Ask An Astrobiologist

Episode 1: November 8th, 2016

Dr. Charles Cockell

NASA Astrobiology Program

1
00:00:34,940 --> 00:00:32,690
hello friends of astrobiology welcome to

2
00:00:37,549 --> 00:00:34,950
our brand new show on Signet ask an

3
00:00:40,100 --> 00:00:37,559
astrobiologist it replaces our previous

4
00:00:41,900 --> 00:00:40,110
show talked to an astrobiologist and the

5
00:00:43,610 --> 00:00:41,910
reason we're upgrading our form a little

6
00:00:46,040 --> 00:00:43,620
bit is we got new resources from the

7
00:00:48,410 --> 00:00:46,050
NASA Astrobiology program as well as

8
00:00:50,389 --> 00:00:48,420
Elsi the earth Life Science Institute at

9
00:00:51,979 --> 00:00:50,399
Tokyo Tech and the nonprofit blue Rubble

10
00:00:53,420 --> 00:00:51,989
space to make this a little bit more

11
00:00:55,279 --> 00:00:53,430
dynamic and hopefully a bit more

12
00:00:57,139 --> 00:00:55,289
interactive and informational for you

13
00:00:59,540 --> 00:00:57,149

all so if you have any questions during

14
00:01:02,599 --> 00:00:59,550
the the program make sure you use the

15
00:01:05,299 --> 00:01:02,609
hashtag ask Astro bio to post your

16
00:01:08,410 --> 00:01:05,309
questions online or use the Signet chat

17
00:01:11,960 --> 00:01:08,420
if you are on Sagan org so it's my great

18
00:01:15,140 --> 00:01:11,970
pleasure to invite back to say Gannett

19
00:01:17,300 --> 00:01:15,150
dr. Charles Cockell Charles is a

20
00:01:19,880 --> 00:01:17,310
professor of astrobiology one of the few

21
00:01:21,890 --> 00:01:19,890
in the world who holds this title the

22
00:01:24,469 --> 00:01:21,900
University of Edinburgh in Scotland he's

23
00:01:26,929 --> 00:01:24,479
also the director of the UK Centre for

24
00:01:28,880 --> 00:01:26,939
astrobiology and all-around baller

25
00:01:30,920 --> 00:01:28,890
astrobiologists if you have not taken

26
00:01:33,170 --> 00:01:30,930
his course on Coursera on an

27
00:01:36,170 --> 00:01:33,180
introduction to astrobiology I highly

28
00:01:40,580 --> 00:01:36,180
recommended Charles what are you wearing

29
00:01:44,300 --> 00:01:40,590
a mining suit and the last few hours

30
00:01:46,460 --> 00:01:44,310
one kilometer below this yes dear it's

31
00:01:48,139 --> 00:01:46,470
good to talk to again thank you and

32
00:01:51,260 --> 00:01:48,149
that's exactly where I've been actually

33
00:01:53,990 --> 00:01:51,270
by coincidence this interview was like

34
00:01:57,020 --> 00:01:54,000
20 minutes after I came up from our

35
00:01:58,819 --> 00:01:57,030
on-the-ground astrobiology lab in the

36
00:02:02,749 --> 00:01:58,829
boobie mine where we've been studying

37
00:02:06,109 --> 00:02:02,759
life are deep in in in 250 million year

38
00:02:07,880 --> 00:02:06,119

old Permian salt deposits so we've been

39
00:02:10,249 --> 00:02:07,890
down there today doing some science

40
00:02:11,960 --> 00:02:10,259
collecting microbes filming with the

41
00:02:13,910 --> 00:02:11,970
National Geographic and then I literally

42
00:02:15,890 --> 00:02:13,920
got up 20 minutes

43
00:02:19,400 --> 00:02:15,900
this interview so that's why I'm in a an

44
00:02:22,540 --> 00:02:19,410
orange mining suit so I'm not actually

45
00:02:26,479 --> 00:02:22,550
in print and I've just done online

46
00:02:28,790 --> 00:02:26,489
collecting some samples doing some doing

47
00:02:30,260 --> 00:02:28,800
some filming and working in our lab

48
00:02:32,690 --> 00:02:30,270
which I should say is actually the first

49
00:02:34,400 --> 00:02:32,700
was the first astrobiology labs we felt

50
00:02:37,699 --> 00:02:34,410
on the ground so it's nice I think

51
00:02:39,199 --> 00:02:37,709
facility you have that's so cool so the

52
00:02:40,970 --> 00:02:39,209
Permian is about two and fifty million

53
00:02:42,380 --> 00:02:40,980
years ago so let's go a bit before that

54
00:02:45,400 --> 00:02:42,390
and give you to tell us a little bit

55
00:02:48,860 --> 00:02:45,410
about your childhood so it's uh 200 to

56
00:02:52,520 --> 00:02:48,870
250 million year old salt deposits it's

57
00:02:54,740 --> 00:02:52,530
very old but but it's not as old say as

58
00:02:56,180 --> 00:02:54,750
the early Mars as early Mars but it is

59
00:02:58,850 --> 00:02:56,190
an environment where we can look at

60
00:03:00,949 --> 00:02:58,860
microbes living in salt environments and

61
00:03:02,330 --> 00:03:00,959
try to understand how they live in

62
00:03:05,000 --> 00:03:02,340
different types of brines

63
00:03:07,820 --> 00:03:05,010

so in the mind we've got sulphate brains

64
00:03:09,770 --> 00:03:07,830
we've got our sodium chloride brains all

65
00:03:11,120 --> 00:03:09,780
the sorts of salts that you see on Mars

66
00:03:13,370 --> 00:03:11,130
so it's a really interesting place to

67
00:03:15,199 --> 00:03:13,380
look at microbial communities and

68
00:03:17,150 --> 00:03:15,209
extreme briny environments and

69
00:03:18,680 --> 00:03:17,160
understand how they adapt to those

70
00:03:22,310 --> 00:03:18,690
extremes and it might tell us something

71
00:03:24,349 --> 00:03:22,320
about the spot of adaptations and

72
00:03:26,810 --> 00:03:24,359
functional capabilities of microbes

73
00:03:29,390 --> 00:03:26,820
living in briny environments on early

74
00:03:31,460 --> 00:03:29,400
Mars and brain is also really important

75
00:03:33,349 --> 00:03:31,470
for thinking about life on Europa but I

76
00:03:35,090 --> 00:03:33,359
want to go back a little bit before that

77
00:03:37,069 --> 00:03:35,100
because you're an astrobiologist today

78
00:03:38,360 --> 00:03:37,079
but when you when you were a kid when

79
00:03:40,190 --> 00:03:38,370
you were growing up I would like to

80
00:03:42,680 --> 00:03:40,200
learn a little bit more about what God

81
00:03:44,090 --> 00:03:42,690
what events made you become a scientist

82
00:03:45,740 --> 00:03:44,100
and how you ended up finding the

83
00:03:46,240 --> 00:03:45,750
astrobiology field and choosing that as

84
00:03:49,849 --> 00:03:46,250
a career

85
00:03:54,710 --> 00:03:49,859
okay well I'll try and keep free this is

86
00:03:56,390 --> 00:03:54,720
a large story I actually began well I

87
00:03:59,270 --> 00:03:56,400
was interested in Natural History from a

88
00:04:02,000 --> 00:03:59,280

very young age so I used to collect

89
00:04:04,280 --> 00:04:02,010
moths and insects and things and then I

90
00:04:07,759 --> 00:04:04,290
when I went to school I couldn't decide

91
00:04:09,890 --> 00:04:07,769
between biochemistry or astrophysics and

92
00:04:12,160 --> 00:04:09,900
I decided in the end to do biochemistry

93
00:04:15,170 --> 00:04:12,170
and that's what I did my first degree in

94
00:04:17,900 --> 00:04:15,180
then I got a fascinating a fascination

95
00:04:20,779 --> 00:04:17,910
in genetic engineering and did medical

96
00:04:22,940 --> 00:04:20,789
molecular biology for my PhD at Oxford

97
00:04:25,940 --> 00:04:22,950
so I actually studied the proteins

98
00:04:27,720 --> 00:04:25,950
involved in blood clotting but that

99
00:04:29,580 --> 00:04:27,730
didn't really satisfy me I

100
00:04:32,880 --> 00:04:29,590
interest in space exploration

101
00:04:36,150 --> 00:04:32,890
astrobiology so I spent one summer

102
00:04:39,330 --> 00:04:36,160
during my PhD at the International Space

103
00:04:41,250 --> 00:04:39,340
University where I met what would become

104
00:04:44,340 --> 00:04:41,260
future colleagues at NASA Ames Research

105
00:04:46,440 --> 00:04:44,350
Center and then I got a postdoctoral

106
00:04:49,410 --> 00:04:46,450
position at a National Research Council

107
00:04:51,120 --> 00:04:49,420
associate chip at NASA Ames and went out

108
00:04:53,580 --> 00:04:51,130
and did a postdoc and that's really when

109
00:04:57,180 --> 00:04:53,590
I became a sort of proper astrobiologist

110
00:04:59,940 --> 00:04:57,190
you like I spent 4 and a half years NASA

111
00:05:01,860 --> 00:04:59,950
and then I came back to the UK and

112
00:05:05,490 --> 00:05:01,870
worked with the British Antarctic Survey

113
00:05:07,830 --> 00:05:05,500

and then I spent four years working on

114
00:05:10,140 --> 00:05:07,840
Antarctic research and then I got my

115
00:05:11,070 --> 00:05:10,150
professorship in astrobiology at the

116
00:05:14,160 --> 00:05:11,080
Open University

117
00:05:16,020 --> 00:05:14,170
so my careers have taken different

118
00:05:18,690 --> 00:05:16,030
directions from biochemistry to

119
00:05:21,260 --> 00:05:18,700
molecular biology to astrobiology but

120
00:05:23,970 --> 00:05:21,270
all the time I've always tried to link

121
00:05:24,960 --> 00:05:23,980
biology with space exploration and

122
00:05:27,090 --> 00:05:24,970
that's always the thing that's

123
00:05:29,370 --> 00:05:27,100
fascinated me and now I find myself as a

124
00:05:32,190 --> 00:05:29,380
professor of astrobiology doing it

125
00:05:37,500 --> 00:05:32,200
full-time been my childhood dream of a

126
00:05:41,160 --> 00:05:37,510
job so I'm very lucky I think space but

127
00:05:43,980 --> 00:05:41,170
yet spend a day one kilometer below the

128
00:05:45,870 --> 00:05:43,990
Earth's surface which is pretty awesome

129
00:05:48,000 --> 00:05:45,880
so but the path you've taken I'm sure

130
00:05:49,350 --> 00:05:48,010
was not a straightforward one I was

131
00:05:50,880 --> 00:05:49,360
wondering if you could tell us a little

132
00:05:53,280 --> 00:05:50,890
bit about like the hurdles you

133
00:05:54,630 --> 00:05:53,290
encountered and the mentors you met who

134
00:05:56,730 --> 00:05:54,640
kind of helped you along the way to

135
00:05:59,520 --> 00:05:56,740
become the amazing scientist you are

136
00:06:01,410 --> 00:05:59,530
today well I'll defer on the amazing

137
00:06:03,360 --> 00:06:01,420
scientist I mean it's rather people to

138
00:06:07,640 --> 00:06:03,370

make a judgement but I can tell you

139
00:06:09,660 --> 00:06:07,650
about the hurdles I to get where I am um

140
00:06:11,580 --> 00:06:09,670
you know one of the most difficult

141
00:06:13,380 --> 00:06:11,590
things I think is is funding and

142
00:06:15,510 --> 00:06:13,390
building a career people see you as a

143
00:06:17,400 --> 00:06:15,520
professor and they think are you know he

144
00:06:19,650 --> 00:06:17,410
must have had an easy time or got there

145
00:06:22,050 --> 00:06:19,660
easily you know I went out to NASA and

146
00:06:24,270 --> 00:06:22,060
then ran out of money and I had to go

147
00:06:26,040 --> 00:06:24,280
and scrounge for money for eight months

148
00:06:28,140 --> 00:06:26,050
from Stanford and then I ran out of

149
00:06:30,390 --> 00:06:28,150
money there and went out to the

150
00:06:32,550 --> 00:06:30,400
University of Arizona where I then ran

151
00:06:35,130 --> 00:06:32,560
out of money there and then I went back

152
00:06:36,810 --> 00:06:35,140
up to Ames and ran out of money there

153
00:06:39,240 --> 00:06:36,820
and then went to the British Antarctic

154
00:06:41,999 --> 00:06:39,250
Survey for two years but I first came

155
00:06:43,679 --> 00:06:42,009
back to the UK to do research here

156
00:06:46,350 --> 00:06:43,689
and then I ran out of money after two

157
00:06:49,499 --> 00:06:46,360
years it's not an easy thing and it's

158
00:06:51,420 --> 00:06:49,509
taken a lot of sort of times of

159
00:06:54,059 --> 00:06:51,430
difficulty and uncertainty with research

160
00:06:55,799 --> 00:06:54,069
positions and and that's not to depress

161
00:06:58,230 --> 00:06:55,809
people it's more to give people hope

