged. This causes cells to become faulty and grow in an out-of-control way. The DNA damage can cause cells to divide non-stop, send out signals to make new blood supplies, and corruption of nearby tissues. Basically, it’s all the ‘wound repair’ mechanisms being put into action at the wrong time, without a ‘stop’ button.

There has been amazing progress towards beating cancer as a whole, and overall survival has doubled in the past 40 years. Unfortunately, pancreatic cancer remains extremely difficult to treat and survival for this particular disease remains stubbornly low.

Why is pancreatic cancer so difficult to treat? One problem is that symptoms don’t usually show until late stages in the disease, when treatments are less effective. The central position of the pancreas the body also makes it easier for the cancer to spread, and more difficult to be remove. In addition to this, pancreatic cancer does not respond in the same way to drugs as other cancers do.
The same mechanisms pancreatic cancer cells use to grow and thrive, such as cell division, new blood supplies, and tissue remodelling, are also used by the body normally, but this is usually in a tightly controlled and regulated way. Normally, these processes help the body to heal an open wound site by filling it with cells, supplying those new cells with blood, and remodelling the tissue.

Because of the similarities, scientists often refer to cancer as a ‘wound that never heals’, and are now looking for ways to stop the abnormal ‘wound repair’ mechanism in tumour cells. Basically, the process of making tumours would be stopped – ending pancreatic cancer for good.

**DISCUSSION QUESTIONS**

1. **IF A PATIENT HAS PANCREATIC CANCER WHAT SYMPTOMS DO YOU THINK THEY WILL HAVE?**

2. **IF SCIENTISTS ARE ABLE TO STOP THE ‘WOUND REPAIR’ MECHANISM TO STOP TUMOURS GROWING, CAN YOU THINK OF ANY POTENTIAL RISKS TO THE PATIENT? ARE THEY WORTH IT?**
WHAT GOES WRONG IN CANCER?

Cancers are very different from each other for many different reasons. It’s not just about the location of the tumour in the body, but also the type of mutation that led to the tumour developing that matters. It may have been a mutation that overrides the “stop growing!” signal within the cell, so the cell keeps multiplying without stopping. A mutation may block the cell from destroying itself when it’s too old, so more and more errors occur and accumulate. Or perhaps a mutation might take away a vital bit of cellular machinery, so the cell doesn’t function properly.

Cancer is a very complex disease and there are many different types and subtypes of cancers. Two of the same types of cancer can be wildly different from another. Because of this, a specific treatment is can be extremely effective with one patient and completely fail with another.

The differences types of mutations that lead to cancer are key in the varying properties between cancer cells themselves.
HOW OUR SCIENCE IS STANDING UP TO CANCER

Scientists want to be able to classify patients into groups of similar mutations. They can then use specific drugs for each group, which hopefully will prove to be more effective.

Doctors could do this by reading (sequencing) the patients DNA using specialist machines. First, they find where the patients DNA has mutated in the cancerous cells. Once they discover the mutations driving the cancer, they know its weakness. Next, they input the mutation into a huge database which calculates exactly what drug would work best for that specific patient. This enables doctors to personalise the treatment to that individual patient.

This could be the future of medicine as we know it, where each treatment is specifically tailored to each person’s genetics.

DISCUSSION QUESTIONS

1. ALL CELL MAKE SOME ERRORS WHEN THEY REPLICATE, BUT NOT ALL CELLS BECOME CANCEROUS. WHY DO YOU THINK THAT IS?

2. WHAT OTHER CASES COULD PERSONALISED MEDICINE BE USED IN?