1
00:00:07,110 --> 00:00:05,510
well good afternoon

2
00:00:09,589 --> 00:00:07,120
and welcome to nasa headquarters here in

3
00:00:12,629 --> 00:00:09,599
washington d.c my name is duane brown

4
00:00:15,430 --> 00:00:12,639
with the office of communications

5
00:00:16,470 --> 00:00:15,440
despite widespread speculation on the

6
00:00:18,470 --> 00:00:16,480
internet

7
00:00:21,269 --> 00:00:18,480
ladies and gentlemen we are not here

8
00:00:23,830 --> 00:00:21,279
today to announce we have found life

9
00:00:25,589 --> 00:00:23,840
elsewhere in the universe

10
00:00:27,670 --> 00:00:25,599
however

11
00:00:30,870 --> 00:00:27,680
as we stated in our announcement for

12
00:00:33,430 --> 00:00:30,880
this event what you will hear today

13
00:00:34,709 --> 00:00:33,440

will in fact impact

14
00:00:38,229 --> 00:00:34,719
the search

15
00:00:39,990 --> 00:00:38,239
for life elsewhere and much much more

16
00:00:42,470 --> 00:00:40,000
so

17
00:00:45,990 --> 00:00:42,480
we end a week of fiction

18
00:00:48,470 --> 00:00:46,000
today we begin the day of facts

19
00:00:50,150 --> 00:00:48,480
let me introduce you to our panel

20
00:00:51,350 --> 00:00:50,160
first up

21
00:00:52,950 --> 00:00:51,360
mary

22
00:00:54,389 --> 00:00:52,960
vortech

23
00:00:57,910 --> 00:00:54,399
director

24
00:01:00,310 --> 00:00:57,920
astrobiology program nasa headquarters

25
00:01:03,910 --> 00:01:00,320
who will lead the panel discussion and

26
00:01:07,030 --> 00:01:05,030
felisa

27
00:01:09,670 --> 00:01:07,040
wolf simon

28
00:01:11,830 --> 00:01:09,680
the lead researcher for the finding in

29
00:01:15,109 --> 00:01:11,840
nasa

30
00:01:19,590 --> 00:01:17,190
stephen benner

31
00:01:20,789 --> 00:01:19,600
distinguished fellow

32
00:01:25,109 --> 00:01:20,799
foundation

33
00:01:28,230 --> 00:01:25,119
for applied molecular evolution

34
00:01:30,230 --> 00:01:28,240
gainesville florida

35
00:01:32,069 --> 00:01:30,240
pamela conrad

36
00:01:33,749 --> 00:01:32,079
astrobiologists

37
00:01:35,830 --> 00:01:33,759
nasa's goddard space flight center

38
00:01:38,950 --> 00:01:35,840

greenbelt maryland

39
00:01:40,789 --> 00:01:38,960
and joining us via phone from tempe

40
00:01:41,830 --> 00:01:40,799
arizona

41
00:01:44,469 --> 00:01:41,840
james

42
00:01:46,630 --> 00:01:44,479
elser professor

43
00:01:47,910 --> 00:01:46,640
arizona state university

44
00:01:50,069 --> 00:01:47,920
and with that

45
00:01:52,469 --> 00:01:50,079
i turn it over to mary

46
00:01:55,510 --> 00:01:52,479
thank you all for joining us today

47
00:01:57,830 --> 00:01:55,520
today's report is going to be on a life

48
00:02:00,550 --> 00:01:57,840
from earth that was discovered that does

49
00:02:03,670 --> 00:02:00,560
something very unusual it is terrestrial

50
00:02:04,950 --> 00:02:03,680
life but not life as we know it

51
00:02:06,789 --> 00:02:04,960
this research was funded by the

52
00:02:08,630 --> 00:02:06,799
astrobiology program

53
00:02:11,110 --> 00:02:08,640
which is a research and analysis program

54
00:02:13,190 --> 00:02:11,120
in nasa that focuses on the origin and

55
00:02:15,430 --> 00:02:13,200
evolution of life the distribution of

56
00:02:17,589 --> 00:02:15,440
life and the future of life on earth to

57
00:02:19,589 --> 00:02:17,599
inform us as to how we might search for

58
00:02:23,270 --> 00:02:19,599
life or evidence of life and other

59
00:02:26,390 --> 00:02:23,280
places in our solar system and beyond

60
00:02:28,390 --> 00:02:26,400
nasa has had a long history of funding

61
00:02:30,070 --> 00:02:28,400
origin of life research

62
00:02:31,750 --> 00:02:30,080
in fact we're celebrating our 50th

63
00:02:32,790 --> 00:02:31,760

anniversary this year

64
00:02:35,110 --> 00:02:32,800
and the research that's going to be

65
00:02:37,830 --> 00:02:35,120
presented here today exemplifies the

66
00:02:39,430 --> 00:02:37,840
goals of our program and our interest in

67
00:02:42,390 --> 00:02:39,440
the origin of life and life in the

68
00:02:45,750 --> 00:02:42,400
universe i'd like to introduce

69
00:02:48,309 --> 00:02:45,760
dr felissa wolf simon the lead author on

70
00:02:51,270 --> 00:02:48,319
the paper to fill us in on what she did

71
00:02:53,190 --> 00:02:51,280
and what she found thanks mary well as

72
00:02:55,190 --> 00:02:53,200
mary can probably knows and as many of

73
00:02:57,190 --> 00:02:55,200
my colleagues would agree with i'm

74
00:02:59,270 --> 00:02:57,200
always interested in exceptions to the

75
00:03:01,990 --> 00:02:59,280
rule and what i'm going to talk about

76
00:03:04,149 --> 00:03:02,000
here today is not that much different

77
00:03:05,030 --> 00:03:04,159
than another exception to the rule and

78
00:03:07,589 --> 00:03:05,040
so

79
00:03:08,790 --> 00:03:07,599
i've discovered i've led a team that has

80
00:03:10,550 --> 00:03:08,800
discovered something that i've been

81
00:03:11,589 --> 00:03:10,560
thinking about for many years and i've

82
00:03:13,190 --> 00:03:11,599
been thinking about an idea of

83
00:03:14,869 --> 00:03:13,200
substitutions and what does it mean to

84
00:03:16,229 --> 00:03:14,879
be substitution what does it mean to be

85
00:03:18,390 --> 00:03:16,239
toxic

86
00:03:20,710 --> 00:03:18,400
so i've led a team that has discovered a

87
00:03:22,309 --> 00:03:20,720
microbe that can substitute arsenic for

88
00:03:24,390 --> 00:03:22,319

phosphorus and its major biomolecules

89
00:03:26,470 --> 00:03:24,400
but let me step back for a minute

90
00:03:28,470 --> 00:03:26,480
all life that we know of requires carbon

91
00:03:31,030 --> 00:03:28,480
hydrogen nitrogen oxygen phosphorus and

92
00:03:32,390 --> 00:03:31,040
sulfur and it uses those six elements

93
00:03:34,550 --> 00:03:32,400
and some of the critical pieces i think

94
00:03:36,550 --> 00:03:34,560
we're all familiar with including dna

95
00:03:38,789 --> 00:03:36,560
and rna or the the information

96
00:03:40,869 --> 00:03:38,799
technology of the cell the proteins

97
00:03:42,390 --> 00:03:40,879
which are the molecular machines and the

98
00:03:43,750 --> 00:03:42,400
lipids which separates you from

99
00:03:46,229 --> 00:03:43,760
everything else

100
00:03:48,710 --> 00:03:46,239
and so by discovering we've discovered

101
00:03:49,990 --> 00:03:48,720
an organism that can substitute one

102
00:03:52,070 --> 00:03:50,000
element for another in these major

103
00:03:53,670 --> 00:03:52,080
biomolecules so i want to put that in

104
00:03:55,110 --> 00:03:53,680
the context of the who what where and

105
00:03:57,429 --> 00:03:55,120
how we did this

106
00:03:59,910 --> 00:03:57,439
and and give us a little bit about in an

107
00:04:01,830 --> 00:03:59,920
astrobiological context or life in a

108
00:04:03,270 --> 00:04:01,840
planetary context

109
00:04:05,350 --> 00:04:03,280
of what this could mean to something

110
00:04:06,550 --> 00:04:05,360
practical and also a bit more esoteric

111
00:04:08,550 --> 00:04:06,560
levels

112
00:04:15,030 --> 00:04:08,560
i'd like to introduce to you today the

113
00:04:19,030 --> 00:04:17,270

these are not little potatoes

114
00:04:20,629 --> 00:04:19,040
they are a microbe that scientists

115
00:04:23,189 --> 00:04:20,639
lovingly call little bugs but they're

116
00:04:24,550 --> 00:04:23,199
not bugs they're microbes and this is a

117
00:04:26,070 --> 00:04:24,560
bacterium

118
00:04:28,310 --> 00:04:26,080
that although looks ordinary and this

119
00:04:30,390 --> 00:04:28,320
may look like a type of micrograph many

120
00:04:33,270 --> 00:04:30,400
of us may have seen in different places

121
00:04:35,749 --> 00:04:33,280
but it's doing something extraordinary

122
00:04:37,510 --> 00:04:35,759
and so we'll talk about that but first

123
00:04:38,790 --> 00:04:37,520
let's find out where this microbe is

124
00:04:40,950 --> 00:04:38,800
from

125
00:04:43,670 --> 00:04:40,960
we're looking at a map of mono lake

126
00:04:46,310 --> 00:04:43,680
california it's in northern california

127
00:04:48,469 --> 00:04:46,320
and east of the sierras just outside of

128
00:04:49,830 --> 00:04:48,479
yosemite national park it's a very

129
00:04:51,189 --> 00:04:49,840
interesting environment and we're going

130
00:04:53,590 --> 00:04:51,199
to we're going to take a look at that if

131
00:04:55,430 --> 00:04:53,600
we could please roll that footage

132
00:04:58,070 --> 00:04:55,440
mono lake is three times the salt of

133
00:04:59,270 --> 00:04:58,080
seawater a peach of ten it's basic like

134
00:05:01,430 --> 00:04:59,280
bleach

135
00:05:03,189 --> 00:05:01,440
and it's it's got very high levels of

136
00:05:05,189 --> 00:05:03,199
arsenic and it's teeming with life so

137
00:05:07,670 --> 00:05:05,199
the seemingly inhospitable environment

138
00:05:09,990 --> 00:05:07,680

teems with life like bacteria and algae

139
00:05:12,230 --> 00:05:10,000
and brine shrimp and is a major stopping

140
00:05:15,350 --> 00:05:12,240
point for migratory birds and they're on

141
00:05:17,029 --> 00:05:15,360
their way through the united states

142
00:05:19,510 --> 00:05:17,039
and we went to look for an interesting

143
00:05:20,950 --> 00:05:19,520
microbe and we went to an unusual place

144
00:05:23,189 --> 00:05:20,960
so let me tell you a little bit about

145
00:05:24,870 --> 00:05:23,199
how how we did this so if you want to

146
00:05:27,029 --> 00:05:24,880
look for an organism that can substitute

147
00:05:28,469 --> 00:05:27,039
one element for another

148
00:05:30,070 --> 00:05:28,479
you might want to think about where that

149
00:05:32,390 --> 00:05:30,080
or where that particular element is

150
00:05:34,070 --> 00:05:32,400
abundant monolake is abundant in arsenic

151
00:05:36,469 --> 00:05:34,080
but why would i come up with the idea of

152
00:05:38,550 --> 00:05:36,479
substituting arsenic for phosphorus if

153
00:05:40,390 --> 00:05:38,560
we think about the periodic table

154
00:05:42,150 --> 00:05:40,400
arsenic lies just below phosphorus on

155
00:05:44,070 --> 00:05:42,160
the periodic table and and so they

156
00:05:45,909 --> 00:05:44,080
actually have a the physical size of

157
00:05:47,990 --> 00:05:45,919
arsenic and phosphorus are very similar

158
00:05:49,590 --> 00:05:48,000
we call it the atomic radii but it's the

159
00:05:51,270 --> 00:05:49,600
physical size of the atom as far as we

160
00:05:53,110 --> 00:05:51,280
can tell it's very very similar

161
00:05:54,390 --> 00:05:53,120
and actually the fact of this chemical

162
00:05:56,469 --> 00:05:54,400
similarity and there's some other other

163
00:05:57,670 --> 00:05:56,479

things i'd be happy to discuss at length

164
00:05:59,350 --> 00:05:57,680
with folks

165
00:06:01,510 --> 00:05:59,360
but that chemical similarity lends

166
00:06:02,710 --> 00:06:01,520
insight into something that arsenic is

167
00:06:04,390 --> 00:06:02,720
toxic

168
00:06:06,150 --> 00:06:04,400
because it looks like phosphorus so your

169
00:06:07,830 --> 00:06:06,160
cells and micelles and microbial cells

170
00:06:09,350 --> 00:06:07,840
they can't tell the difference

171
00:06:11,830 --> 00:06:09,360
and that's that's very interesting to me

172
00:06:13,189 --> 00:06:11,840
as a biochemist so

173
00:06:14,710 --> 00:06:13,199
i went to an environment to look for

174
00:06:17,029 --> 00:06:14,720
this particular microbe and what we did

175
00:06:18,550 --> 00:06:17,039
we took the muds of monolake that we

176
00:06:20,230 --> 00:06:18,560
just were introduced to

177
00:06:21,430 --> 00:06:20,240
and we we wanted to see if anything

178
00:06:23,510 --> 00:06:21,440
would grow

179
00:06:25,350 --> 00:06:23,520
if we took that mud and we gave it in a

180
00:06:27,029 --> 00:06:25,360
laboratory environment

181
00:06:30,390 --> 00:06:27,039
that was rich in everything else it

182
00:06:31,510 --> 00:06:30,400
needed sugar vitamins not not that bad

183
00:06:34,629 --> 00:06:31,520
for us

184
00:06:36,230 --> 00:06:34,639
and we we added no phosphorus and had a

185
00:06:37,590 --> 00:06:36,240
very high doses of arsenic it was a

186
00:06:39,029 --> 00:06:37,600
double whammy you could think of it this

187
00:06:40,790 --> 00:06:39,039
is not an experiment that most people

188
00:06:43,189 --> 00:06:40,800

might run but it was driven by my

189
00:06:44,629 --> 00:06:43,199
question is there a microbe on earth

190
00:06:47,189 --> 00:06:44,639
that could substitute arsenic for

191
00:06:49,270 --> 00:06:47,199
phosphorus and its basic biomolecular

192
00:06:51,430 --> 00:06:49,280
constituents

193
00:06:53,909 --> 00:06:51,440
and so what did we find we found that

194
00:06:56,150 --> 00:06:53,919
not only did this microbe cope or deal

195
00:06:59,510 --> 00:06:56,160
with the toxicity we might say with

196
00:07:01,670 --> 00:06:59,520
arsenic but it grew and it thrived

197
00:07:03,830 --> 00:07:01,680
and that was amazing

198
00:07:06,629 --> 00:07:03,840
nothing should have grown put your plant

199
00:07:08,790 --> 00:07:06,639
in the dark it doesn't grow so something

200
00:07:10,150 --> 00:07:08,800
grew now we wanted to find out what was

201
00:07:11,990 --> 00:07:10,160
happening

202
00:07:13,350 --> 00:07:12,000
so we measured the insides of the cells

203
00:07:15,189 --> 00:07:13,360
we took the cells and we measured the

204
00:07:16,950 --> 00:07:15,199
total arsenic concentration inside the

205
00:07:18,790 --> 00:07:16,960
cells it was taking up this arsenic

206
00:07:20,469 --> 00:07:18,800
that's unusual

207
00:07:21,749 --> 00:07:20,479
