Plastic waste: The science and the theology

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In 2017, David Attenborough concluded his TV series Blue Planet II with these words:
"We are at a unique stage in our history.
Never before have we had such an awareness of what we are doing to the planet.
And never before have we had the power to do something about that.
Surely we have a responsibility to care for our blue planet.
The future of humanity, and indeed all life on earth, now depends on us."

In the final episode of that series, the images of plastic fed by albatrosses to their chicks, brought home how our plastic waste can find its way to the furthest reaches of the planet. And that helped propel the problem of plastic waste to the top of the public's consciousness.

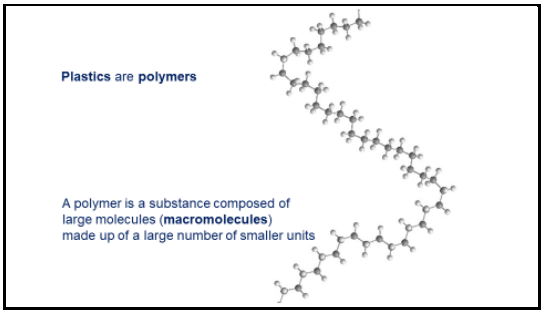
I'm a professor of polymer chemistry.
And plastics are polymers.
So I feel somewhat responsible for all this.
And that's why I'm going to talk about the science of plastics,
and what we can and can't do with them.

But, of course, the problem of plastic waste isn't just about plastics,
or technologies for dealing with them.
It's also about people, about us,
the lifestyles we adopt,
the way we use stuff, and discard stuff,
and on our willingness to change these things
It depends on how we think about this planet and our place within it.
On our world view,
which feeds off our cultural, social, and religious – or perhaps irreligious – background.

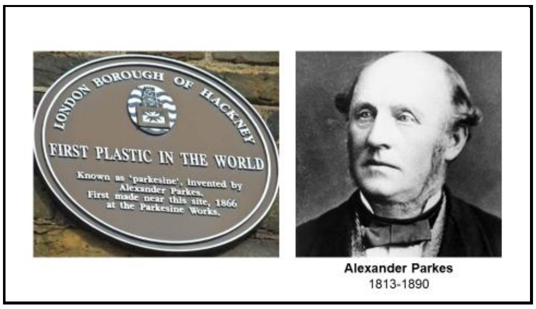
So, if we’re to make progress in tackling the problem of plastic waste,
we have to bring all these things together.
The conversation has to extend across science, politics, philosophy, and religion.
We can’t do everything in one brief lunchtime.
But to make a start, I’ll attempt to say a bit about a theology of plastic waste,
from a Christian and biblical perspective.
Now, I’m not a theologian.
Although I’ve done a little theology
as part of my training to be a lay Reader in the Church of England.
I’m not going to give you many answers.
But I hope I’ll raise some interesting questions, to get the conversation going.

First, let’s talk about science, and a bit of scientific history.
What are these things called plastics?
Where do they come from?
Why are they so useful?
And how can we get rid of them?

The word “plastic” has been around for a long time.
It goes back to the ancient Greek *plastikos* (πλαστικός).
And in the past was used for anything that could be moulded or shaped.
Clay, for example.
But now it tends to be applied to synthetic, or at any rate processed, materials
that can easily be made into objects, films or fibres.

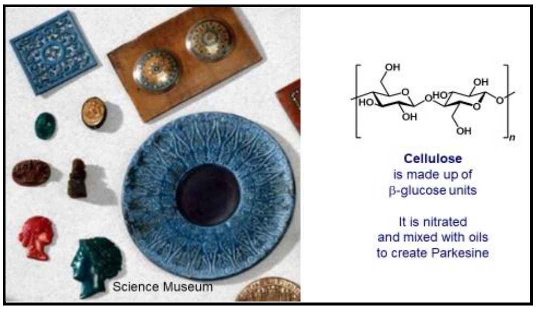


And what modern day plastics have in common
is that they’re composed of very big molecules.
Macromolecules.
They’re polymers.



Probably the first attempt to commercialize something that we might now call plastic,
was Parkesine, created by the English inventor Alexander Parkes.