162
00:06:59,999 --> 00:06:58,240
that you just have to keep going and be

163
00:07:01,859 --> 00:07:00,009

persistent it's not actually easy for

164
00:07:04,049 --> 00:07:01,869
anyone developing a career in science

165
00:07:06,420 --> 00:07:04,059
but if you believe strongly enough in

166
00:07:08,519 --> 00:07:06,430
what you're doing and keep going things

167
00:07:11,459 --> 00:07:08,529
tend to work themselves out but you know

168
00:07:12,029 --> 00:07:11,469
it just takes it takes focus and a lot

169
00:07:16,529 --> 00:07:12,039
of work

170
00:07:19,920 --> 00:07:16,539
mark by step you write papers you know I

171
00:07:22,619 --> 00:07:19,930
know it sounds like a simple piece of

172
00:07:24,290 --> 00:07:22,629
advice but but being productive is is

173
00:07:26,519 --> 00:07:24,300
one of the most important things for

174
00:07:28,589 --> 00:07:26,529
achieving a permanent position and

175
00:07:30,689 --> 00:07:28,599
getting a job at a university as long as

176
00:07:33,059 --> 00:07:30,699
you are productive you demonstrate that

177
00:07:34,709 --> 00:07:33,069
as a scientist you can get information

178
00:07:34,949 --> 00:07:34,719
out there so I think that's an important

179
00:07:37,860 --> 00:07:34,959
thing

180
00:07:39,689 --> 00:07:37,870
persistence being enthusiastic believing

181
00:07:41,519 --> 00:07:39,699
in the dream that you're pursuing for

182
00:07:43,199 --> 00:07:41,529
the same time also getting those papers

183
00:07:47,070 --> 00:07:43,209
written and being productive and you can

184
00:07:49,139 --> 00:07:47,080
really beat that combination things hi I

185
00:07:50,639 --> 00:07:49,149
echo those sentiments and I agree it's

186
00:07:53,549 --> 00:07:50,649
definitely as a personal scientist

187
00:07:55,709 --> 00:07:53,559
myself I definitely appreciate the

188
00:07:57,570 --> 00:07:55,719

challenges of obtaining money to do

189
00:07:59,519 --> 00:07:57,580
science could you tell us a little bit

190
00:08:02,279 --> 00:07:59,529
about the mentors you've had a

191
00:08:04,889 --> 00:08:02,289
throughout your career and the advice of

192
00:08:07,980 --> 00:08:04,899
wise people you've you've taken and that

193
00:08:10,529 --> 00:08:07,990
have helped you guide your career yeah I

194
00:08:13,320 --> 00:08:10,539
mean I've had a lot of I've been lucky a

195
00:08:16,379 --> 00:08:13,330
lot of people helped me out you know

196
00:08:18,509 --> 00:08:16,389
people at Ames Chris McKay

197
00:08:21,239 --> 00:08:18,519
Lynn Rothschild others who supported my

198
00:08:24,029 --> 00:08:21,249
career when I became an astro bar that

199
00:08:25,409 --> 00:08:24,039
led support um this wouldn't have

200
00:08:27,420 --> 00:08:25,419
happened I should also say not just

201
00:08:29,219 --> 00:08:27,430
mentors but colleagues as well people

202
00:08:32,389 --> 00:08:29,229
I've worked with it everything's when I

203
00:08:35,069 --> 00:08:32,399
was a postdoc fellow scientists who were

204
00:08:38,309 --> 00:08:35,079
supportive as well I had a lot of

205
00:08:40,379 --> 00:08:38,319
support from from senior people Barry

206
00:08:42,329 --> 00:08:40,389
Bloomberg who was the first director at

207
00:08:44,790 --> 00:08:42,339
the NASA Astrobiology Institute and

208
00:08:47,220 --> 00:08:44,800
Nobel Prize winner you know wrote me

209
00:08:50,759 --> 00:08:47,230
letters of support for my jobs after I

210
00:08:53,100 --> 00:08:50,769
finished it at NASA and you know it's

211
00:08:54,120 --> 00:08:53,110
not necessary but it doesn't help it

212
00:08:57,200 --> 00:08:54,130
doesn't hurt rather

213
00:08:59,880 --> 00:08:57,210

to have Nobel Prize winners writing

214
00:09:01,200 --> 00:08:59,890
reference letters for jobs but you know

215
00:09:03,300 --> 00:09:01,210
people listening shouldn't think you

216
00:09:05,880 --> 00:09:03,310
need that but but I guess it is an

217
00:09:08,640 --> 00:09:05,890
illustration that it is important to to

218
00:09:10,260 --> 00:09:08,650
you know to work with senior people and

219
00:09:13,130 --> 00:09:10,270
be positive towards your seniors

220
00:09:16,260 --> 00:09:13,140
whatever wherever they might tell you

221
00:09:18,270 --> 00:09:16,270
and that's certainly part of part of the

222
00:09:19,680 --> 00:09:18,280
help that you need to develop a job so

223
00:09:21,420 --> 00:09:19,690
I've been lucky a lot of people have

224
00:09:23,400 --> 00:09:21,430
been very supportive of what I wanted to

225
00:09:26,250 --> 00:09:23,410
do in life and have supported me at

226
00:09:28,410 --> 00:09:26,260
critical times so you know a little

227
00:09:30,360 --> 00:09:28,420
hesitation in saying that that the

228
00:09:33,240 --> 00:09:30,370
papers and the dream and the vision is

229
00:09:35,580 --> 00:09:33,250
important but it is also important to

230
00:09:38,790 --> 00:09:35,590
try and get to know people who can help

231
00:09:40,230 --> 00:09:38,800
you out at critical times yeah I don't

232
00:09:41,730 --> 00:09:40,240
think it's luck Charles I mean you're

233
00:09:43,680 --> 00:09:41,740
very good at communicating your

234
00:09:45,540 --> 00:09:43,690
enthusiasm and it's pretty contagious to

235
00:09:48,810 --> 00:09:45,550
the people around you so give yourself

236
00:09:50,160 --> 00:09:48,820
some credit there yeah I mean that's

237
00:09:52,080 --> 00:09:50,170
hard work there's no you don't get

238
00:09:53,550 --> 00:09:52,090

anything for free in life and it looked

239
00:09:55,410 --> 00:09:53,560
it can always look like to other people

240
00:09:58,290 --> 00:09:55,420
you've been lucky and very little of it

241
00:10:00,660 --> 00:09:58,300
is luck it's hard work and and yeah

242
00:10:02,520 --> 00:10:00,670
persistence but the good news is we live

243
00:10:04,610 --> 00:10:02,530
in a world these days where persistence

244
00:10:07,320 --> 00:10:04,620
and hard work does actually pay off I

245
00:10:09,240 --> 00:10:07,330
think in you know a few centuries ago it

246
00:10:11,460 --> 00:10:09,250
was much more about who you knew and

247
00:10:13,020 --> 00:10:11,470
there was a lot of luck and that's a

248
00:10:14,660 --> 00:10:13,030
good thing that if you believe in what

249
00:10:16,260 --> 00:10:14,670
you're doing and people want to be

250
00:10:18,780 --> 00:10:16,270
astrobiologists if you show that

251
00:10:20,550 --> 00:10:18,790
persistence you have a high chance of of

252
00:10:24,410 --> 00:10:20,560
getting what you want so you have to

253
00:10:26,730 --> 00:10:24,420
keep pushing on that's excellent advice

254
00:10:28,620 --> 00:10:26,740
one thing I really like about your child

255
00:10:30,360 --> 00:10:28,630
is you're very bold scientist then you

256
00:10:32,100 --> 00:10:30,370
do the experiments you carry out are

257
00:10:33,120 --> 00:10:32,110
just really awesome and I was wondering

258
00:10:34,680 --> 00:10:33,130
if you could tell us a little bit about

259
00:10:38,910 --> 00:10:34,690
the experiments you actually flew into

260
00:10:40,890 --> 00:10:38,920
space yeah so we have we have done space

261
00:10:42,810 --> 00:10:40,900
experiments to international space

262
00:10:45,450 --> 00:10:42,820
station I really want to go to the Moon

263
00:10:47,070 --> 00:10:45,460

and Mars so I should this is really just

264
00:10:49,050 --> 00:10:47,080
the first step but I'm not going to

265
00:10:52,380 --> 00:10:49,060
complain anyway but we've been lucky

266
00:10:54,210 --> 00:10:52,390
we've had um European Space Station

267
00:10:55,860 --> 00:10:54,220
experiments where Space Agency

268
00:10:58,440 --> 00:10:55,870
experiments are one of which was quite

269
00:11:00,930 --> 00:10:58,450
fun we took some rocks from a former

270
00:11:03,930 --> 00:11:00,940
cliff in the South of England in a place

271
00:11:06,240 --> 00:11:03,940
called Devon a fishing village took the

272
00:11:07,980 --> 00:11:06,250
rocks and we flew them on the outside of

273
00:11:10,410 --> 00:11:07,990
the International Space Station for you

274
00:11:13,949 --> 00:11:10,420
know how to ask a very simple science

275
00:11:15,449 --> 00:11:13,959
experiment which was um science question

276
00:11:18,690 --> 00:11:15,459
which was to ask did any microbes

277
00:11:20,970 --> 00:11:18,700
survive and and that year-and-a-half in

278
00:11:23,100 --> 00:11:20,980
space and one species survived and we

279
00:11:25,320 --> 00:11:23,110
have that growing in our lab now and

280
00:11:27,360 --> 00:11:25,330
we're trying to understand how it

281
00:11:30,120 --> 00:11:27,370
survived in space and two of the answers

282
00:11:32,310 --> 00:11:30,130
are that it forms biofilms and that it's

283
00:11:34,170 --> 00:11:32,320
also very resistant to ionizing

284
00:11:36,769 --> 00:11:34,180
radiation that was really the first

285
00:11:38,639 --> 00:11:36,779
experiment that I did on Space Station

286
00:11:40,320 --> 00:11:38,649
currently we're preparing another

287
00:11:43,320 --> 00:11:40,330
experiment that's going to fly in two

288
00:11:46,650 --> 00:11:43,330

years which I'm PIR called by a rock and

289
00:11:49,620 --> 00:11:46,660
it's to look at how microbes break down

290
00:11:52,470 --> 00:11:49,630
rocks in microgravity and simulated

291
00:11:54,570 --> 00:11:52,480
Martian gravity using cubic centrifuge

292
00:11:57,690 --> 00:11:54,580
on the space station and this is all

293
00:12:00,240 --> 00:11:57,700
about growing biofilms in regolith on

294
00:12:03,150 --> 00:12:00,250
Mars and on the moon and whether we can

295
00:12:05,550 --> 00:12:03,160
use microbes to break down rocks produce

296
00:12:07,860 --> 00:12:05,560
soils and maybe even do things like bio

297
00:12:10,410 --> 00:12:07,870
mining so extracting useful elements

298
00:12:12,480 --> 00:12:10,420
from rocks like iron entertaining and

299
00:12:14,910 --> 00:12:12,490
precious metals like platinum from

300
00:12:15,810 --> 00:12:14,920
asteroids and use microbes to do this

301
00:12:17,610 --> 00:12:15,820
work for us

302
00:12:20,130 --> 00:12:17,620
just as microbes are used on the earth

303
00:12:23,100 --> 00:12:20,140
to do bio mining so this is a really

304
00:12:25,260 --> 00:12:23,110
exciting experiment it's leading to a

305
00:12:26,940 --> 00:12:25,270
new generation of microbial growth

306
00:12:29,130 --> 00:12:26,950
reactors that we're building with Kaiser

307
00:12:31,170 --> 00:12:29,140
space who are our industrial

308
00:12:32,550 --> 00:12:31,180
collaborators and what we hope to do in

309
00:12:35,460 --> 00:12:32,560
the next three or four years is build

310
00:12:38,100 --> 00:12:35,470
tiny little cubic our microbial growth

311
00:12:40,500 --> 00:12:38,110
chambers you can file CubeSat on space

312
00:12:43,319 --> 00:12:40,510
stations or send to the moon in which

313
00:12:45,569 --> 00:12:43,329

you can do microbial growth experiments

314
00:12:48,690 --> 00:12:45,579
microbial culture experiments so these

315
00:12:50,400 --> 00:12:48,700
are little modularized culture chambers

316
00:12:52,079 --> 00:12:50,410
if you like that you can use in space so

317
00:12:55,500 --> 00:12:52,089
that's another one of our sort of

318
00:12:57,449 --> 00:12:55,510
exciting space experiments so with those

319
00:12:59,160 --> 00:12:57,459
microbes that do bio mining I think

320
00:13:01,319 --> 00:12:59,170
that's really interesting because I mean

321
00:13:03,150 --> 00:13:01,329
one of the big push on from the private

322
00:13:05,340 --> 00:13:03,160
industry these days is to do asteroid