and then we found that the arsenic was

208
00:07:23,589 --> 00:07:21,759
associated

209
00:07:26,790 --> 00:07:23,599
specifically

210
00:07:27,830 --> 00:07:26,800
with a band of genomic dna

211
00:07:29,909 --> 00:07:27,840
and so

212
00:07:31,270 --> 00:07:29,919
we isolated the genomic dna i think a

213
00:07:32,629 --> 00:07:31,280

lot of us have heard this kind of thing

214
00:07:34,710 --> 00:07:32,639
and we measured that there was arsenic

215
00:07:38,070 --> 00:07:34,720
there and then we could tell that the

216
00:07:41,110 --> 00:07:38,080
arsenic wasn't just stuck it was in a an

217
00:07:43,110 --> 00:07:41,120
analogous type of chemical environment

218
00:07:46,469 --> 00:07:43,120
or its nearest neighbors looked like it

219
00:07:48,390 --> 00:07:46,479
was behaving like phosphorus

220
00:07:49,350 --> 00:07:48,400
so it was associated it was inside the

221
00:07:50,469 --> 00:07:49,360
cell

222
00:07:52,150 --> 00:07:50,479
it was

223
00:07:54,070 --> 00:07:52,160
somehow associated with the dna and it

224
00:07:56,550 --> 00:07:54,080
had this chemical environment or it had

225
00:07:58,710 --> 00:07:56,560
an analogous sort of

226
00:08:00,550 --> 00:07:58,720
sort of it's like sitting at a dinner

227
00:08:01,990 --> 00:08:00,560
table and you and your neighbors and how

228
00:08:03,589 --> 00:08:02,000
we might see that you were all around

229
00:08:05,510 --> 00:08:03,599
well what should be in the place of

230
00:08:07,430 --> 00:08:05,520
phosphorus looks like it was arsenic we

231
00:08:08,950 --> 00:08:07,440
measured it as arsenic

232
00:08:10,869 --> 00:08:08,960
and so let's look at an artist's

233
00:08:12,070 --> 00:08:10,879
rendition of what we think is going on

234
00:08:13,430 --> 00:08:12,080
in the cell let's let's roll that

235
00:08:14,790 --> 00:08:13,440
animation please

236
00:08:16,629 --> 00:08:14,800
so here we're seeing the beautiful

237
00:08:17,990 --> 00:08:16,639
elegant structure of the double helix of

238
00:08:19,350 --> 00:08:18,000

dna

239
00:08:21,270 --> 00:08:19,360
and what i want to highlight is the

240
00:08:23,029 --> 00:08:21,280
phosphate backbone we say and that's the

241
00:08:24,950 --> 00:08:23,039
light orange balls

242
00:08:28,790 --> 00:08:24,960
and it stitches together as we see the

243
00:08:30,629 --> 00:08:28,800
edges of dna it holds together the dna

244
00:08:33,029 --> 00:08:30,639
the backbone

245
00:08:34,310 --> 00:08:33,039
and so what we think is happening

246
00:08:36,550 --> 00:08:34,320
all the evidence we've collected

247
00:08:37,909 --> 00:08:36,560
suggests is that instead of these we'll

248
00:08:39,350 --> 00:08:37,919
see these

249
00:08:42,949 --> 00:08:39,360
these orange light orange balls

250
00:08:44,149 --> 00:08:42,959
disappear and represented by green balls

251
00:08:45,829 --> 00:08:44,159
we see that arsenic would be

252
00:08:47,269 --> 00:08:45,839
substituting for phosphorus in the

253
00:08:48,630 --> 00:08:47,279
backbone of dna and you can see how

254
00:08:54,790 --> 00:08:48,640
critical

255
00:08:57,829 --> 00:08:55,829
so

256
00:08:59,190 --> 00:08:57,839
what i've presented to you today is a

257
00:09:01,030 --> 00:08:59,200
microbe

258
00:09:02,389 --> 00:09:01,040
doing something different than life as

259
00:09:04,150 --> 00:09:02,399
we knew it

260
00:09:06,949 --> 00:09:04,160
i was taught as a biochemist that all

261
00:09:08,870 --> 00:09:06,959
life on earth all life we know of to

262
00:09:10,630 --> 00:09:08,880
hearken back to the pale blue dot ideas

263
00:09:13,829 --> 00:09:10,640

of carl sagan

264
00:09:15,350 --> 00:09:13,839
all life we know of is here so far

265
00:09:17,910 --> 00:09:15,360
and if there's an organism on earth

266
00:09:20,070 --> 00:09:17,920
doing something different

267
00:09:21,590 --> 00:09:20,080
we've cracked open the door to what's

268
00:09:23,350 --> 00:09:21,600
possible for life elsewhere in the

269
00:09:26,310 --> 00:09:23,360
universe

270
00:09:28,230 --> 00:09:26,320
and that's profound and to understand

271
00:09:30,470 --> 00:09:28,240
how life is formed

272
00:09:32,949 --> 00:09:30,480
and where life is going

273
00:09:36,710 --> 00:09:32,959
this microbe substitutes arsenic for

274
00:09:39,190 --> 00:09:36,720
phosphorus and its basic biomolecules

275
00:09:43,430 --> 00:09:39,200
and what else might we find

276
00:09:47,350 --> 00:09:45,990
thanks mary thank you felisa it's very

277
00:09:50,310 --> 00:09:47,360
exciting of course

278
00:09:52,630 --> 00:09:50,320
we have several other people up here and

279
00:09:55,350 --> 00:09:52,640
joining us from arizona the next person

280
00:09:58,389 --> 00:09:55,360
who will be speaking is dr james ellser

281
00:09:59,110 --> 00:09:58,399
he's a professor of ecology evolution

282
00:10:01,269 --> 00:09:59,120
and

283
00:10:03,190 --> 00:10:01,279
environmental sciences in the school of

284
00:10:04,870 --> 00:10:03,200
life sciences at arizona state joining

285
00:10:06,710 --> 00:10:04,880
us from tempe

286
00:10:08,870 --> 00:10:06,720
his background in his oncology and he's

287
00:10:11,190 --> 00:10:08,880
going to put into context the importance

288
00:10:14,069 --> 00:10:11,200

of phosphorus and and why this

289
00:10:16,790 --> 00:10:14,079
substitution of this is is of interest

290
00:10:19,910 --> 00:10:18,630
hello everyone greetings from sunny

291
00:10:22,389 --> 00:10:19,920
tempe it's a

292
00:10:24,790 --> 00:10:22,399
very exciting day um congratulations to

293
00:10:26,870 --> 00:10:24,800
felissa and her team on this uh really

294
00:10:29,269 --> 00:10:26,880
uh stimulating uh report that's coming

295
00:10:30,870 --> 00:10:29,279
out and and uh someone who's studied

296
00:10:32,310 --> 00:10:30,880
phosphorus for a long time it's really

297
00:10:34,310 --> 00:10:32,320
quite surprising that we're having this

298
00:10:35,590 --> 00:10:34,320
discussion so what i want to do for

299
00:10:38,069 --> 00:10:35,600
everyone though is try to place

300
00:10:39,829 --> 00:10:38,079
phosphorus in the context of ecology and

301
00:10:42,389 --> 00:10:39,839
the environment and evolution and how

302
00:10:44,710 --> 00:10:42,399
important it is for uh human beings in

303
00:10:46,710 --> 00:10:44,720
our and the operation of our society so

304
00:10:48,790 --> 00:10:46,720
if i could just bring up the first

305
00:10:51,430 --> 00:10:48,800
the first slide there so what we know

306
00:10:53,350 --> 00:10:51,440
from a lot of studies in ecology is that

307
00:10:55,509 --> 00:10:53,360
phosphorus is often limiting to the

308
00:10:56,790 --> 00:10:55,519
growth of all kinds of organisms

309
00:11:00,630 --> 00:10:56,800
bacteria

310
00:11:02,470 --> 00:11:00,640
algae higher plants even higher animals

311
00:11:04,150 --> 00:11:02,480
themselves and this picture from the

312
00:11:06,470 --> 00:11:04,160
tennessee valley authority shows quite

313
00:11:07,910 --> 00:11:06,480

clearly that phosphate added on the

314
00:11:09,910 --> 00:11:07,920
right-hand side of the picture is

315
00:11:12,310 --> 00:11:09,920
limiting also to crop plants and so we

316
00:11:14,470 --> 00:11:12,320
add a lot of phosphorus and fertilizer

317
00:11:16,949 --> 00:11:14,480
and in fact phosphorus based fertilizers

318
00:11:18,630 --> 00:11:16,959
are one of the the the pillars of the

319
00:11:19,829 --> 00:11:18,640
green revolution so phosphorus is

320
00:11:21,190 --> 00:11:19,839
limiting in a lot of different

321
00:11:23,030 --> 00:11:21,200
ecosystems and it's limiting for the

322
00:11:25,190 --> 00:11:23,040
reasons that police have described

323
00:11:27,430 --> 00:11:25,200
because life as we know it organisms

324
00:11:29,670 --> 00:11:27,440
that we know around us rely on

325
00:11:31,430 --> 00:11:29,680
phosphorus to build nucleic acids and

326
00:11:33,670 --> 00:11:31,440
other molecules that they need to grow

327
00:11:36,150 --> 00:11:33,680
and proliferate so phosphorus is well

328
00:11:38,069 --> 00:11:36,160
known to be extremely important for all

329
00:11:39,269 --> 00:11:38,079
kinds of organisms and ecological

330
00:11:41,750 --> 00:11:39,279
systems

331
00:11:43,269 --> 00:11:41,760
so if we're going down to the next one

332
00:11:45,829 --> 00:11:43,279
because phosphorus is limiting and

333
00:11:47,910 --> 00:11:45,839
everything needs it it often turns out

334
00:11:50,150 --> 00:11:47,920
also that when phosphorus leaks out of

335
00:11:52,550 --> 00:11:50,160
systems like out of agricultural fields

336
00:11:54,710 --> 00:11:52,560
or out of cities or such it functions as

337
00:11:56,230 --> 00:11:54,720
a pollutant and here you can see a lake

338
00:11:58,790 --> 00:11:56,240

on the bottom half has received

339
00:12:00,470 --> 00:11:58,800
phosphorus on the top side has only

340
00:12:02,069 --> 00:12:00,480
received carbon and nitrogen the bottom

341
00:12:04,470 --> 00:12:02,079
side has received carbon nitrogen and

342
00:12:06,389 --> 00:12:04,480
phosphorus so phosphorus is necessary to

343
00:12:08,069 --> 00:12:06,399
have massive algal blooms that lead to

344
00:12:10,310 --> 00:12:08,079
the greening of lakes like this and

345
00:12:12,949 --> 00:12:10,320
eutrophication so phosphorus is a big

346
00:12:15,030 --> 00:12:12,959
issue for sustainability uh and aquatic

347
00:12:16,790 --> 00:12:15,040
uh the quad the quality of aquatic

348
00:12:18,470 --> 00:12:16,800
ecosystems so we know that phosphorus

349
00:12:20,870 --> 00:12:18,480
because it's limiting because it's so

350
00:12:23,430 --> 00:12:20,880
important organisms often functions as a

351
00:12:24,389 --> 00:12:23,440
pollutant when it leaves human human

352
00:12:26,949 --> 00:12:24,399
hands

353
00:12:28,550 --> 00:12:26,959
now we go on to the next slide we can

354
00:12:30,550 --> 00:12:28,560
also start to talk about where does this

355
00:12:32,710 --> 00:12:30,560
phosphorus come from that we use in

356
00:12:35,430 --> 00:12:32,720
fertilizer well it comes from just a few

357
00:12:37,910 --> 00:12:35,440
places around earth it comes from mines

358
00:12:40,550 --> 00:12:37,920
of phosphorite deposits that were built

359
00:12:43,350 --> 00:12:40,560
up over tens of and hundreds of millions

360
00:12:44,790 --> 00:12:43,360
of years by biological processes these

361
00:12:47,750 --> 00:12:44,800
mines are located in just a few

362
00:12:49,509 --> 00:12:47,760
countries around the world the american

363
00:12:51,350 --> 00:12:49,519

the united states has phosphorus

364
00:12:53,750 --> 00:12:51,360
reserves in florida and north carolina

365
00:12:56,150 --> 00:12:53,760
that are rapidly being depleted because

366
00:12:58,870 --> 00:12:56,160
of fertilizer consumption morocco has

367
00:13:00,150 --> 00:12:58,880
major phosphorus reserves as does china

368
00:13:02,230 --> 00:13:00,160
but the

369
00:13:05,030 --> 00:13:02,240
distribution of this resource is

370
00:13:07,269 --> 00:13:05,040
relatively scarce around our planet and

371
00:13:10,069 --> 00:13:07,279
so because of this scarcity and its

372
00:13:12,470 --> 00:13:10,079
geographic distribution and because of

373
00:13:14,629 --> 00:13:12,480
the burgeoning demand for phosphorus

374
00:13:17,030 --> 00:13:14,639
fertilizer there's some concern and we

375
00:13:19,750 --> 00:13:17,040
can see the next slide please um

376
00:13:21,190 --> 00:13:19,760
among scientists that the supplies of

377
00:13:23,030 --> 00:13:21,200
phosphorus that support the green

378
00:13:25,670 --> 00:13:23,040
revolution and high agricultural

379
00:13:28,470 --> 00:13:25,680
production might become scarce at least

380
00:13:29,910 --> 00:13:28,480
supplies of cheap phosphorus and so we

381
00:13:32,150 --> 00:13:29,920
need to get a lot cleverer about

382
00:13:33,670 --> 00:13:32,160
phosphorus in society and it's really

383
00:13:36,310 --> 00:13:33,680
exciting to think about the

384
00:13:39,189 --> 00:13:36,320
possibilities that are raised by the a

385
00:13:41,350 --> 00:13:39,199
clever organism that has evolved a way

386
00:13:43,269 --> 00:13:41,360
to do without phosphorus possibly as

387
00:13:45,350 --> 00:13:43,279
we're talking about uh today so we're

388
00:13:47,590 --> 00:13:45,360

going to the next slide so as i think

389
00:13:49,990 --> 00:13:47,600
about the

390
00:13:51,829 --> 00:13:50,000
the ramifications for the possibility of

391
00:13:54,389 --> 00:13:51,839
an organism that doesn't use phosphorus

392
00:13:56,310 --> 00:13:54,399
the the possibilities start to run away

393
00:13:57,910 --> 00:13:56,320
to think about how it might be used in

394
00:13:59,990 --> 00:13:57,920
wastewater treatment how it might be

395
00:14:02,069 --> 00:14:00,000
using recovering phosphorus

396
00:14:03,990 --> 00:14:02,079
from various sources how it might be

397
00:14:07,110 --> 00:14:04,000
used in bioenergy production and other

398
00:14:09,030 --> 00:14:07,120
sorts of possibilities so really uh

399
00:14:11,509 --> 00:14:09,040
we have a new way of thinking now if

400
00:14:13,910 --> 00:14:11,519
this uh if this study holds up that

401
00:14:16,389 --> 00:14:13,920
there are organisms that are possibly

402
00:14:18,949 --> 00:14:16,399
able to grow without phosphorus

403
00:14:20,470 --> 00:14:18,959
and as someone who studied phosphorus

404
00:14:22,870 --> 00:14:20,480
for my entire

405
00:14:24,550 --> 00:14:22,880
career essentially and who regularly

406
00:14:26,949 --> 00:14:24,560
gives lectures about phosphorus in which

407
