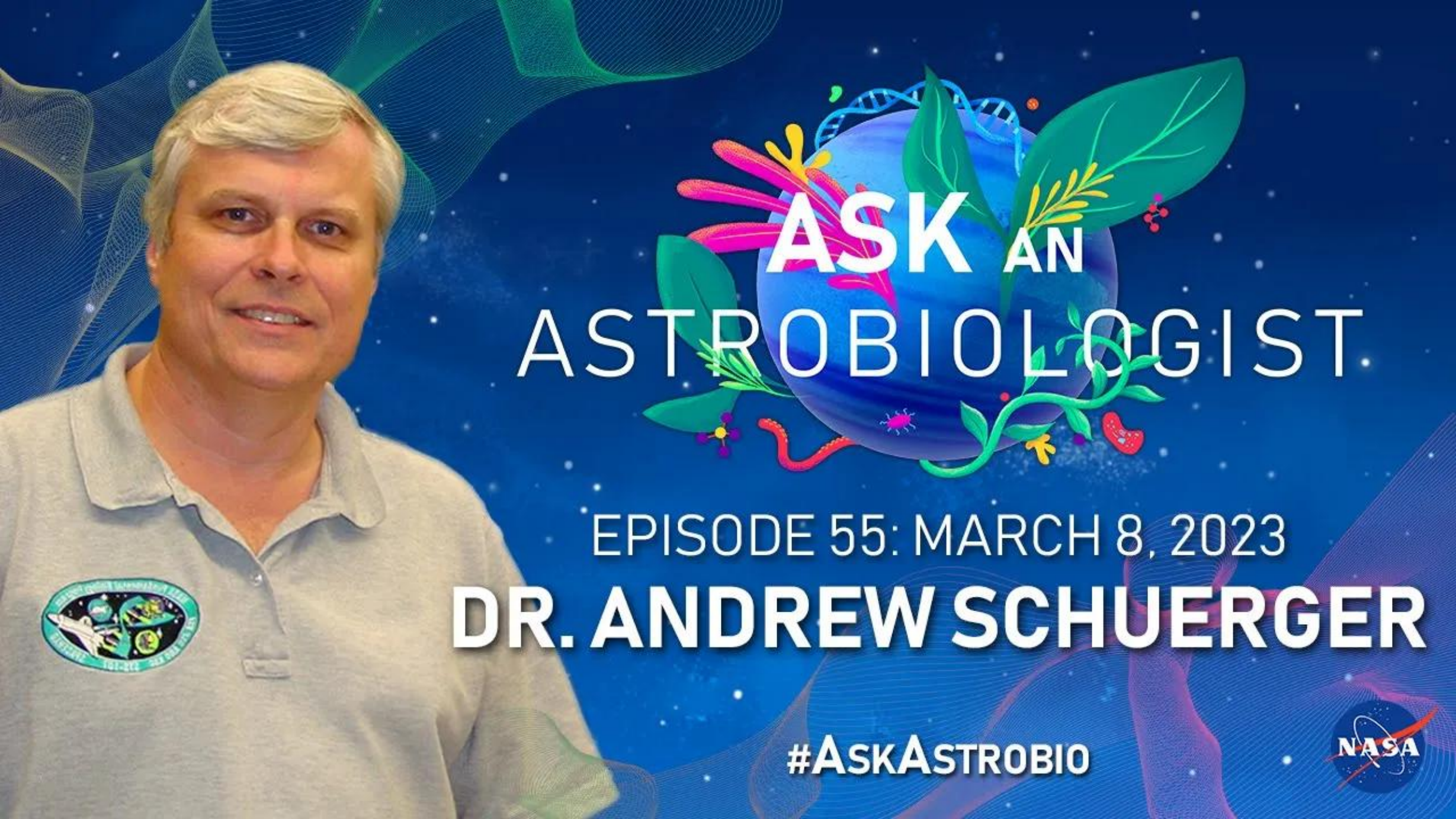
ASK AN
ASTROBIOLOGIST
EPISODE 55: MARCH 8, 2023
DR. ANDREW SCHUERGER
#AskAstrobio
NASA

1
00:00:01,900 --> 00:00:00,470
[Music]

2
00:00:22,720 --> 00:00:01,910
foreign

3
00:00:23,970 --> 00:00:22,730
[Music]

4
00:00:41,889 --> 00:00:23,980
[Applause]

5
00:00:44,930 --> 00:00:41,899
[Music]

