Audio file

118903-Science&SocietyAstrobiologyByLewisDartnell.mp3

Transcript

00:00:00 Speaker 1

So good afternoon, everyone.

00:00:02 Speaker 1

My name's Louis.

00:00:04 Speaker 1

I'm a professor at the University of Westminster, so just a couple of minutes down the road.

00:00:09 Speaker 1

But also I've got a visiting professorship here at UCL, and in fact, it's where I did my first PhD as well.

00:00:15 Speaker 1

So I'm a big fan of UCL.

00:00:18 Speaker 1

And the topic of my science, what my research is all about, is a relatively recent field of science called astrobiology.

00:00:29 Speaker 1

It's all about looking at the possibility of there being life beyond the Earth.

00:00:34 Speaker 1

So I studied biological sciences, and then during my PhD here at UCL, I extended from what we know about life on Earth, what kind of conditions it needs to develop in the 1st place and evolve, what kind of environments are suitable for life, and extending that knowledge to places beyond the Earth in our solar system, some of the other planets and moons,

00:00:58 Speaker 1

that orbit the same sun as us.

00:01:01 Speaker 1

And what I want to do for you, just the next 45 minutes or so, is basically tell you where we've got to so far with astrobiology.

00:01:12 Speaker 1

What have been the most recent big advances and discoveries that give astrobiologists like me a sense of optimism and confidence that we might be right on the brink of finding signs of life

00:01:28 Speaker 1

on another planet.

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And the three main areas where we've been making these big advances are the extremophiles, which are ultra-hardy forms of life on Earth that can survive in very, very hostile, very dangerous environments.

00:01:48 Speaker 1

And we'll also look at our robotic exploration of the solar system, how we've been sending probes and rovers to different planets and moons

00:01:58 Speaker 1

to see what their environment is like and where that environment is compatible with life as we know it.

00:02:03 Speaker 1

And then thirdly, we'll talk a little bit about extra solar planets, planets we've now found orbiting other stars in our galaxy.

00:02:15 Speaker 1

We found solar systems orbiting other suns in the night sky.

00:02:21 Speaker 1

Now, if I say that astrobiology is all about the search for life beyond the Earth,

00:02:27 Speaker 1

we immediately hit a more fundamental problem.

00:02:31 Speaker 1

What do we mean by life?

00:02:34 Speaker 1

How can we define it?

00:02:36 Speaker 1

How do we know it when we've seen it?

00:02:39 Speaker 1

Well, life on Earth is pretty obvious.

00:02:40 Speaker 1

It's trees or elephants or octopuses or ladybirds or toadstools or tiny, squirmy green things and a droplet of pond water, if you zoom in nice and close with a microscope.

00:02:54 Speaker 1

But life on Mars isn't going to be anything

00:02:57 Speaker 1

like this.

00:02:58 Speaker 1

It's going to be difficult to spot.

00:03:01 Speaker 1

It's going to be microscopic.

00:03:03 Speaker 1

It might even have fallen extinct billions of years ago.

00:03:07 Speaker 1

So what we want to be able to do as biologists is draw down from all these instances of the incredible diversity of life on Earth and boil it down to its very essence.

00:03:23 Speaker 1

What do we mean by life?

00:03:25 Speaker 1

How can we define it?

00:03:27 Speaker 1

all life on Earth is effectively A three-part pizza pie.

00:03:33 Speaker 1

It's got to have information, a metabolism, and a membrane.

00:03:39 Speaker 1

Now, starting with information, every one of our cells in our body, every cell of any life form on Earth, has to carry around with it a set of instructions, like an operating manual, that tells that cell how to run.

00:03:56 Speaker 1

how to manufacture the different components, the different bits and pieces of that cell.

00:04:01 Speaker 1

And all life on Earth stores that genetic information in a molecule called DNA.

00:04:08 Speaker 1

And the fact that all life on Earth is DNA-based gives us a very strong clue that everything we see alive around the world today has all descended from the same origin.

00:04:21 Speaker 1

We're all cousins of each other from the same original life form on our planet.

00:04:27 Speaker 1

Now, alongside information, you've got to have metabolism.

00:04:31 Speaker 1

You've got to have a very complicated, interlinked network of chemical reactions that can derive energy from the environment around you.

00:04:43 Speaker 1

Perhaps you're a plant.

00:04:44 Speaker 1

and you're using photosynthesis to absorb the sunlight energy, and use that to power yourself.

00:04:50 Speaker 1

Or you're something like humans that eat plants that have gathered that energy.

00:04:56 Speaker 1

And thirdly, but just as importantly, you've got to have a membrane.

00:05:00 Speaker 1

You've got to have some kind of bag or a sack around your cell simply to hold all these other giblets together, all these different bits and pieces together.

00:05:10 Speaker 1

You need to keep your information bits

00:05:13 Speaker 1

nice and concentrated, nice and close to the metabolism bits so they can work with each other.

00:05:20 Speaker 1

So in a nutshell, this is what life is.

00:05:23 Speaker 1

It's a very complex chemical system that can extract energy from the environment to power itself, and it's able to replicate.

00:05:31 Speaker 1

It can reproduce and divide and build up a bigger and bigger population.

