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Charles Sturt University (Orange) Public Lecture

Science for Regional Australia in the Third Millennium

6:00pm – 7:00pm

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Location
Orange, NSW

Unearthing the story of the carrot

I have to start with a confession. When I saw that I was coming to Orange, my first thought was “carrots”.

Because we all know that orange is the normal and natural way for carrots to be – don’t we?

But I’m a scientist by training. In other words, I’m like a little kid! I want to know *why* all the carrots are orange. And I won’t eat my vegetables until I get a proper answer!

Sometimes *small* questions can be the start of great science careers. And it often pays to do a bit of digging!

Dig into the story of carrots, for example – and you have the story of civilisation, right there on your plate.

It begins 5,000 years ago, just as we were entering the Bronze Age. We have evidence of wild carrot seeds from that time in human campsites.

We don’t know exactly what our ancestors were doing with them – because the carrots they pulled from the wild weren’t orange but *white*. They weren’t sweet – they were terribly bitter. Those wild carrots were thin, woody sticks with a pungent smell.

So if our children think it’s a punishment to eat their vegetables – just think what it was like for the children of Europe 3000 BC.

About 4,000 years later, in medieval times, *cultivated* carrots appeared in Central Asia. They were purple, some were pale yellow. They were, at least, decent for eating, as well as comparatively easy to grow.

But they still looked a lot like parsnips – so much so that medieval scholars rarely bothered to tell them apart.

Those scholars also decided that carrots boiled down with pepper worked as an excellent remedy for toothache – as well as an aphrodisiac, a contraceptive and an aid for women in childbirth. A medieval superfood, as it were.

In any event, it wasn’t until the 1600s that the carrot really hit its strides – when the Dutch successfully bred an orange mutation, and made Holland the centre of a global carrot boom.

Why did the Dutch come to the view that orange was the best carrot colour?

Some think it was a sign of loyalty to William of Orange, and the movement for Dutch independence. Some think that all those Dutch still life artists were sick of dull colours and just wanted something *orange* in the bowl for a change.

Some think that Dutch housewives hated the way that purple carrots stained their plates.

Whatever the truth, orange was the colour that boomed – and it's lucky for us that it did. Today we know that the orange colour comes from beta-carotene – which is converted by the human body into vitamin A.

And the timing was fortuitous. With the eighteenth century came the dawn of the Enlightenment and the scientific method.

For thousands of years, we had fumbled our way in the dark – making the best of the wild cultivars we found, and learning through bitter experience how to farm them better.

But then we discovered science – and with science, we re-discovered the world.

With science, technology and innovation, we had a phenomenal capacity to re-create it.

And with science, technology, innovation and *society* – we have the carrot cake. And yes – we can eat it too.

Over the last 40 years, global carrot consumption has quadrupled – and the carrots we buy today have fifty per cent more carotene than those of my childhood.

Now carrots are turning full circle and going purple and knobbly again – because we are fickle consumers, with time to waste on turning food into Instagram art.

So the answer to "why are carrots orange" is "because human beings made them that way."

And the answer to "what's next?" is increasingly "what do you want?"

From carrots – to CRISPR

True of carrots – and true of all the things we take for granted in our world today, all of them shaped by human ingenuity.

It's a reminder that change touches every part of our lives. And it's a lesson in the way that societies like ours can come to accept and then *embrace* that change over time.

I have a theory about human beings. I think that we respond much better to carrots than we do to sticks. Not surprisingly, my theory is not unique. The legendary American architect and designer Buckminster Fuller, famous as the inventor of the geodesic dome, said it well:

> *"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."*

So don't berate me for eating white and woody sticks of carrot. Instead serve me sweet and juicy orange carrots, and preferably in the form of a cake.

We need to see and *taste* the benefits of change to look to the future with hungry eyes.

And we have already taken that path with so many technologies we now accept as a normal, even an essential, part of life – from electricity, to vaccination, to IVF.

Once, they were unthinkable. Today, we elevate them to the status of human rights.

And that is my point of entry to the important conversations about the future that we need to have today – be it babies with the DNA of three parents, or artificial intelligence, or nuclear power.

Of course, those conversations have to play out at the highest levels of government across the world. But they ought to play out around the dinner table as well.

After all, you can see the fingerprints of incredible change, right there on the plate!

And talking about the plate, let's get back to carrots and the rich farm lands of the Central West that have been producing wonderful quality vegetables for so many years.

The way we farm is changing – and precision is the watchword.

Pesticides are a useful tool in agriculture. But bulk spraying a whole crop or field is a waste, overdosing pest-free plants and contributing to excessive run off.

At the same time, the number of labour hours required to manually check and spray each plant in your crop as needed comes at an equally enormous cost.

So how do you save money, save time, and reduce the risk of chemical resistance?

Australian scientists have come up with a solution – a field robot called The Ladybird.