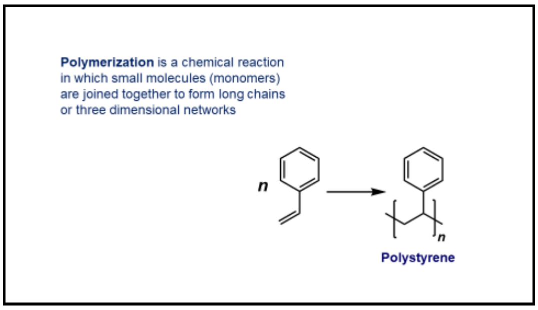
It was intended as a substitute for ivory,
and won a bronze medal at the Great London Exposition of 1862.



Alexander Parkes started with a natural polymer, cellulose.
A polymer we now know to be made of glucose units strung together.
Found in a pretty pure form as cotton.
And along with other stuff in wood, and wood products like paper.
Cellulose can be nitrated with nitric acid.
But you have to be careful, if you overdo it you have an explosive.
Alexander Parkes mixed cellulose nitrate with various oils,
to produce something that can be moulded on heating.
He didn't manage to make money out of it.
But the idea was later developed as Xylonite, and then Celluloid.
And celluloid was used for many years for photographic film.

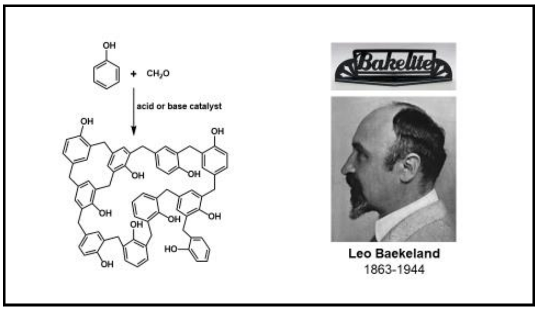
That's one way to make a plastic; by starting with a natural polymer.
And some, but by no means all, materials derived from cellulose, or other plant products,
are compostable
And so are nowadays sometimes called "plastic-free".

If one way to make a plastic is by starting with a natural polymer.

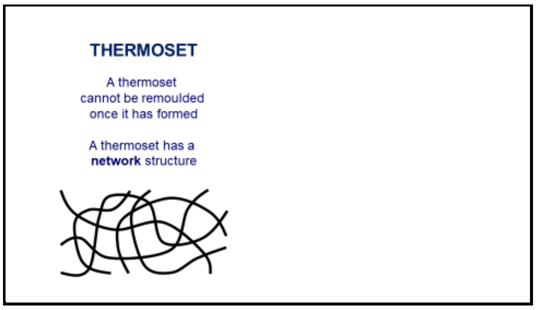


The other way is to start with small molecules, monomers,
and string them together by a chemical reaction.
Polymerization.

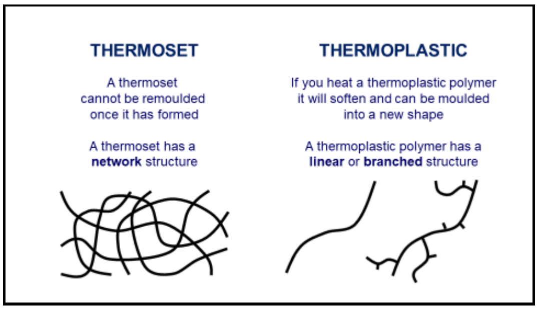
An early example of polymerization was in 1839,
when an apothecary in Berlin, Eduard Simon,
accidentally made what we now call polystyrene.
Although it was not until a hundred years later people grasped
that polystyrene is made up of long, chain-like molecules.



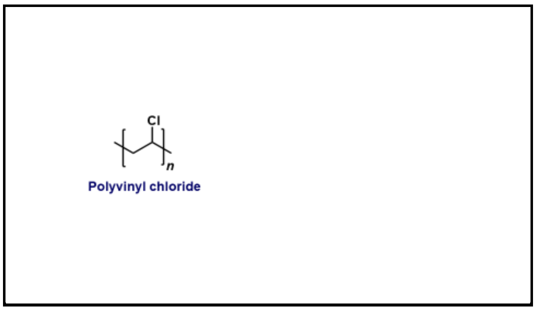
The first commercial, entirely synthetic plastic was Bakelite,
developed in 1907 by the Belgian chemist Leo Baekeland.
Bakelite was made by the reaction of phenol with formaldehyde,
and we still use descendants of Bakelite; phenol-formaldehyde, or phenolic, resins.



