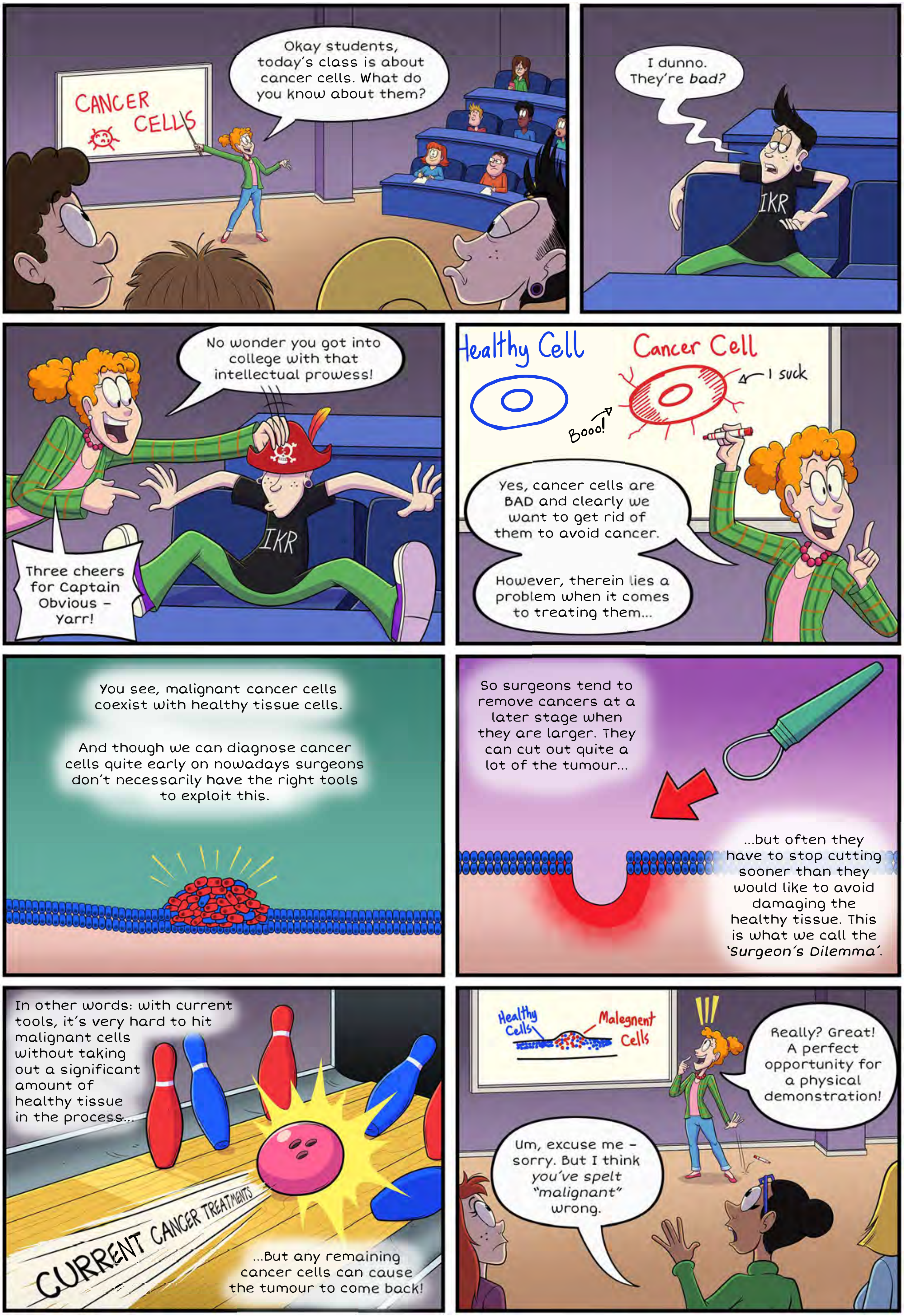
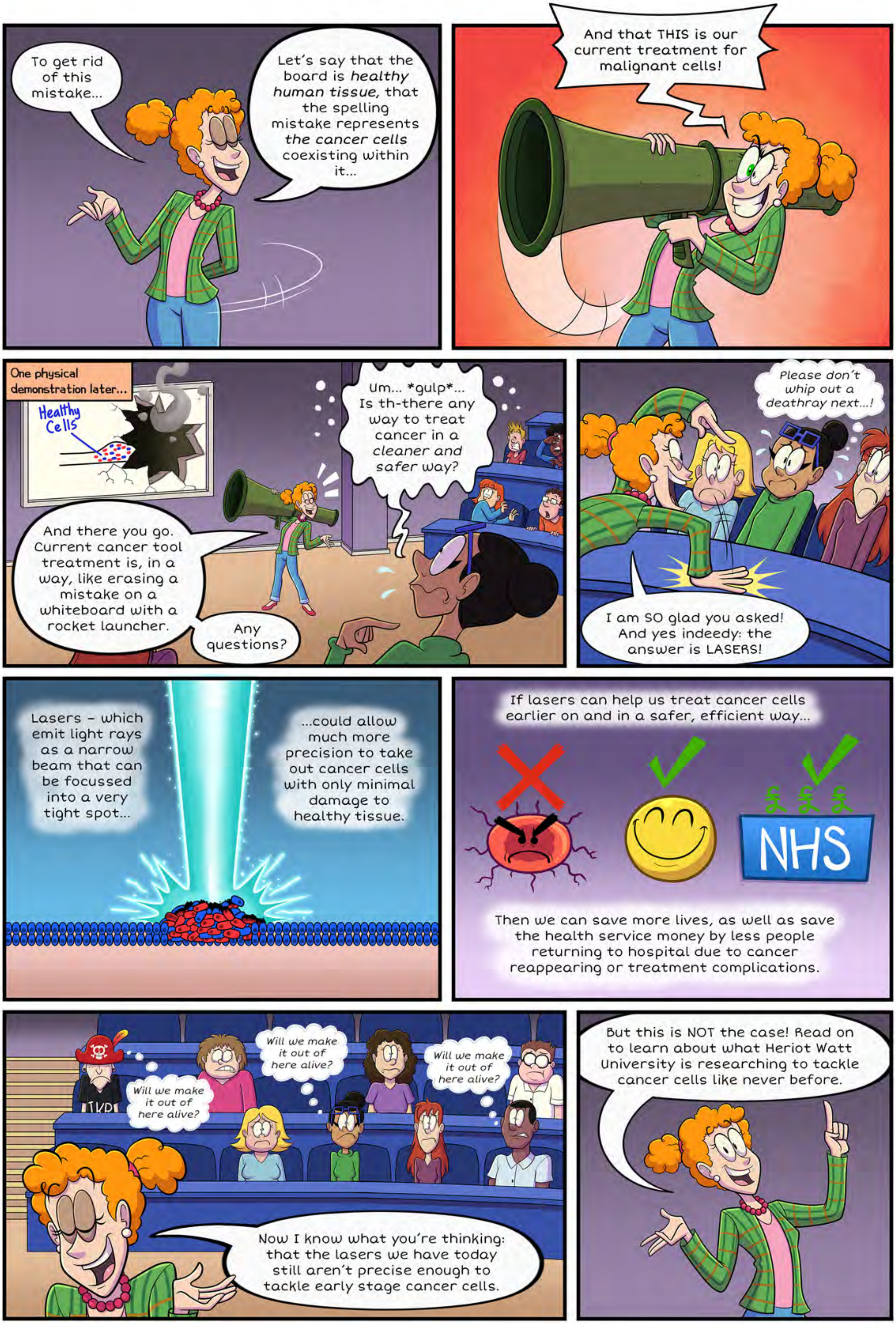
HERIOT WATT UNIVERSITY