6
00:00:48,049 --> 00:00:44,940
greetings friends fellow earthlings and

7
00:00:49,369 --> 00:00:48,059
fans of exploration welcome to ask an

8
00:00:51,590 --> 00:00:49,379
astrobiologist

9
00:00:53,990 --> 00:00:51,600
the show that celebrates the science and

10
00:00:56,090 --> 00:00:54,000
celebrates the scientists involved in

11
00:00:58,970 --> 00:00:56,100
our quest to understand the nature of

12
00:01:01,430 --> 00:00:58,980
life astrobiology where does life come

13
00:01:03,889 --> 00:01:01,440

from how does it change and evolve where

14
00:01:05,750 --> 00:01:03,899
is it located in our universe the

15
00:01:08,750 --> 00:01:05,760
questions we all want to know

16
00:01:11,450 --> 00:01:08,760
I am your host Dr Graham the cosmo

17
00:01:13,910 --> 00:01:11,460
biologist Lao and as always we're

18
00:01:16,130 --> 00:01:13,920
brought to you by segnet.org and the

19
00:01:18,109 --> 00:01:16,140
NASA astrobiology program

20
00:01:19,969 --> 00:01:18,119
as always we want to thank all of you as

21
00:01:22,429 --> 00:01:19,979
well for tuning in asking us questions

22
00:01:23,990 --> 00:01:22,439
during the live stream chat or if you're

23
00:01:25,310 --> 00:01:24,000
watching this later jumping over to the

24
00:01:28,010 --> 00:01:25,320
YouTube channel and adding your

25
00:01:29,270 --> 00:01:28,020
questions in I do my best several of us

26
00:01:31,190 --> 00:01:29,280
come through and look at those questions

27
00:01:32,870 --> 00:01:31,200
try to answer them when we can

28
00:01:34,130 --> 00:01:32,880
I'm so excited for this week now you

29
00:01:35,810 --> 00:01:34,140
might notice I'm in a slightly different

30
00:01:37,969 --> 00:01:35,820
environment I'm actually recording in

31
00:01:40,550 --> 00:01:37,979
Savannah Georgia uh for this month's

32
00:01:42,830 --> 00:01:40,560
episode but I'm so excited to have our

33
00:01:45,230 --> 00:01:42,840
guest on the show this month Dr Andrew

34
00:01:47,450 --> 00:01:45,240
sugar is joining us he's a scientist at

35
00:01:50,030 --> 00:01:47,460
the department of Plant Pathology at the

36
00:01:52,670 --> 00:01:50,040
University of Florida Dr sugar worked

37
00:01:54,410 --> 00:01:52,680
for 18 years the land a hydroponic

38
00:01:57,050 --> 00:01:54,420

research and education facility at

39
00:01:58,969 --> 00:01:57,060
Disney's Epcot Center as well as at

40
00:02:01,429 --> 00:01:58,979
NASA's Kennedy Space Center

41
00:02:03,770 --> 00:02:01,439
his research has gone in many different

42
00:02:05,330 --> 00:02:03,780
directions over the years it includes

43
00:02:07,310 --> 00:02:05,340
studying the effects of Martian

44
00:02:10,130 --> 00:02:07,320
conditions on the survival growth and

45
00:02:11,990 --> 00:02:10,140
adaptation of microorganisms as well as

46
00:02:14,750 --> 00:02:12,000
investigating things like methane on

47
00:02:16,910 --> 00:02:14,760
Mars as a potential biosignature and so

48
00:02:18,949 --> 00:02:16,920
I'm so excited to welcome Dr sugar and I

49
00:02:20,330 --> 00:02:18,959
hope you will as well Dr sugar thank you

50
00:02:21,710 --> 00:02:20,340
very much for joining us for asking

51
00:02:23,809 --> 00:02:21,720
astrobiologist

52
00:02:24,589 --> 00:02:23,819
oh hey it's my pleasure I'm glad to be

53
00:02:26,809 --> 00:02:24,599
here

54
00:02:27,949 --> 00:02:26,819
I'm like I said I'm so happy that you're

55
00:02:29,449 --> 00:02:27,959
joining us

56
00:02:32,150 --> 00:02:29,459
um looking through your bio you've done

57
00:02:33,470 --> 00:02:32,160
so many different things uh you earned

58
00:02:34,910 --> 00:02:33,480
your your bachelor's degree your

59
00:02:36,290 --> 00:02:34,920
master's degree at the University of

60
00:02:37,910 --> 00:02:36,300
Arizona

61
00:02:39,650 --> 00:02:37,920
um then you worked during your PhD you

62
00:02:41,750 --> 00:02:39,660
earned that in 1991 you know the

63
00:02:44,270 --> 00:02:41,760

University of Florida working in this

64
00:02:47,270 --> 00:02:44,280
realm of microbiology microbial ecology

65
00:02:49,190 --> 00:02:47,280
and then Plant Pathology I'm wondering

66
00:02:52,009 --> 00:02:49,200
for our audience could you explain what

67
00:02:55,070 --> 00:02:52,019
really drove you towards these Realms of

68
00:02:57,949 --> 00:02:55,080
like microbiology and Plant Pathology

69
00:03:01,430 --> 00:02:57,959
well uh the biggest reason I got into

70
00:03:03,550 --> 00:03:01,440
Plant Pathology is I immediately had the

71
00:03:06,770 --> 00:03:03,560
sense that it was like being a detective

72
00:03:09,589 --> 00:03:06,780
because you have a series of problems

73
00:03:12,229 --> 00:03:09,599
with a plant or crop there are symptoms

74
00:03:15,050 --> 00:03:12,239
or signs you have to go into it and kind

75
00:03:17,809 --> 00:03:15,060
of use all of your knowledge from every

76
00:03:19,250 --> 00:03:17,819
course you've taken from every uh you

77
00:03:21,710 --> 00:03:19,260
know bit of experience that you've been

78
00:03:23,390 --> 00:03:21,720
able to Garner and then figure out what

79
00:03:26,330 --> 00:03:23,400
the problem is and then it's another

80
00:03:28,009 --> 00:03:26,340
that's first level of detective work and

81
00:03:30,170 --> 00:03:28,019
then the next level is to figure out how

82
00:03:31,729 --> 00:03:30,180
to control that disease so I just

83
00:03:34,850 --> 00:03:31,739
thought it'd be it was a very

84
00:03:37,250 --> 00:03:34,860
challenging Innovative discipline and I

85
00:03:38,570 --> 00:03:37,260
I've been very pleased with a career at

86
00:03:40,550 --> 00:03:38,580
Plant Pathology

87
00:03:42,410 --> 00:03:40,560
it's wonderful and of course you're not

88
00:03:44,149 --> 00:03:42,420

University of Florida but even while

89
00:03:46,670 --> 00:03:44,159
working on your PhD you were working at

90
00:03:48,410 --> 00:03:46,680
the land at Epcot Center kind of in this

91
00:03:49,970 --> 00:03:48,420
realm of hydroponic research and

92
00:03:52,130 --> 00:03:49,980
education

93
00:03:53,570 --> 00:03:52,140
um looking in these Management Systems

94
00:03:55,490 --> 00:03:53,580
um I'm wondering what you know how did

95
00:03:57,170 --> 00:03:55,500
you kind of evolve your career into that

96
00:03:59,449 --> 00:03:57,180
realm of like looking in closed loop

97
00:04:00,589 --> 00:03:59,459
systems and hydroponic systems and kind

98
00:04:02,630 --> 00:04:00,599
of using these as a way to understand

99
00:04:04,610 --> 00:04:02,640
Plant Pathology

100
00:04:07,910 --> 00:04:04,620
well that's a very interesting question

101
00:04:11,210 --> 00:04:07,920
because when I uh before I applied for

102
00:04:14,449 --> 00:04:11,220
the position at Epcot Center at the land

103
00:04:16,969 --> 00:04:14,459
Pavilion that I eventually got uh I was

104
00:04:19,729 --> 00:04:16,979
