well good afternoon and welcome to NASA headquarters here in Washington DC my name is Dwayne brown with the Office of Communications despite widespread speculation on the internet ladies and gentlemen we are not here today to announce we have found life elsewhere in the universe however as we stated in our announcement for this event what you will hear today will in fact impact the search for life elsewhere and much much more so we end a week of fiction today we begin the day of facts let me introduce you to our panel first up Mary
wojtek director astrobiology program

NASA headquarters who will lead a panel
discussion and help facilitate the Q&A

Felisa wolf Simon the lead researcher

for the finding and nasa astrobiology

research fellow Steven binner

Distinguished Fellow foundation for

applied molecular evolution gainesville

florida pamela conrad astrobiologists

NASA's Goddard Space Flight Center in

Greenbelt Maryland and joining us via

phone from Tempe Arizona James L sir

professor Arizona State University and

with that I turn it over to Mary thank
you all for joining us today today's report is going to be on a life from Earth that was discovered that does something very unusual it is terrestrial life but not life as we know it this research was funded by the astrobiology program which is a research and analysis program in NASA that focuses on the origin and evolution of life the distribution of life and the future of life on Earth to inform us as to how we might search for life or evidence of life and other places in our solar system and beyond
NASA has had a long history of funding origin of life research in fact we're celebrating our 50th anniversary this year and the research is going to be presented here today exemplifies the goals of our program and our interest in the origin of life and life in the universe I'd like to introduce dr. Felicia wolf Simon the lead author on the paper to fill us in on what she did and what she found thanks Mary well as meri can probably knows and as many of my colleagues would agree with I'm always interested in exceptions to the rule and what I'm going to talk about
here today is not that much different than another exception to the rule and so I’ve discovered I’ve led a team that is discovered something that I’ve been thinking about for many years and I’ve been thinking about an idea of substitutions and what does it mean to be substitution what does it mean to be toxic so I’ve led a team that has discovered a microbe that can substitute arsenic for phosphorus and its major biomolecules but let me step back for a minute all life that we know of requires carbon hydrogen nitrogen oxygen
phosphorus and sulfur and it uses those six elements in some of the critical pieces I think we're all familiar with including DNA and RNA or the information technology of the cell the proteins which are the molecular machines and the lipids which separates you from everything else and so by discovering we've discovered in our organism that can substitute one element for another knees major biomolecules so I want to put that in the context of the who what where and how we did this and and give us a little bit about in an astro
biological context or life in a planetary context of what this could mean to us on practical and also a bit more esoteric levels I'd like to introduce to you today the bacterium GF aj dash one these are not little potatoes they are a microbe that scientists lovingly call little bugs but they're not bugs they're microbes and this is a bacterium that although looks ordinary and this may look like a type of micrograph many of us may have seen in different places but it's doing something extraordinary and
so we'll talk about that but first let's

find out where this microbe is from

we're looking at a map of a Mono Lake

California it's in Northern California

in east of the Sierras just outside of

Yosemite National Park it's a very

interesting environment and we're going

to we're going to take a look at that if

we could please roll that footage Mono

Lake is three times the salt of seawater

a peach of 10 it's basic like bleach and

arsenic and it's teeming with life so

the seemingly inhospitable environment

tees with life like bacteria and algae
and brine shrimp and is a major stopping point for migratory birds and they're on their way through the United States and we went to look for an interesting microbe we went to an unusual place so let me tell you a little bit about how how we did this so if you want to look for an organism that can substitute one element for another you might want to think about where that or where that particular element is abundant in Mono Lake is abundant in arsenic but why would I come up with the idea of substituting arsenic for phosphorus we
think about the periodic table arsenic lies just below phosphorus on the periodic table and so they actually have the physical size of arsenic and fosters are very similar we called the atomic radii but it's a physical size of the atom as far as we can tell is very similar and actually the fact of this chemical similarity there's mother other things I'd be happy to discuss at length with a with folks but that chemical similarity lens insight into something that arsenic is toxic because it looks like phosphorus so your cells
and my cells and microbial cells they can't tell the difference and that's very interesting to me as a biochemist so I went to an environment to look for this particular microphone what we did we took the muds of Mono Lake that we just were introduced to and we wanted to see if anything would grow if we took that mud and we gave it in a laboratory environment that was rich in everything I it needed sugar vitamins not not that bad for us and we we added no phosphorus and had a very high doses of arsenic it
was a double whammy you could think of

it this is not an experiment that most people might run but it was driven by my question is there a microbe on earth that could substitute arsenic for phosphorus in its basic biomolecular constituents and so what did we find we found that not only did this microbe cope or deal with the toxicity we might say with arsenic but it grew and it thrived and that was amazing nothing should have grown put your plant in the dark it doesn't grow so something grew now we wanted to find out what was happening so we measured the insides of
the cells we took the cells and we measured the total arsenic concentration inside the cells it was taking up this arsenic that's unusual and then we found that the arsenic was associated specifically with a band of genomic DNA and so we isolated the genomic DNA I think a lot of us have heard this kind of thing we measured that there was arsenic there and then we could tell that the arsenic wasn't just stuck it was in alaga seeeee type of chemical was in alaga seeeed type of chemical environment or it has nearest neighbors look like it was behaving like
phosphorus so was associated it was inside the cell it was somehow associated with the DNA and had this chemical environment or it it had an analogous sort of sort of it's like sitting at a dinner table and you and your neighbors and how we might see that you were all around well what should be in the place of phosphorus looked like it was arsenic we measured it as arsenic and so let's look at an artist rendition of what we think is going on in the cell of what we think is going on in the cell let's let's roll that animation please so here we're saying the beautiful
elegant structure of the double helix of DNA and what I want to highlight is the phosphate backbone we say and that's the light orange balls and it stitches together as we see the edges of DNA it holds together the DNA the backbone and so what we think is happening what are all the evidence we've collected suggests is that instead of these will see these these orange light orange balls disappear and represented by green balls we see that arsenic would be substituting for phosphorus in the
backbone of DNA you can see how critical