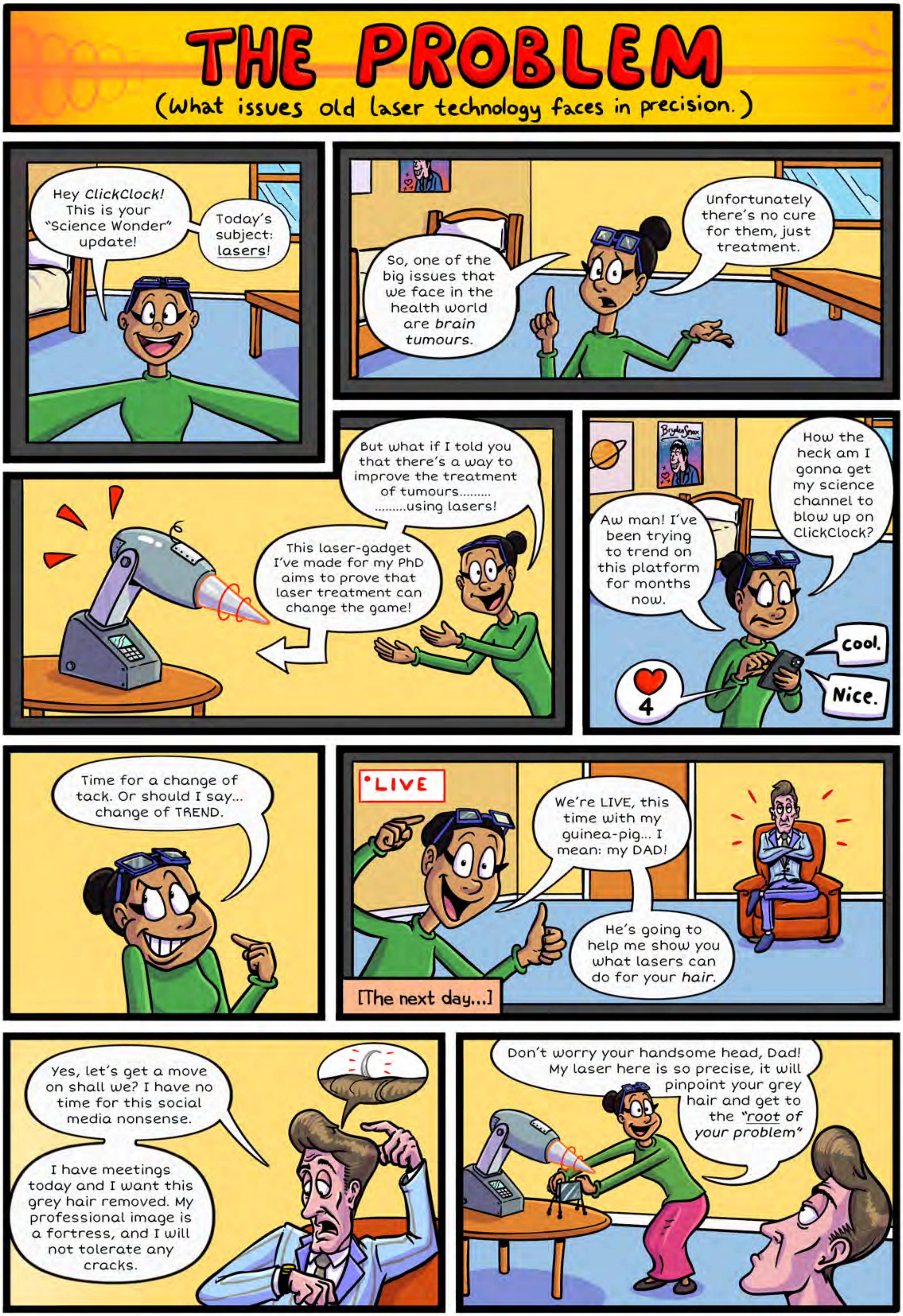
The PROBLEM, The LASER, and the SOLUTION