very interested in going into nature

105
00:04:21,469 --> 00:04:19,739
cinematography but my department chair

106
00:04:23,030 --> 00:04:21,479
and Plant Pathology at the University of

107
00:04:25,790 --> 00:04:23,040
Arizona tracked me down on the hall

108
00:04:28,249 --> 00:04:25,800
carrying a sheet of paper and he said

109
00:04:31,070 --> 00:04:28,259
this job's for you and it was the

110
00:04:35,170 --> 00:04:31,080
announcement of working in a hydroponic

111
00:04:38,090 --> 00:04:35,180
complex hydroponic facility up to 40 50

112
00:04:41,570 --> 00:04:38,100
crops agronomic and Horticultural crops

113
00:04:43,550 --> 00:04:41,580

and I immediately right when that that

114
00:04:46,189 --> 00:04:43,560
department chair showed me that piece of

115
00:04:49,189 --> 00:04:46,199
paper made the connection that that is

116
00:04:51,770 --> 00:04:49,199
the is sort of like a ground test bed

117
00:04:55,430 --> 00:04:51,780
for trying to learn how to grow plants

118
00:04:57,530 --> 00:04:55,440
in outer space so that was the reason I

119
00:05:00,290 --> 00:04:57,540
applied was that NASA was here in

120
00:05:03,230 --> 00:05:00,300
Florida Kennedy Space Center was here in

121
00:05:05,749 --> 00:05:03,240
Florida Epcot was here in Florida and

122
00:05:08,210 --> 00:05:05,759
this facility growing plants

123
00:05:10,310 --> 00:05:08,220
hydroponically was like a ground test

124
00:05:12,590 --> 00:05:10,320
bed for doing it in space so I said I

125
00:05:14,030 --> 00:05:12,600
have to try and I was lucky enough to

126
00:05:16,370 --> 00:05:14,040
get it and it's been it was a real

127
00:05:18,890 --> 00:05:16,380
rewarding experience working for Walt

128
00:05:20,689 --> 00:05:18,900
Disney World well that's really cool I

129
00:05:22,129 --> 00:05:20,699
do have to ask you know since my I

130
00:05:24,770 --> 00:05:22,139
really love this realm not just of

131
00:05:26,450 --> 00:05:24,780
astrobotany but also the future of

132
00:05:27,950 --> 00:05:26,460
Agriculture

133
00:05:29,330 --> 00:05:27,960
um what your view is kind of on the

134
00:05:31,969 --> 00:05:29,340
future of like things like vertical

135
00:05:33,590 --> 00:05:31,979
farms and indoor greenhouses do you

136
00:05:35,990 --> 00:05:33,600
think we kind of need to go that

137
00:05:38,029 --> 00:05:36,000
direction for not just being sustainable

138
00:05:40,909 --> 00:05:38,039

for space exploration but for building a

139
00:05:43,010 --> 00:05:40,919
future for humans as well here on Earth

140
00:05:47,210 --> 00:05:43,020
well that's a good question too because

141
00:05:50,870 --> 00:05:47,220
uh vertical farming has a real important

142
00:05:53,510 --> 00:05:50,880
role to play in urban areas where you're

143
00:05:56,749 --> 00:05:53,520
growing High cash value crops

144
00:06:00,170 --> 00:05:56,759
strawberries lettuce dwarf Tomatoes

145
00:06:02,330 --> 00:06:00,180
things of that nature such that you have

146
00:06:05,529 --> 00:06:02,340
a very short distance from production

147
00:06:07,730 --> 00:06:05,539
facility to sales facility

148
00:06:09,770 --> 00:06:07,740
but you have to it's generally

149
00:06:11,450 --> 00:06:09,780
economical only if it's a high cash

150
00:06:14,870 --> 00:06:11,460
value crop like the ones I just

151
00:06:17,590 --> 00:06:14,880
mentioned for bulk growth of plants like

152
00:06:20,870 --> 00:06:17,600
wheat potatoes some of the Staples

153
00:06:22,909 --> 00:06:20,880
that's probably going to remain for the

154
00:06:26,090 --> 00:06:22,919
foreseeable future as a field

155
00:06:28,909 --> 00:06:26,100
agriculture uh technology so we really

156
00:06:31,249 --> 00:06:28,919
need both we need solid field

157
00:06:33,890 --> 00:06:31,259
agriculture with good control of soils

158
00:06:35,650 --> 00:06:33,900
and pests and and proper nutritional

159
00:06:38,510 --> 00:06:35,660
management of the crops

160
00:06:41,689 --> 00:06:38,520
ecologically sound growing as well as

161
00:06:43,969 --> 00:06:41,699
vertical farmings for a very targeted uh

162
00:06:47,529 --> 00:06:43,979
communities but the the link here is

163
00:06:50,689 --> 00:06:47,539

vertical farming is a very good

164
00:06:53,570 --> 00:06:50,699
proxy for learning how to grow plants in

165
00:06:55,969 --> 00:06:53,580
really small spaces under really tight

166
00:06:57,830 --> 00:06:55,979
light and temperature controls that

167
00:07:01,490 --> 00:06:57,840
would extrapolate to growing on the

168
00:07:02,990 --> 00:07:01,500
surface of Mars or in a habitat on on

169
00:07:04,790 --> 00:07:03,000
the moon

170
00:07:06,170 --> 00:07:04,800
oh that's wonderful yeah there's there's

171
00:07:08,570 --> 00:07:06,180
so much we need to know for better

172
00:07:10,550 --> 00:07:08,580
growing food in our spacecraft you know

173
00:07:13,010 --> 00:07:10,560
we've now grown plants on the ISS that

174
00:07:15,290 --> 00:07:13,020
astronauts have eaten you know homegrown

175
00:07:17,629 --> 00:07:15,300
food on the ISS but it feels like that

176
00:07:18,830 --> 00:07:17,639
realm is still kind of developing

177
00:07:20,990 --> 00:07:18,840
um what do you think are some of the key

178
00:07:23,270 --> 00:07:21,000
things we need to know right now for the

179
00:07:25,129 --> 00:07:23,280
next maybe decade or two and when it

180
00:07:27,469 --> 00:07:25,139
comes to growing plants on a space

181
00:07:30,710 --> 00:07:27,479
station moon or on Mars

182
00:07:33,529 --> 00:07:30,720
right well uh the number one thing is

183
00:07:35,029 --> 00:07:33,539
that uh I I think a lot of your viewers

184
00:07:37,909 --> 00:07:35,039
are probably seeing a lot of very

185
00:07:40,430 --> 00:07:37,919
complex illustrations artist renderings

186
00:07:43,730 --> 00:07:40,440
of a moon base with a very complex

187
00:07:46,610 --> 00:07:43,740
agricultural system inside or Mars base

188
00:07:50,089 --> 00:07:46,620

with something similar but that's the

189
00:07:53,689 --> 00:07:50,099
target that's the goal 10 20 years down

190
00:07:55,850 --> 00:07:53,699
the road right now though we're really

191
00:07:58,189 --> 00:07:55,860
focused we being the community of

192
00:08:00,650 --> 00:07:58,199
astrobiology and plant biology in space

193
00:08:03,230 --> 00:08:00,660
we're really focused on trying to

194
00:08:05,270 --> 00:08:03,240
optimize plant growth in the

195
00:08:08,029 --> 00:08:05,280
microgravity environment on Space

196
00:08:09,529 --> 00:08:08,039
Station uh the number of plant growing

197
00:08:12,770 --> 00:08:09,539
systems have been developed they've

198
00:08:15,589 --> 00:08:12,780
flown and to me as a plant pathologist

199
00:08:18,469 --> 00:08:15,599
one of the most intriguing issues that

200
00:08:20,990 --> 00:08:18,479