00:08:47,928 --> 00:08:57,568
this component of the DNA might be so

00:08:55,188 --> 00:09:00,719
what I presented to you today is a

00:08:57,568 --> 00:09:03,298
microbe doing something different than

00:09:00,720 --> 00:09:05,459
life as we knew it I was taught as a

00:09:03,298 --> 00:09:07,919
biochemist that all life on Earth all

00:09:05,458 --> 00:09:10,678
life we know of to hearken back to the

00:09:07,919 --> 00:09:14,278
pale blue dot ideas of Carl Sagan all

00:09:10,678 --> 00:09:15,600
life we know of is here so far and if

00:09:14,278 --> 00:09:18,838
there's an organism on earth doing

00:09:15,600 --> 00:09:20,999
something different we've cracked open

00:09:18,839 --> 00:09:23,850
the door to what's possible for life

00:09:20,999 --> 00:09:27,149
elsewhere in the universe and that's

00:09:23,850 --> 00:09:30,749
profound and to understand how life is

00:09:27,149 --> 00:09:33,089
formed and where life is going this
229 00:09:30,749 --> 00:09:36,199
microbe substitutes arsenic for

230 00:09:33,089 --> 00:09:39,929
phosphorus in its basic biomolecules and

231 00:09:36,198 --> 00:09:44,909
what else might we find what else might

232 00:09:39,928 --> 00:09:46,649
we want to look for thanks Mary Thank

233 00:09:44,909 --> 00:09:49,259
You felisa looks very exciting of course

234 00:09:46,649 --> 00:09:52,409
and we have several other people up here

235 00:09:49,259 --> 00:09:54,360
and joining us from Arizona the next

236 00:09:52,409 --> 00:09:57,178
person who will be speaking is dr. James

237 00:09:54,360 --> 00:10:00,659
elder he's a professor of ecology

238 00:09:57,178 --> 00:10:02,578
evolution of environmental sciences in

239 00:10:00,659 --> 00:10:05,159
the school of life sciences at Arizona

240 00:10:02,578 --> 00:10:06,958
State joining us from Tempe his

241 00:10:05,159 --> 00:10:09,118
background in his ecology and he's going

242 00:10:06,958 --> 00:10:11,998
to put into context the importance of
phosphorus and why this substitution of
this is of interest Jim hello
everyone greetings from sunny Tempe it's
a very exciting day congratulations to
Felisa and her team on this really stimulating report that's coming out and
someone who's studied phosphorus for a long time it's really quite surprising
that we're having this discussion so what I want to do for everyone though is
try to place phosphorus in the context of ecology and the environment and
of evolution and how important it is for human beings in our and the operation of
our society so if I could just bring up

the first the first slide there so what

we know from a lot of studies in ecology

is

phosphorus is all often limiting to the
growth of all kinds of organisms

bacteria algae higher plants even higher

animals themselves in this picture from

the Tennessee Valley Authority shows

quite clearly that phosphate added on

the right hand side of the picture is

limiting also to crop plants and so we

add a lot of phosphorus and fertilizer

and in fact phosphorus based fertilizers
are one of the pillars of the Green Revolution so phosphorus is limiting in a lot of different ecosystems and it's limiting for the reasons that police have described because life as we know it organisms that we know around us to rely on phosphorus to build nucleic acids and other molecules that they need to grow and proliferate so phosphorus is well known to be extremely important for all kinds of organisms and ecological systems so if we're going on to the next one because phosphorus is limiting and everything needs it it often turns out also that when phosphorus leaks out of
systems like out of agricultural fields

or out of cities or such it functions as a pollutant and here you can see a lake

on the bottom half has received phosphorus the top side has only received carbon and nitrogen the bottom side is received carbon nitrogen and phosphorus of phosphorus is necessary to have massive algal blooms that lead to the greening of lakes like this and eutrophication so phosphorus is a big issue for sustainability and Aquatic the quad and the quality of aquatic ecosystems so we know that phosphorus
because it's limiting because it's so

important organisms often functions as a pollutant when it leaves human hands now we're going to the next slide

we can also strive to talk about well

where does this phosphorous come from that we use in fertilizer well it comes from just a few places around or if it comes from mines of possible right deposits that were built up over tens of hundreds of millions of years by biological processes these mines are located in just a few countries around the world the American the United States
has phosphorus reserves in Florida and North Carolina that are rapidly being depleted because of fertilizer.

Morocco has major phosphorus reserves as this China but the distribution of this resource is relatively scarce around our planet and so because of this scarcity and its geographic distribution and because of the burgeoning demand for phosphorus fertilizer there's some concern that we can see the next slide please among scientists that supplies the fur of phosphorus that support the
Green Revolution and high agricultural production might become scarce at least supplies of cheap phosphorus and so we need to get a lot cleverer about phosphorus in society and it's really exciting to think about the possibilities that are raised by the a clever organism that has evolved a way to do without phosphorus possibly as we're talking about today so if we go on to the next slide so as I think about the ramifications for the possibility of an organism that doesn't use phosphorus that the possibilities start to run away to think about how it might be used in
wastewater treatment how it might be
using recovering phosphorus from various sources how it might be used in bioenergy production and other sorts of possibilities so really we have a new way of thinking now if this is if the study holds up that there are organisms that are possibly able to grow without phosphorus and as someone who studied phosphorus for my entire career essentially and who regularly gives lectures about phosphorus in which I state that every living thing uses phosphorus to build its DNA the idea
that I'm sitting here today discussing