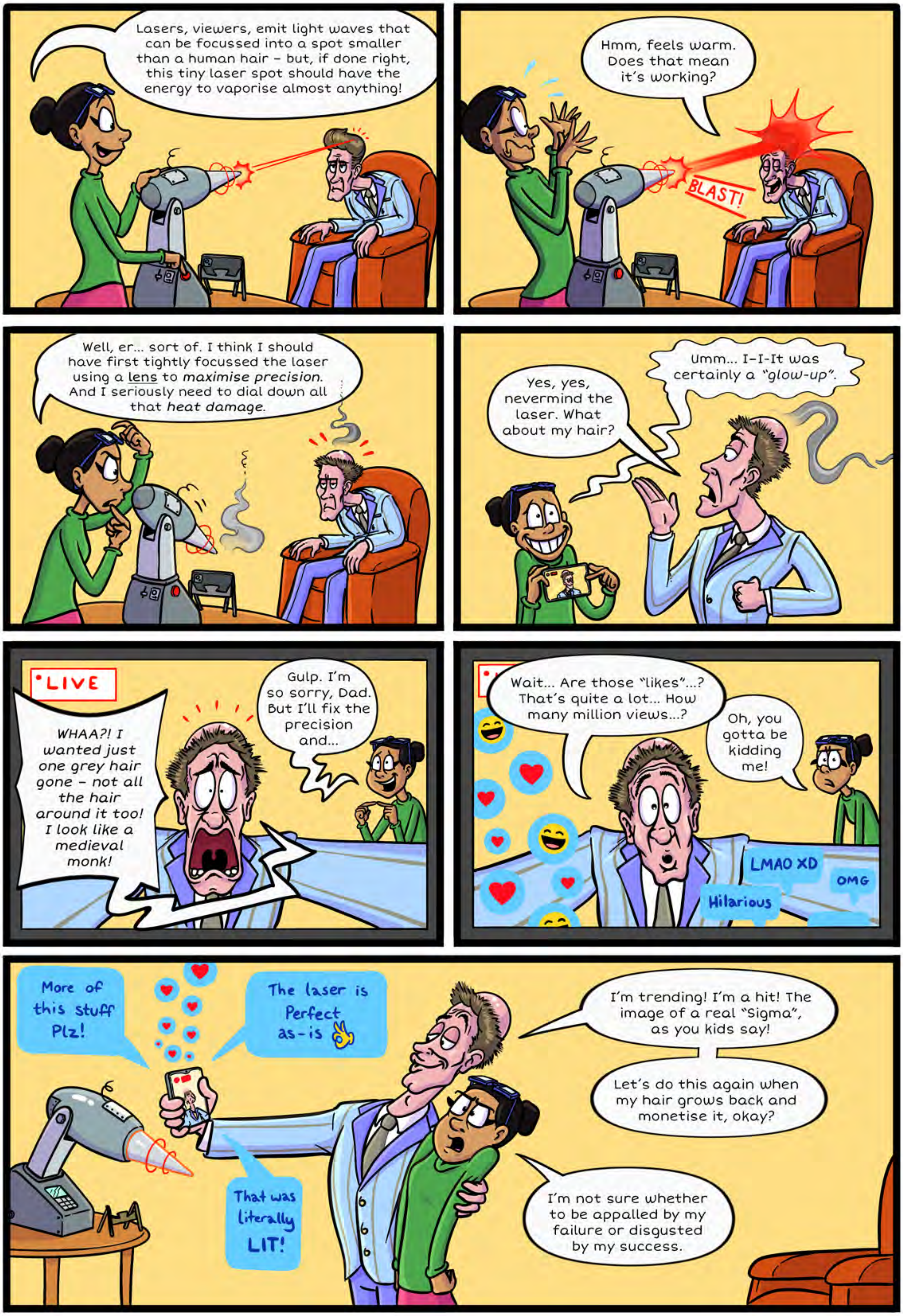
A Heriot Watt Comic about the potential positive impact of lasers in precision surgery.