323
00:13:07,410 --> 00:13:05,350
mining but is the kinetics of the

324
00:13:09,150 --> 00:13:07,420
microbe break down fast enough is it

325
00:13:11,130 --> 00:13:09,160
scalable it seems like it would be good

326
00:13:14,670 --> 00:13:11,140
for a small project but on the larger

327
00:13:16,079 --> 00:13:14,680
scale I'm about 20 percent or so of all

328
00:13:18,300 --> 00:13:16,089
the copper on the earth today is

329
00:13:20,310 --> 00:13:18,310
extracted from rocks using bio mining so

330
00:13:21,430 --> 00:13:20,320
this is not um this is not speculation

331
00:13:23,230 --> 00:13:21,440
this is a matter

332
00:13:26,560 --> 00:13:23,240
the economic Enterprise on the earth and

333
00:13:28,620 --> 00:13:26,570
yes Oh microbes accelerate that you can

334
00:13:30,880 --> 00:13:28,630
think of them simply as catalysts for

335
00:13:33,310 --> 00:13:30,890
accelerating say the oxidation of iron

336
00:13:35,620 --> 00:13:33,320
or sulfur into sulfuric acid and

337
00:13:38,890 --> 00:13:35,630
acidifying the rock environment to break

338
00:13:41,440 --> 00:13:38,900

down Ross so microbes can catalyze

339
00:13:43,750 --> 00:13:41,450
chemical reactions orders of magnitude

340
00:13:45,940 --> 00:13:43,760
sometimes up to a million times faster

341
00:13:48,130 --> 00:13:45,950
than just purely chemical reactions and

342
00:13:50,470 --> 00:13:48,140
that general ability of microbes to

343
00:13:52,630 --> 00:13:50,480
catalyze reactions is at the heart of

344
00:13:54,190 --> 00:13:52,640
bio mining whether that's are

345
00:13:57,280 --> 00:13:54,200
specifically extracting particular

346
00:13:59,140 --> 00:13:57,290
metals from rocks or just using microbes

347
00:14:02,700 --> 00:13:59,150
to help break down the silicate matrix

348
00:14:05,530 --> 00:14:02,710
of rocks and release economically useful

349
00:14:07,840 --> 00:14:05,540
elements so yes microbes can do this on

350
00:14:11,320 --> 00:14:07,850
a big scale how you would do that on an

351
00:14:13,180 --> 00:14:11,330
asteroid or on on the Moon or Mars when

352
00:14:15,010 --> 00:14:13,190
on the earth these microbes generally do

353
00:14:17,230 --> 00:14:15,020
this in aerobic environments but they've

354
00:14:18,970 --> 00:14:17,240
got plenty of oxygen so you'd have to

355
00:14:21,490 --> 00:14:18,980
get the oxygen and that's an energy and

356
00:14:24,880 --> 00:14:21,500
mass cost to do all that so scaling up

357
00:14:27,100 --> 00:14:24,890
by mining to to extraterrestrial

358
00:14:28,690 --> 00:14:27,110
environments is at the moment something

359
00:14:30,640 --> 00:14:28,700
we you know we don't fully understand

360
00:14:32,230 --> 00:14:30,650
whether it would be economically

361
00:14:34,390 --> 00:14:32,240
scaleable I think that's yet to be

362
00:14:37,450 --> 00:14:34,400
demonstrated but it is just one of the

363
00:14:39,850 --> 00:14:37,460

ways in which we could um use use

364
00:14:42,670 --> 00:14:39,860
microbes that use organisms to do things

365
00:14:45,520 --> 00:14:42,680
for us in space that might improve our

366
00:14:49,210 --> 00:14:45,530
ability to get access to resources or

367
00:14:53,200 --> 00:14:49,220
ameliorate soils or even do things like

368
00:14:54,640 --> 00:14:53,210
use microbes for extraterrestrial

369
00:14:57,670 --> 00:14:54,650
gardening something as trivial as

370
00:15:00,550 --> 00:14:57,680
growing plants and microbial mats in in

371
00:15:03,250 --> 00:15:00,560
stations on on Moon and Mars micro yet

372
00:15:04,780 --> 00:15:03,260
why if we were to think about the long

373
00:15:06,670 --> 00:15:04,790
term human space flight we'll definitely

374
00:15:08,200 --> 00:15:06,680
need to have an understanding of how

375
00:15:10,720 --> 00:15:08,210
microbes work in the space environment

376
00:15:12,520 --> 00:15:10,730
so it's kind of cool that you know this

377
00:15:15,250 --> 00:15:12,530
is like one of many examples of

378
00:15:17,050 --> 00:15:15,260
practical astrobiology and and if you

379
00:15:18,700 --> 00:15:17,060
can't talk about geology without talking

380
00:15:22,060 --> 00:15:18,710
about biology and vice-versa so it's

381
00:15:24,160 --> 00:15:22,070
very very exciting field you're you're

382
00:15:25,900 --> 00:15:24,170
also conducting if I remember right one

383
00:15:27,550 --> 00:15:25,910
of the longest-running

384
00:15:28,960 --> 00:15:27,560
astrobiology experiments right you

385
00:15:30,550 --> 00:15:28,970
started something and experiments gonna

386
00:15:34,390 --> 00:15:30,560
last like five hundred years or

387
00:15:35,350 --> 00:15:34,400
something yes yeah sure I was having a

388
00:15:37,420 --> 00:15:35,360

conversation with so

389
00:15:39,730 --> 00:15:37,430
my students in my lab and we were saying

390
00:15:42,400 --> 00:15:39,740
you what is the mathematical function

391
00:15:44,620 --> 00:15:42,410
that describes the loss of viability in

392
00:15:47,949 --> 00:15:44,630
a dessicated microbe whether that's a

393
00:15:50,949 --> 00:15:47,959
microbe that are dried on the surface of

394
00:15:53,139 --> 00:15:50,959
Mars or a microbe in permafrost on earth

395
00:15:55,569 --> 00:15:53,149
what is it that kill the microbes over a

396
00:15:57,550 --> 00:15:55,579
long time period is it that is it

397
00:15:59,620 --> 00:15:57,560
accumulated DNA damage or is it just

398
00:16:02,380 --> 00:15:59,630
damage to the cell membrane over a short

399
00:16:04,150 --> 00:16:02,390
period of time and we looked around and

400
00:16:07,300 --> 00:16:04,160
of course we found papers where people

401
00:16:09,519 --> 00:16:07,310
had looked at survival of desiccation of

402
00:16:11,319 --> 00:16:09,529
microbes so there's a paper about gnaw

403
00:16:13,360 --> 00:16:11,329
stop which is a sign of bacterium

404
00:16:16,150 --> 00:16:13,370
surviving for over a hundred years

405
00:16:18,150 --> 00:16:16,160
that was some herbarium specimens that

406
00:16:20,470 --> 00:16:18,160
people who got out of our botanical

407
00:16:22,630 --> 00:16:20,480
collection but all these papers are

408
00:16:24,940 --> 00:16:22,640
quite haphazard there there's samples

409
00:16:27,610 --> 00:16:24,950
that people are found in museums or or

410
00:16:29,530 --> 00:16:27,620
in other places and we thought well then

411
00:16:31,900 --> 00:16:29,540
we do the experiment properly and set up

412
00:16:33,160 --> 00:16:31,910
a 500-year microbiology experiment so

413
00:16:36,250 --> 00:16:33,170

that's what we've done what we've done

414
00:16:38,019 --> 00:16:36,260
is we've we seal that critically Oxus

415
00:16:40,569 --> 00:16:38,029
which is a desiccation resistant sila

416
00:16:42,610 --> 00:16:40,579
bacterium and spores of bacillus

417
00:16:45,370 --> 00:16:42,620
subtlest so we've got a vegetative in a

418
00:16:47,590 --> 00:16:45,380
spore forming microbe we seal them in

419
00:16:50,650 --> 00:16:47,600
glass vials so what will happen is we

420
00:16:52,810 --> 00:16:50,660
take a triplicate vial every two years

421
00:16:54,340 --> 00:16:52,820
for the next twenty five years and then

422
00:16:56,470 --> 00:16:54,350
every twenty five years for the next

423
00:16:58,810 --> 00:16:56,480
four hundred and seventy-five years and

424
00:17:02,590 --> 00:16:58,820
the experiment ends on June the 30th 25

425
00:17:04,870 --> 00:17:02,600
14 and we've got um we've got in the

426
00:17:07,240 --> 00:17:04,880
experimental box we've got vials that

427
00:17:09,159 --> 00:17:07,250
are just exposed to the environment you

428
00:17:11,230 --> 00:17:09,169
know that are just in the box and then

429
00:17:12,850 --> 00:17:11,240
we also have vials inside a leadbox to

430
00:17:15,069 --> 00:17:12,860
cut down some of the background

431
00:17:17,740 --> 00:17:15,079
radiation to test the hypothesis that

432
00:17:19,809 --> 00:17:17,750
background radiation is one factor in

433
00:17:22,299 --> 00:17:19,819
loss of viability and then the entire

434
00:17:24,100 --> 00:17:22,309
experiment is reproduced so one of these

435
00:17:26,350 --> 00:17:24,110
experiments is in Edinburgh and we have

436
00:17:28,360 --> 00:17:26,360
a complete replicate 500-year experiment

437
00:17:30,430 --> 00:17:28,370
that's being curated by the Natural

438
00:17:32,440 --> 00:17:30,440

History Museum in London to ensure

439
00:17:34,480 --> 00:17:32,450
there's redundancy but it also means we

440
00:17:36,720 --> 00:17:34,490
get two datasets from two different

441
00:17:39,070 --> 00:17:36,730
environments so we've got biological

442
00:17:40,900 --> 00:17:39,080
triplicates in each experiment and then

443
00:17:43,570 --> 00:17:40,910
the final experiment is technically

444
00:17:45,669 --> 00:17:43,580
replicated in two institutes and we took

445
00:17:48,100 --> 00:17:45,679
the first our time point this year so

446
00:17:49,030 --> 00:17:48,110
the experiment began two years ago July

447
00:17:50,770 --> 00:17:49,040
this year with

448
00:17:53,290 --> 00:17:50,780
point one which was a matter of great

449
00:17:55,350 --> 00:17:53,300
excitement in my lab and I can tell you

450
00:17:58,480 --> 00:17:55,360
now that neither organism are

451
00:18:01,360 --> 00:17:58,490
significantly lost any viability in both

452
00:18:03,040 --> 00:18:01,370
the exposed and in the lead boxes that's

453
00:18:04,780 --> 00:18:03,050
good news for a number of reasons not

454
00:18:07,480 --> 00:18:04,790
because it tells us much we know that

455
00:18:09,130 --> 00:18:07,490
spores will survive two years that's a

456
00:18:10,390 --> 00:18:09,140
short time period we know that

457
00:18:12,490 --> 00:18:10,400
critically opposites will survive for

458
00:18:14,680 --> 00:18:12,500
two years but what it has shown us is

459
00:18:16,270 --> 00:18:14,690
that the preservation mechanisms that

460
00:18:17,950 --> 00:18:16,280
the preservation method that we use for

461
00:18:20,290 --> 00:18:17,960
the microbes has worked and so we have

462
00:18:22,300 --> 00:18:20,300
an experiment now after two years

463
00:18:24,250 --> 00:18:22,310

there's no loss of viability so now the

464
00:18:27,580 --> 00:18:24,260
question is what will happen over the

465
00:18:30,340 --> 00:18:27,590
net will we see a sudden crash in

466
00:18:33,460 --> 00:18:30,350
viability maybe over the next few years

467
00:18:36,820 --> 00:18:33,470
as those organisms die or will we see a

468
00:18:38,590 --> 00:18:36,830
crash in viability saying 150 years when

469
00:18:41,680 --> 00:18:38,600
there's a certain accumulated level of

470
00:18:44,680 --> 00:18:41,690
of DNA damage and what is the difference

471
00:18:46,990 --> 00:18:44,690
between a vegetative cell and a spore

472
00:18:48,880 --> 00:18:47,000
forming cell and then even if the cells

473
00:18:49,540 --> 00:18:48,890
die let's say in a hundred years they're

474
00:18:51,820 --> 00:18:49,550
all dead

475
00:18:54,100 --> 00:18:51,830
we can still follow the destruction of

476
00:18:55,930 --> 00:18:54,110
biosignatures over 500 years what

477
00:18:58,690 --> 00:18:55,940
happens to the membranes in the DNA

478
00:19:00,130 --> 00:18:58,700
nucleic acids or proteins so this

479
00:19:02,220 --> 00:19:00,140
experiment provides us with an

480
00:19:05,470 --> 00:19:02,230
understanding of the degradation of

481
00:19:09,640 --> 00:19:05,480
biological macromolecules over century x

482
00:19:11,800 --> 00:19:09,650
scales so we're very excited about I can

483
00:19:15,010 --> 00:19:11,810