the possibility that that's not true is

quite shocking so police' I have to

thank you and blame you for making our

lives somewhat more difficult so it

really is quite a remarkable report in

the context of how of what we know about

phosphorus and its importance in

ecosystems so thank you j im it sounds to

me like you're going to need to go out

and find a new text book to teach all

those students about what build what

elements are used to build life well I

don't know about a whole new textbook
but certainly some paragraphs and
sentences are going to have to be
rewritten as of today I'm at the
beginning of my career so see on the
back end it'll help us ok police out
probably separate the review
get started great thank you Jim our next speaker is Dr. Steven Benner from the
founder and distinguished fellow from
the foundation of applied molecular evolution and he spent a lot of his life
as an organic chemist and just in
studying the chemistry of life what are your thoughts well I'm the curmudgeon
here I’m the chemist who has been

brought in as felisa knows to throw wet

blankets on things and try to damp a

little bit the enthusiasm my next three

minutes will be successful if I convey

to you folks why chemists think that

this is an exceptional result and why

they're for chemists will like Carl

Sagan says require exceptional evidence

support it and I also want to make sure

you folks understand why we nonetheless

fun and interesting on what felisa has

found of course is a microbe that grows

in the environment which has a lot of

arsenic and very little phosphorus the
astrobiology institute which we are parts of our is the one place in American science where you can go to find geologists and microbiologist and astronomers and chemists together where we can have the productive clash that leads to big discoveries about big questions what is life what could alien life look like and so my goal in the next 30 seconds or so is to try to give you as a layman the understanding of how this is an exceptional risotto it might be looked at in greater detail because one thing that will survive is the
felices microbe and that will be an excellent system to explore questions about how arsenic is tolerated and phosphorus is limited in organisms that are placed under environmental stress so I brought my my Richard Feynman props with me and which is a representation of a molecule right and these molecules are saying a bio Palmer and of course we're making them out of steel and the result is it's tough right and of course as police has mentioned arsenate is made out of in this particular case aluminum foil and of course it's not as tough as
steel but when

a bacteria is going to try to form a new

chain it's going to try to find in the

environment the links that go to form a

chain and of course if there's arsenate

around as a weak link it will maybe

confuse and may be deceived by the

structure of arsenate in the

similarities to join two chains together

not by a steel chain but rather by an

arsenate a chain and of course these are

compounds that have been studied in

model form the specific arsenate DNA has

actually never been isolated but there

00:17:30,029 --> 00:17:33,470

00:17:31,279 --> 00:17:36,259

00:17:33,470 --> 00:17:38,210

00:17:36,259 --> 00:17:39,559

00:17:39,559 --> 00:17:41,870

00:17:38,210 --> 00:17:41,870

00:17:39,559 --> 00:17:44,179

00:17:41,869 --> 00:17:45,409

00:17:44,180 --> 00:17:48,080

00:17:45,410 --> 00:17:50,870

00:17:48,079 --> 00:17:53,240

00:17:50,869 --> 00:17:54,709

00:17:53,240 --> 00:17:56,990

00:17:54,710 --> 00:17:58,279

00:17:56,990 --> 00:17:59,809

00:17:58,279 --> 00:18:02,000
are compounds that are similar to it

different kinds of atoms but still

carbon oxygen arsenic oxygen carbon

linkages and so we know they're relatively unstable they fall apart with half-lives measured in the order of minutes conveniently and so when you try to put them into a DNA molecule right and then you put it under stress they fall apart and then of course your biological systems at oh my god I've just destroyed my mom I got to go back again so again if there's arsenate in the environment right even get the story you waste a lot of energy a lot of time
trying to put into DNA backbone arsenate

where if the arson a tester falls apart

you're effectively saying that arsenate

is the this we call it the wolf demon

wolf or demon sheep and sheep's clothing

it pulls the enzymes into taking it

instead of what it should take there are

two ways that biological systems in
general can manage this one way of

course is to be getting very good at

distinguishing between sheep and wolves

in sheep's clothing and therefore

distributes well the the end result is

of course as you don't get fooled by the
analogue the other possibility it's also conceivable that the biological system can have evolved to manage the weak link and they might manage the weak link by for example binding something to the week length sequestering and keeping it tight but the difficulty that we're having almost anybody with chemistry who is familiar with this literature will say as well wait a minute this DNA molecule has allegedly been isolated away from the other molecules in the biological system so we remember all this old chemistry and we don't believe
it and that's what you're going to see a lot of people say now keep in mind old chemistry can be wrong and like one of the wonderful things about being in a science is Richard refinement would say science begins when you distrust experts is the expert in chemistry I'm saying that you should distrust me but the bottom line out of all this is that what you're looking at here is an exceptional claim based on the context of the chemistry and of course when we can go into great details about what experiments you might do in the future
to explore this but what police it has

produced is a very very useful system to

go ask these kind of questions one last

point remember the weakness of the link

is a weakness measured at room

temperature 35 37 degrees centigrade

98.6 degrees fahrenheit in water if you go to an exotic environment and the

national cabinet sciences looked produce

a book which is actually you can go have

is coming out of the National Research Council called the limits of life and

organic of a light of our limits of

organic life in planetary systems you realize that in our solar system there
are places Titan a moon of Saturn is one of them where the temperature is much lower we're very reactive species like arsenic could very well be useful because although there are too unstable to exist in many environments on earth they're not too unstable to exist in an environment like Titan which has had minus 290 degrees Fahrenheit so it's a cold environment in fact you might very well want to have the increased reactivity of arsenate in that environment just to get the reactions as you want to make your bio polymer chains
go a little bit faster so again my role as the curmudgeon is to say this is an exceptional result i hope i can conveyed you a little bit maybe not in technical language but in graphic language why the chemist views this as an exceptional result and so you will understand why in nasa astrobiology program over the years as these various disciplines for chemists and who are the doubters or the deniers the microbiologist the geologists will interact in a way to bring forward the process that science is which is of course the clash of
contradictory cultures in an effort to come up with the truth to inspire a course Americans youth to go through the effort of studying science so they knowing full well that there are these kinds of very interesting questions out there like what is life and where might we find it if not on earth thank you Steve I have a question for you so would you as an organic chemist consider replacing your graduate students with microbes very many are these reactions many of my graduate students are undoubtedly
watching and I love you all what I