00:14:29,670 --> 00:14:26,959
i state that every living thing uses

408
00:14:32,069 --> 00:14:29,680
phosphorus to build its dna

409
00:14:33,990 --> 00:14:32,079
the idea that i'm sitting here today

410
00:14:35,110 --> 00:14:34,000
discussing the possibility that that's

411
00:14:37,189 --> 00:14:35,120
not true

412
00:14:39,829 --> 00:14:37,199
is quite shocking so felisa i have to

413
00:14:41,590 --> 00:14:39,839

thank you and blame you for making our

414
00:14:43,829 --> 00:14:41,600
lives somewhat

415
00:14:45,269 --> 00:14:43,839
more difficult so it really is quite a

416
00:14:47,829 --> 00:14:45,279
remarkable

417
00:14:50,150 --> 00:14:47,839
report in the context of how of what we

418
00:14:52,949 --> 00:14:50,160
know about phosphorus and its importance

419
00:14:54,870 --> 00:14:52,959
in ecosystems

420
00:14:56,230 --> 00:14:54,880
so thank you jim it sounds to me like

421
00:14:57,910 --> 00:14:56,240
you're going to need to go out and find

422
00:15:00,069 --> 00:14:57,920
a new textbook to teach all those

423
00:15:03,509 --> 00:15:00,079
students about uh what build what

424
00:15:04,949 --> 00:15:03,519
elements are used to build life

425
00:15:06,710 --> 00:15:04,959
well i don't know about a whole new

426
00:15:08,389 --> 00:15:06,720
textbook but certainly some paragraphs

427
00:15:10,790 --> 00:15:08,399
and sentences are going to have to be uh

428
00:15:12,629 --> 00:15:10,800
rewritten as of today give me some time

429
00:15:14,790 --> 00:15:12,639
jim i'm at the beginning of my career so

430
00:15:16,389 --> 00:15:14,800
uh see you in the back end of that okay

431
00:15:18,629 --> 00:15:16,399
police out

432
00:15:20,069 --> 00:15:18,639
i'll be happy to review it i'll i'll

433
00:15:21,990 --> 00:15:20,079
get started

434
00:15:25,670 --> 00:15:22,000
great thank you jim

435
00:15:27,110 --> 00:15:25,680
our next speaker is dr stephen benner

436
00:15:29,350 --> 00:15:27,120
from the

437
00:15:32,069 --> 00:15:29,360
founder and distinguished fellow

438
00:15:33,269 --> 00:15:32,079

from the foundation of applied molecular

439
00:15:36,230 --> 00:15:33,279
evolution

440
00:15:39,110 --> 00:15:36,240
and he spent a lot of his life uh

441
00:15:41,590 --> 00:15:39,120
as an organic chemist and just in

442
00:15:43,509 --> 00:15:41,600
studying the chemistry of life um what

443
00:15:45,910 --> 00:15:43,519
are your thoughts well i'm i'm the

444
00:15:47,749 --> 00:15:45,920
curmudgeon here i'm the chemist who has

445
00:15:49,910 --> 00:15:47,759
been brought in as felicia knows to

446
00:15:52,470 --> 00:15:49,920
throw wet blankets on things and to try

447
00:15:55,110 --> 00:15:52,480
to damp a little bit the enthusiasm

448
00:15:57,509 --> 00:15:55,120
my next three minutes will be successful

449
00:15:59,910 --> 00:15:57,519
if i convey to you folks

450
00:16:01,350 --> 00:15:59,920
uh why chemists think that this is an

451
00:16:04,150 --> 00:16:01,360
exceptional result

452
00:16:06,710 --> 00:16:04,160
and why therefore chemists will like

453
00:16:09,430 --> 00:16:06,720
carl sagan says require exceptional

454
00:16:11,269 --> 00:16:09,440
evidence support it and

455
00:16:13,509 --> 00:16:11,279
i also want to make sure you folks

456
00:16:15,590 --> 00:16:13,519
understand why we nonetheless find it

457
00:16:17,910 --> 00:16:15,600
interesting on what felicia has found of

458
00:16:18,949 --> 00:16:17,920
course is a microbe that grows

459
00:16:21,030 --> 00:16:18,959
in the

460
00:16:23,509 --> 00:16:21,040
environment which has a lot of arsenic

461
00:16:25,430 --> 00:16:23,519
and very little phosphorus

462
00:16:27,670 --> 00:16:25,440
the astrobiology institute which we are

463
00:16:29,189 --> 00:16:27,680

parts of uh are is the one place in

464
00:16:31,670 --> 00:16:29,199
american science where you can go to

465
00:16:33,829 --> 00:16:31,680
find geologists and microbiologists and

466
00:16:35,189 --> 00:16:33,839
astronomers and chemists together where

467
00:16:38,069 --> 00:16:35,199
we can have the

468
00:16:40,629 --> 00:16:38,079
productive clash that leads to big

469
00:16:42,710 --> 00:16:40,639
discoveries about big questions what is

470
00:16:44,790 --> 00:16:42,720
life what could alien life look like and

471
00:16:46,629 --> 00:16:44,800
so my goal in the next 30 seconds or so

472
00:16:48,470 --> 00:16:46,639
is to try to give you as a layman the

473
00:16:50,069 --> 00:16:48,480
understanding of how

474
00:16:51,509 --> 00:16:50,079
this is an exceptional result how it

475
00:16:52,790 --> 00:16:51,519
might be

476
00:16:54,629 --> 00:16:52,800
looked at in greater detail because one

477
00:16:56,069 --> 00:16:54,639
thing that will survive is the felices

478
00:16:58,150 --> 00:16:56,079
microbe and that will be an excellent

479
00:17:00,470 --> 00:16:58,160
system to explore questions about how

480
00:17:02,069 --> 00:17:00,480
arsenic is tolerated and phosphorus is

481
00:17:03,749 --> 00:17:02,079
limited in organisms that are placed

482
00:17:06,230 --> 00:17:03,759
under environmental stress so i brought

483
00:17:08,710 --> 00:17:06,240
my my richard feynman props with me and

484
00:17:11,110 --> 00:17:08,720
which is a representation of a molecule

485
00:17:12,710 --> 00:17:11,120
right and these molecules are say

486
00:17:15,909 --> 00:17:12,720
representing a biopolymer and of course

487
00:17:18,470 --> 00:17:15,919
we're making them out of steel

488
00:17:20,470 --> 00:17:18,480

and the result is it's tough

489
00:17:22,949 --> 00:17:20,480
right and of course as felicia has

490
00:17:26,390 --> 00:17:22,959
mentioned arsenate

491
00:17:28,390 --> 00:17:26,400
is made out of in this particular case

492
00:17:30,230 --> 00:17:28,400
aluminum foil

493
00:17:31,510 --> 00:17:30,240
and of course it's not as tough as steel

494
00:17:33,510 --> 00:17:31,520
but when

495
00:17:35,990 --> 00:17:33,520
a bacteria is going to try to form a new

496
00:17:37,750 --> 00:17:36,000
chain it's going to try to find in

497
00:17:39,029 --> 00:17:37,760
the environment the links that go to

498
00:17:40,390 --> 00:17:39,039
form the chain and of course if there's

499
00:17:42,470 --> 00:17:40,400
arsenate around

500
00:17:44,710 --> 00:17:42,480
as a weak link it will may be confused

501
00:17:47,190 --> 00:17:44,720
and may be deceived by the structure of

502
00:17:49,750 --> 00:17:47,200
arsenate and the similarities to join

503
00:17:52,230 --> 00:17:49,760
two chains together not by a steel chain

504
00:17:53,990 --> 00:17:52,240
but rather by an arsenate chain and of

505
00:17:55,990 --> 00:17:54,000
course these are compounds that have

506
00:17:57,510 --> 00:17:56,000
been studied in model form the specific

507
00:17:58,870 --> 00:17:57,520
arsenate dna has actually never been

508
00:18:00,870 --> 00:17:58,880
isolated but there are compounds that

509
00:18:03,270 --> 00:18:00,880
are similar to it different kinds of

510
00:18:05,350 --> 00:18:03,280
atoms but still carbon oxygen arsenic

511
00:18:06,950 --> 00:18:05,360
oxygen carbon linkages and so we know

512
00:18:08,950 --> 00:18:06,960
they're relatively unstable they fall

513
00:18:11,350 --> 00:18:08,960

apart with half-lives measured in the

514
00:18:13,029 --> 00:18:11,360
order of minutes conveniently and so

515
00:18:15,029 --> 00:18:13,039
when you try to put them into a dna

516
00:18:16,230 --> 00:18:15,039
molecule right and then you put it under

517
00:18:17,990 --> 00:18:16,240
stress they fall apart and then of

518
00:18:19,669 --> 00:18:18,000
course your biological system says oh my

519
00:18:21,830 --> 00:18:19,679
god i've just destroyed my molecule i've

520
00:18:23,510 --> 00:18:21,840
got to go back again so again if there's

521
00:18:25,350 --> 00:18:23,520
arsenate in the environment right you

522
00:18:27,669 --> 00:18:25,360
can get the story you waste a lot of

523
00:18:28,950 --> 00:18:27,679
energy and a lot of time trying to put

524
00:18:31,590 --> 00:18:28,960
into

525
00:18:33,510 --> 00:18:31,600
a dna backbone arsenate where if the

526
00:18:36,310 --> 00:18:33,520
arsenate ester falls apart you're

527
00:18:38,070 --> 00:18:36,320
effectively saying that arsenate is the

528
00:18:40,470 --> 00:18:38,080
i guess we call it the wolf

529
00:18:43,510 --> 00:18:40,480
demon wolf or demon sheep in sheep's

530
00:18:45,029 --> 00:18:43,520
clothing it fools the enzymes into

531
00:18:46,470 --> 00:18:45,039
taking it instead of what it should take

532
00:18:48,230 --> 00:18:46,480
there are two ways that biological

533
00:18:50,549 --> 00:18:48,240
systems in general can manage this one

534
00:18:52,950 --> 00:18:50,559
way of course is to get very good at

535
00:18:54,830 --> 00:18:52,960
distinguishing between sheep and wolves

536
00:18:56,150 --> 00:18:54,840
in sheep's clothing and

537
00:18:58,470 --> 00:18:56,160
therefore uh

538
00:19:00,070 --> 00:18:58,480

distribution well the the end result is

539
00:19:02,150 --> 00:19:00,080
of course that you don't get fooled by

540
00:19:03,990 --> 00:19:02,160
the analog the other possibility it's

541
00:19:07,110 --> 00:19:04,000
also conceivable that the biological

542
00:19:09,190 --> 00:19:07,120
system can have evolved to manage

543
00:19:11,430 --> 00:19:09,200
the weak link and they might manage the

544
00:19:12,950 --> 00:19:11,440
weak link by for example binding

545
00:19:15,350 --> 00:19:12,960
something to the weak length

546
00:19:17,430 --> 00:19:15,360
sequestering it keeping it tight but the

547
00:19:19,350 --> 00:19:17,440
difficulty that we're having or like

548
00:19:21,190 --> 00:19:19,360
almost anybody with chemistry who is

549
00:19:23,750 --> 00:19:21,200
familiar with this literature will say

550
00:19:26,549 --> 00:19:23,760
is well wait a minute this dna molecule

551
00:19:27,909 --> 00:19:26,559
has allegedly been isolated

552
00:19:30,549 --> 00:19:27,919
away from the other molecules in the

553
00:19:32,549 --> 00:19:30,559
biological system so we remember all

554
00:19:33,909 --> 00:19:32,559
this old chemistry

555
00:19:35,669 --> 00:19:33,919
and we don't believe it and that's what

556
00:19:37,430 --> 00:19:35,679
you're going to see a lot of people say

557
00:19:39,029 --> 00:19:37,440
now keep in mind old chemistry can be

558
00:19:40,950 --> 00:19:39,039
wrong and in fact one of the wonderful

559
00:19:43,110 --> 00:19:40,960
things about being in a science is as

560
00:19:44,950 --> 00:19:43,120
richard feynman would say science begins

561
00:19:46,549 --> 00:19:44,960
when you distrust experts and of course

562
00:19:48,310 --> 00:19:46,559
as the expert in chemistry i'm saying

563
00:19:50,630 --> 00:19:48,320

that you should distrust me but the

564
00:19:52,150 --> 00:19:50,640
bottom line out of all this is that

565
00:19:54,950 --> 00:19:52,160
what you're looking at here is an

566
00:19:57,270 --> 00:19:54,960
exceptional claim based on the context

567
00:19:58,870 --> 00:19:57,280
of the chemistry and of course when we

568
00:20:00,390 --> 00:19:58,880
can go into great details about what

569
00:20:01,909 --> 00:20:00,400
experiments you might do in the future

570
00:20:04,310 --> 00:20:01,919
to explore this but what felice has

571
00:20:06,230 --> 00:20:04,320
produced is a very very useful system to

572
00:20:09,510 --> 00:20:06,240
ask these kind of questions one last

573
00:20:11,190 --> 00:20:09,520
point remember the weakness of the link

574
00:20:13,510 --> 00:20:11,200
is a weakness measured at room

575
00:20:16,789 --> 00:20:13,520
temperature

576
00:20:18,710 --> 00:20:16,799
35 37 degrees centigrade 98.6 degrees

577
00:20:20,870 --> 00:20:18,720
fahrenheit in water

578
00:20:23,110 --> 00:20:20,880
if you go to an exotic environment and

579
00:20:24,630 --> 00:20:23,120
the national academy of sciences looked

580
00:20:25,990 --> 00:20:24,640
produced a book which is actually you

581
00:20:27,430 --> 00:20:26,000
can go have is coming out of the

582
00:20:29,909 --> 00:20:27,440
national research council called the

583
00:20:31,750 --> 00:20:29,919
limits of life and organic of a light of

584
00:20:33,830 --> 00:20:31,760
limits of organic life and planetary

585
00:20:36,070 --> 00:20:33,840
systems you realize that in our solar

586
00:20:37,590 --> 00:20:36,080
system there are places titan a moon of

587
00:20:39,430 --> 00:20:37,600
saturn is one of them where the

588
00:20:41,430 --> 00:20:39,440

temperature is much lower

589
00:20:43,990 --> 00:20:41,440
where very reactive species like

590
00:20:46,390 --> 00:20:44,000
arsenate could very well be useful

591
00:20:48,549 --> 00:20:46,400
because although they are too unstable

592
00:20:50,630 --> 00:20:48,559
to exist in many environments on earth

593
00:20:53,190 --> 00:20:50,640
they're not too unstable to exist in an

594
00:20:55,830 --> 00:20:53,200
environment like titan which is at minus

595
00:20:57,430 --> 00:20:55,840
290 degrees fahrenheit so it's a cold

596
00:20:59,110 --> 00:20:57,440
environment in fact you might very well

597
00:21:00,630 --> 00:20:59,120
want to have the increased reactivity of

598
00:21:02,230 --> 00:21:00,640
arsenic in that environment just to get

599
00:21:04,950 --> 00:21:02,240
the reactions as you want to make your

600
00:21:06,870 --> 00:21:04,960
biopolymer chains go a little bit faster

601
00:21:09,909 --> 00:21:06,880
so again

602
00:21:11,590 --> 00:21:09,919
my role as the curmudgeon is to say

603
00:21:13,669 --> 00:21:11,600
this is an exceptional result i hope i

604
00:21:15,350 --> 00:21:13,679