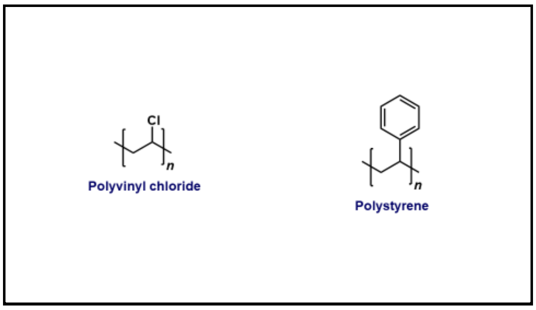
Phenolic resins are examples of thermosets.
They're moulded under heat and pressure into a certain shape,
but then the structure is fixed; they can't be remoulded into a different shape.
That's because they have a highly crosslinked network structure.
Essentially, an object made of a thermoset is one giant molecule.



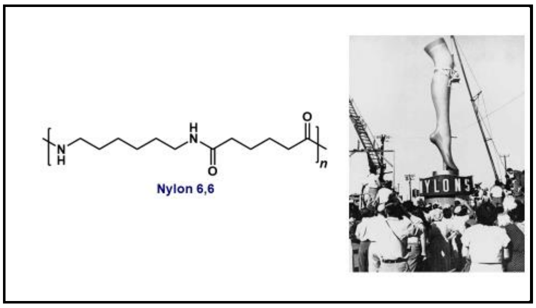
If you want a plastic that can be remoulded – recycled – you want a thermoplastic.
Thermosets like Bakelite may be plastics, but they're not thermoplastics.
However, in the period leading up to the second world war,
a number of thermoplastics were developed.



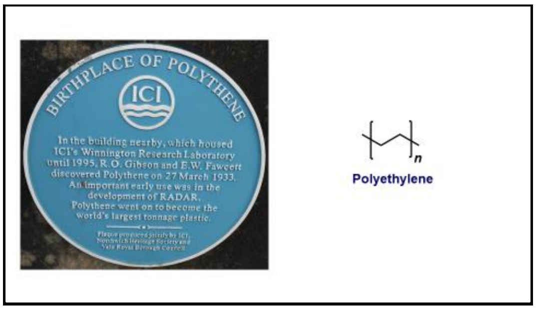
There’s polyvinyl chloride,
a useful, plasticised, form of which was developed in 1926,
by the B.F. Goodrich company in the United States.



There’s polystyrene, accidentally made by Eduard Simon back in 1839,
but finally manufactured about 1930 by BASF in Germany.



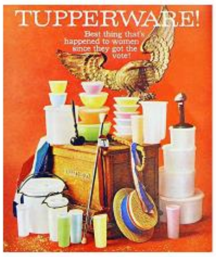
There’s the polyamide nylon, developed by Wallace Carothers at Du Pont in the USA.
Which gave rise to nylon-bristled toothbrushes in 1938.
And women’s stockings in 1939.



And there’s polyethylene,
developed by chemists working for ICI at Winnington, near Northwich, in Cheshire.

The first ton was produced in 1938.
But it soon became a secret,
because during the war it found an important use
as an insulator for coaxial cables in radar systems.

It was the second world war that really drove the growth of the plastics industry.
The new plastics found all kinds of military uses,
as well as substituting for traditional materials that were in short supply.
And after the war, what was to be done with those materials and production facilities?



Along came things like "Tupperware".
Plastics became a part of everyday life.

Since then, the range of plastics available, and the variety of their uses,
has expanded enormously.
And plastics have many advantages.
But with the advantages, come downsides.

ECONOMICAL

Plastics are economical, so it's easy to make products in large quantities.
That makes all kinds of things available to the many, not just the few.
But it can also promote a "throw away" culture,
so plastic waste accumulates.

ECONOMICAL LIGHTWEIGHT

Plastics are lightweight, compared to many of the materials they've replaced,
so transporting them is cheaper and more energy-efficient.
But their low density means they can float across the oceans,
and accumulate in places we really don't want them.

ECONOMICAL LIGHTWEIGHT

VERSATILE

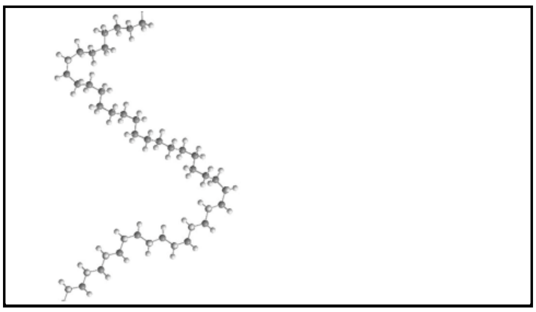
Plastics are versatile,
not only replacing traditional materials;
increasingly finding entirely new and innovative applications.
But that means even more places they can turn up,
at the end of their useful lives.