tell the thing does it have applications

484
00:19:16,230 --> 00:19:15,020
for life on Mars I think it does I mean

485
00:19:19,210 --> 00:19:16,240
of course Mars has a much higher

486
00:19:21,880 --> 00:19:19,220
radiation exposure on the surface but it

487
00:19:23,980 --> 00:19:21,890
might tell us something about life

488
00:19:26,350 --> 00:19:23,990

underground that's desiccated in a

489
00:19:29,320 --> 00:19:26,360
dormant state and and what the processes

490
00:19:31,630 --> 00:19:29,330
are of loss of viability I mean I should

491
00:19:34,690 --> 00:19:31,640
say 500 years it's still a short

492
00:19:37,200 --> 00:19:34,700
experiment crowby align scale

493
00:19:40,630 --> 00:19:37,210
I mean microbes probably can't survive

494
00:19:42,940 --> 00:19:40,640
millennia in permafrost or or completely

495
00:19:45,310 --> 00:19:42,950
desiccated but the purpose of the

496
00:19:47,800 --> 00:19:45,320
experiment was to try and get to time

497
00:19:49,840 --> 00:19:47,810
scales that are more reflective of

498
00:19:53,230 --> 00:19:49,850
microbial timescales than human

499
00:19:54,580 --> 00:19:53,240
timescales that's very cool I like to

500
00:19:57,880 --> 00:19:54,590
change gears a little bit here

501
00:19:59,470 --> 00:19:57,890
um this so you're a professor you're

502
00:20:00,910 --> 00:19:59,480
director of the UK Centre for

503
00:20:01,590 --> 00:20:00,920
astrobiology you do all this amazing

504
00:20:04,590 --> 00:20:01,600
sign

505
00:20:06,630 --> 00:20:04,600
yet you had time to write a book an

506
00:20:09,360 --> 00:20:06,640
astrobiology textbook for that matter

507
00:20:10,980 --> 00:20:09,370
for undergraduates where do I find the

508
00:20:13,310 --> 00:20:10,990
time how do you do it like tell us more

509
00:20:16,890 --> 00:20:13,320
about the process that led to this book

510
00:20:18,450 --> 00:20:16,900
okay well when I went to I went to N for

511
00:20:20,400 --> 00:20:18,460
about five years ago that's when I set

512
00:20:21,960 --> 00:20:20,410
up the center and of course I need to

513
00:20:24,779 --> 00:20:21,970

teach and one of the things I wanted to

514
00:20:27,419 --> 00:20:24,789
teach was astrobiology so after a couple

515
00:20:29,340 --> 00:20:27,429
of years of teaching physics just to get

516
00:20:31,549 --> 00:20:29,350
to know the undergraduates and how the

517
00:20:34,020 --> 00:20:31,559
university works I set up a an

518
00:20:36,750 --> 00:20:34,030
astrobiology course at NREL oops there's

519
00:20:39,060 --> 00:20:36,760
been very popular it attracts students

520
00:20:44,640 --> 00:20:39,070
from 11 different departments across the

521
00:20:47,399 --> 00:20:44,650
university from sciences as part of that

522
00:20:49,440 --> 00:20:47,409
as part of that lecture course I needed

523
00:20:52,080 --> 00:20:49,450
to write lecture notes for my students

524
00:20:53,399 --> 00:20:52,090
to go with the lectures so I wrote on my

525
00:20:54,990 --> 00:20:53,409
lecture notes and at the end of the

526
00:20:57,390 --> 00:20:55,000
first year of teaching I looked at all

527
00:21:00,299 --> 00:20:57,400
my notes and thought hang on this is 50%

528
00:21:02,640 --> 00:21:00,309
of a textbook why don't I just write the

529
00:21:05,159 --> 00:21:02,650
other 50% and then I can publish a

530
00:21:06,690 --> 00:21:05,169
textbook and then and then I won't have

531
00:21:09,000 --> 00:21:06,700
to write lecture notes I can just tell

532
00:21:11,310 --> 00:21:09,010
my students go by the letter by the book

533
00:21:13,380 --> 00:21:11,320
in the bookshop so you know at the end

534
00:21:15,990 --> 00:21:13,390
of the day it is actually a time-saving

535
00:21:18,090 --> 00:21:16,000
with a time-saving move to write a

536
00:21:21,299 --> 00:21:18,100
textbook because it'll be updated by

537
00:21:22,980 --> 00:21:21,309
Wiley hopefully and then it can be used

538
00:21:24,090 --> 00:21:22,990

in other universities but actually

539
00:21:26,010 --> 00:21:24,100
starting model seriously the other

540
00:21:27,390 --> 00:21:26,020
reason for doing it is I thought I've

541
00:21:29,669 --> 00:21:27,400
got all this experience of teaching

542
00:21:31,500 --> 00:21:29,679
astrobiology in a university and I know

543
00:21:34,590 --> 00:21:31,510
now which lectures work and which

544
00:21:36,029 --> 00:21:34,600
material students found exciting it just

545
00:21:37,590 --> 00:21:36,039
seemed like a really good idea to write

546
00:21:39,330 --> 00:21:37,600
a textbook that could be used in other

547
00:21:42,000 --> 00:21:39,340
universities to save other people the

548
00:21:43,440 --> 00:21:42,010
time of having to reinvent astrobiology

549
00:21:45,720 --> 00:21:43,450
courses and figure out all the things

550
00:21:48,000 --> 00:21:45,730
that that I've taken three years to

551
00:21:50,669 --> 00:21:48,010
figure out with what sort of matches to

552
00:21:54,810 --> 00:21:50,679
teethe in mind I should also say that I

553
00:21:57,270 --> 00:21:54,820
wrote 21 um lectures in PowerPoint

554
00:21:58,740 --> 00:21:57,280
slides you can get on the Wiley on the

555
00:22:00,480 --> 00:21:58,750
Wiley website for free

556
00:22:02,730 --> 00:22:00,490
and they go alongside the lecture notes

557
00:22:04,260 --> 00:22:02,740
and they're based on my own lectures so

558
00:22:06,360 --> 00:22:04,270
if anyone out there wants to set up an

559
00:22:10,049 --> 00:22:06,370
astrobiology course at a university you

560
00:22:12,270 --> 00:22:10,059
can download 21 lectures that have 50

561
00:22:13,500 --> 00:22:12,280
minutes worth of powerpoints and then

562
00:22:14,730 --> 00:22:13,510
you use the textbook and you have

563
00:22:16,680 --> 00:22:14,740

instant Astro bar

564
00:22:18,210 --> 00:22:16,690
kourt's so another motive for writing

565
00:22:20,820 --> 00:22:18,220
this textbook to try and encourage

566
00:22:22,470 --> 00:22:20,830
people to set up more astrobiology

567
00:22:24,570 --> 00:22:22,480
courses in universities around the world

568
00:22:26,610 --> 00:22:24,580
and you know as you know the more

569
00:22:28,110 --> 00:22:26,620
astrobiology courses there are the

570
00:22:30,000 --> 00:22:28,120
better for all of us it just means

571
00:22:32,549 --> 00:22:30,010
there's more astrobiologists more

572
00:22:33,960 --> 00:22:32,559
support for astrobiology so in summary

573
00:22:36,450 --> 00:22:33,970
the reason why I did it is because I've

574
00:22:38,280 --> 00:22:36,460
written 50% of a text but already it

575
00:22:41,130 --> 00:22:38,290
seemed like a small step to make a big

576
00:22:43,320 --> 00:22:41,140
impact in improving astrobiology around

577
00:22:45,690 --> 00:22:43,330
the world in universe why I wrote it

578
00:22:48,120 --> 00:22:45,700
it's fun to write I like writing though

579
00:22:50,580 --> 00:22:48,130
you know this was not a chore for me it

580
00:22:52,140 --> 00:22:50,590
was something fun to do good for you

581
00:22:54,470 --> 00:22:52,150
Charles and I read a few chapters and

582
00:22:57,740 --> 00:22:54,480
it's very easy to read in a very

583
00:23:00,419 --> 00:22:57,750
well-designed a textbook so good job and

584
00:23:01,740 --> 00:23:00,429
so before we open it up to the public as

585
00:23:03,060 --> 00:23:01,750
we've been talking for roughly half an

586
00:23:05,520 --> 00:23:03,070
hour have one more thing I'd like to ask

587
00:23:08,010 --> 00:23:05,530
you at the mind you're at now built me

588
00:23:09,780 --> 00:23:08,020

mind you're organizing a course next

589
00:23:11,790 --> 00:23:09,790
year right based on NASA space for bound

590
00:23:14,180 --> 00:23:11,800
yeah could you tell us a bit more when

591
00:23:17,760 --> 00:23:14,190
is it going to be held what it's about

592
00:23:20,130 --> 00:23:17,770
yeah it's in October um it's a

593
00:23:21,780 --> 00:23:20,140
collaboration between the ball be on the

594
00:23:24,180 --> 00:23:21,790
ground science facility here where we're

595
00:23:26,280 --> 00:23:24,190
doing our Stroh biology and NASA space

596
00:23:29,040 --> 00:23:26,290
wood bound and it's to test

597
00:23:32,070 --> 00:23:29,050
instrumentation to do science in a deep

598
00:23:34,620 --> 00:23:32,080
subsurface environment and also to do

599
00:23:36,210 --> 00:23:34,630
education and outreach in the mind a

600
00:23:38,010 --> 00:23:36,220
kilometer underground although people

601
00:23:40,650 --> 00:23:38,020
can also work on the surface and do

602
00:23:42,990 --> 00:23:40,660
outreach activities here we've put out a

603
00:23:46,080 --> 00:23:43,000
general call that you can find on the UK

604
00:23:48,270 --> 00:23:46,090
Center for astrobiology website or you

605
00:23:51,000 --> 00:23:48,280
can contact me directly my emails on my

606
00:23:53,250 --> 00:23:51,010
website and we're inviting anyone with

607
00:23:55,560 --> 00:23:53,260
really good science good technology or

608
00:23:57,630 --> 00:23:55,570
good outreach that involves

609
00:23:59,880 --> 00:23:57,640
understanding life deep on the ground

610
00:24:02,400 --> 00:23:59,890
test these for the subsurface

611
00:24:04,500 --> 00:24:02,410
exploration of the Moon or Mars or just

612
00:24:07,230 --> 00:24:04,510
doing good outreach in astrobiology and

613
00:24:10,049 --> 00:24:07,240

underground science to take part in this

614
00:24:11,520 --> 00:24:10,059
and then what we'll do is we'll look at

615
00:24:14,610 --> 00:24:11,530
all the proposals and come up with a

616
00:24:18,630 --> 00:24:14,620
program so it's a it's October next year

617
00:24:20,160 --> 00:24:18,640
the 9th to the 24th I think I've

618
00:24:21,510 --> 00:24:20,170
completely forgotten the date so think

619
00:24:23,790 --> 00:24:21,520
those are the myth it's midway through

620
00:24:26,430 --> 00:24:23,800
October it's two weeks it's in web feeds

621
00:24:27,840 --> 00:24:26,440
it's not just um in Yorkshire the mine

622
00:24:30,270 --> 00:24:27,850
is just north of Whitby

623
00:24:32,940 --> 00:24:30,280
yeah it's grateful as well fantastic

624
00:24:34,620 --> 00:24:32,950
environment to work with and you will

625
00:24:38,370 --> 00:24:34,630
meet other people working in

626
00:24:40,200 --> 00:24:38,380
astrobiology and and and outreach we

627
00:24:42,240 --> 00:24:40,210
already have JPL involved so they're

628
00:24:44,190 --> 00:24:42,250
going to be here you testing Mars 2020

629
00:24:46,230 --> 00:24:44,200
instruments so it's going to be a really

630
00:24:48,600 --> 00:24:46,240
fantastic our two weeks anyway

631
00:24:50,940 --> 00:24:48,610
interested in in joining us please get

632
00:24:53,190 --> 00:24:50,950
in contact and send our Center it all it

633
00:24:54,990 --> 00:24:53,200
takes is a half page proposal on your

634
00:24:56,970 --> 00:24:55,000
experiments and what you plan to do and

635
00:24:57,750 --> 00:24:56,980
then you can wear one of these very

636
00:25:00,950 --> 00:24:57,760
stylish

637
00:25:03,750 --> 00:25:00,960
orange jumpsuits like I'm wearing now

638
00:25:05,880 --> 00:25:03,760

that's great and as an alumni of two

639
00:25:07,680 --> 00:25:05,890
NASA space program programs I love the

640
00:25:10,500 --> 00:25:07,690
combination of science and art reach

641
00:25:12,030 --> 00:25:10,510
that's just a testament to the program

642
00:25:13,920 --> 00:25:12,040
it's not just science it's not just art

643
00:25:16,080 --> 00:25:13,930
reaches both and both thoroughly which

644
00:25:17,850 --> 00:25:16,090
is awesome so yeah definitely those of

645