is does not have a lot of research is

201
00:08:23,210 --> 00:08:21,000
how do the microorganisms present in

202
00:08:25,610 --> 00:08:23,220
let's say the space station or

203
00:08:28,369 --> 00:08:25,620
eventually those same microorganisms

204
00:08:30,770 --> 00:08:28,379
might be in a a biogenerative life

205
00:08:32,630 --> 00:08:30,780
support system on the moon or Mars how

206
00:08:35,630 --> 00:08:32,640
do those microbes interact with the

207
00:08:38,570 --> 00:08:35,640
plants and is the space environment so

208
00:08:41,089 --> 00:08:38,580
stressful to the plants that host

209
00:08:43,969 --> 00:08:41,099
resistance that we normally expect from

210
00:08:46,430 --> 00:08:43,979
a plant would that break down because of

211
00:08:48,470 --> 00:08:46,440
the stresses in microgravity and that's

212
00:08:51,110 --> 00:08:48,480
an area that I'm actively doing research

213
00:08:53,810 --> 00:08:51,120

right now and it's it's quite enjoyable

214
00:08:56,210 --> 00:08:53,820
and and quite challenging that's

215
00:08:58,310 --> 00:08:56,220
fantastic and I I do want to talk then a

216
00:08:59,509 --> 00:08:58,320
bit about how things will survive on

217
00:09:00,949 --> 00:08:59,519
Mars

218
00:09:02,870 --> 00:09:00,959
um you know Earth life we we are

219
00:09:04,310 --> 00:09:02,880
protected here on our planet by this

220
00:09:06,710 --> 00:09:04,320
beautiful magnetic field that's

221
00:09:08,810 --> 00:09:06,720
generated by the Dynamo of the outer

222
00:09:10,790 --> 00:09:08,820
core of our world you know and I think

223
00:09:12,170 --> 00:09:10,800
some people forget sometimes that you

224
00:09:14,509 --> 00:09:12,180
know astronauts and other terrestrial

225
00:09:16,430 --> 00:09:14,519
organisms going to Mars they're going to

226
00:09:18,350 --> 00:09:16,440
face a different radiation environment

227
00:09:20,750 --> 00:09:18,360
at the surface of Mars as well as things

228
00:09:22,070 --> 00:09:20,760
like the very low pressure the much

229
00:09:24,590 --> 00:09:22,080
lower temperature it's an average of

230
00:09:26,210 --> 00:09:24,600
negative 90 Fahrenheit at the surface of

231
00:09:28,310 --> 00:09:26,220
Mars even though that does drastically

232
00:09:30,050 --> 00:09:28,320
change around the world

233
00:09:31,910 --> 00:09:30,060
um but first for our audience who are

234
00:09:33,530 --> 00:09:31,920
watching live we have a quick pull to

235
00:09:35,389 --> 00:09:33,540
drop in the YouTube chat for those of

236
00:09:37,130 --> 00:09:35,399
you who are watching right now

237
00:09:39,170 --> 00:09:37,140
um we have a question about radiation

238
00:09:41,630 --> 00:09:39,180

and how it affects not just humans but

239
00:09:44,750 --> 00:09:41,640
some of the extremophiles of our world

240
00:09:46,910 --> 00:09:44,760
as well so we humans we get sick with

241
00:09:48,470 --> 00:09:46,920
radiation when we get a dose that's

242
00:09:50,690 --> 00:09:48,480
actually pretty close to the dosage we

243
00:09:55,009 --> 00:09:50,700
would get on the surface of Mars around

244
00:09:56,810 --> 00:09:55,019
0.3 Grays or so a gray is one joule per

245
00:09:59,329 --> 00:09:56,820
kilogram that's the absorbed dose of

246
00:10:00,829 --> 00:09:59,339
radiation and so our question for you in

247
00:10:02,870 --> 00:10:00,839
the YouTube chat and we'll come back to

248
00:10:05,050 --> 00:10:02,880
this in a little bit is how much

249
00:10:08,269 --> 00:10:05,060
radiation do you think the extremophile

250
00:10:09,590 --> 00:10:08,279
dinococcus radio durans can handle and

251
00:10:11,690 --> 00:10:09,600
you'll see the answers popping up right

252
00:10:13,009 --> 00:10:11,700
now in your chat uh Andrew and I can't

253
00:10:14,449 --> 00:10:13,019
see those answers but we'll come back to

254
00:10:15,949 --> 00:10:14,459
that in a little bit

255
00:10:17,090 --> 00:10:15,959
um okay Andrew from you I just want to

256
00:10:18,590 --> 00:10:17,100
hear you know what your what your

257
00:10:20,870 --> 00:10:18,600
research has been kind of looking in

258
00:10:23,030 --> 00:10:20,880
this realm of survival and growth and

259
00:10:25,430 --> 00:10:23,040
the adaptation organisms have had to use

260
00:10:29,150 --> 00:10:25,440
to survive in Martian conditions

261
00:10:30,949 --> 00:10:29,160
all right so I sent a slide uh with the

262
00:10:35,030 --> 00:10:30,959
Mars chamber on it if you could just pop

263
00:10:36,949 --> 00:10:35,040

that up briefly uh I I've designed and

264
00:10:38,930 --> 00:10:36,959
built a mar simulation chamber here in

265
00:10:42,590 --> 00:10:38,940
my lab I've been working with it almost

266
00:10:44,810 --> 00:10:42,600
20 years and it is able to to recreate

267
00:10:47,269 --> 00:10:44,820
five conditions on the surface of the

268
00:10:49,370 --> 00:10:47,279
current Demars low pressure which is

269
00:10:52,250 --> 00:10:49,380
around seven millibars I'm in Florida

270
00:10:54,530 --> 00:10:52,260
near the sea level uh near sea level so

271
00:10:57,949 --> 00:10:54,540
I'm breathing right now 1000 and 15

272
00:11:01,130 --> 00:10:57,959
millibars but the surface of Mars

273
00:11:03,949 --> 00:11:01,140
is actually seven to ten millibar so

274
00:11:06,470 --> 00:11:03,959
it's less than one percent of sea level

275
00:11:09,889 --> 00:11:06,480
pressure on Earth uh so that's the first

276
00:11:11,509 --> 00:11:09,899
Factor second is UV irradiation very

277
00:11:13,550 --> 00:11:11,519
strong ultraviolet irradiation

278
00:11:16,790 --> 00:11:13,560
environment on Mars because there's

279
00:11:18,530 --> 00:11:16,800
literally no ozone layer uh in the

280
00:11:20,810 --> 00:11:18,540
Martian atmosphere which allows a lot of

281
00:11:24,350 --> 00:11:20,820
the biocidal UV to hit the surface

282
00:11:26,630 --> 00:11:24,360
number three is temperature uh gas

283
00:11:28,370 --> 00:11:26,640
compositions number four and then the

284
00:11:31,130 --> 00:11:28,380
Mars chamber also has a way of

285
00:11:33,769 --> 00:11:31,140
simulating either dust free conditions

286
00:11:35,990 --> 00:11:33,779
on mars or Global dust storm conditions

287
00:11:37,850 --> 00:11:36,000
and everything in between so what I've

288
00:11:41,030 --> 00:11:37,860

done if you can then switch to me for a

289
00:11:43,210 --> 00:11:41,040
close-up I I have these little microbial

290
00:11:46,730 --> 00:11:43,220
sample holders this is just one example

291
00:11:49,910 --> 00:11:46,740
and this a little piece of aluminum in

292
00:11:52,730 --> 00:11:49,920
here is what's called a coupon and upon

293
00:11:54,470 --> 00:11:52,740
each of these coupons I would put a

294
00:11:56,750 --> 00:11:54,480
different bacterium and these are

295
00:11:58,970 --> 00:11:56,760
examples just with a felt tip Panda so