can convey to you a little bit maybe not

605
00:21:17,669 --> 00:21:15,360
in technical language but in graphic

606
00:21:20,070 --> 00:21:17,679
language why the chemist views this as

607
00:21:22,149 --> 00:21:20,080
an exceptional result and so

608
00:21:24,310 --> 00:21:22,159
you will understand why in nasa

609
00:21:25,990 --> 00:21:24,320
astrobiology program over the years as

610
00:21:28,630 --> 00:21:26,000
these various disciplines for chemists

611
00:21:30,390 --> 00:21:28,640
and who are the doubters or the deniers

612
00:21:32,870 --> 00:21:30,400
the microbiologists the geologists will

613
00:21:35,029 --> 00:21:32,880

interact in a way to bring forward the

614
00:21:36,870 --> 00:21:35,039
process that science is which is of

615
00:21:38,870 --> 00:21:36,880
course the clash of contradicting

616
00:21:40,230 --> 00:21:38,880
cultures in an effort to come

617
00:21:42,230 --> 00:21:40,240
up with the truth

618
00:21:43,669 --> 00:21:42,240
to inspire of course americans youth to

619
00:21:45,510 --> 00:21:43,679
go through the effort of studying

620
00:21:46,470 --> 00:21:45,520
science so they knowing full well that

621
00:21:47,669 --> 00:21:46,480
there are these kinds of very

622
00:21:49,669 --> 00:21:47,679
interesting questions out there like

623
00:21:51,110 --> 00:21:49,679
what is life and where might we find it

624
00:21:52,630 --> 00:21:51,120
if not on earth

625
00:21:53,590 --> 00:21:52,640
thank you steve i have a question for

626
00:21:55,430 --> 00:21:53,600
you so

627
00:21:56,870 --> 00:21:55,440
would you as an organic chemist consider

628
00:21:59,750 --> 00:21:56,880
replacing your graduate students with

629
00:22:01,110 --> 00:21:59,760
microbes um there are many reactions

630
00:22:03,430 --> 00:22:01,120
many of my graduate students are

631
00:22:06,630 --> 00:22:03,440
undoubtedly watching i love you all i

632
00:22:09,270 --> 00:22:06,640
wouldn't think of replacing it

633
00:22:12,470 --> 00:22:09,280
fair enough answer

634
00:22:14,310 --> 00:22:12,480
okay our next speaker is dr pan conrad

635
00:22:16,470 --> 00:22:14,320
she is a planetary scientist at the

636
00:22:19,350 --> 00:22:16,480
goddard space flight center and also the

637
00:22:21,270 --> 00:22:19,360
deputy pion investigation that will be

638
00:22:23,270 --> 00:22:21,280

flown on the mars science laboratory to

639
00:22:26,789 --> 00:22:23,280
be launched in a year from now it's the

640
00:22:29,669 --> 00:22:26,799
first astrobiology mission since viking

641
00:22:31,830 --> 00:22:29,679
and which is whose goal is to

642
00:22:34,149 --> 00:22:31,840
look for evidence of habitability and

643
00:22:35,990 --> 00:22:34,159
the potential for for current and past

644
00:22:37,270 --> 00:22:36,000
life on mars

645
00:22:39,110 --> 00:22:37,280
please pan

646
00:22:41,750 --> 00:22:39,120
well i don't think i'm going to class on

647
00:22:43,190 --> 00:22:41,760
my classify myself either as curmudgeon

648
00:22:46,470 --> 00:22:43,200
or otherwise

649
00:22:48,549 --> 00:22:46,480
my role in the astrobiology spectrum is

650
00:22:50,470 --> 00:22:48,559
to think about how we might predict the

651
00:22:53,190 --> 00:22:50,480
habitability of environments off the

652
00:22:55,430 --> 00:22:53,200
earth and the way i go about that is to

653
00:22:58,230 --> 00:22:55,440
see what i can learn about environments

654
00:22:59,750 --> 00:22:58,240
on the earth and try to develop metrics

655
00:23:02,549 --> 00:22:59,760
for habitability

656
00:23:06,149 --> 00:23:02,559
so i find this result delightful because

657
00:23:08,710 --> 00:23:06,159
it makes me have to expand my notion of

658
00:23:11,029 --> 00:23:08,720
what environmental constituents

659
00:23:13,270 --> 00:23:11,039
might enable habitability

660
00:23:15,830 --> 00:23:13,280
so for example if you just think about

661
00:23:18,390 --> 00:23:15,840
an environment in terms of what it's

662
00:23:20,789 --> 00:23:18,400
made of and how those things are

663
00:23:22,950 --> 00:23:20,799

arranged you have a concept of an

664
00:23:24,390 --> 00:23:22,960
environment just like the chemical

665
00:23:26,390 --> 00:23:24,400
environment

666
00:23:28,950 --> 00:23:26,400
everything is a function of its

667
00:23:31,029 --> 00:23:28,960
constituents and how they're arranged

668
00:23:34,470 --> 00:23:31,039
so what is really interesting about this

669
00:23:36,870 --> 00:23:34,480
result is if you can make a biomolecule

670
00:23:38,549 --> 00:23:36,880
that has substitutions in it

671
00:23:41,350 --> 00:23:38,559
the properties have to change as a

672
00:23:43,669 --> 00:23:41,360
function of new constituents so it opens

673
00:23:45,510 --> 00:23:43,679
up a whole new line of questioning what

674
00:23:47,510 --> 00:23:45,520
might those changes be

675
00:23:49,590 --> 00:23:47,520
what do they pretend for the evolution

676
00:23:52,070 --> 00:23:49,600
of that chemistry what do they mean

677
00:23:54,310 --> 00:23:52,080
about the environment and by the same

678
00:23:56,870 --> 00:23:54,320
token we might learn something new about

679
00:23:59,190 --> 00:23:56,880
habitable environments by understanding

680
00:24:01,750 --> 00:23:59,200
how organisms that are there adapt to

681
00:24:03,350 --> 00:24:01,760
the presence of new or limited chemical

682
00:24:05,909 --> 00:24:03,360
constituents

683
00:24:07,750 --> 00:24:05,919
with respect to space exploration this

684
00:24:10,630 --> 00:24:07,760
is a very interesting result again

685
00:24:12,789 --> 00:24:10,640
because the implication is that we still

686
00:24:14,390 --> 00:24:12,799
don't know everything there is to know

687
00:24:16,470 --> 00:24:14,400
about what might make a habitable

688
00:24:19,110 --> 00:24:16,480

environment on another planet or a

689
00:24:21,990 --> 00:24:19,120
satellite of another planet we have to

690
00:24:24,710 --> 00:24:22,000
increasingly broaden our perspective

691
00:24:27,350 --> 00:24:24,720
so perhaps arsenic is not an essential

692
00:24:30,230 --> 00:24:27,360
component for habitability or for life

693
00:24:32,390 --> 00:24:30,240
but it may be one that can be tolerated

694
00:24:34,789 --> 00:24:32,400
and that opens up our perspective to try

695
00:24:37,269 --> 00:24:34,799
to understand what other potential

696
00:24:39,269 --> 00:24:37,279
components might be tolerated or in fact

697
00:24:40,950 --> 00:24:39,279
even essential that we presently haven't

698
00:24:42,789 --> 00:24:40,960
thought of

699
00:24:45,510 --> 00:24:42,799
thank you very much so i'd like to bring

700
00:24:47,590 --> 00:24:45,520
this all around and back to felicia

701
00:24:49,830 --> 00:24:47,600
for her to put her findings in a broader

702
00:24:51,990 --> 00:24:49,840
context for us and remind us of exactly

703
00:24:53,430 --> 00:24:52,000
what they are and their importance

704
00:24:54,870 --> 00:24:53,440
so let's remind us what we've learned

705
00:24:56,710 --> 00:24:54,880
here today

706
00:24:58,070 --> 00:24:56,720
i'm interested in exceptions and i think

707
00:25:00,390 --> 00:24:58,080
many of us are interested in those

708
00:25:02,149 --> 00:25:00,400
exceptions to the rules why are things

709
00:25:03,990 --> 00:25:02,159
constant in nature

710
00:25:04,870 --> 00:25:04,000
that keeps me up at night

711
00:25:07,110 --> 00:25:04,880
why

712
00:25:08,950 --> 00:25:07,120
i was probably a very difficult child in

713
00:25:11,029 --> 00:25:08,960

junior high in high school

714
00:25:13,110 --> 00:25:11,039
but what i'll say is that that kind of

715
00:25:15,990 --> 00:25:13,120
openness to questions is part of what i

716
00:25:18,149 --> 00:25:16,000
want i hope that the work of myself and

717
00:25:20,470 --> 00:25:18,159
my team that produce this but i want to

718
00:25:22,630 --> 00:25:20,480
really reiterate it is not about arsenic

719
00:25:24,950 --> 00:25:22,640
and this isn't about mono lake it's

720
00:25:27,909 --> 00:25:24,960
about thinking about life in a planetary

721
00:25:29,990 --> 00:25:27,919
context and asking questions simple

722
00:25:31,669 --> 00:25:30,000
questions with a simple experimental

723
00:25:34,390 --> 00:25:31,679
design

724
00:25:35,990 --> 00:25:34,400
and so in like a bigger scale

725
00:25:38,470 --> 00:25:36,000
let's go from the small and then we'll

726
00:25:40,870 --> 00:25:38,480
go into the abstract

727
00:25:42,390 --> 00:25:40,880
all life on earth required

728
00:25:46,549 --> 00:25:42,400
carbon nitrogen

729
00:25:48,470 --> 00:25:46,559
oxygen hydrogen phosphorus and sulfur

730
00:25:50,230 --> 00:25:48,480
so i've shown here today

731
00:25:52,470 --> 00:25:50,240
that we've discovered a microbe that can

732
00:25:54,230 --> 00:25:52,480
substitute arsenic for phosphorus in its

733
00:25:57,350 --> 00:25:54,240
major biomolecules

734
00:25:58,710 --> 00:25:57,360
not just dna but things like atp that

735
00:26:01,029 --> 00:25:58,720
many of those high school students out

736
00:26:03,430 --> 00:26:01,039
there i hope recognize and also all

737
00:26:05,110 --> 00:26:03,440
sorts of other biomolecules

738
00:26:08,230 --> 00:26:05,120

what does that suggest

739
00:26:10,390 --> 00:26:08,240
it cracks open the door to the potential

740
00:26:12,149 --> 00:26:10,400
you know my niece asks me

741
00:26:14,230 --> 00:26:12,159
how did we get here

742
00:26:15,669 --> 00:26:14,240
and are we alone in the universe and

743
00:26:17,750 --> 00:26:15,679
it's profound that we don't know the

744
00:26:19,590 --> 00:26:17,760
answers exactly to that yet

745
00:26:21,909 --> 00:26:19,600
maybe not in my lifetime but maybe in

746
00:26:23,430 --> 00:26:21,919
her lifetime she'll be able to

747
00:26:25,750 --> 00:26:23,440
to be able to answer that but i hope my

748
00:26:28,549 --> 00:26:25,760
work serves as a proof of concept that

749
00:26:30,710 --> 00:26:28,559
we can experimentally test

750
00:26:31,909 --> 00:26:30,720
and show evidence of what else is

751
00:26:33,510 --> 00:26:31,919
possible

752
00:26:34,710 --> 00:26:33,520
so i'd like to roll

753
00:26:36,470 --> 00:26:34,720
some footage

754
00:26:39,190 --> 00:26:36,480
just to give us the expansive nature of

755
00:26:42,390 --> 00:26:39,200
life from microbes to crustacea

756
00:26:45,350 --> 00:26:42,400
to bugs to mammals to everything you

757
00:26:47,110 --> 00:26:45,360
know that's alive on planet earth again

758
00:26:48,470 --> 00:26:47,120
hearkening back to the idea of the pale

759
00:26:50,390 --> 00:26:48,480
blue dot

760
00:26:52,549 --> 00:26:50,400
understanding life here

761
00:26:53,909 --> 00:26:52,559
all sorts of life lions and tigers

762
00:26:56,149 --> 00:26:53,919
embarrassed

763
00:26:58,470 --> 00:26:56,159

and how everything we know is on this

764
00:27:01,430 --> 00:26:58,480
tree of life

765
00:27:03,269 --> 00:27:01,440
everything you've ever thought of

766
00:27:06,070 --> 00:27:03,279
so far

767
00:27:07,909 --> 00:27:06,080
that we can see on this tree of life so

768
00:27:09,590 --> 00:27:07,919
what we're presenting here today

769
00:27:11,430 --> 00:27:09,600
is a member of this tree of life we're

770
00:27:14,149 --> 00:27:11,440
cracking open that door

771
00:27:16,470 --> 00:27:14,159
strain gfaj1 the bacterium

772
00:27:18,389 --> 00:27:16,480
is a different way to do business

773
00:27:20,149 --> 00:27:18,399
just to open the possibility to what

774
00:27:22,230 --> 00:27:20,159
else is possible it has solved the

775
00:27:24,230 --> 00:27:22,240
challenge of being alive in a very

776
00:27:26,310 --> 00:27:24,240
different way

777
00:27:28,470 --> 00:27:26,320
than than we knew of

778
00:27:30,070 --> 00:27:28,480
what other questions can we ask

779
00:27:31,990 --> 00:27:30,080
this will inform us about life on our

780
00:27:34,389 --> 00:27:32,000
own planet

781
00:27:36,549 --> 00:27:34,399
and it will help inform us of life we

782
00:27:37,590 --> 00:27:36,559
will find it one day elsewhere in the

783
00:27:39,269 --> 00:27:37,600
universe

784
00:27:42,789 --> 00:27:39,279
thank you

785
00:27:44,549 --> 00:27:42,799
going to turn it back over to you dwayne

786
00:27:47,269 --> 00:27:44,559
thank you all and felicia

787
00:27:49,029 --> 00:27:47,279
congratulations to you and your team

788
00:27:51,190 --> 00:27:49,039

okay ladies and gentlemen now

789
00:27:52,950 --> 00:27:51,200
we get to the question and answers to

790
00:27:54,630 --> 00:27:52,960
really even flush it out even more we're

791
00:27:56,549 --> 00:27:54,640
going to start here first

792
00:27:59,750 --> 00:27:56,559
and then go to the west coast i'm going

793
00:28:02,310 --> 00:27:59,760
to ask you to wait for the microphone

794
00:28:04,149 --> 00:28:02,320
give you a name and affiliation and

795
00:28:05,269 --> 00:28:04,159
obviously we have folks here and we also

796
00:28:06,789 --> 00:28:05,279
have a

797
00:28:08,630 --> 00:28:06,799
professor

798
00:28:10,230 --> 00:28:08,640
in arizona so if you can address your

799
00:28:12,070 --> 00:28:10,240
question to the appropriate person

800
00:28:20,870 --> 00:28:12,080
that'd be great

801
00:28:27,350 --> 00:28:25,029
thank you um and congratulations um

802
00:28:29,430 --> 00:28:27,360
what i what i'm intrigued by and trying

803
00:28:31,990 --> 00:28:29,440
to understand is um

804
00:28:35,029 --> 00:28:32,000
you refer here to substitution of the

805
00:28:37,269 --> 00:28:35,039
arsenic uh is there reason to believe

806
00:28:39,110 --> 00:28:37,279
that this was substitution that occurred