This hi-tech piece of machinery is named after the common Ladybird beetle of childhood stories and songs. It has an outer shell painted bright red that is adorned with black solar panels.

As it roams through the fields, the Ladybird computer brain has eyes to detect weeds, and insect-like robotic arms that extend and spray invasive plant predators.

Precision spraying systems are also in use for weed control on bare ground thanks to another Australian invention, WeedSeeker.

This device has a high-tech detection system that identifies every weed then triggers a fast-fire valve to deliver a killer blast. And it can do this racing through the field at 25 km/h!

Precision agricultural equipment like this is a win-win, delivering lower costs for the farmer and lowering the impact on the environment by reducing the harmful run-off into our rivers and waterways.

In North Queensland such technology might help preserve the Great Barrier Reef from devastating run-offs from the sugar cane farms that pollute the water and endanger the coral.

But it’s not just the farms – it’s the carrots themselves that are advancing rapidly!

In May this year, the full gene sequence of the carrot was published for the first time. The researchers identified more than 32,000 genes in the typical carrot, allowing us to trace the evolutionary path back past the white carrot to the age of the dinosaurs.

By the way, you might think that 32,000 genes is not sufficient to define the life cycle of something as complex as a carrot, but incredibly it is 12,000 genes more than a human being. Later, during the question and answer session, I might be able to elaborate on why we humans are more sophisticated than a carrot. But I digress...

Once the gene sequence of a carrot or other plant has been determined, it becomes possible to manipulate it with a powerful new tool called CRISPR.

Remember the term – because all the evidence suggests it is one of the technologies that will define our times.

CRISPR is not genetic modification as people have imagined it since the 1980s.

This is something fundamentally different: CRISPR is like a pair of scissors that we can wield with nuance, efficiency and control.

It's highly responsive – we just need to know the gene we want to target.

This opens a world of possibilities.

Perhaps we could modify the carrot to boost its pest-resistance or shelf-life…

…or perhaps we could take some of the useful properties of carrots – like beta-carotene – and use that knowledge with *other* plants to tackle the problem of Vitamin A deficiency.

But the upshot is the same. With technologies like CRISPR, the question ceases to be simply 'can we do this' – and becomes instead 'should we exercise this power'?

In many ways, the second is far more complicated than the first.

And to highlight this point, last week I had the privilege of being in Europe to speak at conferences in the Austrian capital, Vienna, and in the Belgium capital, Brussels, which is also the home of the European Parliament.

In Brussels, I spoke at the same conference as the European Union Minister for Education, Tibor Navracsics. He assured the audience that the European Ministers truly listen to the explanations from their scientific advisors on the benefits and associated risks of existing and pending science and technology.

But he urged us to accept the constraints of democracy. Ultimately, people's values take precedence over scientific evidence.

Embrace the Carrot!

Having said that, advances in technology never cease. As I see it, we can respond in three possible ways.

ONE: we can try to resist change – and those who choose that path are welcome to continue eating their nasty, bitter, white carrots.

TWO: we can naively hope that all advances will turn out for the best – and those who choose that path are welcome to all the consequences that they refuse to consider in advance.

Which leaves only response number THREE: work out how science can be channelled to optimally serve society's goals.

Think, for example, of the changes currently remaking agricultural regions – and what that means for Orange and its surrounding regions. There are remarkable opportunities, but how do we seize them?

We know there is a global need for more and better food. By 2050 there will be about 2.4 billion more people on earth. They will need 60 to 70 per cent more food than what's currently available.

And what about the agriculture money trail? We know that food and agribusiness form a US $5 trillion global industry. The global venture capital invested in agricultural technologies topped US $2.3 billion in 2014. In 2015, it doubled to US $4.6 billion! The growth is phenomenal.

For Australia, the opportunities in agriculture have never been higher. We can gain from the triple benefit of boosting yield, boosting return, and creating a stronger and more vibrant ag-tech sector.

We see the massive contributions of technology in other sectors, too. In the energy sector, we have solar energy and wind farms. We already have cars powered by electricity driving on our roads (and I drive one). Future opportunities include lithium mining, natural gas exports, battery storage and hydrogen storage.

We've also seen technology contribute greatly to Australia's mining sector. This sector is highly innovative. Our big mining companies control driverless monster trucks, and the biggest train systems in the world are managed from control rooms in Perth.

This automation and semi automation improves product quality, improves efficiency and reduces environmental impact. We are exporting much of this inventiveness and technological know-how to the rest of the world.

Mining, of course, is a big part of your local community, with the Newcrest Cadia Valley gold and copper mine just 25 kilometres from town.

Peeling the carrot

So why do we keep hearing from our public commentators that innovation is something that only happens in Israel or Silicon Valley, when it is everywhere?