296
00:12:01,670 --> 00:11:58,980
they'll show up oh but if you could

297
00:12:04,730 --> 00:12:01,680
think the blue coupons are one species

298
00:12:07,009 --> 00:12:04,740
of bacterium uh and then the red is a

299
00:12:10,130 --> 00:12:07,019
different species I would place this

300
00:12:12,110 --> 00:12:10,140
inside the Mars chamber allow the

301
00:12:15,410 --> 00:12:12,120
ultraviolet irradiation to come down

302
00:12:18,769 --> 00:12:15,420
strike those samples and it's just

303
00:12:21,829 --> 00:12:18,779
looking for survival uh how well Can the

304
00:12:24,410 --> 00:12:21,839
bacteria and fungi survive just exposure

305
00:12:28,430 --> 00:12:24,420
to that solar ultraviolet or radiation

306
00:12:32,389 --> 00:12:28,440
and it turns out uh that if the

307
00:12:35,810 --> 00:12:32,399
bacterian fungi are exposed out on a

308
00:12:38,090 --> 00:12:35,820
flat surface or even if they're kind of

309
00:12:40,730 --> 00:12:38,100
shielded a little bit enough solar UV

310
00:12:43,610 --> 00:12:40,740
irradiation bounces around and Strikes

311
00:12:45,710 --> 00:12:43,620
them that populations as high as two or

312
00:12:48,350 --> 00:12:45,720
three million spores per square

313
00:12:51,889 --> 00:12:48,360

centimeter can be killed off within

314
00:12:55,190 --> 00:12:51,899
three or four hours on the surface of

315
00:12:57,170 --> 00:12:55,200
the Equator of Mars uh just within that

316
00:13:00,470 --> 00:12:57,180
first soul and if you didn't know a day

317
00:13:03,250 --> 00:13:00,480
on Mars is called the soul so in summary

318
00:13:05,810 --> 00:13:03,260
from a survival standpoint

319
00:13:07,970 --> 00:13:05,820
exposing bacteria and fungi just to the

320
00:13:10,190 --> 00:13:07,980
low pressure environment maybe we lose

321
00:13:11,569 --> 00:13:10,200
about 20 percent of a population over a

322
00:13:14,470 --> 00:13:11,579
few Souls

323
00:13:17,329 --> 00:13:14,480
if they're hit with solar UV irradiation

324
00:13:19,730 --> 00:13:17,339
uh they're killed off very very quickly

325
00:13:22,490 --> 00:13:19,740
but those are only two factors there's

326
00:13:24,769 --> 00:13:22,500
there's another 18 to 20 factors that

327
00:13:28,069 --> 00:13:24,779
have been discussed for the service of

328
00:13:30,310 --> 00:13:28,079
Mars High salts in the soil volatile

329
00:13:35,030 --> 00:13:30,320
oxidants in the soil and atmosphere

330
00:13:36,889 --> 00:13:35,040
solar UV radiation solar particle events

331
00:13:39,230 --> 00:13:36,899
from the Sun that might strike the

332
00:13:42,530 --> 00:13:39,240
planet and I won't go on but there's at

333
00:13:45,590 --> 00:13:42,540
least 20 biocidal factors all of them

334
00:13:48,769 --> 00:13:45,600
working synergistically to reduce the

335
00:13:51,949 --> 00:13:48,779
population of spores cells of both

336
00:13:54,110 --> 00:13:51,959
bacteria and fungi on the spacecraft

337
00:13:55,430 --> 00:13:54,120
well that's rather incredible and so I

338
00:13:56,870 --> 00:13:55,440

will come back to our Poll for our

339
00:13:57,949 --> 00:13:56,880
audience then with that too since you

340
00:13:59,509 --> 00:13:57,959
just said you know some of these spores

341
00:14:01,190 --> 00:13:59,519
will Thrive like you know you have this

342
00:14:02,569 --> 00:14:01,200
slow kind of process so something's

343
00:14:04,310 --> 00:14:02,579
dying off

344
00:14:05,930 --> 00:14:04,320
um when it comes to life on Earth there

345
00:14:07,550 --> 00:14:05,940
are different kind of ways for for

346
00:14:09,410 --> 00:14:07,560
organisms to adapt to the radiation

347
00:14:10,610 --> 00:14:09,420
environment for instance in different

348
00:14:12,110 --> 00:14:10,620
places

349
00:14:14,629 --> 00:14:12,120
um E coli for instance can actually take

350
00:14:15,769 --> 00:14:14,639
a much larger dose than humans can

351
00:14:18,650 --> 00:14:15,779
um I think the last I read was something

352
00:14:20,629 --> 00:14:18,660
like 200 to 700 Grays was kind of a an

353
00:14:22,009 --> 00:14:20,639
average decent dose that E coli could

354
00:14:24,470 --> 00:14:22,019
still thrive in which is higher than the

355
00:14:26,389 --> 00:14:24,480
Martian surface for our Poll for

356
00:14:27,949 --> 00:14:26,399
dinococcus radio durans which by the way

357
00:14:30,410 --> 00:14:27,959
still holds the record that we know of

358
00:14:32,269 --> 00:14:30,420
for a radiation dose it looks like most

359
00:14:35,629 --> 00:14:32,279
of our respondents said either a hundred

360
00:14:38,269 --> 00:14:35,639
Grays or a thousand Grays but indeed the

361
00:14:41,449 --> 00:14:38,279
answer was five thousand plus they can

362
00:14:43,730 --> 00:14:41,459
take a dose well over 5 000 times what

363
00:14:46,129 --> 00:14:43,740

would get a human sick and still Thrive

364
00:14:48,650 --> 00:14:46,139
even tartar grades have been put into 4

365
00:14:50,870 --> 00:14:48,660
000 gray dose environments and have

366
00:14:51,889 --> 00:14:50,880
survived and so this is you know that

367
00:14:53,870 --> 00:14:51,899
those are very high radiation

368
00:14:56,389 --> 00:14:53,880
environments we put dinocoxious radio

369
00:14:59,030 --> 00:14:56,399
durans into the the cooling fluid from

370
00:15:02,329 --> 00:14:59,040
from nuclear radioactive uh Radioactive

371
00:15:04,730 --> 00:15:02,339
uh uh plants for energy and they've

372
00:15:06,290 --> 00:15:04,740
survived inside of that cooling fluid

373
00:15:08,389 --> 00:15:06,300
um and so you know these things can take

374
00:15:10,009 --> 00:15:08,399
a pretty hard blast but then you start

375
00:15:11,569 --> 00:15:10,019
adding in all these other conditions

376
00:15:13,670 --> 00:15:11,579
just like Dr sugar mentioned you know

377
00:15:16,009 --> 00:15:13,680
with the low pressure and then salts and

378
00:15:17,629 --> 00:15:16,019
the soil different gas compositions dust

379
00:15:19,730 --> 00:15:17,639
and those are the things that we need to

380
00:15:21,590 --> 00:15:19,740
study together in a systems approach and

381
00:15:24,110 --> 00:15:21,600
so it's really cool your lab is doing

382
00:15:26,030 --> 00:15:24,120
that with this Mars chamber have there

383
00:15:28,069 --> 00:15:26,040
been any really kind of exciting or

384
00:15:30,110 --> 00:15:28,079
surprising results maybe from that

385
00:15:33,110 --> 00:15:30,120
research with the Mars chamber

386
00:15:35,210 --> 00:15:33,120
uh well I I can't go and answer that

387
00:15:37,850 --> 00:15:35,220
question until I make one comment on

388
00:15:39,829 --> 00:15:37,860

dinococcus radio durans I was sort of

389
00:15:42,170 --> 00:15:39,839
shuffling around there just a moment ago

390
00:15:44,509 --> 00:15:42,180
because I literally downloaded a paper

391