557
00:22:03,549 --> 00:22:10,960
wouldn't think of replacing it fair

558
00:22:06,970 --> 00:22:13,450
even answer okay our next speaker is

559
00:22:10,960 --> 00:22:15,039
dr. pan Conrad is she's a planetary

560
00:22:13,450 --> 00:22:17,650
scientist at the Goddard Space Flight

561
00:22:15,039 --> 00:22:20,170
Center and also the deputy p on an

562
00:22:17,650 --> 00:22:21,820
investigation that will be flown on the

563
00:22:20,170 --> 00:22:23,650
Mars Science Laboratory to be launched

564
00:22:21,819 --> 00:22:26,980
in a year for now it's the first

565
00:22:23,650 --> 00:22:30,250
astrobiology mission since Viking and

566
00:22:26,980 --> 00:22:32,049
which is whose goal is to look for

567
00:22:30,250 --> 00:22:34,630
evidence of habitability and the

568
00:22:32,049 --> 00:22:38,529
potential for current and past life on

569
00:22:34,630 --> 00:22:40,540
Mars please depan well I don't think I'm

570
00:22:38,529 --> 00:22:43,480
going to class um i classify myself
either is curmudgeon or otherwise my role in the astrobiology spectrum is to think about how we might predict a habitability of environments off the earth and the way I go about that is to see what I can learn about environments on the earth and try to develop metrics for habitability so I find this result delightful because it makes me have to expand my notion of what environmental constituents might enable habitability so for example if you just think about an environment in terms of what it's made of and how those things are
arranged you have a concept of an

environment just like the chemical

environment everything is a function of

its constituents and how they're

arranged so what is really interesting

about this result is if you can make a

biomolecule that has substitutions in it

the properties have to change as a

function of new constituents so it opens

up a whole new line of questioning what

might those changes be what do they

pretend for the evolution of that

chemistry what do they mean about the

environment and by the same token we
might learn something new about habitable environments by understanding how organisms that are there adapt to the presence of new or limited chemical constituents with respect to space exploration this is a very interesting result again because the implication is that we still don't know everything there is to know about what might make a habitable environment on another planet or a satellite of another planet we have to increasingly broaden our perspective so perhaps arsenic is not an essential component for
habitability or for life but it may be
one that can be tolerated and that opens
up our perspective to try to understand
what other potential components might be
tolerated or in fact even essential that
we presently haven't thought of you very
much so I'd like to bring this all
around and back to felisa for her to put
her findings in a broader context for us
and remind us of exactly what they are
and their importance so let's remind us
what we've learned here today I'm
interested in exceptions and I think
many of us are interested in those
exceptions to the rules why are things
constants in nature that keeps me up at night why I was probably a very difficult child in junior high in high school but what I'll say is that that kind of openness to questions is part of what I want I hope that the work of myself and my team that produced this what I want to really reiterate it it's not about arsenic and this isn't about Mono Lake it's about thinking about life in a planetary context and asking questions simple questions with a simple experimental design and so in like a bigger scale let's go from the small and
then we'll go into the abstract all life

on Earth required carbon nitrogen oxygen

hydrogen phosphorus and sulfur so I've

shown here today that we discovered a

microbe that can substitute arsenic for

phosphorus and its major biomolecules

not just DNA but things like ATP the

many of those high school students out

there I hope recognize and also all

sorts of other biomolecules what does

that suggest it cracks open the door to

the potential you know my niece asks me

how did we get here when are we alone in

the universe and its profound that we
don't know the answer is exactly to that

yet maybe not in my lifetime but maybe

in her lifetime she'll be able to to be

able to answer that but I hope my work

serves as a proof of

concept that we can experimentally test

and show evidence of what else is

possible so I'd like to roll some

footage just to give us the expansive

nature of life from microbes to

crustacea to bugs to mammals to

everything you know that's alive on

planet earth again harkening back to the

idea of the pale blue dot understanding
life here all sorts of life lions and
tigers and bears and now everything we
know is on this tree of life everything
you've ever thought of so far that we
can see on this tree of life so what
we're presenting here today is a member
of this tree of life we're cracking open
that door strange EF aj1 the bacterium
is a different way to do business just
to open the possibility to what else is
possible it has solved the challenge of
being alive in a very different way than
than we knew of what other questions can
we ask this will inform us about life on
our own planet and it will help inform
us of life we will find it one day elsewhere in the universe thank you

thank you very much felisa and I'm going to turn it back over to you Dwayne and police' congratulations to you and your team okay ladies and gentlemen now we get to the question and answers to really even flush it out even more we're going to start here first and then go to the west coast I'm going to ask you to wait for the microphone give you a name folks here and we also have a professor in Arizona so if you can address your
question to the appropriate person that
would be great let's do start with Mark
Kaufmann

thank you and congratulations what I
would when I'm intrigued by and trying
to understand is you refer here to
substitution of the arsenic is there
reason to believe that this was
substitution that occurred in any kind
of a time frame or is it possible that
this is something that has been in the
bacterium or in other bacteria going
back to the beginning of time question
and I think you know we'll have the next
30 years at least of my career and many others to begin to probe that I think what it does suggest I'm saying substitution because we really just want to open this package to be able to think about what else life could be and as an early career scientists I think that's a safe way to go but in terms of whether I think if it just happened recently substituting for what was or how old this is I think we can begin to adjust those questions there's a number of experiments I can think of and I know many of my colleagues who have been a
familiar with this work for a number of