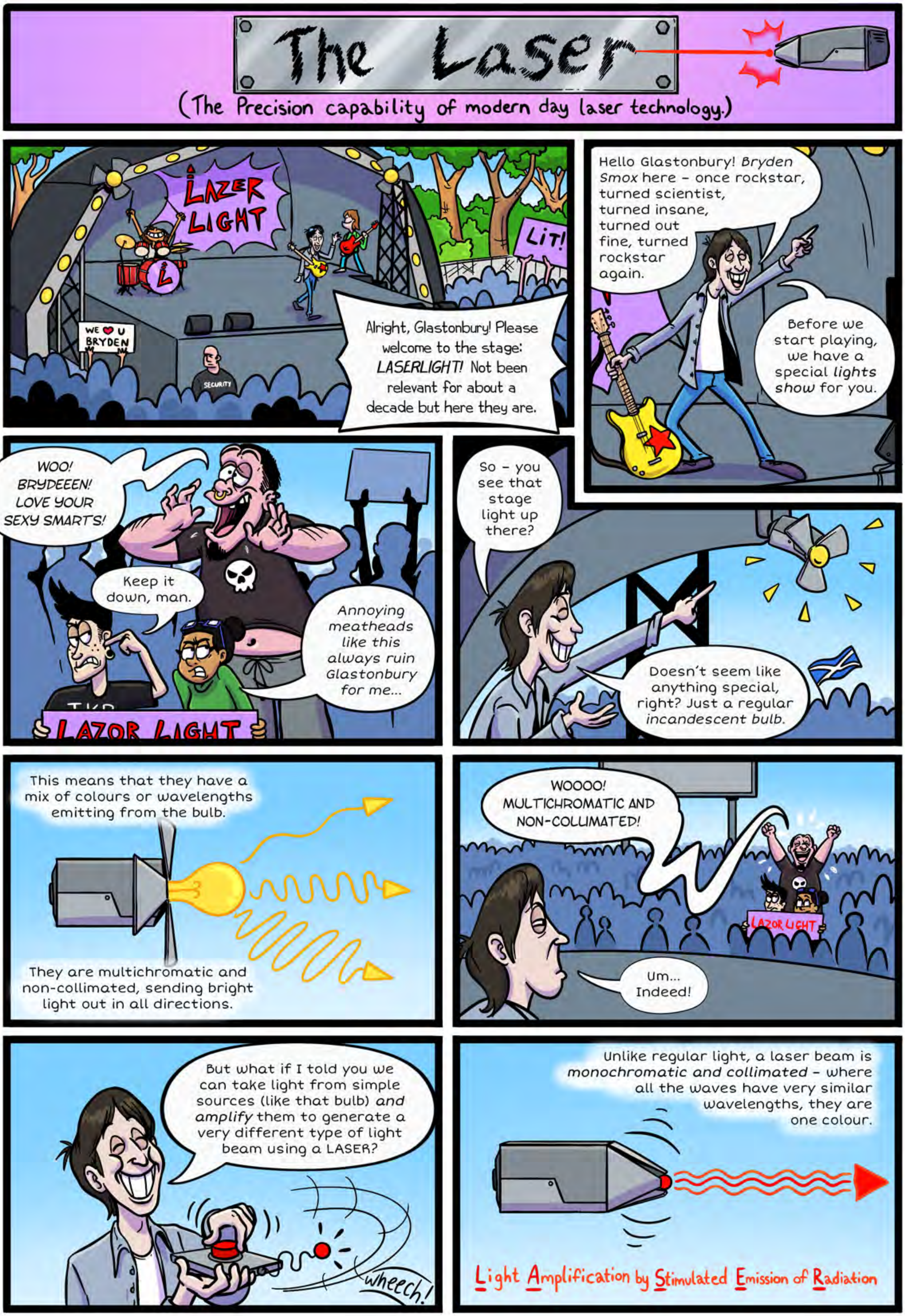


CANCER CELLS
Okay students, today's class is about cancer cells. What do you know about them?
I dunno. They're *bad?*
IKR
No wonder you got into college with that intellectual prowess!
Three cheers for Captain Obvious – Yarr!
Healthy Cell
Cancer Cell
I suck
Booo!
Yes, cancer cells are BAD and clearly we want to get rid of them to avoid cancer.
However, therein lies a problem when it comes to treating them...
You see, malignant cancer cells coexist with healthy tissue cells.
And though we can diagnose cancer cells quite early on nowadays surgeons don't necessarily have the right tools to exploit this.
So surgeons tend to remove cancers at a later stage when they are larger. They can cut out quite a lot of the tumour...
...but often they have to stop cutting sooner than they would like to avoid damaging the healthy tissue. This is what we call the *'Surgeon's Dilemma'*.
In other words: with current tools, it's very hard to hit malignant cells without taking out a significant amount of healthy tissue in the process...
CURRENT CANCER TREATMENTS
...But any remaining cancer cells can cause the tumour to come back!
Healthy Cells
Malegnent Cells
Really? Great! A perfect opportunity for a physical demonstration!
Um, excuse me – sorry. But I think *you've spelt "malignant" wrong.*