00:15:47,509 --> 00:15:44,519
this morning that talked about radio

392
00:15:49,810 --> 00:15:47,519
dinococcus radio durans surviving

393
00:15:54,050 --> 00:15:49,820
exposure up to

394
00:15:56,210 --> 00:15:54,060
120 kilograms now a kilogram is a

395
00:16:00,350 --> 00:15:56,220
thousand gray so that would be a hundred

396
00:16:03,949 --> 00:16:00,360
and twenty thousand Grays the reason why

397
00:16:06,829 --> 00:16:03,959
humans have sort of like a buy I have a

398
00:16:10,310 --> 00:16:06,839
a very severe reaction to even extremely

399
00:16:12,710 --> 00:16:10,320
low dosage of of radiation is that that

400
00:16:15,310 --> 00:16:12,720
radiation is exposing billions and

401
00:16:17,870 --> 00:16:15,320
billions of cells in our body

402
00:16:20,750 --> 00:16:17,880
whereas a bacterium is a single cell

403
00:16:23,569 --> 00:16:20,760
sitting out on a Surface so you have to

404
00:16:26,329 --> 00:16:23,579
get the intensity dramatically higher to

405
00:16:28,730 --> 00:16:26,339
get that same lethality it's just a body

406
00:16:30,889 --> 00:16:28,740
mass issue that's that's uh the

407
00:16:33,650 --> 00:16:30,899
difference between human survival and a

408
00:16:35,389 --> 00:16:33,660
bacterium surviving so I digress what

409
00:16:37,129 --> 00:16:35,399
was the question well that's a very good

410
00:16:39,110 --> 00:16:37,139
point so we we did see that paper as

411
00:16:40,610 --> 00:16:39,120
well and planning for this episode and

412
00:16:43,009 --> 00:16:40,620
it was just so shocking that the

413
00:16:45,350 --> 00:16:43,019

radiation dose was that High

414
00:16:46,550 --> 00:16:45,360
um that we just did 5000 plus

415
00:16:47,990 --> 00:16:46,560
um you know and so there's some more

416
00:16:51,170 --> 00:16:48,000
results to support that conclusion but

417
00:16:52,790 --> 00:16:51,180
there's a rather incredible conclusion

418
00:16:54,829 --> 00:16:52,800
um but I think you know my big question

419
00:16:57,050 --> 00:16:54,839
using this Mars chamber you know really

420
00:16:59,150 --> 00:16:57,060
having kind of the systems approach now

421
00:17:00,470 --> 00:16:59,160
to multiple different scenarios you know

422
00:17:03,230 --> 00:17:00,480
these these five different conditions

423
00:17:05,390 --> 00:17:03,240
that we made experience on Mars right

424
00:17:07,370 --> 00:17:05,400
had any really you know surprising or

425
00:17:09,770 --> 00:17:07,380
drastic results that kind of changed how

426
00:17:14,150 --> 00:17:09,780
you're thinking about life on Mars

427
00:17:16,909 --> 00:17:14,160
yes uh oh about 10 12 years ago I

428
00:17:19,610 --> 00:17:16,919
started research moving from survival

429
00:17:23,090 --> 00:17:19,620
which is in my view survival is a term

430
00:17:26,350 --> 00:17:23,100
that I would use for dormant or inactive

431
00:17:28,909 --> 00:17:26,360
cells or spores persisting through time

432
00:17:31,250 --> 00:17:28,919
uh they don't have to replicate they're

433
00:17:34,130 --> 00:17:31,260
not taking in nutrients metabolizing and

434
00:17:36,890 --> 00:17:34,140
dividing so survival could just be a

435
00:17:39,169 --> 00:17:36,900
dormant cell lasting a long time

436
00:17:41,210 --> 00:17:39,179
I did a lot of work with survival under

437
00:17:42,950 --> 00:17:41,220
in the Mars chamber and under UV

438
00:17:44,870 --> 00:17:42,960

irradiation and vacuum and temperature

439
00:17:46,789 --> 00:17:44,880
extremes and then I started getting

440
00:17:48,710 --> 00:17:46,799
interested in bacterial growth

441
00:17:50,770 --> 00:17:48,720
metabolism and growth

442
00:17:53,210 --> 00:17:50,780
and so I was interested in in

443
00:17:56,630 --> 00:17:53,220
determining at seven millibars of

444
00:17:58,490 --> 00:17:56,640
pressure at a zero centigrade and with

445
00:18:01,730 --> 00:17:58,500
enough liquid water present to keep

446
00:18:04,970 --> 00:18:01,740
cells hydrated could any terrestrial

447
00:18:07,850 --> 00:18:04,980
bacteria actually metabolize and grow

448
00:18:10,190 --> 00:18:07,860
under these Martian surface conditions

449
00:18:13,010 --> 00:18:10,200
and I did experiment after experiment

450
00:18:15,650 --> 00:18:13,020
bacterium after bacterium and I

451
00:18:17,810 --> 00:18:15,660
literally was just ready to say okay

452
00:18:19,490 --> 00:18:17,820
I've tried to write a paper that says

453
00:18:23,690 --> 00:18:19,500
nothing grew under Martian conditions

454
00:18:26,750 --> 00:18:23,700
and the very last bacterium I tested

455
00:18:29,150 --> 00:18:26,760
actually grew under the low pressure low

456
00:18:32,090 --> 00:18:29,160
temperature and gas composition in the

457
00:18:34,549 --> 00:18:32,100
assays so it was a really pleasant

458
00:18:36,770 --> 00:18:34,559
surprise and once you establish a

459
00:18:38,690 --> 00:18:36,780
protocol that confirmed that this

460
00:18:41,570 --> 00:18:38,700
bacterium's name by the way is serratia

461
00:18:44,630 --> 00:18:41,580
liquidations it's a non-spore forming

462
00:18:47,450 --> 00:18:44,640
bacteria found in spacecraft and on

463
00:18:50,150 --> 00:18:47,460

surfaces of Hardware mainly Hardware

464
00:18:52,330 --> 00:18:50,160
associated with human activity like on

465
00:18:55,730 --> 00:18:52,340
the space station or Apollo spacecraft

466
00:18:58,210 --> 00:18:55,740
Skylab things like that but in any event

467
00:19:00,710 --> 00:18:58,220
once you have I have the basic protocol

468
00:19:02,510 --> 00:19:00,720
that I know something will grow under

469
00:19:04,970 --> 00:19:02,520
motion distance then we could start

470
00:19:08,090 --> 00:19:04,980
going through large numbers of bacteria

471
00:19:11,750 --> 00:19:08,100
a lot faster and to date we've

472
00:19:15,950 --> 00:19:11,760
identified approximately 30 bacteria but

473
00:19:17,890 --> 00:19:15,960
no fungi so far that can grow metabolize

474
00:19:20,390 --> 00:19:17,900
and grow under low pressure

475
00:19:23,029 --> 00:19:20,400
hydrated conditions similar to the

476
00:19:25,970 --> 00:19:23,039
surface of Mars so that's that just with

477
00:19:28,070 --> 00:19:25,980
one bacterium one last test changed my

478
00:19:31,010 --> 00:19:28,080
whole perspective on what we what might

479
00:19:32,570 --> 00:19:31,020
be possible on the surface of Mars wow

480
00:19:34,070 --> 00:19:32,580
yeah you know instead of being Eureka it

481
00:19:35,810 --> 00:19:34,080
was a huh I didn't I didn't think that

482
00:19:37,970 --> 00:19:35,820
would happen kind of moment I love that

483
00:19:39,590 --> 00:19:37,980
so much and that kind of also then it's

484
00:19:41,690 --> 00:19:39,600
important for my next topic I kind of

485
00:19:43,549 --> 00:19:41,700
want to discuss here is the idea of

486
00:19:44,750 --> 00:19:43,559