00:25:19,380 --> 00:25:17,860
you who are excited about those two

646
00:25:22,140 --> 00:25:19,390
topics science and art which together

647
00:25:24,870 --> 00:25:22,150
really consider charles of space or van

648
00:25:27,090 --> 00:25:24,880
program next October so okay so that's

649
00:25:29,340 --> 00:25:27,100
that run sums up all the questions I had

650
00:25:31,320 --> 00:25:29,350
I am scanning the the Twitter feed right

651
00:25:34,860 --> 00:25:31,330
now under Sagan a chat to see if there

652
00:25:38,910 --> 00:25:34,870
any questions there's one from JP heavy

653
00:25:41,340 --> 00:25:38,920
industries at JP heavy who asks what

654
00:25:46,620 --> 00:25:41,350
would a methane-based ecology look like

655
00:25:48,180 --> 00:25:46,630
on say Titan well that's interesting I

656
00:25:51,240 --> 00:25:48,190
mean Titan it has a bit of a problem

657
00:25:53,580 --> 00:25:51,250
because it's at about 94 Kelvin which is

658
00:25:57,180 --> 00:25:53,590
some way below what we think is the

659
00:25:59,100 --> 00:25:57,190
lower temperature limit for life so you

660
00:26:01,260 --> 00:25:59,110
know certainly there's the raw material

661
00:26:02,910 --> 00:26:01,270
for life there lots of organic materials

662
00:26:04,470 --> 00:26:02,920
complex organic materials and

663
00:26:07,080 --> 00:26:04,480

interesting photo chemical cycles

664
00:26:09,450 --> 00:26:07,090
generating complex organics the sort of

665
00:26:11,010 --> 00:26:09,460
things you might build living things

666
00:26:13,050 --> 00:26:11,020
from although we haven't yet detected

667
00:26:17,340 --> 00:26:13,060
things like amino acids and sugars that

668
00:26:19,410 --> 00:26:17,350
that's yet to be demonstrated but but

669
00:26:21,630 --> 00:26:19,420
real problem is can you have life

670
00:26:23,880 --> 00:26:21,640
working at 94 Kelvin there have been

671
00:26:27,210 --> 00:26:23,890
some interesting ideas about life on

672
00:26:29,190 --> 00:26:27,220
Titan so for example ideas from from

673
00:26:32,730 --> 00:26:29,200
Chris McKay and Heather Smith at NASA

674
00:26:34,500 --> 00:26:32,740
Ames who proposed life using acetylene

675
00:26:36,900 --> 00:26:34,510
and hydrogen as an energy source so

676
00:26:40,770 --> 00:26:36,910
there are molecules as well on Titan

677
00:26:41,970 --> 00:26:40,780
that might be plausible reduction

678
00:26:44,640 --> 00:26:41,980
oxidation reaction

679
00:26:45,539 --> 00:26:44,650
for getting energy but I think still the

680
00:26:48,510 --> 00:26:45,549
problem remains

681
00:26:50,730 --> 00:26:48,520
what's the solvent liquid methane maybe

682
00:26:52,490 --> 00:26:50,740
but liquid methane has some some

683
00:26:54,990 --> 00:26:52,500
disadvantages with respect to doing

684
00:26:56,280 --> 00:26:55,000
dissolving polar substances and doing

685
00:26:58,140 --> 00:26:56,290
the sorts of things that we associate

686
00:27:00,150 --> 00:26:58,150
with biochemistry and I think the real

687
00:27:02,970 --> 00:27:00,160
problem is low temperature I mean okay

688
00:27:05,580 --> 00:27:02,980

you might say maybe life is just working

689
00:27:09,360 --> 00:27:05,590
very very slowly there at literally

690
00:27:11,700 --> 00:27:09,370
glacial timescales and and you know

691
00:27:13,740 --> 00:27:11,710
organisms just divide every few hundred

692
00:27:16,260 --> 00:27:13,750
million years but but it's very

693
00:27:18,060 --> 00:27:16,270
difficult to get it's very difficult to

694
00:27:20,010 --> 00:27:18,070
get reasonable kinetics going at those

695
00:27:24,000 --> 00:27:20,020
temperatures where you can conceive of

696
00:27:25,470 --> 00:27:24,010
an organism that can adapt to changes in

697
00:27:27,450 --> 00:27:25,480
environmental conditions that we

698
00:27:30,180 --> 00:27:27,460
associate even with environments like

699
00:27:32,430 --> 00:27:30,190
Titan Titan is a dynamic world despite

700
00:27:33,810 --> 00:27:32,440
the low temperatures can you have an

701
00:27:36,570 --> 00:27:33,820
organism that can adapt to those changes

702
00:27:37,799 --> 00:27:36,580
quick enough when it's operating at 94

703
00:27:41,130 --> 00:27:37,809
kelvin i think that's an interesting

704
00:27:42,900 --> 00:27:41,140
question to ask yeah it's a bit warmer

705
00:27:45,150 --> 00:27:42,910
underground there is a liquid ocean but

706
00:27:47,039 --> 00:27:45,160
it sits between ice it's not UNTAC tting

707
00:27:49,950 --> 00:27:47,049
was rock so it's I'm still not convinced

708
00:27:51,299 --> 00:27:49,960
oh great ladies your life absolutely

709
00:27:52,860 --> 00:27:51,309
maybe that's what the questioner was

710
00:27:55,440 --> 00:27:52,870
asking so yes I mean if there's a

711
00:27:57,960 --> 00:27:55,450
subsurface ocean that would be another

712
00:28:00,000 --> 00:27:57,970
another question altogether if there's

713
00:28:03,030 --> 00:28:00,010

liquid water even maybe liquid water and

714
00:28:05,280 --> 00:28:03,040
ammonia mixed ocean that might be a more

715
00:28:08,880 --> 00:28:05,290
plausible environment for life than the

716
00:28:12,480 --> 00:28:08,890
near surface environment yeah well I

717
00:28:16,380 --> 00:28:12,490
cream um let's see what else is on the

718
00:28:19,350 --> 00:28:16,390
Twitter feed on a cigarette chat Ben

719
00:28:21,330 --> 00:28:19,360
Pierce asks where will we find the first

720
00:28:24,090 --> 00:28:21,340
evidence of life beyond Earth will it be

721
00:28:27,270 --> 00:28:24,100
Mars Europa ah maybe an exoplanet

722
00:28:29,039 --> 00:28:27,280
oh yeah well this is always you know I

723
00:28:32,190 --> 00:28:29,049
mean my guess is as good as anyone where

724
00:28:35,010 --> 00:28:32,200
do I know where life is but it's an

725
00:28:36,690 --> 00:28:35,020
interesting question because I you know

726
00:28:39,030 --> 00:28:36,700
there is a possibility that we might

727
00:28:41,549 --> 00:28:39,040
find life on an exoplanet before we find

728
00:28:44,340 --> 00:28:41,559
life in our own solar system unless

729
00:28:46,289 --> 00:28:44,350
there's life in Enceladus in Europa

730
00:28:49,650 --> 00:28:46,299
that's being spewed out into space in

731
00:28:52,289 --> 00:28:49,660
clues and that might be relatively easy

732
00:28:54,299 --> 00:28:52,299
to to capture but you know organizing a

733
00:28:55,550 --> 00:28:54,309
sample return mission or a life detects

734
00:28:58,520 --> 00:28:55,560
your mission to Europa

735
00:29:00,920 --> 00:28:58,530
and Enceladus to sample those plumes may

736
00:29:03,560 --> 00:29:00,930
well be a decade or more in the future

737
00:29:05,150 --> 00:29:03,570
um finding evidence for life on Mars

738
00:29:08,180 --> 00:29:05,160

might require drilling into the

739
00:29:10,310 --> 00:29:08,190
subsurface that could be a decade or two

740
00:29:13,250 --> 00:29:10,320
decades ahead to really get good samples

741
00:29:16,160 --> 00:29:13,260
out that unequivocally show light within

742
00:29:18,260 --> 00:29:16,170
that period of a couple of decades it's

743
00:29:21,140 --> 00:29:18,270
not impossible that we might be able to

744
00:29:23,750 --> 00:29:21,150
find a an oxygen bio signature on a on

745
00:29:26,030 --> 00:29:23,760
an exoplanet so I think you know it

746
00:29:27,290 --> 00:29:26,040
would be remarkable in astrobiology if

747
00:29:29,390 --> 00:29:27,300
we actually found evidence of life

748
00:29:31,940 --> 00:29:29,400
beyond our own solar system before we

749
00:29:33,590 --> 00:29:31,950
found like in our own solar system but

750
00:29:35,570 --> 00:29:33,600
who knows I mean we may find we're in a

751
00:29:40,160 --> 00:29:35,580
biological desert and that all

752
00:29:43,040 --> 00:29:40,170
earth-like exoplanets have no life in

753
00:29:45,530 --> 00:29:43,050
which case we're back back to you for

754
00:29:47,960 --> 00:29:45,540
life in our own solar system so my guess

755
00:29:49,310 --> 00:29:47,970
as to where we'll find life is it's no

756
00:29:51,350 --> 00:29:49,320
better than anyone else's guess

757
00:29:53,240 --> 00:29:51,360
I don't know but what's exciting what's

758
00:29:54,710 --> 00:29:53,250
really exciting for astrobiologists is

759
00:29:57,650 --> 00:29:54,720
the discovery of liquid water

760
00:30:01,220 --> 00:29:57,660
environments in our own solar system and

761
00:30:03,530 --> 00:30:01,230
beyond discovery of our super arts that

762
00:30:05,450 --> 00:30:03,540
may be ocean world the discovery of

763
00:30:09,230 --> 00:30:05,460

liquid water coming out of Enceladus

764
00:30:11,480 --> 00:30:09,240
liquid water in Europa extraordinary

765
00:30:13,400 --> 00:30:11,490
evidence for long-lived water bodies and

766
00:30:16,100 --> 00:30:13,410
petechiae sediments on the surface of

767
00:30:18,560 --> 00:30:16,110
Mars incredible images from curiosity of

768
00:30:21,230 --> 00:30:18,570
sedimentary layers all of these things

769
00:30:22,820 --> 00:30:21,240
provide us with the impetus to search

770
00:30:25,310 --> 00:30:22,830
for life regardless of whether we

771
00:30:27,410 --> 00:30:25,320
actually find it or not so we've got the

772
00:30:29,510 --> 00:30:27,420
point I think my summary would be we've

773
00:30:30,700 --> 00:30:29,520
got plenty of places to look for it and

774
00:30:34,370 --> 00:30:30,710
that's the good news

775
00:30:36,380 --> 00:30:34,380
what does your intuition lead you to in

776
00:30:38,900 --> 00:30:36,390
terms of the where in our solar system

777
00:30:42,230 --> 00:30:38,910
you think life is just gut feeling you

778
00:30:44,210 --> 00:30:42,240
know it it's the ocean so it depends

779
00:30:46,910 --> 00:30:44,220
what all my world cup in the morning and

780
00:30:49,160 --> 00:30:46,920
what I ate that day you know I sometimes

781
00:30:51,890 --> 00:30:49,170
I look at pictures of sedimentary as

782
00:30:53,900 --> 00:30:51,900
taken by curiosity in a volcanic

783
00:30:55,970 --> 00:30:53,910
environment that looks so like Iceland

784
00:30:57,980 --> 00:30:55,980
and you just think is it really the case

785
00:31:00,650 --> 00:30:57,990
all of those sediments that curiosity of

786
00:31:02,480 --> 00:31:00,660
study were completely sterile and I find

787
00:31:04,310 --> 00:31:02,490
it difficult to believe that they are

788
00:31:07,280 --> 00:31:04,320

and then another day you know I'll see a

789
00:31:08,830 --> 00:31:07,290
new story about plumes on Enceladus and

790
00:31:12,909 --> 00:31:08,840
I'll just think that's incredible

791
00:31:14,950 --> 00:31:12,919
you have you know large water bodies you

792
00:31:16,630 --> 00:31:14,960
know in the case of Europa that have two

793
00:31:18,519 --> 00:31:16,640
times as much liquid water as the

794
00:31:21,220 --> 00:31:18,529
Earth's oceans combined you think how

795
00:31:22,659 --> 00:31:21,230
can that completely sterile but maybe

796
00:31:24,549 --> 00:31:22,669
these places are I mean it's very

797
00:31:26,529 --> 00:31:24,559
difficult for us on the earth to accept

798
00:31:28,360 --> 00:31:26,539
the idea of large bodies of liquid water

799
00:31:30,549 --> 00:31:28,370
that are habitable but completely

800
00:31:33,460 --> 00:31:30,559
sterile and that's a paradigm that's

801
00:31:35,350 --> 00:31:33,470
very difficult to that's very alien to

802
00:31:37,390 --> 00:31:35,360
ecologist and to most of us as

803
00:31:39,279 --> 00:31:37,400
biologists but it's possible that if the

804
00:31:41,680 --> 00:31:39,289
place has never had an origin of life or

805
00:31:44,380 --> 00:31:41,690