00:05:37 Speaker 1

So it's that kind of complex chemistry

00:05:40 Speaker 1

They were going to places like Mars to look for, or maybe looking for molecular fossils.

00:05:46 Speaker 1

Maybe life on Mars is long since extinct, but we can still see the fragments left behind from complex chemistry, or things like DNA.

00:05:57 Speaker 1

Now, I think this three-part pizza pie gives us a very good idea of what we mean by life and what we're looking for.

00:06:04 Speaker 1

But it really overlooks the incredible complexity of life

00:06:09 Speaker 1

on a molecular level.

00:06:12 Speaker 1

All these molecular machines that have particular jobs and roles inside the cell, they all have to work together to keep that cell alive.

00:06:21 Speaker 1

And I've got a short video for you that shows some of that molecular complexity inside one of our cells.

00:06:30 Speaker 1

So this is a computer-generated video.

00:06:33 Speaker 1

This isn't a real microscope slide.

00:06:35 Speaker 1

Actually, Martin, if you can find the light switches, they might be here.

00:06:40 Speaker 1

Can everyone still see one enough to right?

00:06:42 Speaker 1

Was that a bit dark?

00:06:43 Speaker 1

A bit dark.

00:06:47 Speaker 1

Let's try that one.

00:06:49 Speaker 1

That is right back to where we got to.

00:06:53 Speaker 1

I'll fiddle with the lights in a second.

00:06:56 Speaker 1

But we've zoomed into one of our cells and that membrane surrounding it.

00:07:00 Speaker 1

And as we zoom in deeper, we find this crisscrossed network of scaffolding proteins.

00:07:08 Speaker 1

These are just like the metal tubes we put up outside of a building to give it strength.

00:07:13 Speaker 1

We've got the same structures on a microscopic scale inside of all of our cells to give them strength.

00:07:20 Speaker 1

And these scaffolding proteins have to spontaneously form from their Lego bricks and their building blocks.

00:07:26 Speaker 1

And then when a pair of molecular scissors comes across and cuts that chain, it falls apart again and returns those building blocks to be used again to be recycled inside the cell.

00:07:37 Speaker 1

That was another kind of scaffolding protein.

00:07:40 Speaker 1

And this here is my favorite protein of them all.

00:07:44 Speaker 1

It's a molecular walking machine.

00:07:47 Speaker 1

It plods its way, one clown-like foot in front of the other, transporting things inside the cell, taking them to where they need to be to do their job.

00:07:58 Speaker 1

I'm now zooming in to the very core of our form of life, the warehouse.

00:08:03 Speaker 1

where we store and protect that vital genetic information inside the nucleus.

00:08:08 Speaker 1

And that information that's stored on DNA gets copied into another molecule called RNA, which is slightly chemically simpler.

00:08:18 Speaker 1

We think that in the origins of life on Earth, RNA came first.

00:08:23 Speaker 1

And then at some point, we upgraded ourselves from being RNA-based to being DNA-based.

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in the way you might upgrade your smartphone.

00:08:33 Speaker 1

When a better model came out, life on Earth upgraded itself to using DNA for its operating system.

00:08:40 Speaker 1

We just saw that walking machine plodding its way along again.

00:08:44 Speaker 1

And then once the information on that DNA has been copied and acted upon like a computer program, telling the cell how to make different components, different proteins, they're transported to the outside of the cell,

00:08:58 Speaker 1

And these handshaped proteins here then change their shape.

00:09:01 Speaker 1

They reach their arms outwards, hold hands with their counterparts outside the cell.

00:09:07 Speaker 1

And then using those handshaped proteins and those scaffolding proteins and those molecular walking machines, the cell can now ooze and change its shape, a bit like an amoeba, and force its way out of this blood vessel.

00:09:22 Speaker 1

to fight a scene of infection.

00:09:24 Speaker 1

This is a white blood cell.

00:09:25 Speaker 1

It's about to go gobble some bacteria, some germs, to stop this person getting sick.

00:09:31 Speaker 1

So that is what life is.

00:09:34 Speaker 1

Or more to the point, that's what life does.

00:09:37 Speaker 1

Life is an incredibly complex process being run by molecular machinery.

00:09:44 Speaker 1

This is how all life on Earth works.

00:09:46 Speaker 1

We'd be looking for similar chemical complexity on other planets and moons.

00:09:51 Speaker 1

if they ever developed life of their own.

00:09:55 Speaker 1

So let's move on and talk about these extremophiles, these ultra-hardy organisms surviving in very, very dangerous, hostile places on Earth.

00:10:06 Speaker 1

These extremophiles are like survival superheroes.

00:10:11 Speaker 1

They can survive in environments that kill you or I pretty much immediately.

00:10:16 Speaker 1

I'm going to stop off first

00:10:18 Speaker 1

on this extremophile safari in this place.

00:10:23 Speaker 1

This is Yellowstone Park in North America.

00:10:27 Speaker 1

It's a very, very volcanically active region of the planet.

00:10:32 Speaker 1

There's a lot of magma sat just underground.

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And so many lakes or puddles of water in Yellowstone Park are bubbling and boiling and steaming hot.