ECONOMICAL LIGHTWEIGHT

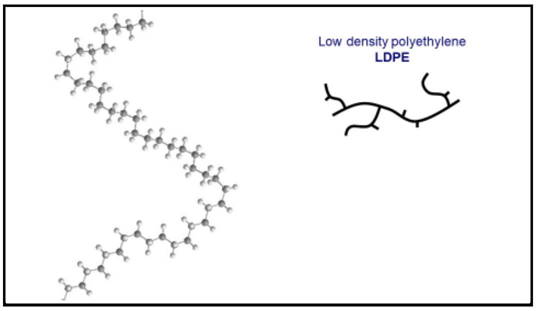
VERSATILE DURABLE

Plastics are durable.
They don't corrode like metals or break as easily as many ceramics.
But that means they hang around long, long after we've finished with them.
That durability is at the heart of the problem we now face.
The problem of plastic waste.

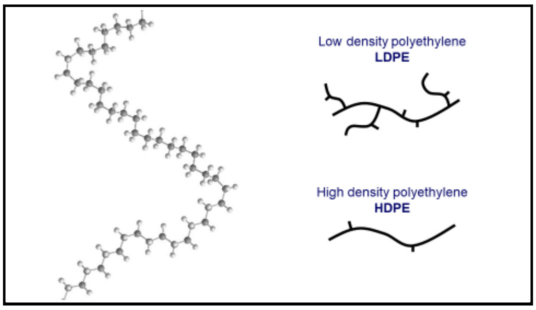
And if we're thinking about plastic waste,
the first problem we have is that there are so many different sorts of plastic.
Even if we just think about polyethylene,
the most common plastic,
there are different sorts of polyethylene.



On the face of it, polyethylene has one of the simplest chemical structures you could imagine. It's just a long, long string of carbon atoms, with two hydrogens attached to each carbon. But, depending on exactly how it's made,
you can get short or long branches coming off the main chain.



The original polyethylene made in Cheshire,
low density polyethylene, or LDPE,
has a lot of long branches.



But later, ways were found to make polyethylene with fewer, or shorter, branches.
There's high density polyethylene, HDPE, and other sorts too.

The branching affects the way the polymer can crystallize,
which in turn affects its density, its properties, and the ways in which it can be used.
You have to use not just the right plastic for a particular job,
but the right grade of that plastic.
And when it comes to dealing with plastic waste,
what works for one type of plastic may not be right for another.
And many products contain several different types of plastic,
sometimes bonded tightly together,
which can make dealing with the waste even more tricky.

And if there are many different types of plastic,

there are also many things that can be mixed into the plastic.
When you use a plastic,
you rarely use it on its own.
There are all sorts of additives.
Additives that make them tougher or cheaper, or that give them colour.
And in many cases, ironically, additives that make them more durable.
That prevent them being damaged by light or being attacked by microbes.
All that has to be taken into account, when thinking about plastic waste.

So how can we tackle the plastic waste problem?

REDUCE REUSE
RECYCLE DEGRADE

Some of the main approaches can be categorised under the headings
REDUCE. REUSE. RECYCLE. DEGRADE.
Let’s consider each of these in turn.

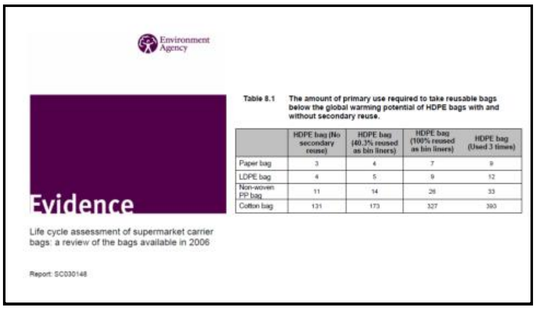
REDUCE

REDUCE.
A good place to start is by reducing our use of plastics,
especially single-use or disposable plastic items.
Things we use briefly and then throw away.
And if you go into the café down the concourse in this building,
you’ll find you have to pay extra for a disposable cup.
You’re encouraged to bring a reusable mug.
Similarly, you now have to pay for carrier bags in supermarkets,
and that has brought about a reduction in plastic bag sales.