life was never successfully transferred

806
00:31:48,100 --> 00:31:44,390
to them from the earth then they may be

807
00:31:51,130 --> 00:31:48,110
sterile so I don't know I go from

808
00:31:53,019 --> 00:31:51,140
optimism to to less optimism depending

809
00:31:55,419 --> 00:31:53,029
on what I thought about and what papers

810
00:31:56,980 --> 00:31:55,429
I've read but you know that something

811
00:31:58,450 --> 00:31:56,990
would've astrobiology the fact that

812
00:32:01,090 --> 00:31:58,460
there are these incredibly arguments to

813
00:32:03,310 --> 00:32:01,100

have liquid water look like plausible

814
00:32:05,200 --> 00:32:03,320
locations for life are they inhabited or

815
00:32:08,320 --> 00:32:05,210
not you know that's what we all really

816
00:32:09,940 --> 00:32:08,330
want to find out yeah it's really

817
00:32:12,070 --> 00:32:09,950
definitely good for our civilization to

818
00:32:13,539 --> 00:32:12,080
go and find out it I think the answer to

819
00:32:15,610 --> 00:32:13,549
that question will have not only very

820
00:32:17,830 --> 00:32:15,620
profound scientific implications but

821
00:32:20,500 --> 00:32:17,840
also philosophically ones as well that

822
00:32:23,919 --> 00:32:20,510
would be a good for us to think about so

823
00:32:24,669 --> 00:32:23,929
Graham Lau hi Graham has a question this

824
00:32:27,220 --> 00:32:24,679
very good one

825
00:32:28,990 --> 00:32:27,230
so you you taught on the Coursera you've

826
00:32:31,630 --> 00:32:29,000
reached many thousands of people with

827
00:32:32,080 --> 00:32:31,640
your class but his questions is more how

828
00:32:34,779 --> 00:32:32,090
can we

829
00:32:37,659 --> 00:32:34,789
I guess share astrobiology in a more

830
00:32:39,250 --> 00:32:37,669
hands-on manner than just listening to

831
00:32:43,240 --> 00:32:39,260
lectures online what are your thoughts

832
00:32:45,130 --> 00:32:43,250
on that yeah I you know I think that's a

833
00:32:47,860 --> 00:32:45,140
really good question I think there's a

834
00:32:49,779 --> 00:32:47,870
huge amount of potential out there I

835
00:32:52,360 --> 00:32:49,789
mean in some sense there is some out

836
00:32:55,870 --> 00:32:52,370
there like for example the citizen

837
00:32:58,240 --> 00:32:55,880
science exoplanet projects are looking

838
00:33:01,630 --> 00:32:58,250

for exoplanets in in data that's been

839
00:33:04,510 --> 00:33:01,640
sent back by Kepler and being produced

840
00:33:07,230 --> 00:33:04,520
by others there are projects where

841
00:33:09,310 --> 00:33:07,240
there's a possibility of real hands-on

842
00:33:12,820 --> 00:33:09,320
projects I think looking at the Mars

843
00:33:15,490 --> 00:33:12,830
Curiosity images and orbital images is

844
00:33:18,220 --> 00:33:15,500
something that could can be handed over

845
00:33:20,260 --> 00:33:18,230
to citizen science it would be great to

846
00:33:22,480 --> 00:33:20,270
come up with more lab based experiments

847
00:33:25,780 --> 00:33:22,490
there are people currently

848
00:33:29,740 --> 00:33:25,790
trying to build desktop Mars chambers

849
00:33:31,360 --> 00:33:29,750
that you can make by 3d printing I had a

850
00:33:33,430 --> 00:33:31,370
conversation with people who are

851
00:33:36,490 --> 00:33:33,440
building 3d printed Mars simulation

852
00:33:38,980 --> 00:33:36,500
chambers so that I think again with 3d

853
00:33:40,900 --> 00:33:38,990
printing maybe there are planetary

854
00:33:43,419 --> 00:33:40,910
simulation chambers that people can fill

855
00:33:47,080 --> 00:33:43,429
at home and do real astrobiology type

856
00:33:49,060 --> 00:33:47,090
experiments um but but yeah I think his

857
00:33:51,340 --> 00:33:49,070
question is a really good one I think if

858
00:33:53,290 --> 00:33:51,350
anyone out there has ideas for hands-on

859
00:33:56,590 --> 00:33:53,300
astrobiology experiments either through

860
00:33:59,049 --> 00:33:56,600
citizen science type projects or things

861
00:34:00,430 --> 00:33:59,059
that people can buy and do experiments

862
00:34:03,460 --> 00:34:00,440
in their own homes that would be a

863
00:34:05,710 --> 00:34:03,470

fantastic Avenue for increasing the

864
00:34:08,169 --> 00:34:05,720
outreach of astrobiology on a more sort

865
00:34:10,300 --> 00:34:08,179
of popular level but also giving people

866
00:34:13,720 --> 00:34:10,310
who are not professional astrobiologists

867
00:34:15,129 --> 00:34:13,730
do real experiments yes I survive

868
00:34:16,600 --> 00:34:15,139
definitely still a young field that

869
00:34:18,609 --> 00:34:16,610
needs a lot of ideas from the earlier

870
00:34:21,340 --> 00:34:18,619
early career community and how to make

871
00:34:25,119 --> 00:34:21,350
it how to make it grow there's a

872
00:34:26,950 --> 00:34:25,129
question on asteroid mining sorry

873
00:34:28,659 --> 00:34:26,960
there's a question on asteroid mining by

874
00:34:30,940 --> 00:34:28,669
Elizabeth Frank hi Elizabeth

875
00:34:33,550 --> 00:34:30,950
regarding are you the first one to do

876
00:34:35,710 --> 00:34:33,560
microbes on asteroids in terms of bio

877
00:34:37,000 --> 00:34:35,720
mining or is there is an established

878
00:34:40,300 --> 00:34:37,010
literature on that that you're building

879
00:34:42,460 --> 00:34:40,310
on now there's a couple of papers out

880
00:34:44,919 --> 00:34:42,470
there where people have are looked at

881
00:34:48,280 --> 00:34:44,929
microbes growing on meteoritic material

882
00:34:50,889 --> 00:34:48,290
in the lab so there's a couple of papers

883
00:34:53,430 --> 00:34:50,899
by mort nur who did who grew plants

884
00:34:56,050 --> 00:34:53,440
actually as well as microbes on

885
00:34:57,460 --> 00:34:56,060
contracted carbonaceous chondrites so

886
00:34:59,500 --> 00:34:57,470
it's not the first time anyone's looked

887
00:35:01,150 --> 00:34:59,510
at whether things will grow on on on

888
00:35:03,670 --> 00:35:01,160

meteorites and things will grow on

889
00:35:05,140 --> 00:35:03,680
meteorites meteorites are just silicate

890
00:35:07,210 --> 00:35:05,150
rocks and there's plenty of good stuff

891
00:35:09,580 --> 00:35:07,220
in there for things to grow I think ours

892
00:35:12,070 --> 00:35:09,590
is the first experiment that has been

893
00:35:15,310 --> 00:35:12,080
approved for spaceflight certainly the

894
00:35:18,210 --> 00:35:15,320
first experiment proposed for a space

895
00:35:22,390 --> 00:35:18,220
station that these are deliberately folk

896
00:35:24,730 --> 00:35:22,400
might being in the use of microbes to to

897
00:35:27,310 --> 00:35:24,740
break down rocks and play a role in bio

898
00:35:29,380 --> 00:35:27,320
mining and also in other microbial

899
00:35:31,150 --> 00:35:29,390
immediated sort of reactions and and

900
00:35:34,810 --> 00:35:31,160
useful things we can do with regolith

901
00:35:39,790 --> 00:35:37,870
fascinating I have another question from

902
00:35:43,600 --> 00:35:39,800
penny Boston hi penny

903
00:35:45,460 --> 00:35:43,610
she asks so biofilms are so central to

904
00:35:48,520 --> 00:35:45,470
the microbial Way of life here on earth

905
00:35:50,410 --> 00:35:48,530
do you think that a biofilm lifestyle is

906
00:35:54,190 --> 00:35:50,420
going to be a lifestyle chase of

907
00:35:55,810 --> 00:35:54,200
microbes everywhere in a galaxy ha it's

908
00:35:57,460 --> 00:35:55,820
a really good question so hi penny by

909
00:36:00,820 --> 00:35:57,470
the way good really glad you could make

910
00:36:02,320 --> 00:36:00,830
it um yeah I think so as penny knows you

911
00:36:03,880 --> 00:36:02,330
know these things biofilms are

912
00:36:07,060 --> 00:36:03,890
everywhere in extreme environments in

913
00:36:09,610 --> 00:36:07,070

caves and in other situations very few

914
00:36:11,500 --> 00:36:09,620
microbes in the natural world live alone

915
00:36:14,740 --> 00:36:11,510
and we call these things unicellular

916
00:36:17,430 --> 00:36:14,750
micro unicellular organisms but very few

917
00:36:19,780 --> 00:36:17,440
microbes are truly unicellular that's a

918
00:36:21,940 --> 00:36:19,790
generally an artifact of the laboratory

919
00:36:24,190 --> 00:36:21,950
when you go into natural environments

920
00:36:28,300 --> 00:36:24,200
microbes cooperate in a whole variety of

921
00:36:30,820 --> 00:36:28,310
ways either up provokes energy sources

922
00:36:33,370 --> 00:36:30,830
and other microbes will waste they

923
00:36:34,870 --> 00:36:33,380
collaborate in terms of extracting

924
00:36:37,150 --> 00:36:34,880
nutrients from rocks you know one

925
00:36:39,070 --> 00:36:37,160
microbe might excrete an acid that will

926
00:36:41,320 --> 00:36:39,080
break down rocks that helps the whole

927
00:36:43,540 --> 00:36:41,330
community to grow and they cycle

928
00:36:45,460 --> 00:36:43,550
elements as well carbon sulfur nitrogen

929
00:36:47,380 --> 00:36:45,470
and all these elements cycle through

930
00:36:50,770 --> 00:36:47,390
biofilms through different types of

931
00:36:53,590 --> 00:36:50,780
microbes I think on any planet where you

932
00:36:55,480 --> 00:36:53,600
have microbes there has to be a very

933
00:36:58,860 --> 00:36:55,490
strong evolutionary selection pressure

934
00:37:02,020 --> 00:36:58,870
for those microbes to start cooperating

935
00:37:05,410 --> 00:37:02,030
in the Darwinian struggle for survival

936
00:37:07,300 --> 00:37:05,420
in the classical view of that it would

937
00:37:09,100 --> 00:37:07,310
be it's sort of biologically

938
00:37:11,260 --> 00:37:09,110

inconceivable you would have microbes to

939
00:37:12,790 --> 00:37:11,270
sitting on a planetary surface just

940
00:37:15,040 --> 00:37:12,800
doing their own thing completely

941
00:37:17,560 --> 00:37:15,050
separated because somewhere in that

942
00:37:19,840 --> 00:37:17,570
mixture of microbes there's going to be

943
00:37:21,820 --> 00:37:19,850
a selective advantage for two microbes

944
00:37:24,280 --> 00:37:21,830
to work together even as I say if it's

945
00:37:26,410 --> 00:37:24,290
just one microbe using another microbe

946
00:37:29,290 --> 00:37:26,420
waste as an energy source so I think

947
00:37:30,700 --> 00:37:29,300
there has to be a drive towards biofilms

948
00:37:32,350 --> 00:37:30,710
I think on any planet where you had

949
00:37:37,809 --> 00:37:32,360
microbes you would find things growing

950
00:37:40,749 --> 00:37:37,819
in biofilms great question penny thanks

951
00:37:44,499 --> 00:37:40,759
Gramp has another one good question

952
00:37:46,839 --> 00:37:44,509
again go tickle the brain here if you

953
00:37:49,239 --> 00:37:46,849
are allowed to say one sentence on a

954
00:37:51,699 --> 00:37:49,249
future Golden Record that will be sent

955
00:37:53,620 --> 00:37:51,709
to space that kind of summarizes

956
00:37:56,019 --> 00:37:53,630
humanity almost what would you what

957
00:38:00,099 --> 00:37:56,029
would you say or in addition to that

958
00:38:03,039 --> 00:38:00,109
what would you put on that record my

959
00:38:09,160 --> 00:38:03,049
message would be we do good things as

960
00:38:13,239 --> 00:38:09,170
well you know indeed that's a very

961
00:38:15,099 --> 00:38:13,249
cynical reply you know the alien species

962
00:38:17,680 --> 00:38:15,109
was watching what we get up to I think

963
00:38:20,680 --> 00:38:17,690

they would be they would be in despair

964
00:38:22,439 --> 00:38:20,690
you know we do do a lie there's sort of

965
00:38:25,029 --> 00:38:22,449
serious side to that comment

966