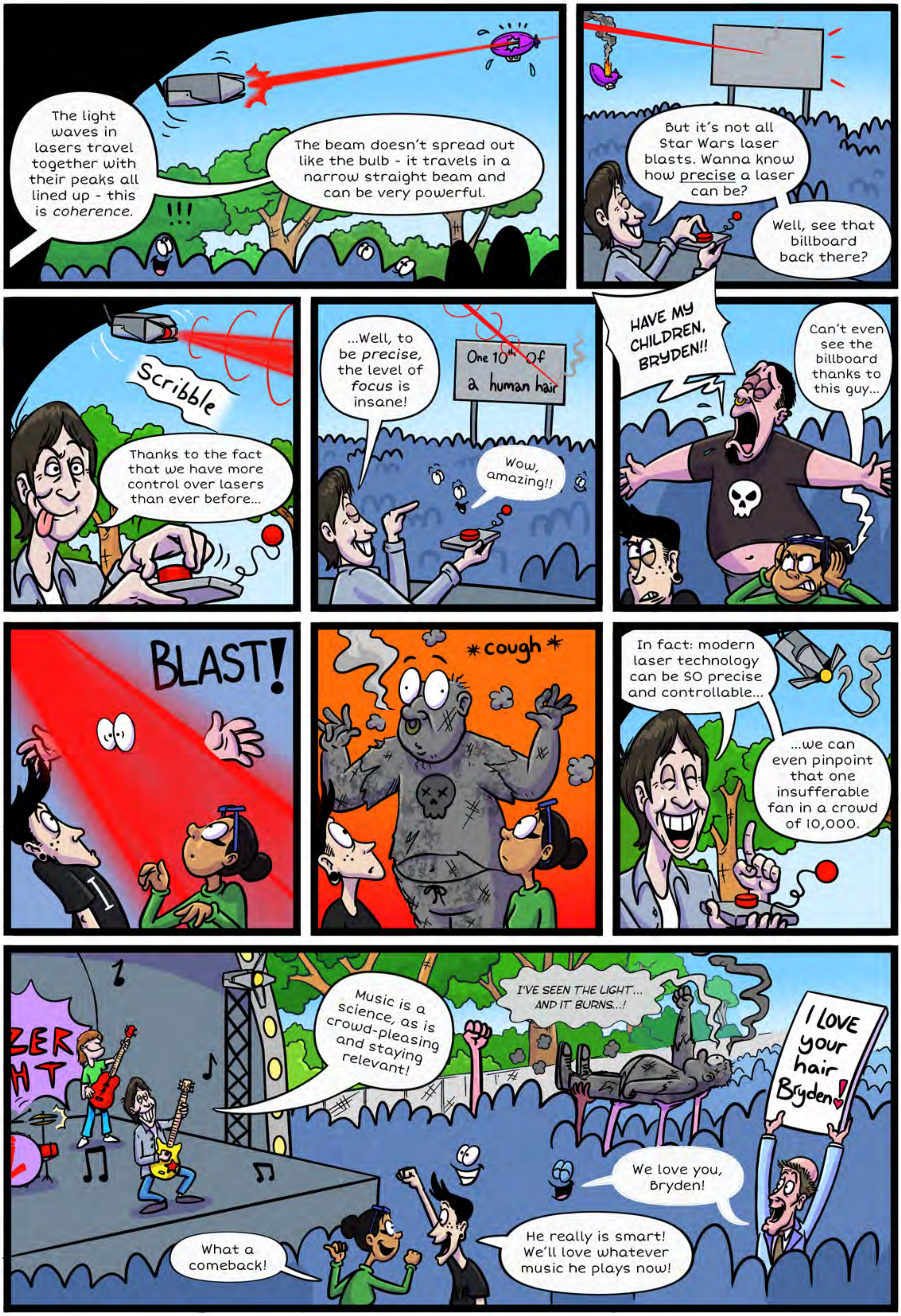

To get rid of this mistake...
Let's say that the board is *healthy human tissue*, that the spelling mistake represents *the cancer cells* coexisting within it...
And that THIS is our current treatment for malignant cells!
One physical demonstration later...
Healthy Cells
Um... *gulp*... Is th-there any way to treat cancer in a *cleaner and safer* way?
And there you go. Current cancer tool treatment is, in a way, like erasing a mistake on a whiteboard with a rocket launcher.
Any questions?
Please don't whip out a deathray next...!
I am SO glad you asked! And yes indeedy: the answer is LASERS!
Lasers - which emit light rays as a narrow beam that can be focussed into a very tight spot...
...could allow much more precision to take out cancer cells with only minimal damage to healthy tissue.
If lasers can help us treat cancer cells earlier on and in a safer, efficient way...
NHS
Then we can save more lives, as well as save the health service money by less people returning to hospital due to cancer reappearing or treatment complications.
Will we make it out of here alive?
Will we make it out of here alive?
Will we make it out of here alive?
Now I know what you're thinking: that the lasers we have today still aren't precise enough to tackle early stage cancer cells.
But this is NOT the case! Read on to learn about what Heriot Watt University is researching to tackle cancer cells like never before.


THE PROBLEM
(What issues old laser technology faces in precision.)
Hey ClickClock! This is your "Science Wonder" update!
Today's subject: lasers!
So, one of the big issues that we face in the health world are brain tumours.
Unfortunately there's no cure for them, just treatment.
But what if I told you that there's a way to improve the treatment of tumours......... ....using lasers!
This laser-gadget I've made for my PhD aims to prove that laser treatment can change the game!
Aw man! I've been trying to trend on this platform for months now.
How the heck am I gonna get my science channel to blow up on ClickClock?
Cool.
Nice.
4
Time for a change of tack. Or should I say... change of TREND.
•LIVE
We're LIVE, this time with my guinea-pig... I mean: my DAD!
He's going to help me show you what lasers can do for your hair.
[The next day...]
Yes, let's get a move on shall we? I have no time for this social media nonsense.
I have meetings today and I want this grey hair removed. My professional image is a fortress, and I will not tolerate any cracks.
Don't worry your handsome head, Dad! My laser here is so precise, it will pinpoint your grey hair and get to the "root of your problem"


Lasers, viewers, emit light waves that can be focussed into a spot smaller than a human hair – but, if done right, this tiny laser spot should have the energy to vaporise almost anything!
Hmm, feels warm. Does that mean it's working?
BLAST!
Well, er... sort of. I think I should have first tightly focussed the laser using a lens to *maximise precision*. And I seriously need to dial down all that *heat damage*.
Yes, yes, nevermind the laser. What about my hair?
Umm... I-I-It was certainly a *"glow-up"*.
LIVE
WHAA?! I wanted just one grey hair gone – not all the hair around it too! I look like a medieval monk!
Gulp. I'm so sorry, Dad. But I'll fix the precision and...
Wait... Are those "likes"...? That's quite a lot... How many million views...?
Oh, you gotta be kidding me!
LMAO XD
OMG
Hilarious
More of this stuff Plz!
The laser is Perfect as-is 👌
That was literally LIT!
I'm trending! I'm a hit! The image of a real "Sigma", as you kids say!
Let's do this again when my hair grows back and monetise it, okay?
I'm not sure whether to be appalled by my failure or disgusted by my success.