I don't know – but it's a perception I want to change. Encouragingly, when I replace the word innovation with 'ingenuity' people realise that it is happening extensively around us every day.

The innovation economy is not just the university that develops a fantastic new battery, or the start-up that forms to manufacture it.

It is also the business person who works out how to make a profit as a distributor. It is the early adopter who works out how to use the battery to cut costs. It is the local council that gets in early and sorts out the regulations. It is the exporter who sees a way to sell the new battery technology to other countries.

Our innovation economy is what attracted the global aeroplane manufacturer Boeing Corporation to Australia, and now 3,000 of its employees work here – making Australia home to the largest Boeing workforce outside the USA.

Boeing has a highly-collaborative approach to research & development. By partnering with research institutes here in Australia, the innovative work carried out on our doorstep is having a profoundly positive impact on its global operations.

At every point in the supply chain, there are opportunities for people with imagination to follow a novel path.

Some of them will have a so-called STEM degree – science, technology, engineering and mathematics.

But many of them will be law graduates! They will be economists, teachers, nurses, town planners, winemakers and farmers.

There is no single model of the modern worker – simply a shared determination to be the architect of your own success.

To take my own story, I founded a company in California in 1983. Fifteen years later we saw an opportunity to dramatically expand from being a manufacturer of equipment for brain research to also become a manufacturer of equipment for genetics research.

This was a moment of opportunity but it was also very confronting. We were entering unknown territory.

I remember going to lunch with my four key managers and over that meal our thoughts crystallised.

We went back to the office and I gathered all the company employees. I informed them that the company had a new direction. Equipment for genetic research would be our new number one priority. Everything else would be number two.

This focussed approach led to product development in record time. The key driver of success was having the right attitude, from the top down.

Everybody in the company was working towards the same clearly defined target and creatively used technology and innovation to achieve the goal.

Since then, I have reflected on what makes an innovative organisation successful. I have come up with my own four-point formula:

- ONE: Leadership commitment
- TWO: Effective regulations
- THREE: Human capital
- FOUR: Financial capital

Starting with leadership commitment, the challenge is to keep the bar high – and then support the troops to deliver. It is about driving a culture of success, of relentlessly questioning what we have and wanting to do better. There is always a better way to do things.

On to the second ingredient. Effective regulations exist for two purposes. First, to protect the public. Second to facilitate commerce. They are both crucially important, and any perceived conflict between them can be resolved if there is determination to do so.

The third ingredient is human capital. There is no greater asset than committed, skilled people. They are the lifeblood of any organisation.

And the fourth ingredient for success is financial capital. I mean this in the broadest sense. It could be a loan, a government grant or a concession. Financing must be generous for innovation to flourish.

And everything's coming up Orange…

Do we find these four ingredients for success here in Orange? On the evidence I've seen today, I believe we do.

Especially in consideration of human capital. It is always refreshing to see a university that understands how important science is for the future.

What strikes me is the decision by Charles Sturt University to make Orange campus a centre for excellence through specialisation, with the focus on science and health courses including dental science, pharmacy and physiotherapy.

I am sure that here on the Orange campus, we are training the scientists and health professionals of the future. And because they have trained in regional Australia, the data shows that they are more likely to stay in the regions and benefit our regional cities and rural areas.

It seems that in Orange you are building a bright future based on a respect and understanding of your past.

This campus is built on the foundation of the Orange Agricultural College that was established in 1973, and is in the process of being transformed. I am impressed by the training laboratories and research facilities here at the campus and by the knowledge and enthusiasm of both students and staff whom I met today.

The university is also embracing online learning and collapsing the barriers of distance.

There is much to be proud of in Orange and the surrounding region with your reputation for boutique food and wine drawing in tourists from afar.

On my drive from Canberra today, I saw green countryside bursting with life and energy, and adorned with the wind farms that will help to preserve that beauty for our grandchildren.

Here in Orange, I have been struck by the magnificent historic buildings explicitly preserved for all to enjoy. Orange is preserving the past while creating a bright future.

Conclusion and challenge

To conclude, I want to challenge you to think about how science shapes the way you live and your quality of life.

Technology is often accompanied by side effects, such as pollution, but with time variations are developed that eliminate the side effects so that we can enjoy the benefits guilt free.

With technology, we can continue to enjoy sustainable, productive agricultural landscapes that co-exist with pristine rivers.

Let me close with a tribute to Israel’s former President, Shimon Peres, who passed away two weeks ago. I heard this in Brussels from the European Minister for Science, Carlos Moedas.

Shimon Peres was a visionary who knew the importance of science and innovation to building a community, and building a country.

He said: “There is no way to escape poverty without science; there is no way to achieve peace without science.”

It is a message from the other side of the world that applies equally to us gathered here tonight in this lecture hall.

With science and innovation, we can shape the future and put ourselves on a path to greater prosperity.

Thank you.