00:10:43 Speaker 1

They're being heated underneath, just like a hob put on the kitchen, put on the stove.

00:10:48 Speaker 1

And because of all those volcanic gases bubbling up through these lakes, they're also very, very acidic.

00:10:56 Speaker 1

Now, just for scale, you can see in this photograph, there's a path here running alongside this volcanic lake with some people walking along it.

00:11:08 Speaker 1

And if you are lucky enough to trip on that path and splash into this volcanic pond, as someone does every couple of years,

00:11:18 Speaker 1

Although it's never the same person twice.

00:11:21 Speaker 1

Because you die.

00:11:22 Speaker 1

Of course you die.

00:11:24 Speaker 1

You're boiled to death in a steaming hot, volcanic, acidic lake of water.

00:11:32 Speaker 1

And if they don't fish your corpse, your body, out of this lake quickly enough, the skin and the flesh and the muscles are dissolved off your bones.

00:11:40 Speaker 1

It is that hot and that acidic.

00:11:43 Speaker 1

Do not ever go swimming.

00:11:45 Speaker 1

and any lakes you might find in Yellowstone Park.

00:11:48 Speaker 1

The environment is simply not compatible with our kind of life.

00:11:53 Speaker 1

But the colors of this lake, the greens and the yellows and the oranges and the reds, those are the colors of life.

00:12:01 Speaker 1

They're the colors of thermophiles, or heat-loving organisms, and acidophiles, acid-loving organisms.

00:12:11 Speaker 1

They're bacteria which have adapted

00:12:14 Speaker 1

to call this hellhole of a place their home, and they thrive under those very, very hostile conditions that would kill us pretty much immediately.

00:12:25 Speaker 1

And if you look to the opposite extreme, from very hot places to very cold places, let's imagine we've all flown right down to the bottom of the world, off the coast of the South Pole, off the coast of Antarctica, and we're sat in a rubber dinghy, bobbing up and down on the waves,

00:12:44 Speaker 1

And we roll ourselves up to the side of one of these great big icebergs we find floating there.

00:12:50 Speaker 1

And we scrape off some of the ice and put it under a microscope just to see what we can see.

00:12:58 Speaker 1

And this view on the right here is what we'd be able to see looking through our microscope at some of this iceberg.

00:13:03 Speaker 1

And most of what we see are solid chunks of ice crystal.

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I mean, this makes sense.

00:13:11 Speaker 1

We're looking at a frozen solid iceberg.

00:13:15 Speaker 1

But because this was seawater that froze, the water that gets left behind gets saltier and saltier and saltier until eventually it doesn't freeze.

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So riddling their way throughout the solid iceberg are thousands of tunnels and channels and pockets and pores of very, very salty, but still liquid water.

00:13:40 Speaker 1

And if we zoomed in even closer to one of these briny veins, we'd find them absolutely jam-packed full of bacteria, like kind of crammed in there, head to toe, like some kind of microscopic traffic jam, alive and well, and doing many of the things we saw in that video, and dividing and replicating in the cold depths of a solid iceberg right down to about minus 20 degrees Celsius.

00:14:10 Speaker 1

So even colder than the deep freeze you might have in your kitchen at home or your student accommodation.

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Something we've invented to stop stuff growing.

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These psychrophiles, these cold tolerant organisms, thrive under those sub-zero temperatures.

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And actually, if I were to reach inside this iceberg, pluck out some of that psychrophile life and hold it in the palm of my hand, just the warmth of my body

00:14:39 Speaker 1

would be enough to kill and literally cook those cells.

00:14:44 Speaker 1

They can survive at sub-zero temperatures.

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They die not much above the freezing point.

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They're adapted to very, very cold temperatures.

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Now, not all of these extremophiles on Earth are boring, tiny, little organisms, single-celled life that you can only see with a microscope.

00:15:05 Speaker 1

There are also some incredible examples of complex

00:15:09 Speaker 1

life forms, multicellular life, animal life forms living in very, very hostile environments.

00:15:16 Speaker 1

An example of an animal extremophile that I've got to show for you, I think is also quite possibly the ugliest form of life on Earth.

00:15:25 Speaker 1

So apologies if you had quite a big lunch before coming to this talk.

00:15:29 Speaker 1

This here is the methane worm.

00:15:31 Speaker 1

Oh, man.

00:15:33 Speaker 1

This one, I reckon, is a girl.

00:15:35 Speaker 1

You can see she's got lips around her mouth here.

00:15:37 Speaker 1

She's got tentacles sprouting out the top of her head.

00:15:40 Speaker 1

She's got row upon row of hairy legs running down both sides of her body.

00:15:45 Speaker 1

Now this is a scanning electron microscope view.

00:15:49 Speaker 1

This is a very, very zoomed in microscopic view.

00:15:53 Speaker 1

And these worms are only about a centimeter or two from head to toe.

00:15:57 Speaker 1

They're quite small.

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But when we discovered them about 20 years ago, they were completely and utterly

00:16:04 Speaker 1

new to science.

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No one was expecting to find anything like this in our own seas.

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And these methane worms were discovered in the Gulf of Mexico, right on the bottom of the seafloor.

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But it's very, very cold.

00:16:19 Speaker 1

It's very, very high pressure.