forward contamination

487
00:19:46,909 --> 00:19:44,760
um you know there's a whole department

488
00:19:48,110 --> 00:19:46,919

an office at Nasa that does planetary

489
00:19:49,730 --> 00:19:48,120
protection

490
00:19:51,130 --> 00:19:49,740
um figuring out you know how do we you

491
00:19:53,570 --> 00:19:51,140
know just not not only avoid

492
00:19:55,250 --> 00:19:53,580
contaminating Earth with possible things

493
00:19:57,230 --> 00:19:55,260
from elsewhere but how do we avoid

494
00:19:59,750 --> 00:19:57,240
taking Earth life and contaminating

495
00:20:01,730 --> 00:19:59,760
other places and you know no matter how

496
00:20:04,070 --> 00:20:01,740
much we try to clean our cleanest clean

497
00:20:06,169 --> 00:20:04,080
rooms are still going to have some some

498
00:20:08,510 --> 00:20:06,179
biology we're still going to send some

499
00:20:10,250 --> 00:20:08,520
things with our Rovers and when we send

500
00:20:12,350 --> 00:20:10,260
humans it gets even more crazy because

501
00:20:14,210 --> 00:20:12,360
you know we humans have a microbiome and

502
00:20:16,130 --> 00:20:14,220
we're shedding off organisms all the

503
00:20:18,110 --> 00:20:16,140
time not just our own cells but other

504
00:20:19,430 --> 00:20:18,120
organisms with us

505
00:20:21,289 --> 00:20:19,440
um and so you know we'll have this this

506
00:20:23,330 --> 00:20:21,299
moment when we get to Mars when humans

507
00:20:25,430 --> 00:20:23,340
start exploring especially where you

508
00:20:27,529 --> 00:20:25,440
know we are you know putting out Earthly

509
00:20:28,669 --> 00:20:27,539
organisms on the surface of Mars and I

510
00:20:30,770 --> 00:20:28,679
know you've done some work in that

511
00:20:33,529 --> 00:20:30,780
looking at at how we're going to have

512
00:20:34,610 --> 00:20:33,539
some issues with forward contamination

513
00:20:36,590 --> 00:20:34,620

um I wonder if you can speak to that

514
00:20:38,450 --> 00:20:36,600
issue with how we might you know try to

515
00:20:40,310 --> 00:20:38,460
avoid you know dumping a bunch of

516
00:20:42,110 --> 00:20:40,320
organisms on mars or or can we even

517
00:20:44,810 --> 00:20:42,120
avoid that at all

518
00:20:46,370 --> 00:20:44,820
well uh we have to step back a little

519
00:20:47,990 --> 00:20:46,380
bit before we go to that specific

520
00:20:50,930 --> 00:20:48,000
question

521
00:20:53,090 --> 00:20:50,940
um look at any image of a Rover like the

522
00:20:56,750 --> 00:20:53,100
perseverance we're over right now or

523
00:20:59,330 --> 00:20:56,760
curiosity uh and you see this structure

524
00:21:01,789 --> 00:20:59,340
these very fairly large structures with

525
00:21:03,650 --> 00:21:01,799
all these little nooks and crannies in

526
00:21:06,289 --> 00:21:03,660
it uh

527
00:21:08,510 --> 00:21:06,299
but if everybody's got to kind of keep

528
00:21:10,669 --> 00:21:08,520
in mind that even if there are bacteria

529
00:21:13,549 --> 00:21:10,679
and maybe a few fungi and a few of the

530
00:21:16,850 --> 00:21:13,559
prokaryotes called archaea if those are

531
00:21:19,789 --> 00:21:16,860
all present on the surface that surface

532
00:21:23,289 --> 00:21:19,799
is being immediately bathed on as soon

533
00:21:26,870 --> 00:21:23,299
as it lands in an extremely strong

534
00:21:30,190 --> 00:21:26,880
ultraviolet radiation environment and

535
00:21:32,750 --> 00:21:30,200
photons of light are incredibly small

536
00:21:35,870 --> 00:21:32,760
scientific Community doesn't even have a

537
00:21:38,810 --> 00:21:35,880
consensus on how big they are the best

538
00:21:42,830 --> 00:21:38,820

eye estimate I have is 10 to the minus

539
00:21:44,930 --> 00:21:42,840
18 centimeters as the upper limit of how

540
00:21:47,870 --> 00:21:44,940
big they might be it's believed to be

541
00:21:50,210 --> 00:21:47,880
much smaller so these incredibly tiny

542
00:21:53,210 --> 00:21:50,220
little energy packets can get into

543
00:21:55,190 --> 00:21:53,220
almost every pit every crack Bounce

544
00:21:58,490 --> 00:21:55,200
Around bounce off of one surface to get

545
00:22:01,490 --> 00:21:58,500
into a shaded area and I've been doing

546
00:22:03,230 --> 00:22:01,500
modeling several papers out working with

547
00:22:07,669 --> 00:22:03,240
other colleagues to try to push the

548
00:22:10,490 --> 00:22:07,679
modeling and the UV environment alone is

549
00:22:12,890 --> 00:22:10,500
so strong on the surface of Mars most of

550
00:22:16,190 --> 00:22:12,900
these surfaces of spacecraft and rovers

551
00:22:19,070 --> 00:22:16,200
are being sterilized within a few souls

552
00:22:21,049 --> 00:22:19,080
for the upper deck and maybe a few

553
00:22:24,049 --> 00:22:21,059
months for the stuff that's underneath

554
00:22:27,190 --> 00:22:24,059
on the belly of the spacecraft so it's

555
00:22:31,310 --> 00:22:27,200
not the bacteria are not lasting for

556
00:22:33,830 --> 00:22:31,320
Generations uh it's very likely that the

557
00:22:36,470 --> 00:22:33,840
microbiota on these Rovers is being

558
00:22:38,510 --> 00:22:36,480
inactivated very quickly okay so we

559
00:22:41,510 --> 00:22:38,520
pause there now let's look at human

560
00:22:44,450 --> 00:22:41,520
missions human missions yes humans will

561
00:22:46,789 --> 00:22:44,460
have a much richer biome that they will

562
00:22:48,649 --> 00:22:46,799
bring with them but that biome is

563
00:22:51,470 --> 00:22:48,659

contained within a habitat

564
00:22:53,930 --> 00:22:51,480
and when they go out and do an Eva it's

565
00:22:55,250 --> 00:22:53,940
can that microbiome is contained within

566
00:22:57,890 --> 00:22:55,260
their spacesuits

567
00:23:00,770 --> 00:22:57,900
so when an astronaut just can think of

568
00:23:02,690 --> 00:23:00,780
this as uh just conceptually they may

569
00:23:06,350 --> 00:23:02,700
have contamination on the outside of

570
00:23:08,990 --> 00:23:06,360
their uh spacesuit they walk out into

571
00:23:11,630 --> 00:23:09,000
that incredibly Rich intense UV

572
00:23:14,149 --> 00:23:11,640
environment on Mars we're not going to

573
00:23:17,149 --> 00:23:14,159
do Evas at night because of temperature

574
00:23:19,190 --> 00:23:17,159
issues it's and lighting issues so it'll

575
00:23:20,750 --> 00:23:19,200
almost always be done in the daytime

576
00:23:24,230 --> 00:23:20,760
and that

577
00:23:27,289 --> 00:23:24,240
the data from multiple Labs supports a

578
00:23:30,529 --> 00:23:27,299
conclusion that most of the microbiomes

579
00:23:33,169 --> 00:23:30,539
on the outside surfaces of objects on

580
00:23:34,310 --> 00:23:33,179
Mars can be sterilized within a few

581
00:23:37,669 --> 00:23:34,320
hours

582
00:23:40,549 --> 00:23:37,679
on one Soul so if an astronaut goes out

583
00:23:42,049 --> 00:23:40,559