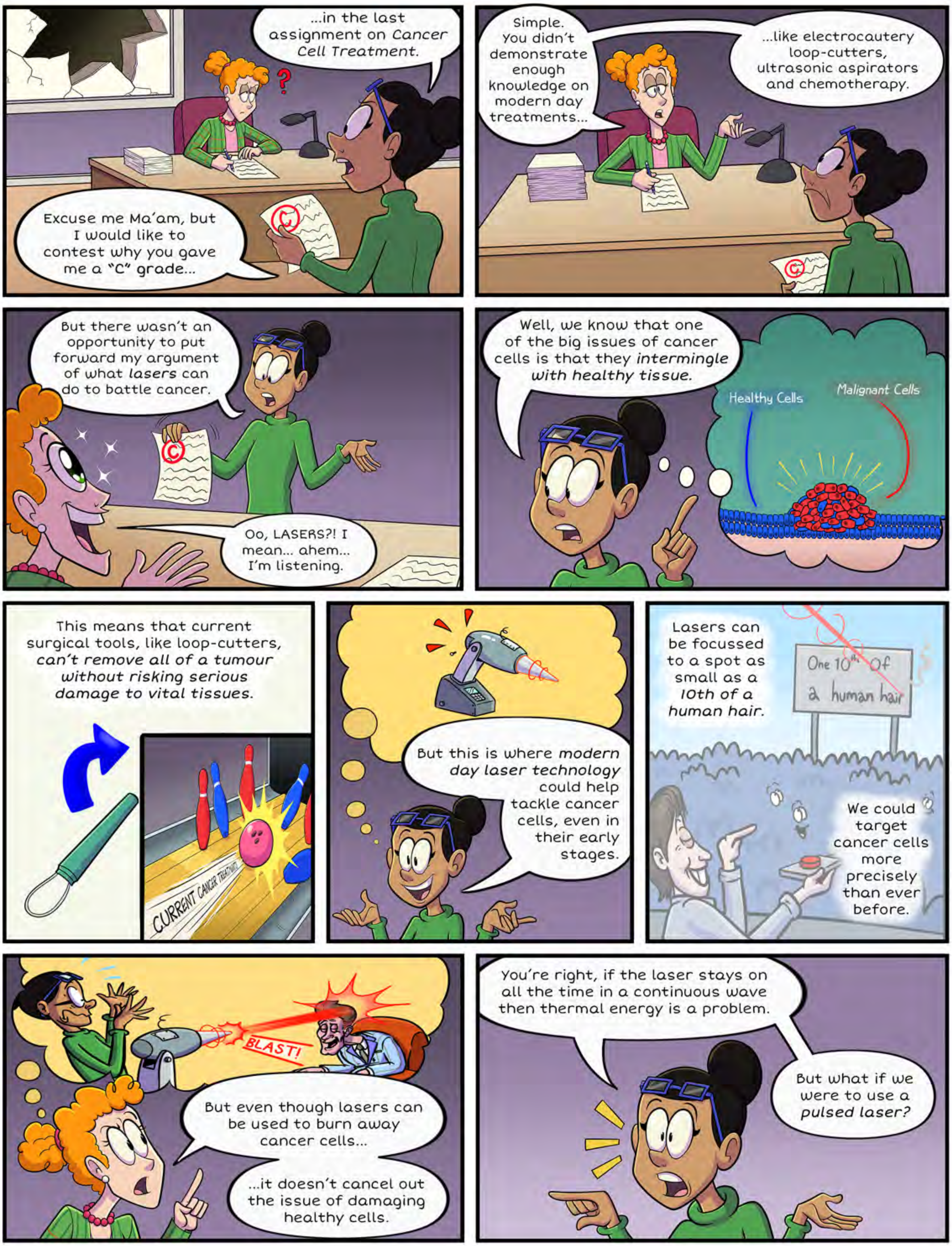


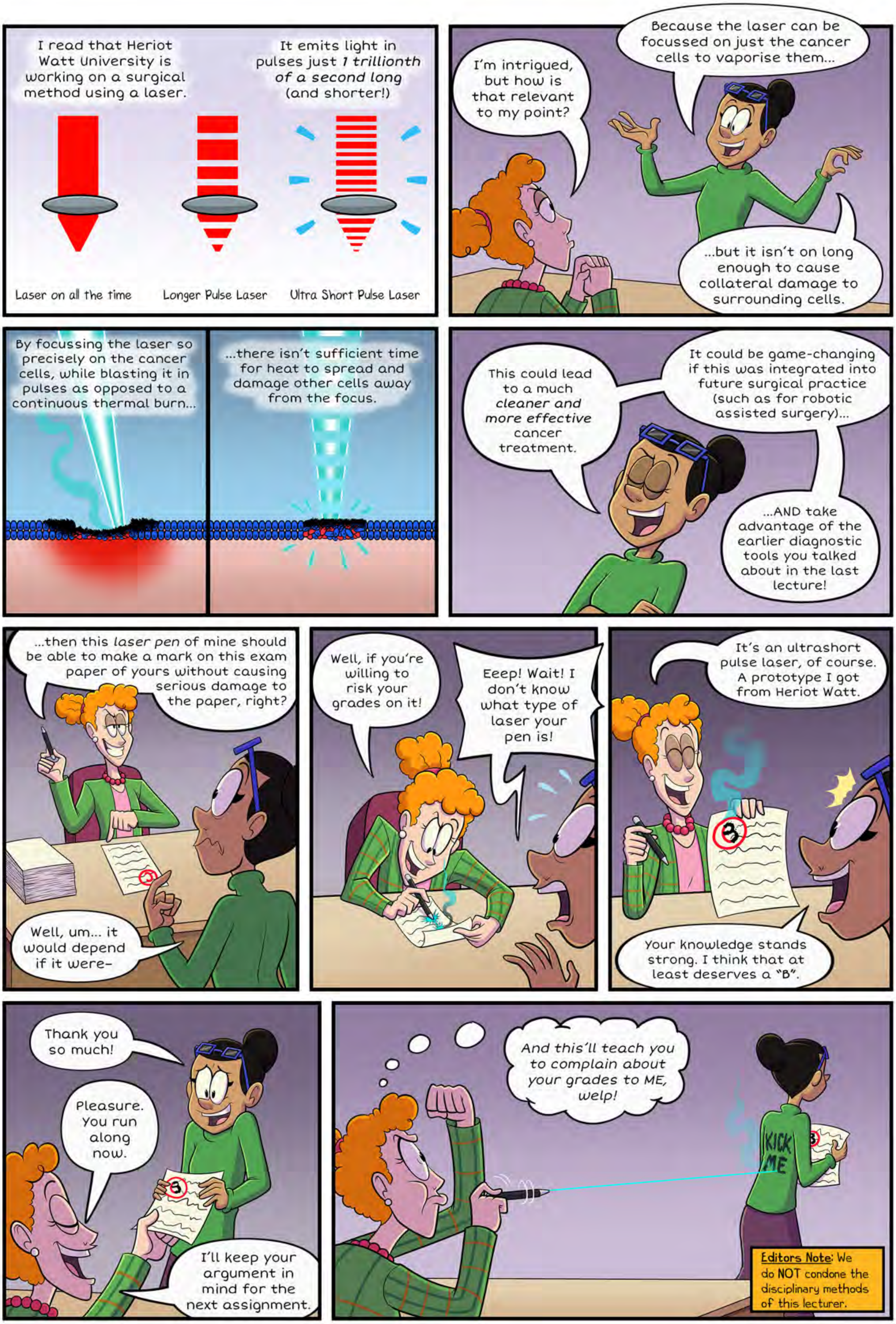
The Laser
(The Precision capability of modern day laser technology.)
LAZER LIGHT
LIT!
WE ♥ U BRYDEN
SECURITY
Alright, Glastonbury! Please welcome to the stage: LASERLIGHT! Not been relevant for about a decade but here they are.
Hello Glastonbury! Bryden Smox here - once rockstar, turned scientist, turned insane, turned out fine, turned rockstar again.
Before we start playing, we have a special lights show for you.
WOO! BRYDEEEN! LOVE YOUR SEXY SMARTS!
Keep it down, man.
Annoying meatheads like this always ruin Glastonbury for me...
LAZOR LIGHT
So - you see that stage light up there?
Doesn't seem like anything special, right? Just a regular incandescent bulb.
This means that they have a mix of colours or wavelengths emitting from the bulb.
They are multichromatic and non-collimated, sending bright light out in all directions.
WOOOO! MULTICHROMATIC AND NON-COLLIMATED!
LAZOR LIGHT
Um... Indeed!
But what if I told you we can take light from simple sources (like that bulb) and amplify them to generate a very different type of light beam using a LASER?
wheech!
Unlike regular light, a laser beam is monochromatic and collimated - where all the waves have very similar wavelengths, they are one colour.
Light Amplification by Stimulated Emission of Radiation


The light waves in lasers travel together with their peaks all lined up - this is *coherence*.
The beam doesn't spread out like the bulb - it travels in a narrow straight beam and can be very powerful.
!!!
But it's not all Star Wars laser blasts. Wanna know how precise a laser can be?
Well, see that billboard back there?
Scribble
Thanks to the fact that we have more control over lasers than ever before...
...Well, to be *precise*, the level of *focus* is insane!
One 10th of a human hair
Wow, amazing!!
HAVE MY CHILDREN, BRYDEN!!
Can't even see the billboard thanks to this guy...
BLAST!
cough
In fact: modern laser technology can be SO precise and controllable...
...we can even pinpoint that one insufferable fan in a crowd of 10,000.
Music is a science, as is crowd-pleasing and staying relevant!
I'VE SEEN THE LIGHT... AND IT BURNS...!
I Love your hair Bryden!
We love you, Bryden!
What a comeback!
He really is smart! We'll love whatever music he plays now!