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And that water freezes under those conditions into a special kind of ice called methane clathrate ice.

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It's ice that traps methane gas

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inside the crystal of ice itself.

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And these worms were discovered swarming all over those mounds of clathrate ice on the seafloor.

00:16:45 Speaker 1

They were burrowing and tunneling down into the ice and eating that clathrate.

00:16:52 Speaker 1

So as well as being quite possibly the ugliest form of life on Earth, this complex, multicellular

00:17:02 Speaker 1

animal life form.

00:17:04 Speaker 1

This thing isn't all that far removed at all from your eye when you look at the whole family tree of life on Earth.

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This is one of our closest cousins.

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And this animal can subsist by eating nothing more than fart gas and pulps.

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It eats methane for breakfast and lunch and dinner.

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It's completely disgusting.

00:17:27 Speaker 1

But it's an incredible example of the sheer adaptability

00:17:32 Speaker 1

of life on our planet.

00:17:35 Speaker 1

And when we look at all of the extremophiles together and the different ranges of conditions they can survive under, very hot conditions or very cold conditions, very acidic, very alkaline, very salty, high radiation environments, we can build up a kind of three-dimensional graph and display the extremophiles on it.

00:17:57 Speaker 1

So on this axis here, we've got temperature,

00:18:02 Speaker 1

down to about minus 20 degrees Celsius in the icebergs we looked at, all the way up to plus 120 degrees Celsius.

00:18:11 Speaker 1

There's life on Earth that thrives beyond the boiling point of water.

00:18:17 Speaker 1

And then pH, from very acidic conditions, in the volcanic lakes we looked at, down to very alkaline conditions.

00:18:24 Speaker 1

So a place like the Soda Lakes in East Africa, in Kenya, where incidentally I grew up, I spent my childhood

00:18:30 Speaker 1

visiting places like Lake Nivasha, one of the most extreme alkaline environments on Earth.

00:18:37 Speaker 1

And then salinity from pure distilled water up to saturated salt solutions.

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Places like the Dead Sea turned out to not be all that dead at all once biologists bothered to actually go there and check that water and see if anything was surviving in those saturated salt solutions.

00:18:59 Speaker 1

And on this graph,

00:19:00 Speaker 1

We put all of the extremophiles we found in any place around the world, and it builds up this green, boot-shaped cloud.

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That is the survival envelope of all life on Earth.

00:19:15 Speaker 1

At any point inside their shape, there's an extremophile we've already discovered that can survive that particular combination of nasty, extreme conditions.

00:19:29 Speaker 1

An exciting thing for astrobiology and the possibility of life on other planets is that this survival envelope of life on Earth overlaps with the conditions in extraterrestrial places.

00:19:43 Speaker 1

So if we're talking about very cold, very acidic water that we believe existed on ancient Mars, there's life on Earth we've discovered that could survive those conditions.

00:19:55 Speaker 1

Or if we're talking about very alkaline water,

00:19:59 Speaker 1

beneath the face of Europa, one of the moons orbiting Jupiter.

00:20:03 Speaker 1

There's life on Earth, we've already discovered, that could survive those conditions.

00:20:09 Speaker 1

It's not all that crazy at all to be talking about alien life, about bacterial extremophiles elsewhere in our solar system, because the extremophiles on Earth teach us these are habitable environments.

00:20:24 Speaker 1

These environments are the kind of environment

00:20:26 Speaker 1

These are places that have the kind of environment where life could survive.

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The extremophiles give astrobiology a lot of confidence and optimism that places beyond the Earth have got the right conditions for life as well.

00:20:41 Speaker 1

And so we're very keen, we're very excited to be exploring some of these other planets and moons in our solar system.

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So far, we've been sending robots

00:20:53 Speaker 1

We've been sending machines to explore these other places.

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Hopefully, in the not-too-distant future, humans will go further than just our moon.

00:21:03 Speaker 1

We'll be sending humans to Mars, maybe further out through the solar system.

00:21:07 Speaker 1

But at the moment, we're exploring via our robots.

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I'm going to take a little tour of the solar system to see where we think are the best chances for discovering alien life.

00:21:22 Speaker 1

And we'll start

00:21:24 Speaker 1

in this place.

00:21:26 Speaker 1

You'll see that this is a desert.

00:21:29 Speaker 1

You can see that the very fine, sandy, dusty surface has been blown into these ripples and sand dunes by the wind.

00:21:40 Speaker 1

You can see some wispy clouds right up in the top of the sky there.

00:21:45 Speaker 1

But this desert is no place on Earth.

00:21:50 Speaker 1

This is the face of another world.

00:21:51 Speaker 1

This is what Mars would look like if you could hitchhike a lift with NASA, or probably, to be honest, more likely nowadays hitchhike a lift with Elon Musk.

00:22:00 Speaker 1

Fly out to Mars, put on your spacesuit.

00:22:04 Speaker 1

This is exactly what our next door neighbor planet would look like if you could take an afternoon stroll across the Martian landscape.

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And in many respects, Mars is the most Earth-like

00:22:17 Speaker 1

place we know about.

00:22:19 Speaker 1

And certainly, billions of years ago, primordial Mars was much warmer and wetter, much more Earth-like than it is today.