But if we simply shift from plastic to something else,
that can have a worse impact than the problem we’re trying to solve.

We need to think, not just about the plastic waste problem in isolation,
but about the overall environmental impact of any materials and processes we use.
That means thinking about the energy required, the impact of water and land use,
the carbon dioxide emissions and the effects of by-products,

associated with every stage of the production of raw materials,
the manufacture and transport of products,
and what happens to them at the end of their useful life.
That’s what’s known as life cycle assessment or analysis.
And life cycle assessment can give surprising results.



Environment Agency

Evidence

Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Report: SC030148

Table 8.1 The amount of primary use required to take reusable bags below the global warming potential of HDPE bags with and without secondary reuse.

	HDPE bag (No secondary reuse)	HDPE bag (40.3% reused as bin liners)	HDPE bag (100% reused as bin liners)	HDPE bag (Used 3 times)
Paper bag	3	4	7	9
LDPE bag	4	5	9	12
Non-woven PP bag	11	14	26	33
Cotton bag	131	173	327	393

For example, a report issued by the Environment Agency in 2011
on life cycle assessment of supermarket carrier bags available in 2006,
indicated that a cotton bag would have to be used over 130 times,
before its global warming potential fell below that of
a single-use bag made of high density polyethylene.
If the high density polyethylene bags were all reused as bin liners,
then it would take over 320 uses of the cotton bag
for it to be favourable in terms of global warming potential.
A cotton bag isn’t necessarily better than a plastic bag.
It depends on how much we use it.
And, of course, if we do use it that many times, that may raise other issues.
Issues of hygiene.

Unfortunately, thorough life cycle assessments are few and far between.
There’s a need for more studies of this type,
and for the information to be made accessible,
so we can all make informed, evidence-based, sustainable choices.
We should aim to reduce our use of plastics.
But we want to do it in an intelligent and informed way,
that doesn’t just replace one problem with another.

And if we’re thinking about reducing plastic waste,
there are things manufacturers can do.
To design products and packaging
to make them easier to deal with when we want to get rid of them.
This may mean reducing their complexity,
so different types of material are easier to separate.
This may mean finding an optimum balance
between materials that are lightweight but difficult to reprocess,
and materials that are more readily reused or recycled.
In the long term, this may mean reducing the number of different types of plastic
that are utilised in consumer products.

We should aim to reduce our use of plastics.
But we’ve already seen, in the context of life cycle assessment,

that the overall environmental impact of any material depends on how much it's reused.
Which brings us to

REUSE.

Now, there are simple and obvious things we can do here, as already mentioned.
Such as taking our own mug to the café.
But reuse isn't just about reusing products.
It can also be about reusing the materials.
This needs improved technologies for separating out the materials we want.
And technologies for labelling them,
for example with chemical or spectroscopic markers,
so their provenance can be checked,
responsibility assigned,
and appropriate processes followed.
And this is relevant not only to reusing, but also to recycling plastics.

RECYCLE.
In the simplest case, recycling involves mechanically chopping something up,
and reprocessing it into something new.
However, you can't keep on recycling a plastic indefinitely.
Plastics are polymers – big molecules – and it matters just how big they are.
Their properties depend on their molecular weight and molecular weight distribution.
Each time they're processed, the molecules themselves get chopped up.
Until, sooner or later, they really can't be used.

An approach that researchers are looking at is chemical recycling.
This uses chemistry to "depolymerise" a polymer,
breaking it down into small molecules, monomers,
that can then be re-polymerised into a high quality polymer.
However, a lot more work needs to be done to turn this into a viable technology.

Depolymerisation is an example of degradation, which brings us to

DEGRADE.

There are many things that can bring about degradation of a polymer.
Light.
Heat.
And, in some cases, microorganisms.
Biodegradation.
But, whatever the mode of degradation, we need to understand
what actually happens to the polymer in the environment where it ends up.
For example, just because something <u>can</u> biodegrade,
doesn't mean it <u>will</u>, if the conditions aren't right.
Paper doesn't degrade significantly faster than plastic under the conditions of a landfill site.
And not everything that's labelled biodegradable is suitable for composting, for example.