00:38:26,859 --> 00:38:25,039
astrobiology the search for life beyond

967
00:38:28,900 --> 00:38:26,869
the earth for me at least is one of the

968
00:38:31,029 --> 00:38:28,910
things that demonstrates the best in our

969
00:38:32,650 --> 00:38:31,039
civilization and I'm not just saying

970
00:38:33,130 --> 00:38:32,660
that because I want funding I really

971
00:38:36,279 --> 00:38:33,140
mean that

972
00:38:37,989 --> 00:38:36,289
um asking the question of are we alone

973
00:38:39,969 --> 00:38:37,999
in the universe I don't know of any

974
00:38:43,449 --> 00:38:39,979
other species on the earth that asks

975
00:38:45,999 --> 00:38:43,459
that planet that ask that question a lot

976
00:38:48,039 --> 00:38:46,009
of species attack each other they do

977
00:38:50,890 --> 00:38:48,049
warfare obviously in a more rudimentary

978
00:38:53,620 --> 00:38:50,900
way than us but a lot of the things that

979
00:38:55,660 --> 00:38:53,630
we do that are bad are products of

980
00:38:57,519 --> 00:38:55,670
animal instinct but asking questions

981
00:39:00,640 --> 00:38:57,529
like what's the what's the universe made

982
00:39:02,920 --> 00:39:00,650
of is there life out there these are

983
00:39:05,099 --> 00:39:02,930
questions that that really define us as

984
00:39:07,269 --> 00:39:05,109
a species that can think as a

985
00:39:09,609 --> 00:39:07,279
civilization that can go beyond purely

986
00:39:11,170 --> 00:39:09,619
animal instincts so I would like to

987
00:39:12,819 --> 00:39:11,180
think that these are things that we

988
00:39:14,769 --> 00:39:12,829

would want to tell other species in the

989
00:39:16,059 --> 00:39:14,779
universe that yeah we have our failings

990
00:39:18,249 --> 00:39:16,069
we have our faults and if you're

991
00:39:20,769 --> 00:39:18,259
observing our planet you probably see

992
00:39:22,479 --> 00:39:20,779
some quite bad stuff going on but we

993
00:39:24,430 --> 00:39:22,489
also think about these higher-level

994
00:39:25,359 --> 00:39:24,440
questions there really is hope for our

995
00:39:27,969 --> 00:39:25,369
civilzation

996
00:39:31,150 --> 00:39:27,979
to break beyond violence and destruction

997
00:39:33,640 --> 00:39:31,160
and and to to move out into the universe

998
00:39:35,650 --> 00:39:33,650
and and contribute in a very positive

999
00:39:38,769 --> 00:39:35,660
way if there are other species out there

1000
00:39:41,380 --> 00:39:38,779
so that that would be my message to to

1001
00:39:43,509 --> 00:39:41,390
other species and and maybe they would

1002
00:39:45,609 --> 00:39:43,519
recognize that you know if they come if

1003
00:39:47,289 --> 00:39:45,619
they are species at the end of a food

1004
00:39:50,250 --> 00:39:47,299
chain maybe they are understand

1005
00:39:54,180 --> 00:39:50,260
aggression as an evolutionary product

1006
00:39:56,160 --> 00:39:54,190
and I like the rule or what we actually

1007
00:39:57,870 --> 00:39:56,170
do good stuff as well they might

1008
00:39:59,910 --> 00:39:57,880
actually understand that and understand

1009
00:40:02,640 --> 00:39:59,920
the conflict in ourselves in our

1010
00:40:04,099 --> 00:40:02,650
civilization and the work that we have

1011
00:40:06,450 --> 00:40:04,109
to do to try and reach beyond

1012
00:40:09,270 --> 00:40:06,460
destruction to the positive side of our

1013
00:40:12,870 --> 00:40:09,280

own natures I think all intelligent

1014
00:40:14,340 --> 00:40:12,880
species have that conflict there's some

1015
00:40:17,340 --> 00:40:14,350
beautiful world Charles you get that

1016
00:40:19,740 --> 00:40:17,350
Graham yeah I agree with you that

1017
00:40:21,540 --> 00:40:19,750
astrobiology is a very unifying as a

1018
00:40:23,460 --> 00:40:21,550
discipline because you know looking up

1019
00:40:24,960 --> 00:40:23,470
at the stars and wondering what's out

1020
00:40:28,230 --> 00:40:24,970
there is definitely not something that's

1021
00:40:30,810 --> 00:40:28,240
limited to individuals you know pockets

1022
00:40:32,340 --> 00:40:30,820
on the earth everybody has done that and

1023
00:40:33,810 --> 00:40:32,350
it's it makes for wonderful

1024
00:40:36,000 --> 00:40:33,820
conversations and the fact that we can

1025
00:40:37,740 --> 00:40:36,010
tackle that scientifically in this early

1026
00:40:39,870 --> 00:40:37,750
21st century is an awesome time to be

1027
00:40:41,790 --> 00:40:39,880
alive

1028
00:40:43,890 --> 00:40:41,800
so astrobiology is a fairly young field

1029
00:40:45,570 --> 00:40:43,900
as you know um what do you think are the

1030
00:40:47,700 --> 00:40:45,580
challenges going to face in the future

1031
00:40:49,380 --> 00:40:47,710
like there's no yet Department of

1032
00:40:51,420 --> 00:40:49,390
astrobiology and personally I think

1033
00:40:53,690 --> 00:40:51,430
that's probably a good thing but how do

1034
00:40:57,690 --> 00:40:53,700
you see the field evolving and and

1035
00:41:01,380 --> 00:40:57,700
maturing I guess yeah I mean I'm not the

1036
00:41:03,690 --> 00:41:01,390
first one is really that one of Astra

1037
00:41:07,170 --> 00:41:03,700
body's biggest challenges is that it's

1038
00:41:10,530 --> 00:41:07,180

so broad it's difficult to condense it

1039
00:41:12,450 --> 00:41:10,540
into a single field when you can put up

1040
00:41:14,970 --> 00:41:12,460
a building and say that the Department

1041
00:41:17,370 --> 00:41:14,980
of XYZ it's a lot easier to get funding

1042
00:41:19,620 --> 00:41:17,380
because people can put you in a in a

1043
00:41:22,320 --> 00:41:19,630
pigeonhole and they can understand what

1044
00:41:24,060 --> 00:41:22,330
you're trying to do um astrobiology is

1045
00:41:26,430 --> 00:41:24,070
so broad it's sometimes difficult for

1046
00:41:27,990 --> 00:41:26,440
people to understand what we're really

1047
00:41:29,790 --> 00:41:28,000
doing because we ask these very broad

1048
00:41:31,859 --> 00:41:29,800
questions but that's also its strength

1049
00:41:34,140 --> 00:41:31,869
that's one of the most exciting things

1050
00:41:36,630 --> 00:41:34,150
about astrobiology is it cuts across

1051
00:41:39,060 --> 00:41:36,640
disciplinary boundaries and that's where

1052
00:41:40,980 --> 00:41:39,070
some of the most exciting science is so

1053
00:41:43,020 --> 00:41:40,990
it's challenge I think ahead and this is

1054
00:41:45,510 --> 00:41:43,030
a challenge I see at Edinboro nets

1055
00:41:48,060 --> 00:41:45,520
I don't think a unique challenge it is

1056
00:41:51,240 --> 00:41:48,070
is trying to consolidate around

1057
00:41:53,220 --> 00:41:51,250
particular questions in my case any of

1058
00:41:56,070 --> 00:41:53,230
life in extremes other people have other

1059
00:41:57,930 --> 00:41:56,080
questions in astrobiology but to try and

1060
00:42:00,300 --> 00:41:57,940
keep that momentum going and creating

1061
00:42:03,540 --> 00:42:00,310
new jobs our new funding that can

1062
00:42:05,100 --> 00:42:03,550
sustain a new generation um

1063
00:42:07,830 --> 00:42:05,110

really sad thing to see is lots of

1064
00:42:09,960 --> 00:42:07,840
people coming up in astral and not

1065
00:42:11,730 --> 00:42:09,970
sufficient jobs to give them permanent

1066
00:42:13,650 --> 00:42:11,740
positions in universities I mean that's

1067
00:42:15,210 --> 00:42:13,660
not just that's not just unique to

1068
00:42:18,210 --> 00:42:15,220
astrobiology it's true of a lot of

1069
00:42:19,740 --> 00:42:18,220
science but but in astrobiology we also

1070
00:42:22,830 --> 00:42:19,750
have to confront that challenge of

1071
00:42:26,550 --> 00:42:22,840
trying to keep the momentum of the field

1072
00:42:28,980 --> 00:42:26,560
going um I would say to anyone listening

1073
00:42:31,170 --> 00:42:28,990
who's an early career researcher don't

1074
00:42:34,130 --> 00:42:31,180
forget astrobiology if you go into a

1075
00:42:36,390 --> 00:42:34,140
university and get a conventional

1076
00:42:39,060 --> 00:42:36,400
conventional job in something like

1077
00:42:41,040 --> 00:42:39,070
microbiology and astronomy do really

1078
00:42:44,490 --> 00:42:41,050
make an effort to set up astrobiology

1079
00:42:47,070 --> 00:42:44,500
under graduate undergraduate lecture

1080
00:42:49,980 --> 00:42:47,080
courses they're incredibly popular

1081
00:42:52,170 --> 00:42:49,990
amongst students but what that also does

1082
00:42:54,090 --> 00:42:52,180
is it will it will keep momentum and

1083
00:42:55,920 --> 00:42:54,100
critical mass in astrobiology going

1084
00:42:57,780 --> 00:42:55,930
globally by keeping it healthy in

1085
00:42:59,490 --> 00:42:57,790
universities so I think that's a really

1086
00:43:01,530 --> 00:42:59,500
important way of addressing the

1087
00:43:03,780 --> 00:43:01,540
challenge of critical mass and

1088
00:43:06,480 --> 00:43:03,790

sustainability keep that excitement and

1089
00:43:10,020 --> 00:43:06,490
those courses going in in academic

1090
00:43:11,700 --> 00:43:10,030
institutions yeah and here I have to do

1091
00:43:13,590 --> 00:43:11,710
a little parent assist and commend an

1092
00:43:15,060 --> 00:43:13,600
SSO velji program and Institute for

1093
00:43:17,010 --> 00:43:15,070
really being supportive of the early

1094
00:43:19,560 --> 00:43:17,020
career Network especially so the era

1095
00:43:22,260 --> 00:43:19,570
conference AB grad con which is has been

1096
00:43:25,860 --> 00:43:22,270
formative for me and I know for others

1097
00:43:31,530 --> 00:43:25,870
and let's see any other questions do I

1098
00:43:33,180 --> 00:43:31,540
see online there's one by Indra and I

1099
00:43:34,950 --> 00:43:33,190
think you've tackled this one already a

1100
00:43:39,170 --> 00:43:34,960
little bit she was asking like if

1101
00:43:42,270 --> 00:43:39,180
contact was made by was made with et

1102
00:43:44,280 --> 00:43:42,280
what kind of scientists would be the

1103
00:43:45,840 --> 00:43:44,290
ones making a contact but I think

1104
00:43:47,790 --> 00:43:45,850
astrobiologists are the ones we're going

1105
00:43:49,950 --> 00:43:47,800
to make that contact whether it's

1106
00:43:52,140 --> 00:43:49,960
geologist or biologist or astronomers

1107
00:43:55,200 --> 00:43:52,150
depends where we find that life but what

1108
00:43:56,670 --> 00:43:55,210
are your thoughts yeah no I agree you

1109
00:43:58,680 --> 00:43:56,680
know that's what I scribble Hajis for

1110
00:44:01,770 --> 00:43:58,690
one of the things that's one of the

1111
00:44:03,570 --> 00:44:01,780
things we're supposed to do is is be

1112
00:44:06,060 --> 00:44:03,580
that connection if that ever happened of

1113
00:44:07,800 --> 00:44:06,070

course you know that's a very optimistic

1114
00:44:10,050 --> 00:44:07,810
thing to happen in the field

1115
00:44:11,730 --> 00:44:10,060
we'll be very happy if we find microbes

1116
00:44:14,040 --> 00:44:11,740
on another planet that'll give us plenty

1117
00:44:15,810 --> 00:44:14,050
of work to do but but yes I mean

1118
00:44:16,860 --> 00:44:15,820
thinking hypothetically if we made

1119
00:44:23,550 --> 00:44:16,870
contact with

1120
00:44:25,680 --> 00:44:23,560
intelligent an intelligent and that I

1121
00:44:27,630 --> 00:44:25,690
think that astrobiologists would play

1122
00:44:28,260 --> 00:44:27,640
that role because astrobiologists bring

1123
00:44:32,250 --> 00:44:28,270
together

1124
00:44:35,160 --> 00:44:32,260
astronomers geoscientists ephesus are

1125
00:44:36,690 --> 00:44:35,170
all under one one subject so so the

1126
00:44:38,820 --> 00:44:36,700