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We know for a fact that ancient Mars had a much thicker atmosphere to shield and blanket that planet, to keep the surface much warmer.

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It had seas and lakes and rivers of liquid water gushing

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across its face.

00:22:46 Speaker 1

We see a lot of evidence for ancient rivers and deltas and lakes and seas on Mars.

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And it would have had simple organic chemistry.

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The building blocks of all the stuff we saw on that video earlier would have been present on the surface of early Mars.

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Maybe falling down aboard asteroids and meteorites.

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Perhaps helping life get kick-started on Mars.

00:23:12 Speaker 1

and around the same time that we were getting started here on Earth.

00:23:17 Speaker 1

Maybe Mars had an independent genesis of life.

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Maybe Mars is a living planet, or has been alive in its past.

00:23:28 Speaker 1

And so, as scientists, as astrobiologists, as explorers, we dearly like to go to Mars and have a look around, see if we can find signs of past or present life.

00:23:43 Speaker 1

And one of the missions I've been involved in, one of the missions that UCL is very deeply involved in, is this next generation Mars rover called ExoMars, or the Rosalind Franklin rover, named after the female scientist, the British scientist, who did a lot of the work that demonstrated that DNA has got a double helix structure.

00:24:06 Speaker 1

She's a very, very influential scientist, missed out on the Nobel Prize basically because of sexism.

00:24:13 Speaker 1

So we've named our life-hunting Mars rover after Rosalind Franklin.

00:24:18 Speaker 1

And you'll recognize some features of this robot.

00:24:22 Speaker 1

It's got solar panels on its back to absorb sunshine, to generate electricity, to run our robot.

00:24:30 Speaker 1

It's got six-wheel dr, which is even better than four-wheel dr, to not try and get stuck on a sand dune when you're millions of miles away from the nearest tow truck.

00:24:41 Speaker 1

The camera system, right on the top of this thin, stalk-like neck, has got twin cameras.

00:24:47 Speaker 1

This robot can see in 3D in the same way that you and I can see in 3D.

00:24:53 Speaker 1

And in fact, this camera system has been designed and built here at UCL, at the Mullard Space Science Laboratory.

00:25:01 Speaker 1

But most excitingly, for the first time ever, with this ExoMars rover, we're sending one of these

00:25:11 Speaker 1

to Mars.

00:25:11 Speaker 1

This black box on the front of the rover has got a drill inside it.

00:25:17 Speaker 1

A drill that is 2 meters long.

00:25:21 Speaker 1

Because up until now, with the NASA rovers, they've had a drill that's basically no longer than your little finger.

00:25:28 Speaker 1

It's nearly an inch or two long.

00:25:30 Speaker 1

And they trundle up to the side of a rock, **** their little finger inside, analyze the material from just under the surface.

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With ExoMars, we're getting 2 meters.

00:25:40 Speaker 1

underground.

00:25:41 Speaker 1

We're going to grab handfuls of that Martian dirt, bring that soil back up to the surface from where it's being shielded and protected underground.

00:25:52 Speaker 1

And then we're going to scrutinize and analyze that Martian soil.

00:25:58 Speaker 1

We're going to try to taste organic molecules, the building blocks of life, and hopefully detect biosignatures themselves.

00:26:08 Speaker 1

Conclusive evidence

00:26:10 Speaker 1

of the current or past existence of simple life on the red planet.

00:26:16 Speaker 1

So this is a very, very exciting mission.

00:26:18 Speaker 1

It's just on the horizon.

00:26:19 Speaker 1

We'll be launching ExoMars in the next two years.

00:26:22 Speaker 1

So it's a very exciting time right now for space exploration and particularly the exploration of Mars.

00:26:29 Speaker 1

But a lot of missions there at the moment and an armada of missions and space probes on the way in the coming years.

00:26:38 Speaker 1

And if you look a bit further afield,

00:26:40 Speaker 1

beyond Mars, out through the asteroid belt, to the next planet we come across, which is Jupiter.

00:26:49 Speaker 1

Now, Jupiter is a fat gas giant of a planet.

00:26:55 Speaker 1

It's basically nothing but gas and atmosphere and swirling storm clouds.

00:27:01 Speaker 1

This hurricane here, the Great Red Spot, is bigger than three Earths put together.

00:27:08 Speaker 1

So Jupiter is a very dynamic place, but it doesn't have any kind of surface or oceans for life to get started in, as we would understand it.

00:27:17 Speaker 1

So when astrobiologists talk about Jupiter, they don't care about the planet itself.

00:27:24 Speaker 1

We care about the moons that are orbiting Jupiter.

00:27:28 Speaker 1

The four large moons are Io, the innermost moon, and then Europa, Ganymede,

00:27:38 Speaker 1

and Callisto.

00:27:39 Speaker 1

And just by looking at these moons, you'll spot something strange about them, something that doesn't quite make sense at first.

00:27:49 Speaker 1

Because to Io, the innermost moon, is this angry, orangey, yellow color.

00:27:56 Speaker 1

That's the color of volcanic sulfur.

00:27:59 Speaker 1

Io is a very hot, violent, tortured little moon.