807
00:28:42,070 --> 00:28:39,120
in any kind of a time frame or is it

808
00:28:42,950 --> 00:28:42,080
possible that this is something that has

809
00:28:47,029 --> 00:28:42,960
been

810
00:28:48,789 --> 00:28:47,039
in the bacterium or in other bacteria

811
00:28:50,310 --> 00:28:48,799
going back to the beginning of time

812
00:28:51,909 --> 00:28:50,320
that's a great question

813
00:28:53,430 --> 00:28:51,919

and i think

814
00:28:55,510 --> 00:28:53,440
you know we'll have the next 30 years at

815
00:28:57,590 --> 00:28:55,520
least of my career and many others to to

816
00:28:59,269 --> 00:28:57,600
begin to probe that i think what it does

817
00:29:01,190 --> 00:28:59,279
suggest i'm saying substitution because

818
00:29:03,430 --> 00:29:01,200
we really just want to open this package

819
00:29:04,549 --> 00:29:03,440
to be able to think about what else life

820
00:29:06,789 --> 00:29:04,559
could be

821
00:29:08,950 --> 00:29:06,799
and as an early career scientist i think

822
00:29:10,710 --> 00:29:08,960
that's a safe way to go

823
00:29:13,029 --> 00:29:10,720
but in terms of whether i think if it

824
00:29:15,909 --> 00:29:13,039
just happened recently substituting for

825
00:29:17,269 --> 00:29:15,919
what was or how old this is i think we

826
00:29:18,549 --> 00:29:17,279
can begin to adjust those questions

827
00:29:19,669 --> 00:29:18,559
there's a number of experiments i can

828
00:29:20,710 --> 00:29:19,679
think of and i know many of my

829
00:29:22,470 --> 00:29:20,720
colleagues

830
00:29:24,310 --> 00:29:22,480
who have been familiar with this work

831
00:29:25,750 --> 00:29:24,320
for for a number of months now have

832
00:29:28,070 --> 00:29:25,760
suggested

833
00:29:29,669 --> 00:29:28,080
i what we can say and dangerously to

834
00:29:30,549 --> 00:29:29,679
speculate just a little bit if you let

835
00:29:31,590 --> 00:29:30,559
me

836
00:29:33,590 --> 00:29:31,600
is that

837
00:29:35,430 --> 00:29:33,600
phosphate and it's phosphate in

838
00:29:37,029 --> 00:29:35,440

biomolecules so phosphorus so and i'll

839
00:29:38,070 --> 00:29:37,039
go between those you'll have to pardon

840
00:29:40,310 --> 00:29:38,080
me

841
00:29:41,750 --> 00:29:40,320
on earth is locked up in rock so your

842
00:29:44,230 --> 00:29:41,760
bones are made of phosphate because it's

843
00:29:45,590 --> 00:29:44,240
a good idea and it's very

844
00:29:47,669 --> 00:29:45,600
one of the reasons it just doesn't do a

845
00:29:49,190 --> 00:29:47,679
lot of chemistry and in fact i hope that

846
00:29:51,830 --> 00:29:49,200
steve would agree and that phosphate

847
00:29:55,110 --> 00:29:51,840
chemistry is very difficult

848
00:29:57,110 --> 00:29:55,120
and we can speculate a little bit about

849
00:29:59,590 --> 00:29:57,120
can be very difficult

850
00:30:01,350 --> 00:29:59,600
we can speculate about and we have no

851
00:30:02,230 --> 00:30:01,360
evidence of how life yet to start that

852
00:30:04,630 --> 00:30:02,240
started

853
00:30:06,710 --> 00:30:04,640
okay given that there are a number of

854
00:30:08,870 --> 00:30:06,720
scientists who've proposed that in

855
00:30:10,870 --> 00:30:08,880
hydrothermal vent systems where we have

856
00:30:12,230 --> 00:30:10,880
a gradient so different chemicals coming

857
00:30:14,310 --> 00:30:12,240
together

858
00:30:15,990 --> 00:30:14,320
arsenic would have been available for

859
00:30:18,549 --> 00:30:16,000
prebiotic chemistry whether it was or

860
00:30:19,669 --> 00:30:18,559
not i i can't we can't speak to i wasn't

861
00:30:22,230 --> 00:30:19,679
there

862
00:30:23,830 --> 00:30:22,240
but it does chemistry rapidly it can do

863
00:30:25,350 --> 00:30:23,840

chemistry more rapidly

864
00:30:27,750 --> 00:30:25,360
so i think that

865
00:30:31,590 --> 00:30:27,760
it will be a fun thing to try and test

866
00:30:35,190 --> 00:30:33,590
randy shostak reporter with eos the

867
00:30:38,310 --> 00:30:35,200
newspaper of the american geophysical

868
00:30:41,669 --> 00:30:38,320
union how does and might this finding

869
00:30:42,710 --> 00:30:41,679
affect nasa's and others astrobiology

870
00:30:45,269 --> 00:30:42,720
programs

871
00:30:46,950 --> 00:30:45,279
including the mars science lab and other

872
00:30:50,630 --> 00:30:46,960
ongoing and planned missions and

873
00:30:54,070 --> 00:30:52,470
do you want me to you can start all

874
00:30:55,990 --> 00:30:54,080
right i'll start that

875
00:30:58,470 --> 00:30:56,000
with respect to

876
00:31:00,310 --> 00:30:58,480
mars science laboratory or in general

877
00:31:01,830 --> 00:31:00,320
the problem of studying habitability on

878
00:31:04,710 --> 00:31:01,840
other planets

879
00:31:06,549 --> 00:31:04,720
the way that one could be affected is to

880
00:31:08,870 --> 00:31:06,559
think more broadly about what sorts of

881
00:31:11,830 --> 00:31:08,880
environments one might characterize as

882
00:31:13,990 --> 00:31:11,840
habitable in specific with respect to

883
00:31:16,870 --> 00:31:14,000
experiments that we could do on mars

884
00:31:18,789 --> 00:31:16,880
science laboratory we do have payload

885
00:31:20,470 --> 00:31:18,799
investigations that can measure the

886
00:31:22,710 --> 00:31:20,480
chemical elements

887
00:31:24,630 --> 00:31:22,720
we do have a payload investigation that

888
00:31:27,269 --> 00:31:24,640

i'm associated with that can actually

889
00:31:30,310 --> 00:31:27,279
measure organic molecules

890
00:31:32,389 --> 00:31:30,320
so one way that you can tell

891
00:31:34,630 --> 00:31:32,399
what you have is by putting together a

892
00:31:36,630 --> 00:31:34,640
number of investigations and like all

893
00:31:38,630 --> 00:31:36,640
science independent lines of

894
00:31:39,669 --> 00:31:38,640
corroboration help you paint a bigger

895
00:31:41,269 --> 00:31:39,679
picture

896
00:31:43,110 --> 00:31:41,279
so for example on mars science

897
00:31:44,950 --> 00:31:43,120
laboratory if you had an environment

898
00:31:47,350 --> 00:31:44,960
that appeared to be rich in arsenic or

899
00:31:49,669 --> 00:31:47,360
some unanticipated metal

900
00:31:51,669 --> 00:31:49,679
and you also had a finding of organic

901
00:31:53,509 --> 00:31:51,679
molecules you could begin to put a

902
00:31:57,830 --> 00:31:53,519
picture together about what the

903
00:32:02,549 --> 00:32:00,149
and i'll take a shot at that um i think

904
00:32:04,070 --> 00:32:02,559
this finding points to a challenge that

905
00:32:05,830 --> 00:32:04,080
we've known we've had for a while

906
00:32:08,149 --> 00:32:05,840
clearly if we went to

907
00:32:10,310 --> 00:32:08,159
another planet and another body in in

908
00:32:12,789 --> 00:32:10,320
the universe and we saw a human we would

909
00:32:14,149 --> 00:32:12,799
recognize it as life

910
00:32:16,310 --> 00:32:14,159
and there are many other forms we could

911
00:32:18,149 --> 00:32:16,320
probably recognize the challenge of

912
00:32:20,230 --> 00:32:18,159
finding something that is significantly

913
00:32:22,710 --> 00:32:20,240

different than terrestrial life and life

914
00:32:23,590 --> 00:32:22,720
as we know it is really what

915
00:32:25,590 --> 00:32:23,600
um

916
00:32:27,029 --> 00:32:25,600
plagues us when we think about spending

917
00:32:28,470 --> 00:32:27,039
the money that we do

918
00:32:30,389 --> 00:32:28,480
developing the instruments that we do

919
00:32:32,070 --> 00:32:30,399
and sending them off on a mission and so

920
00:32:33,750 --> 00:32:32,080
i think it's been our strategy with the

921
00:32:35,990 --> 00:32:33,760
support of the scientific community to

922
00:32:38,149 --> 00:32:36,000
think as broadly as possible

923
00:32:41,269 --> 00:32:38,159
to put measurements that we may deem

924
00:32:43,830 --> 00:32:41,279
reasonable in a context so make the

925
00:32:46,310 --> 00:32:43,840
context of the environment to explore

926
00:32:49,110 --> 00:32:46,320
possibilities that are not so focused on

927
00:32:50,630 --> 00:32:49,120
a specific molecule for example

928
00:32:52,470 --> 00:32:50,640
we would not want to at this point

929
00:32:55,110 --> 00:32:52,480
necessarily go to look for specifically

930
00:32:57,190 --> 00:32:55,120
dna that had arsenic in its backbone we

931
00:32:59,830 --> 00:32:57,200
want to keep them very broad and keep

932
00:33:01,750 --> 00:32:59,840
our strategy and seeking signs of life

933
00:33:03,350 --> 00:33:01,760
open to the possibility of things we

934
00:33:06,389 --> 00:33:03,360
would hate to go somewhere and not see

935
00:33:10,070 --> 00:33:08,149
yes good morning good afternoon

936
00:33:13,110 --> 00:33:10,080
my name is luis fernando civapinto from

937
00:33:15,430 --> 00:33:13,120
tv global in brazil

938
00:33:19,190 --> 00:33:15,440

my curiosity is whether the door that

939
00:33:21,590 --> 00:33:19,200
you that you say has been open

940
00:33:26,470 --> 00:33:24,230
take scientists more in the direction of

941
00:33:29,190 --> 00:33:26,480
looking for different

942
00:33:33,669 --> 00:33:29,200
environments for life here on earth

943
00:33:38,710 --> 00:33:36,070
pick another element another medium

944
00:33:41,350 --> 00:33:38,720
other than arsenic which one would you

945
00:33:42,630 --> 00:33:41,360
explore first

946
00:33:43,990 --> 00:33:42,640
so i'll answer the back end of your

947
00:33:46,870 --> 00:33:44,000
question first

948
00:33:50,549 --> 00:33:46,880
and i'll tell you i have a lot of ideas

949
00:33:53,190 --> 00:33:50,559
and we all knew how ideas uh let's say

950
00:33:54,710 --> 00:33:53,200
propagated through the nets and so

951
00:33:56,789 --> 00:33:54,720
i'd love to talk to you offline about

952
00:33:58,149 --> 00:33:56,799
that but there's a lot you know i have a

953
00:34:00,070 --> 00:33:58,159
long career ahead and i have a lot of

954
00:34:01,830 --> 00:34:00,080
ideas i'd like to test

955
00:34:03,590 --> 00:34:01,840
so i think we have lots of questions in

956
00:34:05,509 --> 00:34:03,600
terms of other elemental substitutions

957
00:34:07,110 --> 00:34:05,519
other types of metabolism

958
00:34:09,750 --> 00:34:07,120
you know not just the way you make a

959
00:34:11,270 --> 00:34:09,760
cell but also the way the cells can can

960
00:34:13,510 --> 00:34:11,280
do their business

961
00:34:15,030 --> 00:34:13,520
so i i won't i won't really uh talk

962
00:34:17,589 --> 00:34:15,040
anymore about that right now but i'd say

963
00:34:19,510 --> 00:34:17,599

stay tuned for the next uh 15 to 30

964
00:34:20,710 --> 00:34:19,520
years let's say that

965
00:34:22,310 --> 00:34:20,720
that said the front end of your

966
00:34:25,270 --> 00:34:22,320
questions in terms of looking here on

967
00:34:27,270 --> 00:34:25,280
earth or elsewhere i think yes and yes

968
00:34:29,990 --> 00:34:27,280
i think that we can learn a lot here um

969
00:34:31,909 --> 00:34:30,000
not not just my work but many of the

970
00:34:34,149 --> 00:34:31,919
folks the other scientists supported in

971
00:34:35,829 --> 00:34:34,159
the astrobiology program and again

972
00:34:37,430 --> 00:34:35,839
astrobiology the study of life in a

973
00:34:39,030 --> 00:34:37,440
planetary context

974
00:34:41,669 --> 00:34:39,040
we don't want to be terran-centric

975
00:34:44,149 --> 00:34:41,679
earth-centric life in any planetary

976
00:34:45,349 --> 00:34:44,159
context or asteroid context or moon

977
00:34:46,710 --> 00:34:45,359
context

978
00:34:48,950 --> 00:34:46,720
i think that

979
00:34:50,069 --> 00:34:48,960
i think it's it's all very important and

980
00:34:51,829 --> 00:34:50,079
so

981
00:34:53,510 --> 00:34:51,839
uh i guess what i'd say is i'd be i'm

982
00:34:56,310 --> 00:34:53,520
happy to be involved in in both of those

983
00:34:59,109 --> 00:34:56,320
and i admit perhaps mary you want to

984
00:35:04,710 --> 00:35:00,829
that answers your

985
00:35:08,870 --> 00:35:06,150
give me your name affiliation please

986
00:35:09,829 --> 00:35:08,880
sure louisa villala from tv record in

987
00:35:12,470 --> 00:35:09,839
brazil

988
00:35:14,310 --> 00:35:12,480

um i was wondering um from what i

989
00:35:17,829 --> 00:35:14,320
understood you you now open two

990
00:35:20,390 --> 00:35:17,839
different doors uh here or many more but

991
00:35:22,550 --> 00:35:20,400
one is exploration life as we knew so

992
00:35:24,630 --> 00:35:22,560
expanding the idea what life is and

993
00:35:26,069 --> 00:35:24,640
where it can be sustained

994
00:35:27,430 --> 00:35:26,079
and the other that i was wondering if

995
00:35:29,670 --> 00:35:27,440
you could comment a little more is

996
00:35:31,990 --> 00:35:29,680
possible um

997
00:35:33,349 --> 00:35:32,000
applications here like the professor

998
00:35:34,710 --> 00:35:33,359
mentioned the

999
00:35:35,829 --> 00:35:34,720
um

1000
00:35:40,390 --> 00:35:35,839
water

1001
00:35:42,950 --> 00:35:40,400
phosphorus or what kind of other

1002
00:35:44,230 --> 00:35:42,960
possible applications you see

1003
00:35:46,230 --> 00:35:44,240
i think we're going to direct that to

1004
00:35:48,790 --> 00:35:46,240
jim since he introduced that and is our

1005
00:35:50,630 --> 00:35:48,800
phosphorus expert um jim are you still

1006
00:35:52,230 --> 00:35:50,640
with us

1007
00:35:53,829 --> 00:35:52,240
yeah i'm still here

1008
00:35:55,990 --> 00:35:53,839
so yeah

1009
00:35:58,069 --> 00:35:56,000
this is all new and spinning out so a

1010
00:36:00,470 --> 00:35:58,079
lot of things just come into your head

1011
00:36:02,710 --> 00:36:00,480