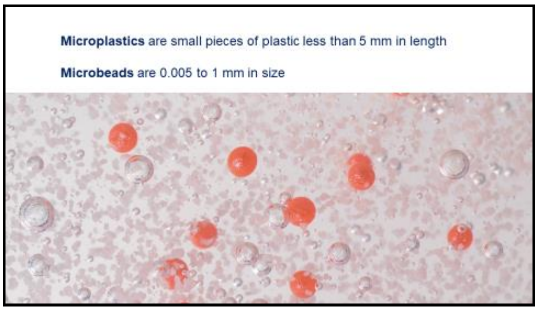
Recently, a variety of plastic-like materials have come onto the market
that are described as "compostable."
Some of these are derived from natural polymers like cellulose.
Some are based on polylactic acid,
produced by polymerization of lactic acid,
which in turn can be produced by the fermentation of sugars from crops such as corn.

We really need more information about how good these materials are in practice.
And there's an opportunity for you to get involved in a citizen science experiment.

It's called the "Big compost experiment."
It's run by the plastic waste innovation hub at University College London.
And you can find out more about it at: https://www.bigcompostexperiment.org.uk/

REDUCE REUSE
RECYCLE DEGRADE

REDUCE. REUSE. RECYCLE. DEGRADE.
There's a lot being done, and a lot more to be done, in developing these approaches.
I've said a bit about what we can do generally, and what scientists can do specifically,
to help deal with the problem of plastic waste.
But perhaps we'd never have had such a problem,
if we'd all been more <u>responsible</u> in how we develop, use and dispose of things.



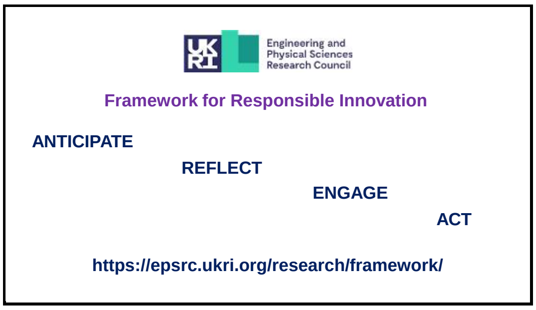
One concern about plastics is about microplastics.
Tiny plastic particles that find their way into the sea, and all sorts of other places.
The irony is that, until fairly recently,
plastic microbeads were deliberately added to many personal care products:
Exfoliating scrubs, shampoos, toothpastes, soaps and such like.
As of 19th June 2018, they've been banned
from rinse-off cosmetics and personal care products sold in the UK.
But one might ask, why were they ever there in the first place?
Surely the very bright people developing those products should have realised,
all those microbeads would end up somewhere?

In industrial research and development,
the focus has tended to be on getting a product that does a good job,
that can be manufactured economically,
that people will buy.
But now it's increasingly being recognised there's a need to look beyond that.
To consider the whole life cycle of a product.
To think through the consequences of its use.

And there's a change, too, in how we approach research and innovation in Universities.

The Engineering and Physical Sciences Research Council, EPSRC,
which funds a lot of research taking place in this building,
are actively promoting what they call a "Framework for responsible innovation."
(https://epsrc.ukri.org/research/framework/)

As they put it on their website:
"we have a responsibility to ensure that our activities and the research we fund,
are aligned with the principles of Responsible Innovation,
creating value for society in an ethical and responsible way."



The EPSRC framework for responsible innovation has four elements:
ANTICIPATE. REFLECT. ENGAGE. ACT.

ANTICIPATE.
Researchers are expected to describe and analyse
the economic, social, environmental and other impacts
that might arise from their research.
Exploring implications that may otherwise remain uncovered and little discussed.

REFLECT.
Researchers are expected to consider
the purposes of, motivations for, and potential implications of, their research.
To work through the associated assumptions, uncertainties, areas of ignorance and dilemmas.

ENGAGE.
Researchers need to break out of the academic bubble.
To open up their visions, impacts and questions to wider deliberation and debate.
It's a bit of that I'm doing today.

ACT.
Researchers are expected to use these processes to influence the direction and trajectory of the research and innovation process.