00:28:05 Speaker 1

It's very, very volcanically active.

00:28:07 Speaker 1

It's constantly vomiting its own innards out onto its own face in this never-ending cycle of hot, intense volcanism.

00:28:14 Speaker 1

Don't go to Io for your holidays in outer space.

00:28:19 Speaker 1

On the other hand, Callisto, you can see, is still pockmarked and scarred with all of these impact craters left over from the very earliest epoch of our solar system's history, a time when all the rubble

00:28:35 Speaker 1

left behind from the building of the planets, were still flying around through space, slamming down onto our moon, slamming down onto the surface of Callisto.

00:28:46 Speaker 1

And in all of that time since, all those billions of years of solar system history, Callisto has never changed its face.

00:28:56 Speaker 1

It's a cold, dead world, contrasting against the hot, violent world of Io.

00:29:05 Speaker 1

And in between the two, we find Europa.

00:29:09 Speaker 1

And we think that Europa is a lovely, warm, wet world.

00:29:15 Speaker 1

But beneath its face of cold, hard-frozen water ice, there lays a deep, dark, alien ocean.

00:29:26 Speaker 1

An ocean inside Europa with more liquid water in it than all the seas and lakes and rivers and oceans of the whole of the earth

00:29:35 Speaker 1

put together.

00:29:36 Speaker 1

It is Europa that is the water world of our solar system and not the Earth.

00:29:43 Speaker 1

So even here, in the cold, outer recesses of the solar system, there seem to be environments that provide the basic prerequisites for life.

00:29:54 Speaker 1

Liquid water, organic chemistry, an energy source for fueling life, for fueling ecosystems.

00:30:02 Speaker 1

And again, we would dearly like to get out to Europa to explore, see if we can find that life.

00:30:08 Speaker 1

Maybe land some kind of probe on the outside of this eggshell of ice and then drill or melt away straight down to try to get into that ocean.

00:30:20 Speaker 1

Maybe release some kind of robotic submarine to explore the Europan seas, test the chemistry of its water, maybe dive to the very bottom of the seafloor

00:30:31 Speaker 1

and try to find things like black smokers or hydrothermal vents that serve as oasis of life in the dark depths of our own oceans.

00:30:39 Speaker 1

So we're a very, very different world to Mars or Earth, but the possibility, the potential for life even here.

00:30:47 Speaker 1

I'm going to skip over Saturn and Titan in the interest of time.

00:30:52 Speaker 1

If anyone's got any questions about Saturn or Titan, we can totally talk about those.

00:30:57 Speaker 1

Because I wanted to save enough time in the last 10 minutes

00:31:01 Speaker 1

to talk about extra solar planets, this third big chunk of astrobiology, where we've been making huge advances in recent years.

00:31:14 Speaker 1

And this is where we live.

00:31:18 Speaker 1

This is our galaxy, the Milky Way.

00:31:20 Speaker 1

Or at least this is what it would look like if you could ever travel far enough and then back over your shoulder at our own galaxy.

00:31:27 Speaker 1

This isn't a photograph.

00:31:29 Speaker 1

This is an artist's impression of what our spiral galaxy looks like.

00:31:34 Speaker 1

It's almost like this swirl that you get when you stir your cappuccino or your coffee, this big, graceful swirl of a galaxy.

00:31:42 Speaker 1

And this is where we are right now.

00:31:44 Speaker 1

Just there is UCL, London, Britain, Europe, the Earth, the solar system.

00:31:53 Speaker 1

We are just on the inside edge of one of these spiral arms.

00:31:57 Speaker 1

of this glorious pinwheel of a galaxy.

00:32:01 Speaker 1

And in the last 20 years or so, we've now discovered over 5,000 new worlds orbiting other suns in our galaxy.

00:32:11 Speaker 1

We are finding planets orbiting other stars in the night sky.

00:32:14 Speaker 1

Twenty years ago, we knew of only one solar system, our own.

00:32:19 Speaker 1

We now know of hundreds and hundreds of them.

00:32:22 Speaker 1

They seem so common

00:32:24 Speaker 1

that probably the majority of stars in our galaxy have got planets, at least one planet orbiting it.

00:32:30 Speaker 1

Planets are common, worlds are common in outer space.

00:32:35 Speaker 1

Now some of these first alien solar systems that we discovered, I've drawn up on this diagram here.

00:32:43 Speaker 1

So I've lined up their suns, all on the left-hand side, and compared them against our own solar system on the bottom.

00:32:51 Speaker 1

So Mercury, Venus,

00:32:54 Speaker 1

Earth, that's where we are.

00:32:55 Speaker 1

Jupiter on this scale will be kind of way out here somewhere, far outer recesses of the solar system.

00:33:02 Speaker 1

So the first thing you notice, just by looking at this plot, this diagram of the first solar systems we found beyond our own, they don't look anything at all like ours.

00:33:14 Speaker 1

These are very different kinds of solar systems.

00:33:17 Speaker 1

On the whole, these are big,

00:33:20 Speaker 1

******** fat, enormous planets.

00:33:23 Speaker 1

This one here is almost six times more massive than Jupiter, which is itself over 300 times bigger than the Earth.

00:33:32 Speaker 1

This is a very, very big planet.