00:29:23,319 --> 00:29:28,928
months now have suggested at what we can

00:29:26,679 --> 00:29:31,169
say and dangerously to speculate just a

00:29:28,929 --> 00:29:33,940
little bit if you'd let me is that

00:29:31,169 --> 00:29:35,710
phosphate in its phosphate in bio

00:29:33,940 --> 00:29:37,269
molecules so phosphorus so and I'll go

00:29:35,710 --> 00:29:40,269
between those you'll have to pardon me

00:29:37,269 --> 00:29:41,740
and on earth is locked up in rock so

00:29:40,269 --> 00:29:44,679
your bones are made of phosphate because

00:29:41,740 --> 00:29:45,940
it's a good idea and it's very one of

00:29:44,679 --> 00:29:48,038
the reasons it just doesn't do a lot of

00:29:45,940 --> 00:29:49,269
chemistry and in fact I hope that Steve

00:29:48,038 --> 00:29:52,720
would agree in that phosphate

00:29:49,269 --> 00:29:55,630
chemistry's there difficult and we can

00:29:52,720 --> 00:29:58,210
speculate a little bit about can be
there difficult we can speculate about

and we have no evidence of how life you

had a start let started okay given that

there are a number of scientists who

proposed that in hydrothermal vent

systems where we have a gradient so

different chemicals coming together

arsenic would have been available for

prebiotic chemistry whether it was or

not I I can't we can't speak to I wasn't

there but it does chemistry rapidly it

can do chemistry more rapidly so I think

that it will be a fun thing to try and

test but it's not an easy problem
Randy Shostak reported with EOS the newspaper of the American Geophysical Union how does and might this finding effect NASA's and others astrobiology programs including the Mars Science Lab and other ongoing and planned missions and programs do you want me to all right I'll start then with respect to mars science laboratory or in general the problem of studying habitability on other planets the way that one could be affected is to think more broadly about what sorts of environments one might characterize is habitable in specific
with respect to experiments that we could do on Mars Science Laboratory we do have payload investigations that can measure the chemical elements we do have a payload investigation that I'm associated with that can actually measure organic molecules so one way that you can tell what you have is by putting together a number of investigations and like all science independent lines of corroboration help you paint a bigger picture so for example on Mars Science Laboratory if you had an environment that appeared to
be rich in arsenic or some unanticipated
metal and you also had a finding of
organic molecules you could begin to put
a picture together about what the
environmental chemistry might portend I
think this finding points to a challenge
that we've known we've had for a while
clearly if we went to another planet or
another body in in the universe and we
saw a human we would recognize that his
life and there are many other forms we
could probably recognize the challenge
of finding something that is
significantly different than terrestrial
life and life as we know it is really
what plagues us when we think about spending the money that we do developing the instruments that we do and sending them off on a mission and so I think it's been our strategy with the support of the scientific community to think as broadly as possible to put measurements that we may deem reasonable in a context so make the context of the environment to explore pasta that are not so focused on a specific molecule for example we would not want to at this point necessarily go to look for specifically DNA that had arsenic in
its backbone we want to keep them very broad and keep our strategy and seeking signs of life open to the possibility of things we would hate to go somewhere and not see it yes good morning good afternoon my name is Luis Fernando Soo bahk winter from TV Globo in Brazil my curiosity is whether the door that you say has been open it will take that you say has been open it will take scientists more in the direction of looking for different environments for life here on earth or outside and if you had to pick another element another medium other than arsenic which one
would you explore first so I'll answer

I'll tell you I have a lot of ideas and

we all knew how ideas let's say

propagated through the nets and so I

love to talk to you offline about that

but there's a lot you don't have a long

career ahead and I have a lot of ideas

I'd like to test so I think we have lots

of questions in terms of other elemental

substitutions other types of metabolism

you know not just the way you make a

cell but also the way the cells can can

do their business so I won't I won't
really talk anymore about that right now

00:34:14,590 --> 00:34:20,559
but i'd say stay tuned the next 15 to 30

00:34:17,648 --> 00:34:21,940
years let's say that that said the front

00:34:20,559 --> 00:34:24,128
of your questions in terms of looking

00:34:21,940 --> 00:34:26,409
here on earth or elsewhere i think yes

00:34:24,128 --> 00:34:29,829
and yes i think that we can learn a lot

00:34:26,409 --> 00:34:31,990
here not not just my work but many of

00:34:29,829 --> 00:34:34,299
the folks the other scientists supported

00:34:31,989 --> 00:34:35,949
in the astrobiology program and again

00:34:34,300 --> 00:34:38,200
astrobiology the study of life in a

00:34:35,949 --> 00:34:40,989
planetary context we don't want to be

00:34:38,199 --> 00:34:43,868
Terran centric or a centrist life in any

00:34:40,989 --> 00:34:47,259
planetary context or asteroid context or

00:34:43,869 --> 00:34:50,889
moon context I think that I think it's

00:34:47,260 --> 00:34:52,389
all very important and so I guess what
I'd say is I'd be I'm happy to be involved in both of those and I'd perhaps marry you want to address that that answers your question give your name in Philly a sure elouesa vilela from TV record in Brazil I was wondering from what I understood you you'll now open to different doors here or many more but one is exploration life as we knew so expanding the idea what life is and where it can be sustained in the audit that I was wondering if you could comment a little more it's possible practical applications here
like the professor mentioned the water

water waste treatments or recovery of phosphorus or what kind of all the possible applications you see I think we're going to direct that to gym since he introduced that and is our phosphorus expert Jim are you still with us yeah I'm still here so yeah that I this is all new and spinning out so a lot of the things just come into your head instantaneously so for example tying together the bioenergy and the phosphorus sustainability issues so we know we have to begin to develop
alternative bio energy sources for fossil fuels and so people are growing a lot of plants and trying to figure out a way to grow algae to make bioenergy but all of the existing plants and an algae that we know of need fertilizer themselves they need phosphorus so what if someone was clever enough to be able to develop a bioenergy creature microorganism based on this metabolism if it holds up that doesn't need phosphorus so you don't need to drain the fertilizer supply in order to solve the bioenergy problem so we're a
long way off but I mean I would think