instantaneously so for example tying

1012
00:36:04,150 --> 00:36:02,720
together the bioenergy and the

1013
00:36:06,069 --> 00:36:04,160

phosphorus

1014
00:36:08,630 --> 00:36:06,079
sustainability issues so we know we have

1015
00:36:11,270 --> 00:36:08,640
to begin to develop

1016
00:36:13,030 --> 00:36:11,280
alternative bioenergy sources for uh

1017
00:36:15,030 --> 00:36:13,040
fossil fuels and so people are growing a

1018
00:36:17,510 --> 00:36:15,040
lot of plants and trying to figure out a

1019
00:36:20,150 --> 00:36:17,520
way to grow algae to make bioenergy but

1020
00:36:22,069 --> 00:36:20,160
all of the existing plants and

1021
00:36:23,670 --> 00:36:22,079
algae that we know of need fertilizer

1022
00:36:25,910 --> 00:36:23,680
themselves they need phosphorus

1023
00:36:28,950 --> 00:36:25,920
themselves so what if someone was clever

1024
00:36:32,230 --> 00:36:28,960
enough to be able to develop a bioenergy

1025
00:36:34,630 --> 00:36:32,240
creature a microorganism based on this

1026
00:36:36,550 --> 00:36:34,640
metabolism if it holds up that doesn't

1027
00:36:39,349 --> 00:36:36,560
need phosphorus so you don't need to

1028
00:36:41,750 --> 00:36:39,359
drain the fertilizer supply in order to

1029
00:36:43,589 --> 00:36:41,760
solve the bioenergy problem so we're a

1030
00:36:45,750 --> 00:36:43,599
long way off but i mean i would think

1031
00:36:47,270 --> 00:36:45,760
that this if this holds up and if we can

1032
00:36:49,430 --> 00:36:47,280
figure out a way to do it right then you

1033
00:36:52,069 --> 00:36:49,440
can have a whole bioenergy technology

1034
00:36:54,150 --> 00:36:52,079
that's based on an arsenate uh type

1035
00:36:55,910 --> 00:36:54,160
organism that's kind of science fiction

1036
00:37:00,069 --> 00:36:55,920
probably more realistic are things like

1037
00:37:01,589 --> 00:37:00,079
uh treating uh arsenate waste uh dumps

1038
00:37:03,190 --> 00:37:01,599

and this sort of thing to find organisms

1039
00:37:05,270 --> 00:37:03,200
that are capable of tolerating that or

1040
00:37:06,870 --> 00:37:05,280
in fact thriving on that as this one

1041
00:37:08,870 --> 00:37:06,880
does um so there seems to be

1042
00:37:11,430 --> 00:37:08,880
applications for for toxic waste

1043
00:37:13,030 --> 00:37:11,440
treatment where arsenate is often

1044
00:37:14,790 --> 00:37:13,040
often an issue so i think that's another

1045
00:37:17,270 --> 00:37:14,800
practical aspect that people will start

1046
00:37:19,430 --> 00:37:17,280
to work on once we we start to learn

1047
00:37:21,430 --> 00:37:19,440
more about the situation so yeah it's

1048
00:37:24,310 --> 00:37:21,440
pretty exciting to think about the

1049
00:37:25,990 --> 00:37:24,320
possibility of organisms and

1050
00:37:28,230 --> 00:37:26,000
living things that might be able to live

1051
00:37:29,750 --> 00:37:28,240
without phosphorus and for example just

1052
00:37:32,069 --> 00:37:29,760
going back to the bioenergy situation

1053
00:37:33,589 --> 00:37:32,079
one of the big problems that bioenergy

1054
00:37:36,470 --> 00:37:33,599
schemes have is that if you make an

1055
00:37:38,710 --> 00:37:36,480
algae or a cyanobacteria based bioenergy

1056
00:37:40,150 --> 00:37:38,720
system with a regular organism so pretty

1057
00:37:41,589 --> 00:37:40,160
soon it's going to get infected with

1058
00:37:44,069 --> 00:37:41,599
other organisms like it's going to be

1059
00:37:47,270 --> 00:37:44,079
invaded by things you don't want

1060
00:37:48,790 --> 00:37:47,280
well uh one way you could avoid that

1061
00:37:50,310 --> 00:37:48,800
all those other invaders are probably

1062
00:37:52,470 --> 00:37:50,320
going to need phosphorus and so if you

1063
00:37:55,349 --> 00:37:52,480

had a phosphorus free environment with a

1064
00:37:56,630 --> 00:37:55,359
bioenergy organism based on arsenate

1065
00:37:58,870 --> 00:37:56,640
instead that's going to be pretty

1066
00:38:01,270 --> 00:37:58,880
resistant to being contaminated by

1067
00:38:02,870 --> 00:38:01,280
invaders that you don't want so i think

1068
00:38:05,510 --> 00:38:02,880
you know there's pretty exciting stuff

1069
00:38:07,910 --> 00:38:05,520
here if this uh if this holds up

1070
00:38:10,230 --> 00:38:07,920
i i could also comment i think on the on

1071
00:38:12,470 --> 00:38:10,240
the end of that gym and that

1072
00:38:14,550 --> 00:38:12,480
so if this microbe has been something we

1073
00:38:16,310 --> 00:38:14,560
knew so when i said it looked ordinary

1074
00:38:18,230 --> 00:38:16,320
also what it does is very ordinary so

1075
00:38:20,790 --> 00:38:18,240
you and i breathe oxygen and we burn

1076
00:38:22,550 --> 00:38:20,800
sugar same thing this microbe does so

1077
00:38:24,710 --> 00:38:22,560
metabolically scientifically we'd say

1078
00:38:26,710 --> 00:38:24,720
metabolically it's not very interesting

1079
00:38:28,230 --> 00:38:26,720
it's it's something very normal in terms

1080
00:38:30,550 --> 00:38:28,240
of its metabolism

1081
00:38:32,390 --> 00:38:30,560
and the way it looks again we would look

1082
00:38:33,990 --> 00:38:32,400
in the environment we may not know that

1083
00:38:36,150 --> 00:38:34,000
one thing it wiggles it moves really

1084
00:38:38,150 --> 00:38:36,160
fast they swim quite quite rapidly we

1085
00:38:39,030 --> 00:38:38,160
may not notice that oh that microbe is

1086
00:38:40,550 --> 00:38:39,040
making

1087
00:38:41,670 --> 00:38:40,560
its biomolecules out of some other

1088
00:38:44,150 --> 00:38:41,680

element

1089
00:38:46,230 --> 00:38:44,160
so if for every one of your cells in

1090
00:38:49,270 --> 00:38:46,240
your body right now there are 10

1091
00:38:49,990 --> 00:38:49,280
microbial cells

1092
00:38:52,790 --> 00:38:50,000
so

1093
00:38:54,550 --> 00:38:52,800
you are mostly micro

1094
00:38:56,630 --> 00:38:54,560
what might we not understand about those

1095
00:38:57,990 --> 00:38:56,640
microbes so that's in you now let's go

1096
00:39:00,710 --> 00:38:58,000
global

1097
00:39:02,230 --> 00:39:00,720
so on planet earth we know that it's

1098
00:39:03,670 --> 00:39:02,240
very well supported now that microbes

1099
00:39:05,349 --> 00:39:03,680
are some of the major drivers of the

1100
00:39:06,950 --> 00:39:05,359
biogeochemical cycles on earth like

1101
00:39:09,349 --> 00:39:06,960
carbon cycle

1102
00:39:11,510 --> 00:39:09,359
so if if microbes are doing these major

1103
00:39:14,550 --> 00:39:11,520
players in our own bodies and in the in

1104
00:39:16,150 --> 00:39:14,560
the earth so on our planet if we're

1105
00:39:17,349 --> 00:39:16,160
missing a population maybe based on

1106
00:39:19,750 --> 00:39:17,359
arsenic but maybe these other

1107
00:39:21,589 --> 00:39:19,760
possibilities that we don't even know

1108
00:39:24,310 --> 00:39:21,599
yet

1109
00:39:26,550 --> 00:39:24,320
i think it has vast implications in in

1110
00:39:29,109 --> 00:39:26,560
understanding the way our own bodies

1111
00:39:31,430 --> 00:39:29,119
might work and help inform us about that

1112
00:39:33,990 --> 00:39:31,440
but also in the way our planet works

1113
00:39:35,829 --> 00:39:34,000

so that i think it's i think jim

1114
00:39:37,990 --> 00:39:35,839
suggested in practical applications that

1115
00:39:39,589 --> 00:39:38,000
it's absolutely

1116
00:39:42,230 --> 00:39:39,599
but some of the practical applications

1117
00:39:45,270 --> 00:39:42,240
will develop over time and understand

1118
00:39:47,190 --> 00:39:45,280
well here's the fundamental discovery

1119
00:39:48,790 --> 00:39:47,200
and you know it's going to take an army

1120
00:39:51,270 --> 00:39:48,800
of scientists not

1121
00:39:53,030 --> 00:39:51,280
clearly not just myself and my team but

1122
00:39:55,829 --> 00:39:53,040
other other people to bear on this

1123
00:39:57,190 --> 00:39:55,839
problem with their tools and their ideas

1124
00:39:58,710 --> 00:39:57,200
i think it's clear from both of their

1125
00:40:01,109 --> 00:39:58,720
answers that there's

1126
00:40:02,310 --> 00:40:01,119
we're opening up all sorts of new areas

1127
00:40:03,910 --> 00:40:02,320
of research

1128
00:40:05,910 --> 00:40:03,920
jim you're practically breathless with

1129
00:40:07,190 --> 00:40:05,920
your ideas

1130
00:40:08,069 --> 00:40:07,200
i'm sure you'll be looking for money

1131
00:40:09,589 --> 00:40:08,079
soon

1132
00:40:12,069 --> 00:40:09,599
um

1133
00:40:13,990 --> 00:40:12,079
uh yeah so you know this this this the

1134
00:40:16,309 --> 00:40:14,000
ramifications of this finding are pretty

1135
00:40:18,230 --> 00:40:16,319
significant

1136
00:40:20,390 --> 00:40:18,240
before we go to the west coast we uh

1137
00:40:22,069 --> 00:40:20,400
have some time for some uh the gentleman

1138
00:40:23,910 --> 00:40:22,079

here if you can give your name

1139
00:40:25,510 --> 00:40:23,920
affiliation sir sure it's ivan seminic

1140
00:40:27,030 --> 00:40:25,520
with nature i just have two very short

1141
00:40:29,589 --> 00:40:27,040
technical questions not technical

1142
00:40:31,829 --> 00:40:29,599
questions but just detailed questions um

1143
00:40:33,990 --> 00:40:31,839
i'm wondering about the fraction of the

1144
00:40:36,069 --> 00:40:34,000
the swap out it the the video kind of

1145
00:40:38,309 --> 00:40:36,079
implied all the phosphorous molecules

1146
00:40:39,750 --> 00:40:38,319
disappearing or atoms disappearing being

1147
00:40:41,510 --> 00:40:39,760
replaced with arsenic do you have a

1148
00:40:43,190 --> 00:40:41,520
sense of whether it's that complete or

1149
00:40:45,829 --> 00:40:43,200
whether it's some fraction

1150
00:40:48,150 --> 00:40:45,839
uh and and if there's some level some

1151
00:40:49,829 --> 00:40:48,160
threshold there and and for steve benner

1152
00:40:51,910 --> 00:40:49,839
if you could just clarify what it is

1153
00:40:53,670 --> 00:40:51,920
about arsenic arsenate that makes it a

1154
00:40:56,710 --> 00:40:53,680
weaker link

1155
00:40:56,720 --> 00:40:59,750
yeah i mean the

1156
00:41:05,109 --> 00:41:02,150
i'm just trying to understand what the

1157
00:41:06,710 --> 00:41:05,119
level of explanation should be how the

1158
00:41:08,710 --> 00:41:06,720
explanation should be crafted to meet

1159
00:41:11,190 --> 00:41:08,720
the the level at which you're interested

1160
00:41:12,790 --> 00:41:11,200
in an answer arsenic has of course a

1161
00:41:15,030 --> 00:41:12,800
position below phosphorus on the

1162
00:41:17,670 --> 00:41:15,040
periodic table that has been mentioned

1163
00:41:19,990 --> 00:41:17,680

because of that it has orbitals which we

1164
00:41:22,069 --> 00:41:20,000
chemists like to talk about d orbitals f

1165
00:41:25,109 --> 00:41:22,079
orbitals that are lower in energy and

1166
00:41:26,790 --> 00:41:25,119
that permits arsenate to fall apart as

1167
00:41:28,710 --> 00:41:26,800
uh by what is called in the business an

1168
00:41:30,550 --> 00:41:28,720
associative mechanism that isn't

1169
00:41:32,150 --> 00:41:30,560
the attacking water doesn't have to wait

1170
00:41:34,550 --> 00:41:32,160
until something leaves in order to

1171
00:41:36,069 --> 00:41:34,560
attack it attacks without waiting for

1172
00:41:38,470 --> 00:41:36,079
something to leave and that's quite

1173
00:41:40,230 --> 00:41:38,480
different than what molecules farther up

1174
00:41:43,349 --> 00:41:40,240
in the periodic table do

1175
00:41:46,069 --> 00:41:43,359
and so this is why again my curmudgeon

1176
00:41:47,670 --> 00:41:46,079
wet blanket rolls i sit here and say

1177
00:41:49,670 --> 00:41:47,680
it's wonderful to say that we're going

1178
00:41:52,550 --> 00:41:49,680
to go to other planets and get a

1179
00:41:55,510 --> 00:41:52,560
phosphorous free energy right what we

1180
00:41:56,870 --> 00:41:55,520
believe based on prior experience is

1181
00:41:58,870 --> 00:41:56,880
that what will certainly survive from

1182
00:42:00,790 --> 00:41:58,880
felice's work is the microbe and that

1183
00:42:01,990 --> 00:42:00,800
microbe if it grows in low phosphorus

1184
00:42:04,230 --> 00:42:02,000
environments that's wonderful i mean

1185
00:42:05,510 --> 00:42:04,240
that can be used practically but we

1186
00:42:08,390 --> 00:42:05,520
don't

1187
00:42:10,790 --> 00:42:08,400
believe right now that the body of

1188
00:42:13,270 --> 00:42:10,800

evidence saying that that molecule can't

1189
00:42:15,030 --> 00:42:13,280
exist at the present time overwhelms the

1190
00:42:17,109 --> 00:42:15,040
body of evidence that says that molecule

1191
00:42:18,470 --> 00:42:17,119
does exist and that's not a theoretical

1192
00:42:21,030 --> 00:42:18,480
argument that's an argument based on

1193
00:42:22,550 --> 00:42:21,040
empirical thinking i'm sorry yes

1194
00:42:24,390 --> 00:42:22,560
and maybe i should have answered first

1195
00:42:25,430 --> 00:42:24,400
and it's true what steve's saying

1196
00:42:28,230 --> 00:42:25,440
i'd like to let him know get the

1197
00:42:32,870 --> 00:42:30,150
so disposing with the whip blanket what

1198
00:42:34,069 --> 00:42:32,880
i will say is um what we've presented so

1199
00:42:35,750 --> 00:42:34,079
that was an artist's rendition

1200
00:42:37,510 --> 00:42:35,760
absolutely to illustrate the point if

1201
00:42:39,270 --> 00:42:37,520
you're not so familiar with seeing those

1202
00:42:41,349 --> 00:42:39,280
molecular structures

1203
00:42:43,750 --> 00:42:41,359
i think what we've presented the

1204
00:42:45,670 --> 00:42:43,760
parsimonious way to interpret this