00:33:35 Speaker 1

And most of the first ones we found orbit very, very closely to their star.

00:33:40 Speaker 1

They're scorched, burned worlds.

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We call them hot Jupiters.

00:33:46 Speaker 1

But it stands to reason.

00:33:48 Speaker 1

When you think about it,

00:33:50 Speaker 1

that the first planets we found were the easy planets to find.

00:33:54 Speaker 1

These are the low-hanging fruit, the big planets orbiting closely to their star that gives a clear effect that we can detect, we can spot down our telescopes.

00:34:04 Speaker 1

And over time, astronomers have found more and more planets which are smaller and smaller and orbiting further from their star.

00:34:15 Speaker 1

And one of the planets, sorry, one of the planet-hunting telescopes

00:34:18 Speaker 1

that has made huge advances in this hunt for other worlds is called the Kepler Space Telescope.

00:34:26 Speaker 1

It's a bit like the Hubble Space Telescope.

00:34:28 Speaker 1

But unlike the Hubble, which you've probably heard about before, which is always looking around at different galaxies, different nebulae, different planets, different supernovae, Kepler, for its entire lifetime, its entire mission, was ordered to stare at the same tiny patch of night sky.

00:34:47 Speaker 1

and never got to look around in different directions.

00:34:51 Speaker 1

And we pointed this ultra-sophisticated, planet-hunting space telescope to look back along the spiral arm of our galaxy.

00:35:03 Speaker 1

We pointed it to a place in the night sky where there's lots and lots of stars all crowned very closely together.

00:35:12 Speaker 1

And the Kepler Space Telescope was monitoring

00:35:17 Speaker 1

over 100,000 stars simultaneously, all at the same time, waiting for when one of those stars blinked back at it.

00:35:28 Speaker 1

Because if a star blinks at you, there's a good chance it's because a planet has just passed across its face and blocked out some of that starlight.

00:35:37 Speaker 1

You can use this transit method, it's called, as a very, very effective way of finding new worlds in our neck of the woods.

00:35:46 Speaker 1

in our spiral arm of the galaxy.

00:35:49 Speaker 1

And we found thousands of them using methods like this.

00:35:53 Speaker 1

And we think that we are right on the brink now of discovering a very, very special kind of planet indeed.

00:36:03 Speaker 1

A second Earth.

00:36:05 Speaker 1

So not a giant, gassy planet like Jupiter, not one that's scorchingly hot, too close to its star, but a small, rocky,

00:36:15 Speaker 1

Earth-sized world, orbiting a sun-like star with an orbit of almost exactly one year.

00:36:24 Speaker 1

So it's the same distance from the heat of its campfire as way off from ours.

00:36:29 Speaker 1

It's not too close and boiling hot.

00:36:32 Speaker 1

It's not too far away and freezing cold.

00:36:35 Speaker 1

It's just right.

00:36:37 Speaker 1

Just the right temperature, just the right climate for liquid water and oceans on its surface.

00:36:44 Speaker 1

We call these kind of worlds Goldilocks planets, after the fairy tale about the three bears and the porridge being just the right temperature.

00:36:52 Speaker 1

And in fact, if you've understood how planets form correctly, in the coming years, we'll find not just one other Earth-like planet, but perhaps dozens and dozens of them.

00:37:05 Speaker 1

We'll be able to write a list of the nearest Earth-like planets to us, and then we'll check them with our telescopes

00:37:13 Speaker 1

one by one, and read the chemistry of their atmospheres.

00:37:19 Speaker 1

We can tell what that air is made-up of by using spectroscopy through a telescope.

00:37:25 Speaker 1

And if we see a small, rocky planet, a Goldilocks planet with the right kind of climate, that has got the telltale signature of oxygen and methane gas in its atmosphere, the only way that we would know how to explain that is because life has pumped out those gases.

00:37:43 Speaker 1

The only reason that right now every single one of us is breathing deep lungfuls of oxygen gas is because oxygen is the waste product.

00:37:52 Speaker 1

It's the pollution released by photosynthesis, by algae or forests growing by the energy of sunlight and releasing oxygen as a byproduct.

00:38:03 Speaker 1

There aren't any geological processes that would create an atmosphere like that.

00:38:09 Speaker 1

So perhaps in the next 10

00:38:12 Speaker 1

20 years.

00:38:14 Speaker 1

You'll be able to go out in a back garden on a nice, clear, dark night, away from the city lights of London, where you can really see the stars.

00:38:24 Speaker 1

And you'll be able to point to a particular star in the night sky and say, there is a sun with an Earth-like planet orbiting it.

00:38:34 Speaker 1

And there is oxygen in that planet's air.

00:38:37 Speaker 1

There is life on a planet orbiting that star there.

00:38:41 Speaker 1

That

00:38:42 Speaker 1

is where our neighbors live.

00:38:44 Speaker 1

And for me, that would be a really exciting outcome for astrobiology, finding evidence of life on another planet.

00:38:53 Speaker 1

Personally, I'd be a lot more excited about finding life not on a planet far, far away, too far that we could realistically ever get there and explore it.

00:39:05 Speaker 1

I'd be so much more excited if you found even simple bacterial life on somewhere like Mars.