that this if this holds up and we can

figure out a way to do it right then you

can have a whole bioenergy technology

that's based on an arsenate type

organism that's kind of science fiction

probably more realistic are things like

treating arsenate waste dumps and this

sort of thing to find organisms that are

capable of tolerating that or in fact

thriving on that as this one does so

there seem to be applications for for

toxic waste treatment where

arsenate is often often an issue so i

think that's another practical aspect
that people will start to work on once we start to learn more about this situation so yeah it's pretty exciting to think about the possibility of organisms and living things that might be able to live without phosphorus and for example just going back to the bioenergy situation one of the big problems that bio energy schemes have is that if you make it algae or cyanobacteria based bioenergy system with the regular organisms a pretty soon it's going to get infected with other organisms like it's going to be invaded
by things you don't want well one way

you could avoid back all those other

invaders are probably going to need

phosphorus and so if you had a

phosphorus free environment with a

bioenergy organism based on arsenic

instead that's going to be pretty

resistant to being contaminated by

invaders that you don't want so I think

you know there's pretty exciting stuff

here if this if this holds up I could

also comment I think I'm the end of that

Jim and that so if this microbe has been

something we knew so when I said it
looked ordinary also what it does is

very ordinary so you and I breathe

oxygen and we burn sugar same thing this

microbe does so metabolically

scientifically would say metabolically

it's not very interesting it did

something very normal in terms of its

metabolism in the way it looks again we

would look in the environment we may not

know that one thing and wiggles it moves

really fast they swim quite quite

rapidly we may not notice that that

microbe is making its bond molecules out

of some other elements so if for every
one of your cells in your body right now

00:38:45,039 --> 00:38:53,559
there are ten microbial cells so you are

00:38:50,440 --> 00:38:55,599
mostly micro what might we not

00:38:53,559 --> 00:38:58,480
understand about those microbes so

00:38:55,599 --> 00:39:01,299
that's in you now let's go global so on

00:38:58,480 --> 00:39:02,619
planet Earth we know that it's very well

00:39:01,300 --> 00:39:04,570
supported now that microbes are some of

00:39:02,619 --> 00:39:07,420
the major drivers of the biogeochemical

00:39:04,570 --> 00:39:09,309
cycles on earth like carbon cycle so if

00:39:07,420 --> 00:39:11,619
microbes are doing are these major

00:39:09,309 --> 00:39:14,739
players in our own bodies and in the in

00:39:11,619 --> 00:39:16,210
the earth so on our bus planet if we're

00:39:14,739 --> 00:39:17,439
missing a population may be based on

00:39:16,210 --> 00:39:19,750
arsenic but maybe these other

00:39:17,440 --> 00:39:21,570
possibilities that we don't even know
yet
I think it has vast implications in understanding the way our own bodies might work and in help inform us about that but also in the way our planet works so that I think it's I think Jim suggested in practical applications it's absolutely but some of the practical applications will develop over time understand well here's the fundamental discovery and you know it's going to take an army of scientists not clearly not just myself in my team but other other people to bear on this problem
with their tools and their ideas I think it's clear from both of their answers that there's we're opening up all sorts of new areas of research Jim you're practically breathless with your ideas well I'm sure you'll be looking for money soon yeah so you know this is this are the ramifications of this finding or pretty significant we have some time for the gentleman here you can give you a name affiliation sir surance Ivan I just have two very short technical questions not technical cautious but just detailed questions I'm
wondering about the fraction of the swap
out the the video kind of implied all
the phosphorus molecules disappearing
atoms disappearing being replaced with arsenic do you have a sense of whether it's that complete or whether it's some fraction and and if there's some level some threshold there and and for Steve better if you could just clarify what it is about arsenic arsenate that makes it a weaker link specifically yeah i mean the i'm just trying to understand what the level of explanation should be how the explanation should be crafted to
meet the the level at which you're interested in answer arsenic has of course a position below phosphorus on the periodic table that has been mentioned because of that it has orbitals which we can must like to talk about d orbitals F orbitals that are lower in energy and that permits arsenate to fall apart as by what is called in the business and associative mechanism that is it the attacking water doesn't have to wait until something leaves in order to attack it attacks without waiting for something that's quite different than what
molecules farther up in the periodic table do and so this is why again my curmudgeon wet blanket rolls I sit here and say it's wonderful to say think we're good to go to other planets and get a phosphorous free energy right what we believe based on prior experience is that what will certainly survive from felices work is the microbe and that microbe if it grows and low phosphorus environments that's wonderful I mean I can be used practically but we don't believe right now that the body of evidence saying that that molecule can't
exist at the present time overwhelms the body of evidence that says that molecule does exist and that's not a theoretical argument that's an argument based on empirical I'm sorry yes that and maybe I should have answered first and it is true what Steve staying I'd like to let it or get the Whitman yeah so disposing with the web lakid what I will say is what we've presented so that was an artist rendition absolutely to illustrate the point if you're not so familiar with seeing those molecular structures I think what we've presented
the parsimonious way to interpret this arsenic was absolutely associated with
the DNA fraction purified on a gel to address what Steve saying how it survived all the manipulation that you're aware of how we do DNA extraction
unknown it migrates at a different level
I'll be a bit technical for a second
migrates at a different rate I think it's super coiled I've done things like cesium chloride gradients again a little bit technical it's weird and I'll be honest that I've been asked a question like well what did you think were your
Eureka no I'm a biochemist I said this