1205
00:42:48,550 --> 00:42:45,680
arsenic was absolutely associated with

1206
00:42:50,309 --> 00:42:48,560
the dna fraction purified on a gel

1207
00:42:52,309 --> 00:42:50,319
to address what steve's saying how it

1208
00:42:54,470 --> 00:42:52,319
survived all the manipulation if you're

1209
00:42:56,630 --> 00:42:54,480
aware of how we do dna extraction

1210
00:42:58,470 --> 00:42:56,640
unknown it migrates at a different level

1211
00:42:59,829 --> 00:42:58,480
i'll be a bit technical for a second

1212
00:43:01,910 --> 00:42:59,839
migrates at a different rate i think

1213
00:43:03,670 --> 00:43:01,920

it's super coiled i've done things like

1214
00:43:05,990 --> 00:43:03,680
cesium chloride gradients again a little

1215
00:43:07,510 --> 00:43:06,000
bit technical it's weird

1216
00:43:09,430 --> 00:43:07,520
and i'll be honest i've been asked a

1217
00:43:11,670 --> 00:43:09,440
question like well what did you think

1218
00:43:13,349 --> 00:43:11,680
were you eureka no i'm a biochemist i

1219
00:43:14,790 --> 00:43:13,359
said this isn't right

1220
00:43:15,750 --> 00:43:14,800
something's wrong i must have made a

1221
00:43:17,670 --> 00:43:15,760
mistake

1222
00:43:19,589 --> 00:43:17,680
and you'll see there's a laundry list of

1223
00:43:22,150 --> 00:43:19,599
fantastic co-authors

1224
00:43:23,670 --> 00:43:22,160
and i got a reputation at meetings

1225
00:43:25,109 --> 00:43:23,680
somebody would give a talk whoa i think

1226
00:43:26,950 --> 00:43:25,119
that's a type of mass spectrometry you

1227
00:43:28,710 --> 00:43:26,960
could do this and so they see me coming

1228
00:43:29,829 --> 00:43:28,720
they wouldn't know who i was but they

1229
00:43:31,990 --> 00:43:29,839
knew that i was going to ask them to

1230
00:43:34,069 --> 00:43:32,000
measure something for me and often i

1231
00:43:36,390 --> 00:43:34,079
asked them to do it blindly

1232
00:43:38,390 --> 00:43:36,400
and they often said and if i were there

1233
00:43:40,309 --> 00:43:38,400
we would stare at the data

1234
00:43:42,150 --> 00:43:40,319
and they would sit back very experienced

1235
00:43:43,589 --> 00:43:42,160
scientists

1236
00:43:44,950 --> 00:43:43,599
what am i looking at

1237
00:43:46,390 --> 00:43:44,960
no no what what do you think it looks

1238
00:43:47,670 --> 00:43:46,400

like no no felicia what's in the sample

1239
00:43:50,309 --> 00:43:47,680
no no what do you think it looks like

1240
00:43:52,870 --> 00:43:50,319
it's often 2 a.m you know so so the

1241
00:43:55,430 --> 00:43:52,880
answer is from my viewpoint and how much

1242
00:43:57,349 --> 00:43:55,440
arsenic is substituting

1243
00:43:58,950 --> 00:43:57,359
i i think right now we don't know if you

1244
00:44:01,510 --> 00:43:58,960
look at the data that we're presenting

1245
00:44:03,270 --> 00:44:01,520
in the paper it varies and again to be

1246
00:44:05,030 --> 00:44:03,280
technical for one moment we've measured

1247
00:44:06,470 --> 00:44:05,040
these cells in stationary so it's old

1248
00:44:08,069 --> 00:44:06,480
age for the cell

1249
00:44:09,910 --> 00:44:08,079
so they've reached a point you grow go

1250
00:44:12,470 --> 00:44:09,920
grow stop

1251
00:44:14,069 --> 00:44:12,480
and and so the idea there is there

1252
00:44:16,150 --> 00:44:14,079
normally we run experiments a little

1253
00:44:18,150 --> 00:44:16,160
differently so if you look on our

1254
00:44:20,069 --> 00:44:18,160
supplementary evidence we've showed all

1255
00:44:21,910 --> 00:44:20,079
we're very transparent there is

1256
00:44:24,550 --> 00:44:21,920
absolutely some phosphorus left in these

1257
00:44:27,430 --> 00:44:24,560
cells but what's unambiguous about those

1258
00:44:29,670 --> 00:44:27,440
numbers is it is not enough to support

1259
00:44:31,430 --> 00:44:29,680
the growth that we observe

1260
00:44:32,790 --> 00:44:31,440
right 2.8 femtograms it's just not

1261
00:44:34,710 --> 00:44:32,800
enough

1262
00:44:36,550 --> 00:44:34,720
so to support that growth

1263
00:44:37,750 --> 00:44:36,560

we can estimate what we call this in

1264
00:44:39,750 --> 00:44:37,760
science the back of the envelope

1265
00:44:41,430 --> 00:44:39,760
calculation we can

1266
00:44:42,870 --> 00:44:41,440
squint and see that pattern in nature

1267
00:44:45,030 --> 00:44:42,880
that our data are telling us we can

1268
00:44:47,270 --> 00:44:45,040
estimate how much total phosphorus you

1269
00:44:48,470 --> 00:44:47,280
need at a very low how many ribosomes

1270
00:44:49,910 --> 00:44:48,480
how much gene how much you need in the

1271
00:44:51,190 --> 00:44:49,920
genome how much you need on your

1272
00:44:52,470 --> 00:44:51,200
proteins to turn them on and off it's

1273
00:44:54,550 --> 00:44:52,480
called protein phosphorylation if we

1274
00:44:56,790 --> 00:44:54,560
have the analogous problem with arsenic

1275
00:44:58,870 --> 00:44:56,800
how much you might need in a lipid

1276
00:45:01,430 --> 00:44:58,880
it's just too little

1277
00:45:03,030 --> 00:45:01,440
it's just flat out too little do we have

1278
00:45:05,190 --> 00:45:03,040
a crystal structure yet

1279
00:45:07,349 --> 00:45:05,200
no i have collaborators working on that

1280
00:45:09,829 --> 00:45:07,359
do we know the genome yet no but we're

1281
00:45:11,829 --> 00:45:09,839
gonna work on that and the point was it

1282
00:45:13,430 --> 00:45:11,839
could be maybe it's just a's and t's

1283
00:45:15,990 --> 00:45:13,440
maybe it's just g's and c's maybe it's

1284
00:45:17,109 --> 00:45:16,000
one out of every ten or two out of four

1285
00:45:19,270 --> 00:45:17,119
great question

1286
00:45:20,630 --> 00:45:19,280
so what we're not suggesting in my paper

1287
00:45:21,829 --> 00:45:20,640
i tried to write it in a very clear

1288
00:45:23,589 --> 00:45:21,839

manner

1289
00:45:25,510 --> 00:45:23,599
what i'm not suggesting is that if the

1290
00:45:27,430 --> 00:45:25,520
entire microbe is made of arsenic

1291
00:45:29,349 --> 00:45:27,440
absolutely not i'm very very transparent

1292
00:45:31,349 --> 00:45:29,359
my co-authors we've we spent a lot of

1293
00:45:33,109 --> 00:45:31,359
time being very careful we're not really

1294
00:45:35,030 --> 00:45:33,119
speculating we wanted to present the

1295
00:45:39,349 --> 00:45:35,040
phenomena to the community and to the

1296
00:45:41,670 --> 00:45:39,359
public say oh my gosh this is amazing

1297
00:45:43,510 --> 00:45:41,680
if you notice how i end it you know i

1298
00:45:44,870 --> 00:45:43,520
had been reviewing some of the greats i

1299
00:45:47,109 --> 00:45:44,880
stand on the shoulders of giants and i

1300
00:45:49,750 --> 00:45:47,119
know that i went to mono lake because

1301
00:45:51,510 --> 00:45:49,760
it's well studied it's easy accessible

1302
00:45:53,030 --> 00:45:51,520
it's in the united states we studied an

1303
00:45:56,230 --> 00:45:53,040
america with an american team on

1304
00:45:58,550 --> 00:45:56,240
american soil with american money

1305
00:46:00,230 --> 00:45:58,560
and i went to this to really you know i

1306
00:46:01,829 --> 00:46:00,240
reread the double helix paper and i

1307
00:46:03,349 --> 00:46:01,839
reread stanley miller's paper and plate

1308
00:46:05,510 --> 00:46:03,359
tectonics

1309
00:46:07,030 --> 00:46:05,520
just present the observation and the

1310
00:46:08,790 --> 00:46:07,040
data

1311
00:46:10,950 --> 00:46:08,800
so that we can make those forward

1312
00:46:12,710 --> 00:46:10,960
progress i think understanding how much

1313
00:46:14,870 --> 00:46:12,720

what does it do during law growth let's

1314
00:46:16,630 --> 00:46:14,880
say we give it arsenic and phosphorus

1315
00:46:18,710 --> 00:46:16,640
what happens i actually know but i'm not

1316
00:46:20,870 --> 00:46:18,720
going to talk about it here today

1317
00:46:21,990 --> 00:46:20,880
i'm well on to the next paper so i'm a

1318
00:46:23,910 --> 00:46:22,000
little more confident than i would have

1319
00:46:26,230 --> 00:46:23,920
normally been with someone is esteemed

1320
00:46:27,030 --> 00:46:26,240
as steve benner in the room

1321
00:46:28,630 --> 00:46:27,040
uh

1322
00:46:30,950 --> 00:46:28,640
i i've been working on the next paper

1323
00:46:32,550 --> 00:46:30,960
should be submitted in february

1324
00:46:33,990 --> 00:46:32,560
maybe we can turn the question back to

1325
00:46:35,829 --> 00:46:34,000
our colleague from nature i mean the

1326
00:46:37,750 --> 00:46:35,839
question is you've taken a biochemistry

1327
00:46:39,510 --> 00:46:37,760
course and what do you remember from

1328
00:46:41,349 --> 00:46:39,520
your metabolic pathways that you were

1329
00:46:43,990 --> 00:46:41,359
taught forced to memorize for the

1330
00:46:47,109 --> 00:46:44,000
examination then perhaps promptly forgot

1331
00:46:49,589 --> 00:46:47,119
so when you biosynthesize dna right the

1332
00:46:51,030 --> 00:46:49,599
phosphate comes from nucleoside

1333
00:46:52,550 --> 00:46:51,040
triphosphate

1334
00:46:55,589 --> 00:46:52,560
where the phosphorus that ends up in the

1335
00:46:58,790 --> 00:46:55,599
dna is the one directly bound to the atp

1336
00:47:00,790 --> 00:46:58,800
deoxy atp deoxy gtp and so on and that

1337
00:47:03,109 --> 00:47:00,800
phosphorus gets to that species by a

1338
00:47:05,510 --> 00:47:03,119

17-step metabolic pathway which i'm sure

1339
00:47:06,390 --> 00:47:05,520
you can write out on a piece of paper

1340
00:47:07,670 --> 00:47:06,400
i mean i'm going to interrupt you

1341
00:47:09,430 --> 00:47:07,680
stephen i'm sorry

1342
00:47:12,230 --> 00:47:09,440
a-m-a-m-a-s

1343
00:47:14,069 --> 00:47:12,240
adenosine mono arsenate which would be

1344
00:47:15,430 --> 00:47:14,079
you saw that backbone we went down the i

1345
00:47:17,670 --> 00:47:15,440
call that the roller coaster when we

1346
00:47:20,150 --> 00:47:17,680
made the animation

1347
00:47:22,309 --> 00:47:20,160
one of those nucleotides so atgc that

1348
00:47:24,710 --> 00:47:22,319
you're all hopefully familiar with

1349
00:47:25,910 --> 00:47:24,720
is is has a sugar as a base and the

1350
00:47:29,109 --> 00:47:25,920
phosphate

1351
00:47:31,589 --> 00:47:29,119
amas forms spontaneously in a test tube

1352
00:47:34,390 --> 00:47:31,599
while amp does not

1353
00:47:35,829 --> 00:47:34,400
and so in terms of thinking about

1354
00:47:38,230 --> 00:47:35,839
he hasn't read the paper

1355
00:47:40,630 --> 00:47:38,240
so amas does form spontaneously in test

1356
00:47:43,030 --> 00:47:40,640
tube on the order of minutes well amp

1357
00:47:45,910 --> 00:47:43,040
requires an enzymatic system this isn't

1358
00:47:47,589 --> 00:47:45,920
my work this was done in the 80s

1359
00:47:49,109 --> 00:47:47,599
it was to understand it was actually an

1360
00:47:50,710 --> 00:47:49,119
accident of the finding and i'd be happy

1361
00:47:52,150 --> 00:47:50,720
to give you the citation and recite it

1362
00:47:55,030 --> 00:47:52,160
in the paper it was to understand the

1363
00:47:56,549 --> 00:47:55,040

toxicity of arsenic amas

1364
00:47:59,270 --> 00:47:56,559
forms spontaneously at room temperature

1365
00:48:02,150 --> 00:47:59,280
in a test tube

1366
00:48:06,309 --> 00:48:02,160
phosphorus that ends up in the dna yeah

1367
00:48:09,990 --> 00:48:08,069
get into a scientific debate here we

1368
00:48:11,829 --> 00:48:10,000
have some questions from the west coast

1369
00:48:14,470 --> 00:48:11,839
and following you guys can get together

1370
00:48:16,230 --> 00:48:14,480
and hash it out um

1371
00:48:18,710 --> 00:48:16,240
let's let's let's go to the west coast

1372
00:48:22,790 --> 00:48:18,720
uh the ames research center uh we have

1373
00:48:26,470 --> 00:48:24,870
hi good afternoon this is rob ardego at

1374
00:48:28,150 --> 00:48:26,480
kgo radio

1375
00:48:30,309 --> 00:48:28,160
in the bay area

1376
00:48:33,589 --> 00:48:30,319
and the question should be directed to

1377
00:48:34,790 --> 00:48:33,599
dr wolf simon uh as to your non-eureka

1378
00:48:35,829 --> 00:48:34,800
moment

1379
00:48:37,430 --> 00:48:35,839
um

1380
00:48:39,589 --> 00:48:37,440
apparently you didn't suspect this might

1381
00:48:40,710 --> 00:48:39,599
be the case or hypothesize this might be

1382
00:48:42,870 --> 00:48:40,720
the case

1383
00:48:45,109 --> 00:48:42,880
what were you doing at the moment what

1384
00:48:46,870 --> 00:48:45,119
were you looking for at the moment that

1385
00:48:47,750 --> 00:48:46,880
you stumbled across this or did you in

1386
00:48:51,829 --> 00:48:47,760
fact

1387
00:48:55,670 --> 00:48:53,750
i'm sorry i don't exactly understand the

1388
00:48:57,670 --> 00:48:55,680

question um what was i doing at the

1389
00:49:00,069 --> 00:48:57,680
particular moment in terms of what of

1390
00:49:03,750 --> 00:49:00,079
the analyses or what kind of

1391
00:49:05,109 --> 00:49:03,760
experiments i was running

1392
00:49:07,109 --> 00:49:05,119
look at it this way what were you

1393
00:49:08,630 --> 00:49:07,119
looking for

1394
00:49:11,030 --> 00:49:08,640
so that you uh

1395
00:49:13,910 --> 00:49:11,040
you didn't hypothesize that this

1396
00:49:14,870 --> 00:49:13,920
this microbe lived as it did or as it

1397
00:49:17,589 --> 00:49:14,880
does

1398
00:49:19,829 --> 00:49:17,599
um but you found it anyway i mean that

1399
00:49:22,950 --> 00:49:19,839
happens all the time in science

1400
00:49:25,589 --> 00:49:22,960
i'm sorry perhaps uh we were unclear i i

1401
00:49:27,430 --> 00:49:25,599
i had i had been thinking about the idea

1402
00:49:28,870 --> 00:49:27,440