00:39:12 Speaker 1

Because we can go to Mars, we can recover that life, we can culture it, we can grow it in our labs, we can understand how it works.

00:39:20 Speaker 1

Does Martian life use DNA or does it use something completely different?

00:39:25 Speaker 1

Imagine a biology class when you've got two completely separate examples of biology and you can compare them against each other.

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So for me, that's the promise of astrobiology.

00:39:37 Speaker 1

It asks some very big questions

00:39:40 Speaker 1

And hopefully, we're on the brink in our generation of being able to answer some of those questions.

00:39:47 Speaker 1

If anyone is interested in getting involved in astrobiology down the line, I've written a page up on my own website about how to become an astrobiologist.

00:39:58 Speaker 1

And it basically doesn't matter, whatever kind of science you want to study, you can get into astrobiology later.

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There's also lots of roles in astrobiology for artists and project managers and robotics.

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people.

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It's a very, very interdisciplinary field with lots of different opportunities.

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But we've got some time for maybe 3 or 4 minutes.

00:40:20 Speaker 1

If anyone's got any questions about anything I was talking about in terms of the extremophiles and these survival superheroes who've been discovering or exploring our own solar system or looking for Earth-like planets orbiting other suns.

00:40:35 Speaker 1

If anyone's got any questions, we have a little bit of time now.

00:40:38 Speaker 1

Your hand went up, yeah?

00:40:40 Speaker 1

You never said anything about Ganymede.

00:40:42 Speaker 1

So Ganymede is another icy moon orbiting Jupiter.

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But Ganymede may have some liquid water very, very deep inside.

00:40:56 Speaker 1

But it's basically between Europa and Callisto.

00:40:59 Speaker 1

Callisto is rock solid.

00:41:01 Speaker 1

Europa's got a very deep liquid water ocean.

00:41:04 Speaker 1

Ganymede might have some liquid water very, very deep.

00:41:07 Speaker 1

but probably not in the sort of situation where life could survive in that ocean.

00:41:11 Speaker 1

If everyone else can keep nice and quiet so we can all hear the questions and answers, there'll be plenty of time for you to put your pencil cases back in your bag when we leave in about five minutes.

00:41:21 Speaker 1

Yeah?

00:41:22 Speaker 1

Considering there is a system which has a star and a planet, and the planet orbiting the star is in a plane that the planet

00:41:35 Speaker 1

It does not pass through the sun in our line of sight.

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How can we identify that this exoplanet exists?

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So this is a good point.

00:41:44 Speaker 1

I talked about the transit method, where if a planet orbits in front of its star from our perspective, from our point of view, it blocks out some of the starlight, and we can infer there's a planet orbiting there.

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That only works if the planet happens to line up perfectly with our line of sight.

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But there are other methods that can also detect planets that don't happen to perfectly line up.

00:42:07 Speaker 1

So if it orbits at more of an angle from our point of view.

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And one of these other techniques is called radial velocity.

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We can measure very accurately as a star is wobbled, pulled back and forth towards us or away from us by a planet that we cannot see, and then we can do some simple maths and calculate what's the orbit of that planet, what's its mass, what's its gravity like.

00:42:31 Speaker 1

So there are several different techniques we can use for detecting extrasolar planets.

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I only mentioned one of them in this short talk.

00:42:41 Speaker 1

Do we have one last question before we head off?

00:42:44 Speaker 1

Yeah?

00:42:44 Speaker 1

What do you think of the, is it?

00:42:47 Speaker 1

Yeah.

00:42:48 Speaker 1

What do you think of the leopard spots that we found on Mars recently?

00:42:50 Speaker 1

Is that something that's really exciting for us?

00:42:55 Speaker 1

So if you haven't seen the news, it did make quite a big splash a couple of weeks ago that

00:43:00 Speaker 1

One of the NASA, one of the American rovers, is also looking for signs of life in habitable environments, found tiny little dark specks or spots inside of sedimentary rocks, a rock that had been laid down in liquid water in an ancient river on Mars.

00:43:18 Speaker 1

And these have been nicknamed the leopard spots.

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And the chemistry of the minerals, the geochemistry of those spots, is consistent with what we'd expect if life had played

00:43:28 Speaker 1

a role in the creation of those spots.

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So it is very exciting.

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We don't know of any good ways that geology could also explain that, but we don't really know.

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And if you're making such a profound statement, like life on Mars has been discovered, we kind of want to be certain about it.

00:43:45 Speaker 1

We want to be sure before we start making the announcement and rewriting the textbooks.

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So people are tentatively very excited about the leopard spots.

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And we're going to certainly be focusing a lot of attention on that sort of sample, that kind of discovery on Mars in the coming years.

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Ideally, we'd like to be able to bring samples of those rocks back to the Earth, so we can study them using all the labs around the world, not just using little robots that we send.

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So that is one of the upcoming steps for Mars exploration.

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Thank you ever so much for listening so attentively.

00:44:18 Speaker 1

I hope you enjoyed your first lecture on your course.

00:44:21 Speaker 1

And you've got something immediately after this now?

00:44:24 Speaker 1

No, you've got lunch?

00:44:28 Speaker 1

Thank you.