isn't right something's wrong I must

have made a mistake and you'll see

there's a laundry list of fantastic

c-co-authors and I got a reputation at

meetings somebody would give a talk whoa

I think that's a type of mass

spectrometry you can do this and so they

see me coming they wouldn't know who I

was but they knew that I was going to

ask them to measure something for me and

often I asked them to do it blindly and

they often said and if i were there we

would stare at the data and they would

sit back very experienced scientists
well what am I looking at no no what

what do you think it looks like no no

felisa what's in the sample I don't know

what do you think

it's often too AM you know so so the

answer is from my viewpoint in how much

arsenic is substituting I think right

now we don't know if you look at the

data that we're presenting in the paper

it varies and again to be technical for

one moment we've measured these cells in

stationary so its old age for the cell

so they've reached a point you grow grow

grow stop and and so the idea there is
there normally we run experiments a
little differently so if you look on our
supplementary evidence we've showed all
we're very transparent there is
absolutely some phosphorus left in these
cells but what's unambiguous about those
numbers is it is not enough to support
the growth that we observe my 2.8 from
two grams it's just not enough so to
support that growth we can estimate what
it would call this in science the back
of the envelope calculation we can
squint and see that pattern in nature
that our data are telling us we can
estimate how much total phosphorus you need at a very low how many ribosomes how much gene how much you need the genome how much you need on your proteins the turn them on and off is called protein phosphorylation if we have the analogous problem with arsenic how much you might need and lipid it's just too little it's just flat out too little do we have a crystal structure yet no I have collaborators working on that do we know the genome yet no but we're going to work on that and the point was it could be maybe it's just a
Xand tease maybe he's just geez and sees

maybe it's one out of every ten or

twelve hundred for a great question so

what we're not suggesting in my paper I

tried to write it in a very clear manner

what I'm not suggesting is that if the

entire microbe is made of arsenic

absolutely not I'm very very transparent

my co-authors we spent a lot of time

being very careful we're not really

speculating we wanted to present the

phenomena to the community and to the

public say oh my gosh this is amazing if

you notice how i an't ended you know i

had been reviewing some of the Great's i
stand on the shoulders of giants and I know that I went to Mono Lake because it's well studied it's easy accessible it's in the United States we studied in America with an American team on American soil with American money and I went to this to really you know I reread the double helix paper and I reread Stan Lee Miller's paper and plate tectonics just present the observation and the data so that we can make those forward progress I think understanding how much what does it do during law growth let's say we give it arson again
1155 00:46:13,909 --> 00:46:17,920
phosphorus what happens I actually know

1156 00:46:16,309 --> 00:46:20,960
but I’m not going to talk about it today

1157 00:46:17,920 --> 00:46:22,070
I’m well on to the next paper so I’m a

1158 00:46:20,960 --> 00:46:23,900
little more confident than I would have

1159 00:46:22,070 --> 00:46:27,860
normally been with someone as esteemed

1160 00:46:23,900 --> 00:46:29,000
as Steve Benner in the room I’ve been

1161 00:46:27,860 --> 00:46:32,450
working on the next paper should be

1162 00:46:29,000 --> 00:46:34,130
submitted in February the question back

1163 00:46:32,449 --> 00:46:35,809
to our colleague from nature I mean the

1164 00:46:34,130 --> 00:46:37,849
question is you taken a biochemistry

1165 00:46:35,809 --> 00:46:39,500
course and what do you remember from

1166 00:46:37,849 --> 00:46:41,449
your metabolic pathways that you were

1167 00:46:39,500 --> 00:46:43,460
taught forced to memorize for the

1168 00:46:41,449 --> 00:46:46,789
examination and perhaps promptly forgot

1169
so when you buy a synthesized DNA right

the phosphate comes from nucleoside

triphosphate where the phosphorus that

ends up in the DNA is the one directly

bound to the ATP oxy ATP deoxy GTP and

so on and that phosphorus gets to that

species by a 17 step metabolic pathway

which I'm sure you can write out on a

piece of paper having to interest I mean

I getting rusty stevens am a mas

adenosine mono arsenate which would be

saw that backbone we went down the I

call that the roller coaster when we

made the animation one of those
nucleotides so AEG see that you're all

00:47:20,510 --> 00:47:26,630
hopefully familiar with is is has a

00:47:23,090 --> 00:47:28,450
sugar as a base and the phosphate aamas

00:47:26,630 --> 00:47:32,570
formed spontaneously in a test tube

00:47:28,449 --> 00:47:35,000
while a MP does not and so in terms of

00:47:32,570 --> 00:47:38,120
thinking about mmm he isn't read the

00:47:35,000 --> 00:47:40,280
paper so a mas does form taneously and

00:47:38,119 --> 00:47:42,859
test tube on the order of minutes well

00:47:40,280 --> 00:47:45,160
A&P requires an enzymatic system this

00:47:42,860 --> 00:47:47,660
isn't my work this was done in the 80s

00:47:45,159 --> 00:47:49,279
it was to understand it was actually an

00:47:47,659 --> 00:47:50,960
accident of the finding and I'd be happy

00:47:49,280 --> 00:47:52,340
to give you the citation and we cited in

00:47:50,960 --> 00:47:55,429
the paper it was to understand the

00:47:52,340 --> 00:47:56,870
toxicity of arsenic aamas formed
spontaneously at room temperature in a test tube a vital thing phosphorus that ends up in the DNA yeah I'm gonna jump in here this is laughing get to a scientific debate here we have some questions from the west coast and following you guys can get together and hash it out let's go to the west coast of the ames research center we have questions go ahead hi good afternoon mrs. Raab or to go at kgo radio in the bay area and the question should be directed to dr. Wolfe Simon after your non Eureka moment
apparently you didn't suspect this might

be the case or hypothesized this might

be the case what were you doing at the

moment what were you looking for at the

moment and that you stumbled across this

or did you in fact think potentially

this was the case I'm sorry I don't

exactly understand the question what was

I doing at the particular moment in

terms of what of the analyses or what

kind of experiments I was running but

you know look at this way what were you

looking for so that you uh you didn't

hypothesize that this this microbe lived
as it did or as it does but you found it