of arsenic substituting for phosphorus

1403
00:49:32,630 --> 00:49:28,880
for some time

1404
00:49:34,470 --> 00:49:32,640
so i it was a absolutely directed test

1405
00:49:36,309 --> 00:49:34,480
the question i was asking was can

1406
00:49:37,670 --> 00:49:36,319
arsenic substitute for phosphorus in a

1407
00:49:39,829 --> 00:49:37,680
living microbe

1408
00:49:41,990 --> 00:49:39,839
so i ran the experiment where we grew it

1409
00:49:43,589 --> 00:49:42,000
in a broth and a liquid an artificial

1410
00:49:45,430 --> 00:49:43,599
liquid where we gave

1411
00:49:47,750 --> 00:49:45,440
the the mud from mono lake as the

1412
00:49:49,510 --> 00:49:47,760
initial source of the microbes

1413
00:49:51,510 --> 00:49:49,520

everything it needed except no

1414
00:49:53,109 --> 00:49:51,520
phosphorus with a high dose of arsenic

1415
00:49:54,790 --> 00:49:53,119
so um

1416
00:50:00,470 --> 00:49:54,800
i'm sorry if that was unclear this was a

1417
00:50:00,480 --> 00:50:03,430
that answer your question

1418
00:50:05,990 --> 00:50:04,710
we'll go to the next question i think

1419
00:50:12,470 --> 00:50:06,000
that did

1420
00:50:16,069 --> 00:50:14,870
usa today a lot of our readers are

1421
00:50:17,750 --> 00:50:16,079
already commenting online they're

1422
00:50:19,190 --> 00:50:17,760
disappointed you didn't pull an e.t out

1423
00:50:20,790 --> 00:50:19,200
of a hat and have them dance on the

1424
00:50:23,190 --> 00:50:20,800
stage uh i was wondering if you could

1425
00:50:25,990 --> 00:50:23,200
talk about those expectations uh

1426
00:50:28,069 --> 00:50:26,000
uh you know our readers are seem to be

1427
00:50:29,109 --> 00:50:28,079
have been expecting a walking talking

1428
00:50:30,470 --> 00:50:29,119
alien

1429
00:50:33,109 --> 00:50:30,480
can you put this into perspective for

1430
00:50:35,109 --> 00:50:33,119
them instead of what you found

1431
00:50:37,190 --> 00:50:35,119
that's a that's a question

1432
00:50:40,790 --> 00:50:37,200
and perspective of

1433
00:50:43,990 --> 00:50:40,800
the speculation was fiction the facts

1434
00:50:46,150 --> 00:50:44,000
right yes um i i guess what i would say

1435
00:50:48,230 --> 00:50:46,160
is that well um

1436
00:50:49,829 --> 00:50:48,240
certainly being able to announce the

1437
00:50:52,150 --> 00:50:49,839
discovery of an extraterrestrial would

1438
00:50:55,349 --> 00:50:52,160

be an incredible announcement

1439
00:50:57,589 --> 00:50:55,359
we feel that uh from our perspective and

1440
00:50:59,829 --> 00:50:57,599
our understanding of biology here on

1441
00:51:02,790 --> 00:50:59,839
earth and what we base all the research

1442
00:51:05,990 --> 00:51:02,800
that we do because in astrobiology to

1443
00:51:09,430 --> 00:51:06,000
some extent on our laboratory earth this

1444
00:51:11,589 --> 00:51:09,440
is a phenomenal finding we are talking

1445
00:51:13,430 --> 00:51:11,599
about taking the fundamental building

1446
00:51:15,990 --> 00:51:13,440
blocks of life

1447
00:51:17,910 --> 00:51:16,000
and replacing one of them with an

1448
00:51:20,950 --> 00:51:17,920
unusual or with a

1449
00:51:23,030 --> 00:51:20,960
perhaps not unpredicted but but another

1450
00:51:24,870 --> 00:51:23,040
compound in our mind this is the

1451
00:51:26,950 --> 00:51:24,880
equivalent and there are some of us that

1452
00:51:28,630 --> 00:51:26,960
remember seeing these original star trek

1453
00:51:30,710 --> 00:51:28,640
episodes and others that maybe see them

1454
00:51:33,270 --> 00:51:30,720
on rerun on tv land

1455
00:51:34,470 --> 00:51:33,280
but if you remember as a dark evil and

1456
00:51:36,710 --> 00:51:34,480
the horta

1457
00:51:38,309 --> 00:51:36,720
so this is in our mind the equivalent of

1458
00:51:40,150 --> 00:51:38,319
finding that hordo which is a

1459
00:51:41,829 --> 00:51:40,160
silicon-based life

1460
00:51:43,430 --> 00:51:41,839
substituting carbon which is what we

1461
00:51:45,190 --> 00:51:43,440
think all life forms are made of with

1462
00:51:46,950 --> 00:51:45,200
silica now we're talking about an

1463
00:51:49,510 --> 00:51:46,960

organism that we think

1464
00:51:52,950 --> 00:51:49,520
if not replacing all of it is it appears

1465
00:51:54,950 --> 00:51:52,960
to be using another fundamental

1466
00:51:57,750 --> 00:51:54,960
component of life the story isn't

1467
00:51:59,349 --> 00:51:57,760
entirely carbon nitrogen phosphorus

1468
00:52:01,270 --> 00:51:59,359
the other elements we mentioned are

1469
00:52:03,589 --> 00:52:01,280
important as well it's replacing

1470
00:52:04,630 --> 00:52:03,599
phosphorus with arsenic this is a huge

1471
00:52:06,230 --> 00:52:04,640
deal

1472
00:52:08,309 --> 00:52:06,240
this is you know we mentioned it's going

1473
00:52:10,390 --> 00:52:08,319
to require at least some paragraphs in a

1474
00:52:13,750 --> 00:52:10,400
textbook to be rewritten

1475
00:52:15,750 --> 00:52:13,760
uh perhaps and um you know this is a big

1476
00:52:18,309 --> 00:52:15,760
finding and so that's

1477
00:52:20,790 --> 00:52:18,319
i'm sorry if they are disappointed

1478
00:52:22,549 --> 00:52:20,800
but there are lots of people including

1479
00:52:26,230 --> 00:52:22,559
jim in the future research he's already

1480
00:52:29,430 --> 00:52:26,240
planning that see this is a huge

1481
00:52:31,270 --> 00:52:29,440
finding and a significant

1482
00:52:33,510 --> 00:52:31,280
a significant finding that's going to

1483
00:52:35,589 --> 00:52:33,520
lead to new areas of research and will

1484
00:52:37,349 --> 00:52:35,599
fundamentally change how we define life

1485
00:52:39,589 --> 00:52:37,359
and therefore how we will look for maybe

1486
00:52:41,270 --> 00:52:39,599
we'll be able to find et now because

1487
00:52:43,109 --> 00:52:41,280
we've got more information about what we

1488
00:52:44,390 --> 00:52:43,119

might be looking for

1489
00:52:45,270 --> 00:52:44,400
okay here's what i'm going to do here

1490
00:52:48,950 --> 00:52:45,280
i'm going to

1491
00:52:51,349 --> 00:52:48,960
take one more question we have many more

1492
00:52:53,510 --> 00:52:51,359
but we we can do that as follow-ups so

1493
00:52:55,270 --> 00:52:53,520
irene from discovery go ahead and have

1494
00:52:59,510 --> 00:52:55,280
the last question and then swing it back

1495
00:53:03,109 --> 00:53:01,430
thanks very much um i actually have two

1496
00:53:05,430 --> 00:53:03,119
questions the first um

1497
00:53:07,109 --> 00:53:05,440
is about the experiment itself how much

1498
00:53:09,270 --> 00:53:07,119
time passed um

1499
00:53:12,309 --> 00:53:09,280
before the microbes were able to make

1500
00:53:15,109 --> 00:53:12,319
the transition from their normal media

1501
00:53:16,309 --> 00:53:15,119
to one that was primarily

1502
00:53:18,230 --> 00:53:16,319
arsenic

1503
00:53:20,069 --> 00:53:18,240
and then for steve

1504
00:53:22,790 --> 00:53:20,079
maybe if you could just maybe generally

1505
00:53:24,950 --> 00:53:22,800
discuss a follow-up experiment that

1506
00:53:26,950 --> 00:53:24,960
would leave you more of a believer

1507
00:53:29,430 --> 00:53:26,960
that'd be really helpful thank you so

1508
00:53:32,230 --> 00:53:29,440
i'll answer first apparently this time

1509
00:53:34,230 --> 00:53:32,240
i learned that lesson quick uh so

1510
00:53:36,549 --> 00:53:34,240
in terms of the time frame the the

1511
00:53:38,549 --> 00:53:36,559
microbes never experienced normal what

1512
00:53:40,710 --> 00:53:38,559
you might call normal environment i went

1513
00:53:42,950 --> 00:53:40,720

straight from the environments

1514
00:53:44,710 --> 00:53:42,960
straight from mono lake into this this

1515
00:53:46,630 --> 00:53:44,720
artificial lake water where we mimic

1516
00:53:48,230 --> 00:53:46,640
what the lake would look like we had

1517
00:53:49,750 --> 00:53:48,240
everything it needs again vitamins and

1518
00:53:51,990 --> 00:53:49,760
sugar and everything else

1519
00:53:53,750 --> 00:53:52,000
just no phosphorus and lots of arsenic

1520
00:53:58,230 --> 00:53:53,760
so there was never a transition

1521
00:54:02,069 --> 00:54:00,549
stephen did you want to yeah i guess

1522
00:54:03,990 --> 00:54:02,079
that's a good question

1523
00:54:05,430 --> 00:54:04,000
keep in mind that as i think i mentioned

1524
00:54:07,589 --> 00:54:05,440
a moment ago

1525
00:54:09,510 --> 00:54:07,599
i think that the organism the reported

1526
00:54:10,630 --> 00:54:09,520
organism will survive scrutiny i think

1527
00:54:11,589 --> 00:54:10,640
that this is going to be a very

1528
00:54:13,349 --> 00:54:11,599
important

1529
00:54:15,270 --> 00:54:13,359
organism for us to study to try to

1530
00:54:17,510 --> 00:54:15,280
understand how an organism adapts to

1531
00:54:19,349 --> 00:54:17,520
phosphorus poor and arsenic rich

1532
00:54:21,589 --> 00:54:19,359
environments because certainly me as an

1533
00:54:23,670 --> 00:54:21,599
organism cannot do so

1534
00:54:26,150 --> 00:54:23,680
the kinds of experiments that i would of

1535
00:54:27,990 --> 00:54:26,160
course start with would be

1536
00:54:31,030 --> 00:54:28,000
i hate to be too technical but

1537
00:54:32,710 --> 00:54:31,040
radioactive isotope labeling experiments

1538
00:54:34,470 --> 00:54:32,720

felicia did do some work with her paper

1539
00:54:36,309 --> 00:54:34,480
with radioactive arsenic there's also

1540
00:54:38,630 --> 00:54:36,319
radioactive phosphorus i would be

1541
00:54:41,109 --> 00:54:38,640
looking at for example that band on the

1542
00:54:42,870 --> 00:54:41,119
gel and figure 2a the one in lane 2 with

1543
00:54:45,349 --> 00:54:42,880
a box around it for those of you who

1544
00:54:47,829 --> 00:54:45,359
have the paper looking at that by

1545
00:54:49,829 --> 00:54:47,839
arsenic radioactive autoradiography

1546
00:54:51,990 --> 00:54:49,839
arsenic radioactive imaging after i had

1547
00:54:54,549 --> 00:54:52,000
fed radioactive arsenic to the bug and

1548
00:54:55,829 --> 00:54:54,559
to see whether it's in fact concentrated

1549
00:54:57,670 --> 00:54:55,839
in that band

1550
00:54:59,430 --> 00:54:57,680
i would certainly of course do the same

1551
00:55:00,630 --> 00:54:59,440
thing with radioactive phosphorus in a

1552
00:55:02,150 --> 00:55:00,640
ratio i would start with a lot of

1553
00:55:03,910 --> 00:55:02,160
phosphorous a little arsenic both

1554
00:55:06,309 --> 00:55:03,920
labeled to a lot of arsenic and little

1555
00:55:08,309 --> 00:55:06,319
phosphorus both labeled and see how the

1556
00:55:10,630 --> 00:55:08,319
labels because label reactive labels are

1557
00:55:12,549 --> 00:55:10,640
very easy to see in a cell see how they

1558
00:55:14,789 --> 00:55:12,559
evolve in time and

1559
00:55:16,390 --> 00:55:14,799
i mean but felicia you know i mean i one

1560
00:55:17,910 --> 00:55:16,400
actually i think you've actually got the

1561
00:55:21,750 --> 00:55:17,920
sense of this when felice and i have

1562
00:55:25,430 --> 00:55:21,760
talked about this for hours may not days

1563
00:55:28,309 --> 00:55:25,440

the disagreement in science need not be

1564
00:55:30,150 --> 00:55:28,319
personal it can be factual friendly and

1565
00:55:32,069 --> 00:55:30,160
constructive that way the nasa

1566
00:55:33,829 --> 00:55:32,079
astrobiology institute sort of

1567
00:55:35,910 --> 00:55:33,839
emphasizes that in the astrobiology

1568
00:55:38,390 --> 00:55:35,920
program overall brings us together in a

1569
00:55:39,829 --> 00:55:38,400
way that we you know have

1570
00:55:41,910 --> 00:55:39,839
we have

1571
00:55:43,190 --> 00:55:41,920
different backgrounds different contexts

1572
00:55:44,309 --> 00:55:43,200
different cultures and therefore we

1573
00:55:45,670 --> 00:55:44,319
approach problems differently and

1574
00:55:46,710 --> 00:55:45,680
therefore the standards of proof but

1575
00:55:48,950 --> 00:55:46,720
each of us have to meet in our

1576
00:55:50,230 --> 00:55:48,960
respective communities are different and

1577
00:55:51,990 --> 00:55:50,240
so what you're seeing here is a

1578
00:55:53,510 --> 00:55:52,000
perfectly healthy interaction between

1579
00:55:55,670 --> 00:55:53,520
two different communities as we try to

1580
00:55:57,829 --> 00:55:55,680
apply our standards of proof to somebody

1581
00:56:00,390 --> 00:55:57,839
else's results so these are the kinds of

1582
00:56:02,630 --> 00:56:00,400
experiments as a chemist i would do next

1583
00:56:05,109 --> 00:56:02,640
okay we're gonna wrap it up and for the

1584
00:56:06,789 --> 00:56:05,119
media and there are many on the line and

1585
00:56:08,549 --> 00:56:06,799
elsewhere these uh

1586
00:56:11,109 --> 00:56:08,559
incredible scientists will be available

1587
00:56:13,670 --> 00:56:11,119
for follow-up interviews i want to thank

1588
00:56:15,270 --> 00:56:13,680

the panelists and of course the gem down

1589
00:56:18,150 --> 00:56:15,280
in tempe

1590
00:56:20,390 --> 00:56:18,160
kudos again to you felicia and your team

1591
00:56:21,990 --> 00:56:20,400
i also want to acknowledge the continued

1592
00:56:23,589 --> 00:56:22,000
incredible work of nasa's science

1593
00:56:26,549 --> 00:56:23,599
mission directorate

1594
00:56:29,190 --> 00:56:26,559
which continues to are and inspire the

1595
00:56:31,589 --> 00:56:29,200
world with scientific discoveries

1596
00:56:35,030 --> 00:56:31,599
you can get all of the information on

1597
00:56:39,910 --> 00:56:37,109
and for those who know me you know i

1598
00:56:42,150 --> 00:56:39,920
cannot leave without saying it science