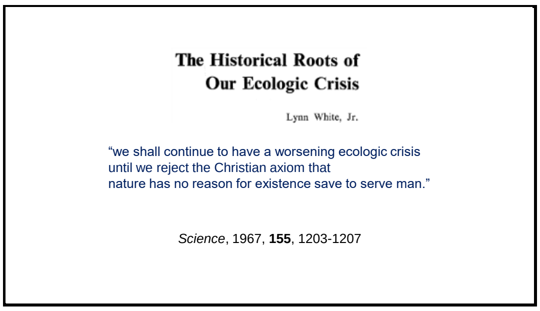
This explicit framework is rather new and unfamiliar to us.
And quite how it'll all work remains to be seen.
But the point is, as researchers we're expected to act in an ethical and responsible way.
We have to think through questions of what's "right" and what's "wrong".
Which brings us into territory that's traditionally associated with religion.
And that brings us to theology.

A theology of plastic waste.

Of course, a theology of plastic waste can't be considered in isolation,
but rather in the context of broader issues.
And there are lots of issues we could think about.
Our attitude to possessions,
whether in terms of wanting more and more things,
or in terms of our thoughtless discarding of things.
Our attitude to the poor and vulnerable in the world,
whether in terms of creating opportunities for their development,
or in terms of our willingness to transfer our waste problem onto their doorstep.

There are lots of issues we could think about.
But the one we'll focus on is:
Our attitude to the planet we live on.

The planet we live on.
When it comes to the environmental problems we face,
whether it's plastic waste, climate change, deforestation, loss of biodiversity
or polluted water,
theology, and specifically Christian theology, is seen by some as an eco-villain.



Back in 1967, an American historian, Lynn White,
published a paper in the journal *Science* entitled

“The Historical Roots of our Ecologic Crisis”.
In it, he argued
“we shall continue to have a worsening ecologic crisis
until we reject the Christian axiom that
nature has no reason for existence save to serve man.”

Christian teaching is charged with promoting a destructive arrogance towards nature.
And the evidence for the prosecution is a verse from the very first chapter of the Bible.

Then God said,
‘Let us make mankind in our image,
in our likeness,
so that they may rule over
the fish in the sea and the birds in the sky,
over the livestock and all the wild animals,
and over all the creatures
that move along the ground.’

Genesis 1:26

Genesis chapter 1 verse 26.
Then God said, ‘Let us make mankind in our image, in our likeness,
so that they may rule over – or have dominion over –
the fish in the sea and the birds in the sky,
over the livestock and all the wild animals,
and over all the creatures that move along the ground.’
It’s that “rule” or “dominion” that’s seen as encouraging thoughtless exploitation.

But what I know, even from reading scientific papers,
is that it’s always a good idea to go back to the source material and study it carefully,
because things so easily get distorted in transmission.

Was Lynn White right in saying it’s a Christian axiom
that nature has no reason for existence save to serve man?
If we go back to the Bible, back to the source, is that what it teaches?
Yes, Genesis 1 gives humankind rule over nature.
But the context is that of being made in God’s image.
And while that phrase itself promotes a great deal of debate,
surely the implication is a relationship with nature that’s intended to be
a reflection of God’s relationship with nature.
A reflection of the God who thinks it all up.
Of the God who sees it all and sees that it is good.
Of the God who cares for all and makes provision for all. *(Genesis 1:29,30)*
In that context, what sort of rule is humankind intended to exercise?
Surely a rule that is responsible and caring,
not domineering and exploitative.

responsibility

Humankind has responsibility for nature, not carte-blanche to destroy it.
Which brings us back to what we've already said
about being responsible in how we develop, use and dispose of things.

If we continue the story of the Bible,
we see humankind's repeated failure to exercise their responsibility well.
So that the planet we inhabit is fundamentally different from what might have been.
"The whole creation", as the Apostle Paul expresses it in Romans 8:22
"has been groaning as in the pains of childbirth right up to the present time."
The Good News in the Bible is that there's hope.
Hope that begins with a renewed relationship with God,
that God himself makes possible.
Hope that manifests itself in people who,
even as they look ultimately to something altogether better,
live out, while on this planet, their God-given responsibilities,
towards God,
towards other people,
and towards the natural world.

What does a truly Biblical theology say about our attitude to the planet we live on?
As I read the Bible, it spells out our responsibility to all that God has made.
And that surely includes being responsible in how we develop, use and dispose of plastics.

Whether or not we believe in a God.
The message is the same.
We have a responsibility.

David Attenborough said it in his TV programme.
"Surely we have a responsibility to care for our blue planet."
The Engineering and Physical Sciences Research Council says it,
in its framework for responsible innovation,
seeking to create value for society in an ethical and responsible way.
And, I believe, the Bible says it.
But over to you, for discussion.