anyway I mean that happens all the time

unclear I had I been thinking about

the idea of arsenic substituting for

phosphorus for some time so I it was a

directed test the question I was asking

was can arsenic substitute for

phosphorus in a living microbe so I ran

the experiment where we grew it in a

broth and a liquid an artificial liquid

where we gave the the mud for mono lake

is the initial source of the microbes

everything it needed except no
phosphorus with a high dose of arsenic

so um I'm sorry if that was unclear I

this was a directed search

Ted answer your question we'll go to the

next question I think that did we have

USA Today on the line go ahead on USA

Today a lot of our readers already

commenting online they're disappointed

you didn't pull an EP out of a hat and

dance on the stage uh I was wondering if

you could talk about those expectations

uh uh you know our readers are seem to

be have been expecting a walking talking

alien can you put this into perspective

for them instead of what you found
that's a question and perspective the

speculation was fiction the facts right

I I guess what I would say is that well

certainly being able to announce the
discovery of an extraterrestrial would

be an incredible announcement we feel

that from our perspective in our

understanding of biology here on earth

and what we base all the research that

we do because in astrobiology to some

extent on our laboratory earth this is a

phenomenal finding we are talking about

taking the fundamental building blocks

of life and replacing one of them with
an unusual or perhaps not unpredicted but another compound in our mind this is the equivalent and there are some of us that remember seeing these original Star Trek episodes and others that maybe see them on rerun on TV land but if you remember as a dark evil and the Horta so this is in our mind the equivalent of finding that Horta which is a silicon-based life substituting carbon which is what we think all life forms are made of with silica now we're talking about an organism that we think if not replacing
all of it is it appears to be using another fundamental component of life if the story is an entirely carbon nitrogen phosphorus the other elements we mentioned are important as well it's replacing phosphorus with arsenic this is a huge deal this is you know we mentioned it's going to require at least some paragraphs in a textbook to be rewritten perhaps and you know this is a big finding and so that's I'm sorry if they are disappointed but there are lots of people including Jim and the future
research he's already planning let's see

1298
00:52:23,858 --> 00:52:31,449
this is a huge finding and a significant

1299
00:52:27,880 --> 00:52:33,640
a significant finding that's going to

1300
00:52:31,449 --> 00:52:35,588
lead to new areas of research and will

1301
00:52:33,639 --> 00:52:37,480
fundamentally change how we define life

1302
00:52:35,588 --> 00:52:39,699
and therefore how we will look for maybe

1303
00:52:37,480 --> 00:52:41,380
we'll be able to find et now because

1304
00:52:39,699 --> 00:52:43,960
we've got more information about what we

1305
00:52:41,380 --> 00:52:46,088
might be looking for ok here's what I'm

1306
00:52:43,960 --> 00:52:47,559
going to do I'm going to keep this under

1307
00:52:46,088 --> 00:52:49,929
an hour so I'm going to take one more

1308
00:52:47,559 --> 00:52:52,358
question we have many more but we we can

1309
00:52:49,929 --> 00:52:53,919
do that as follow-ups so I rained from

1310
00:52:52,358 --> 00:52:55,750
Discovery you go ahead and have the last

1311
00:52:53,920 --> 00:52:59,980
question and then swing it back to me
and what close out go ahead Irene thanks

very much actually have two questions

the first term is about the experiment

itself how much time passed before the

microbes were able to make the

transition from their normal media to

one that was primarily arsenic and then

for Steve maybe if you could just maybe

generally discuss a follow-up experiment

that would leave you more of a believer

that'd be really helpful thank you so

I'll answer first apparently this time I

learned that lesson quick uh so in terms

of the time frame they the microbes
never experienced normal what you might
call normal environment I went straight
from the environments straight from mono
lake into this artificial lake
water where we mimic what the lake would
look like we had everything it needs
again vitamins and sugar and everything
else just no phosphorus and lots of
arsenic so there was never a transition
transition period
yeah I guess that's a good question keep
in mind that I as I think I mentioned a
moment ago I think that the organism
reported organism will survive scrutiny
I think that this is going to be a very important organism for us to study to try to understand how an organism adapts to phosphorus poor and arsenic rich environments because certainly knee is an organism cannot do so the kinds of experiments that I would of course start with would be I hate to be too technical but radioactive isotope labeling experiments felisa did do some work with her paper with radioactive arsenic way there's also reactive phosphorus I would be looking at for example that band on the gel and figure 2a the one in lane 2
with a box around it for those of you

who have the paper looking at that by

arsenic radioactive autoradiography

arsenic radioactive imaging after I had

to see whether is in fact concentrated

in that band I would certainly of course

do the same thing with radioactive

phosphorus in a ratio I would start with

a lot of fosters a little arsenic both

labeled to a lot of arsenic and little

phosphorus both labeled and see how the

labels because label reductive labels

are very easy to see in a Cell see how

they evolve in time and I mean but
police say you know I mean I one

actually I think you've actually got the sensitive when police and I have talked about this for hours may not days the disagreement in science need not be personal it can be factual friendly and constructive that way the nasa astrobiology institute sort of emphasizes that and the astrobiology program overall brings us together in a way that we you know have we have different backgrounds different contexts different cultures and therefore we approach problems differently and
therefore the standards are proof that each of us have to meet in our respective communities are different and so what you're saying here is a perfectly healthy interaction between two different communities as we try to apply our standards approved to somebody else's results so these are the kinds of experiments as a chemist I would do next okay we're going to wrap it up and for the media and there are many on the line and elsewhere these incredible scientists will be available for follow-up interviews I want to thank the
and of course the gem down in tempe

kudos again to you felisa in your team I

also want to acknowledge the continued

incredible work of NASA's science

Mission Directorate which continues to

our and inspire the world with

scientific discoveries you can get all

the information on ww NSA gov and for

those who know me you know I cannot

leave without saying it science never

sleeps thanks for joining us

you