THE SOLUTION

(What Ultra Short Pulse Lasers Could Do For Cancer Treatment)




I read that Heriot Watt University is working on a surgical method using a laser.
It emits light in pulses just 1 trillionth of a second long (and shorter!)
Laser on all the time
Longer Pulse Laser
Ultra Short Pulse Laser
I'm intrigued, but how is that relevant to my point?
Because the laser can be focussed on just the cancer cells to vaporise them...
...but it isn't on long enough to cause collateral damage to surrounding cells.
By focussing the laser so precisely on the cancer cells, while blasting it in pulses as opposed to a continuous thermal burn...
...there isn't sufficient time for heat to spread and damage other cells away from the focus.
This could lead to a much cleaner and more effective cancer treatment.
It could be game-changing if this was integrated into future surgical practice (such as for robotic assisted surgery)...
...AND take advantage of the earlier diagnostic tools you talked about in the last lecture!
...then this laser pen of mine should be able to make a mark on this exam paper of yours without causing serious damage to the paper, right?
Well, um... it would depend if it were-
Well, if you're willing to risk your grades on it!
Eeep! Wait! I don't know what type of laser your pen is!
It's an ultrashort pulse laser, of course. A prototype I got from Heriot Watt.
Your knowledge stands strong. I think that at least deserves a "B".
Thank you so much!
Pleasure. You run along now.
I'll keep your argument in mind for the next assignment.
And this'll teach you to complain about your grades to ME, welp!
KICK ME
Editors Note: We do NOT condone the disciplinary methods of this lecturer.

Summary:

The world's population is growing and ageing, leading to a significant increase in cancer cases, expected to rise from 18.5 million in 2018 to 29.5 million by 2040. Early cancer detection through screening programs is crucial as it allows for treatment at a curable stage and enables less invasive surgeries.

Minimally invasive surgeries are becoming more common, often with robotic assistance. However, new surgical tools are needed, especially those that can diagnose and treat cancer in real-time.
One major challenge in treating cancer is that tumour cells are often intermingled with healthy tissue, making it difficult to remove only the "bad" cells without affecting the surrounding healthy ones too.
Surgeons face significant limitations when trying to remove tumours, especially in critical areas like the brain. They cannot always remove all of the tumour without risking damage to vital tissues or brain functions. This is particularly problematic for dgbrain tumours, where even a small amount of damage to healthy tissue can have severe consequences. Currently, there is no cure for brain tumours; treatments available can only prolong life but are not very effective.

Existing procedures using cumbersome electrical cutting devices or long pulsed and continuous wave lasers to apply heat to tissue are challenging due to restricted access and lack of fine control for surgeons. Current surgical tools lack the precision, control, and selectivity needed, making them an order of magnitude worse than required. The default practice is to remove cancers with a margin of normal tissue, but this can leave cancer cells behind, leading to recurrent disease. This is the surgeon's dilemma.

Our team is developing a laser-based approach using ultrashort picosecond lasers, which can remove tumours with extreme precision and minimal damage to surrounding tissue. These lasers deliver energy in very short pulses, preventing heat from spreading to nearby tissues. This precision could revolutionize surgeries for colorectal cancer and other areas like neurosurgery and head and neck surgery, where preserving healthy tissue is vital. We are also working on integrating real-time diagnostic imaging to enhance these procedures further.

In laboratory tests, we've shown that picosecond laser ablation can significantly improve the precision of tissue removal, potentially transforming cancer surgery. Additionally, these laser pulses can be delivered through novel hollow core optical fibres, making endoscopic deployment feasible and opening up new possibilities for minimally invasive procedures.

We are always looking to expand our clinical expertise network and identifying new areas where our technology could be transformative. Neurosurgery requires extreme precision, as even microscopic loss of healthy tissue can greatly impact quality of life. In head and neck surgery, minimizing the removal of normal tissue helps preserve functions like speech and swallowing.

Find out more at:
https://aop.site.hw.ac.uk/surgical-applications/

Contact:
Professor Jon Shephard
j.d.shephard@hw.ac.uk

Applied Optics and Photonics Group
Institute of Photonics and Quantum Sciences
Heriot Watt University
Edinburgh, UK

Professor Jon Shephard

Currently Professor at Heriot-Watt University, School of Engineering and Physical Sciences. Prof Shephard's research (Applied Optics and Photonics) is targeted at number of areas: He leads the development of high power laser processes for surgery and other novel laser processes for medicine and also develops novel optical fibres for high power laser delivery and technologies for integrating lasers into manufacturing processes. There is an emphasis on developing multidisciplinary links with academic and industrial partners and medical end users such as surgeons and dentists.

Prof Shephard received the BA degree in Engineering at St Johns College, Cambridge University in 1994 and then joined Pilkington Plc (1994-1995) working within R&D. He then returned to study within the Department of Engineering Materials, University of Sheffield and was awarded an MSc (Eng) with Distinction in 1996. He subsequently remained at the University of Sheffield where he worked on developing novel mid-IR transmitting optical fibres and waveguides. He obtained his PhD in 2000 for his work on "Surface modification of IR transmitting glasses for integrated optics" and continued to work in the area of novel mid-infrared fibres and optical materials. In 2003 he joined the Applied Optics and Photonics Group at Heriot-Watt University, working on the development of novel micro-structured (Photonic Crystal) fibres, and is now a Professor within the Institute of Photonics and Quantum Sciences.

Key Paper:

Beck, R.J., Bitharas, I., Hand, D.P. et al. Dynamics of picosecond laser ablation for surgical treatment of colorectal cancer. Sci Rep 10, 20261 (2020). https://doi.org/10.1038/s41598-020-73349-w

Funded via EPSRC grant:
PreCisE: A Precision laser scalpel for Cancer diagnostics and Eradication
EP/V006185/1