astrobiology community would be the

1127
00:44:40,680 --> 00:44:38,830
obvious communities to try and find the

1128
00:44:44,010 --> 00:44:40,690
particular expertise that was needed at

1129
00:44:45,930 --> 00:44:44,020
the time whether that's reproducing a

1130
00:44:48,000 --> 00:44:45,940
signal that might need astronomers with

1131
00:44:51,510 --> 00:44:48,010
instruments whether that's deciding on

1132
00:44:53,250 --> 00:44:51,520
the ethical implications or if it was a

1133
00:44:56,640 --> 00:44:53,260
contact that actually happened for real

1134
00:44:58,170 --> 00:44:56,650
you know being actually landed on the

1135
00:44:59,910 --> 00:44:58,180
earth and you need some biologists and

1136
00:45:02,910 --> 00:44:59,920
biochemists to figure out what's going

1137
00:45:05,880 --> 00:45:02,920
on so yep whatever the situation is

1138
00:45:07,950 --> 00:45:05,890

astrobiology I think probably has the

1139
00:45:10,260 --> 00:45:07,960
widest diversity of expertise that could

1140
00:45:13,470 --> 00:45:10,270
be brought to bear on that challenge of

1141
00:45:15,870 --> 00:45:13,480
dealing with that situation agreed

1142
00:45:18,420 --> 00:45:15,880
there's a great question by Julia hi

1143
00:45:20,940 --> 00:45:18,430
Julia who is asking about phosphorus so

1144
00:45:22,620 --> 00:45:20,950
as you know phosphorus is a key key

1145
00:45:24,840 --> 00:45:22,630
element for life on Earth but how would

1146
00:45:28,220 --> 00:45:24,850
we get it how would we find that on on

1147
00:45:33,030 --> 00:45:28,230
the moons in the outer solar system

1148
00:45:35,850 --> 00:45:33,040
yeah well the phosphorus detectors this

1149
00:45:37,740 --> 00:45:35,860
is not really my my expertise but there

1150
00:45:41,220 --> 00:45:37,750
are electrochemical methods of detecting

1151
00:45:44,100 --> 00:45:41,230
phosphorus in in liquids or or in rocks

1152
00:45:48,900 --> 00:45:44,110
you can also look at particular minerals

1153
00:45:50,850 --> 00:45:48,910
for example using XRD and an XRF are two

1154
00:45:53,610 --> 00:45:50,860
methods x-ray fluorescence an x-ray

1155
00:45:56,430 --> 00:45:53,620
x-ray diffraction and so x-ray x-ray of

1156
00:45:58,890 --> 00:45:56,440
fluorescence will give you the elemental

1157
00:46:00,630 --> 00:45:58,900
composition of rocks and that's used to

1158
00:46:02,660 --> 00:46:00,640
find phosphorous for example on Mars

1159
00:46:07,110 --> 00:46:02,670
it's been demonstrated in Martian rocks

1160
00:46:09,180 --> 00:46:07,120
x-ray diffraction gives you information

1161
00:46:11,550 --> 00:46:09,190
on particular minerals so you could find

1162
00:46:13,950 --> 00:46:11,560
things like apatite which is a phosphate

1163
00:46:16,620 --> 00:46:13,960

mineral if you're looking in liquids

1164
00:46:18,390 --> 00:46:16,630
like the plumes of Enceladus then you

1165
00:46:21,200 --> 00:46:18,400
might want some electrode that will

1166
00:46:24,690 --> 00:46:21,210
detect our phosphorus or phosphate

1167
00:46:27,060 --> 00:46:24,700
compounds in in different oxidation

1168
00:46:29,250 --> 00:46:27,070
states of phosphorus rather in liquids

1169
00:46:30,090 --> 00:46:29,260
so there are enormous number of chemical

1170
00:46:32,640 --> 00:46:30,100
and

1171
00:46:34,560 --> 00:46:32,650
x-ray mineralogical methods of detecting

1172
00:46:37,230 --> 00:46:34,570
phosphorus in different states in liquid

1173
00:46:40,170 --> 00:46:37,240
and rocks that that will be used in

1174
00:46:42,450 --> 00:46:40,180
future planet Americans are used on the

1175
00:46:44,070 --> 00:46:42,460
surface of Mars to detect phosphate

1176
00:46:45,900 --> 00:46:44,080
containing rocks but that's a good

1177
00:46:47,790 --> 00:46:45,910
question because actually rightly points

1178
00:46:50,610 --> 00:46:47,800
out phosphorus is one of the two knobs

1179
00:46:52,320 --> 00:46:50,620
elements and at least the life on Earth

1180
00:46:57,090 --> 00:46:52,330
is an essential ingredient of things

1181
00:47:00,600 --> 00:46:57,100
like nucleic acids other other molecules

1182
00:47:02,880 --> 00:47:00,610
such as adenosine triphosphate and parts

1183
00:47:06,390 --> 00:47:02,890
of enzymes as well so so looking for

1184
00:47:09,840 --> 00:47:06,400
phosphorus is a key part of biochemistry

1185
00:47:11,370 --> 00:47:09,850
of astrobiology and so we're getting

1186
00:47:13,410 --> 00:47:11,380
close on time so we have time for one

1187
00:47:15,990 --> 00:47:13,420
more question and I see grams one up

1188
00:47:17,100 --> 00:47:16,000

there on on bio minerals so you kind of

1189
00:47:19,890 --> 00:47:17,110
talked about a little bit about

1190
00:47:21,390 --> 00:47:19,900
detecting bio minerals on on other

1191
00:47:22,980 --> 00:47:21,400
worlds what are your favorite

1192
00:47:26,430 --> 00:47:22,990
instruments but what would you like to

1193
00:47:28,050 --> 00:47:26,440
see on honor on a Mars rover okay so now

1194
00:47:30,900 --> 00:47:28,060
I'm going to be I'm going to be flippant

1195
00:47:35,370 --> 00:47:30,910
again my favorite instrument is a human

1196
00:47:37,230 --> 00:47:35,380
being um oh yeah I mean I really again

1197
00:47:39,030 --> 00:47:37,240
you know I'm so laughing but I there's a

1198
00:47:41,610 --> 00:47:39,040
serious side to it as well very very

1199
00:47:43,260 --> 00:47:41,620
difficult to detect truly iron minerals

1200
00:47:45,840 --> 00:47:43,270
even on the earth when you find minerals

1201
00:47:48,150 --> 00:47:45,850
in in extreme environments you have to

1202
00:47:50,760 --> 00:47:48,160
do a lot of Dentistry whether they have

1203
00:47:53,430 --> 00:47:50,770
been produced by biology or whether they

1204
00:47:56,190 --> 00:47:53,440
are the product of abiotic chemical

1205
00:47:57,870 --> 00:47:56,200
reactions and the way around that is to

1206
00:47:59,340 --> 00:47:57,880
look at the structure of the minerals to

1207
00:48:01,500 --> 00:47:59,350
see whether they're associated with

1208
00:48:04,620 --> 00:48:01,510
microfossils whether they contain

1209
00:48:08,010 --> 00:48:04,630
isotopic signatures of life maybe carbon

1210
00:48:09,930 --> 00:48:08,020
fractionation negative Delta c-13 values

1211
00:48:11,640 --> 00:48:09,940
of that sort of thing that might tell

1212
00:48:14,120 --> 00:48:11,650
you that biology has been involved in

1213
00:48:16,880 --> 00:48:14,130

their formation whether that things like

1214
00:48:21,000 --> 00:48:16,890
carbonates different iron minerals um

1215
00:48:23,250 --> 00:48:21,010
ultimately to produce a suite of

1216
00:48:26,040 --> 00:48:23,260
minerals on a rover that will truly

1217
00:48:27,600 --> 00:48:26,050
detect a bio mineral and say that's life

1218
00:48:29,400 --> 00:48:27,610
is a very very difficult thing to do

1219
00:48:30,810 --> 00:48:29,410
it's difficult on earth it's difficult

1220
00:48:34,440 --> 00:48:30,820
when you're trying to put it on a robot

1221
00:48:36,630 --> 00:48:34,450
so I am a true supporter of of sending

1222
00:48:38,970 --> 00:48:36,640
humans to places like Mars with a

1223
00:48:41,280 --> 00:48:38,980
laboratory and time on their hands a

1224
00:48:43,710 --> 00:48:41,290
good year or so on the surface to do

1225
00:48:45,330 --> 00:48:43,720
science are to use sophisticated

1226
00:48:47,400 --> 00:48:45,340
instruments to be able to go back into

1227
00:48:51,330 --> 00:48:47,410
the field and collect samples in a

1228
00:48:53,400 --> 00:48:51,340
real-time way and you know unless we

1229
00:48:56,700 --> 00:48:53,410
stumble across something on Mars using a

1230
00:48:58,349 --> 00:48:56,710
robo that's unequivocal the best way at

1231
00:49:01,410 --> 00:48:58,359
least to look at the possibility of

1232
00:49:03,089 --> 00:49:01,420
biology on Mars over large areas even if

1233
00:49:05,940 --> 00:49:03,099
we find life on Mars look at the spatial

1234
00:49:08,700 --> 00:49:05,950
distribution of fire minerals and life

1235
00:49:11,040 --> 00:49:08,710
on Mars is to send human explorers there

1236
00:49:13,050 --> 00:49:11,050
in the long term and as I say even if we

1237
00:49:16,260 --> 00:49:13,060
did find evidence of life using a rover

1238
00:49:18,240 --> 00:49:16,270

bio mineral you still can't beat having

1239
00:49:19,589 --> 00:49:18,250
a human there for a year and a lab going

1240
00:49:21,720 --> 00:49:19,599
out and collecting a vast number of

1241
00:49:23,339 --> 00:49:21,730
samples and looking at spatial

1242
00:49:26,640 --> 00:49:23,349
distribution looking at different types

1243
00:49:28,560 --> 00:49:26,650
of minerals collecting fresh samples

1244
00:49:30,870 --> 00:49:28,570
based on samples they've looked at say

1245
00:49:32,670 --> 00:49:30,880
the day before or the week before so I

1246
00:49:34,890 --> 00:49:32,680
am a fan of the human exploration of

1247
00:49:38,040 --> 00:49:34,900
Mars of course that's not eat so easy to

1248
00:49:40,410 --> 00:49:38,050
are to implement for places like Europa

1249
00:49:42,390 --> 00:49:40,420
with extreme radiation or Enceladus so

1250
00:49:43,890 --> 00:49:42,400
for those sorts of environments if we

1251
00:49:46,470 --> 00:49:43,900
want to look for minerals that have

1252
00:49:48,839 --> 00:49:46,480
interacted with biology are we at least

1253
00:49:51,839 --> 00:49:48,849
for the near term we're limited to two

1254
00:49:53,520 --> 00:49:51,849
robotic missions I think if we do find

1255
00:49:55,079 --> 00:49:53,530
microbes also there'll be another big

1256
00:49:56,970 --> 00:49:55,089
conversation about whether or not it's

1257
00:49:59,190 --> 00:49:56,980
Earth contaminants before we can make

1258
00:50:01,650 --> 00:49:59,200
the claim that if that's it's Exeter sto

1259
00:50:03,810 --> 00:50:01,660
Charles this has been absolutely

1260
00:50:05,910 --> 00:50:03,820
delightful thank you so much for taking

1261
00:50:08,640 --> 00:50:05,920
the time in your fantastic orange

1262
00:50:11,250 --> 00:50:08,650
jumpsuit chatting with us today about

1263
00:50:13,920 --> 00:50:11,260

your career and your words of wisdom on

1264
00:50:17,370 --> 00:50:13,930
astrobiology any last words of wisdom

1265
00:50:19,170 --> 00:50:17,380
you want to share no I just want to say

1266
00:50:20,520 --> 00:50:19,180
thank you for inviting me to take

1267
00:50:23,730 --> 00:50:20,530
partners has been a pleasure as usual

1268
00:50:25,380 --> 00:50:23,740
and you know my only last comment is to

1269
00:50:28,079 --> 00:50:25,390
everyone out there ticket early career

1270
00:50:29,670 --> 00:50:28,089
researchers I'll stick with astrobiology

1271
00:50:31,260 --> 00:50:29,680
it's an incredibly exciting field

1272
00:50:32,880 --> 00:50:31,270
there's a lot of great stuff that's

1273
00:50:35,820 --> 00:50:32,890
going to happen over the coming decades

1274
00:50:37,320 --> 00:50:35,830
and it you know wherever you end up in

1275
00:50:39,480 --> 00:50:37,330
whatever type of scientific career

1276
00:50:41,550 --> 00:50:39,490
remain amongst the astrobiology

1277
00:50:44,550 --> 00:50:41,560
community because it's a great field to

1278
00:50:46,920 --> 00:50:44,560
be in and I encourage you to to keep

1279
00:50:49,200 --> 00:50:46,930
involved and keep contributing and

1280
00:50:51,390 --> 00:50:49,210
thanks a lot again for inviting me in

1281
00:50:53,760 --> 00:50:51,400
grey arts channels thank you so

1282
00:50:55,800 --> 00:50:53,770
listeners join us next month for ask an

1283
00:50:57,550 --> 00:50:55,810
astrobiologist our guest will be dr.