for eight hours nine hours of an Eva on

584
00:23:44,090 --> 00:23:42,059
the surface of Mars

585
00:23:46,490 --> 00:23:44,100
his outside or her outside of that

586
00:23:48,710 --> 00:23:46,500
spacesuit might be sterilized during the

587
00:23:51,649 --> 00:23:48,720
middle of it by the time he gets to the

588
00:23:55,010 --> 00:23:51,659

four hour mark in uh

589
00:23:57,590 --> 00:23:55,020
in his Eva so I'm not that concerned

590
00:24:01,010 --> 00:23:57,600
we're going to overtly ruin the surface

591
00:24:04,130 --> 00:24:01,020
and contaminate the service I think the

592
00:24:07,010 --> 00:24:04,140
more intriguing issue is how do we

593
00:24:07,850 --> 00:24:07,020
prevent bringing stuff back that might

594
00:24:12,230 --> 00:24:07,860
have

595
00:24:14,570 --> 00:24:12,240
a martian microbiota on it uh because we

596
00:24:15,710 --> 00:24:14,580
don't we don't know if one exists and if

597
00:24:17,510 --> 00:24:15,720
it does we don't know the

598
00:24:19,909 --> 00:24:17,520
characteristics of that life so that's

599
00:24:22,010 --> 00:24:19,919
back contamination I'm not so worried

600
00:24:24,409 --> 00:24:22,020
about forward contamination I'm a little

601
00:24:26,810 --> 00:24:24,419
bit more interested now on what might

602
00:24:29,750 --> 00:24:26,820
happen bringing a martian microbiota

603
00:24:31,190 --> 00:24:29,760
back to Earth if it's present which we

604
00:24:33,649 --> 00:24:31,200
don't it's a very good point we're going

605
00:24:34,669 --> 00:24:33,659
to do Mars sample return soon

606
00:24:37,130 --> 00:24:34,679
um starting with the samples being

607
00:24:39,169 --> 00:24:37,140
cached right now from perseverance but

608
00:24:40,190 --> 00:24:39,179
very likely in the not too distant

609
00:24:41,690 --> 00:24:40,200
future

610
00:24:43,430 --> 00:24:41,700
um maybe not you know tomorrow but in

611
00:24:45,289 --> 00:24:43,440
the next you know a couple of decades

612
00:24:47,149 --> 00:24:45,299
once humans do go to Mars we'll most

613
00:24:48,710 --> 00:24:47,159

likely bring humans back from Mars too

614
00:24:49,669 --> 00:24:48,720
eventually

615
00:24:51,770 --> 00:24:49,679
um and they'll probably bring some

616
00:24:54,110 --> 00:24:51,780
samples back with them and so that

617
00:24:55,430 --> 00:24:54,120
possibility is really important I do

618
00:24:57,649 --> 00:24:55,440
want to bring up another Twitter poll

619
00:24:58,310 --> 00:24:57,659
that we had uh through the NASA oh go

620
00:24:59,930 --> 00:24:58,320
ahead

621
00:25:02,870 --> 00:24:59,940
I was just going to say one other

622
00:25:03,890 --> 00:25:02,880
important point though is that

623
00:25:06,409 --> 00:25:03,900
um

624
00:25:09,950 --> 00:25:06,419
absence of data

625
00:25:12,350 --> 00:25:09,960
does not confirm anything

626
00:25:14,930 --> 00:25:12,360
so as a scientist you have to just say

627
00:25:17,390 --> 00:25:14,940
there's no data to say this

628
00:25:21,649 --> 00:25:17,400
now don't conclude something from that

629
00:25:23,510 --> 00:25:21,659
lack of data it's just no data and so

630
00:25:26,149 --> 00:25:23,520
you keep your options open you think of

631
00:25:28,430 --> 00:25:26,159
all the possibilities but it is it is

632
00:25:31,250 --> 00:25:28,440
equally plausible that the surface of

633
00:25:32,750 --> 00:25:31,260
Mars and all the regolith is literally

634
00:25:40,730 --> 00:25:32,760
sterilized

635
00:25:44,510 --> 00:25:40,740
those 20 volocital factors that is as

636
00:25:48,130 --> 00:25:44,520
equally plausible as some life form that

637
00:25:52,370 --> 00:25:48,140
evolved three billion years ago actually

638
00:25:54,490 --> 00:25:52,380

uh persisting in learning how to to grow

639
00:25:58,970 --> 00:25:54,500
metabolize and evolve on the surface

640
00:26:00,830 --> 00:25:58,980
equal no data so that's we we don't jump

641
00:26:03,950 --> 00:26:00,840
to either one of those as a scientist

642
00:26:05,110 --> 00:26:03,960
and the same thing should hold for the

643
00:26:10,970 --> 00:26:05,120
uh

644
00:26:12,230 --> 00:26:10,980
are going to help decide the protocols

645
00:26:13,549 --> 00:26:12,240
for both forward and backward

646
00:26:15,529 --> 00:26:13,559
contamination

647
00:26:17,810 --> 00:26:15,539
absolutely

648
00:26:20,090 --> 00:26:17,820
um so I will say uh of our audience we

649
00:26:22,730 --> 00:26:20,100
we did ask through Twitter uh through

650
00:26:24,289 --> 00:26:22,740
the at Nasa astrobio Twitter account we

651
00:26:25,730 --> 00:26:24,299
we asked people what they thought would

652
00:26:27,890 --> 00:26:25,740
be the most important obstacle that

653
00:26:29,930 --> 00:26:27,900
Earth life might face on Mars with

654
00:26:33,049 --> 00:26:29,940
options like radiation low gravity low

655
00:26:34,789 --> 00:26:33,059
temperature the very dry conditions and

656
00:26:36,649 --> 00:26:34,799
you know overwhelmingly people said

657
00:26:38,149 --> 00:26:36,659
radiation

658
00:26:39,590 --> 00:26:38,159
um was the largest factor they think

659
00:26:41,510 --> 00:26:39,600
would be an issue out of these other

660
00:26:43,430 --> 00:26:41,520
possible factors

661
00:26:46,370 --> 00:26:43,440
um so do you think you know if there was

662
00:26:48,590 --> 00:26:46,380
Martian biota in the distant past that

663
00:26:50,630 --> 00:26:48,600

may still be alive or went extinct long

664
00:26:52,970 --> 00:26:50,640
ago but if there were some possibility

665
00:26:54,769 --> 00:26:52,980
for there to be life on Mars do you

666
00:26:56,990 --> 00:26:54,779
think we'd have to get a sample from

667
00:26:59,630 --> 00:26:57,000
deeper down under the surface to avoid

668
00:27:01,970 --> 00:26:59,640
the radiation to really find any fines

669
00:27:04,130 --> 00:27:01,980
of any signs of possible past or present

670
00:27:06,289 --> 00:27:04,140
life that's Martian life

671
00:27:08,930 --> 00:27:06,299
uh okay so there's two types of

672
00:27:11,110 --> 00:27:08,940
radiation the radiation the way you're

673
00:27:14,450 --> 00:27:11,120
using the word refers to probably

674
00:27:17,990 --> 00:27:14,460
ionizing radiation this is like x-rays

675
00:27:21,590 --> 00:27:18,000
gamma rays protons helium atoms

676
00:27:25,149 --> 00:27:21,600
Etc uh very high energies uh and they

677
00:27:29,990 --> 00:27:25,159
can ionize molecules there's also the

678
00:27:32,570 --> 00:27:30,000
electromagnetic radiation of UV light so

679
00:27:34,730 --> 00:27:32,580
UV light in my view is the strongest

680
00:27:38,149 --> 00:27:34,740
biocidal Factor on the surface of Mars

681
00:27:39,370 --> 00:27:38,159
followed by desiccation low pressure and

682
00:27:41,710 --> 00:27:39,380
low temperature

683
00:27:44,810 --> 00:27:41,720
uh the

684
00:27:48,890 --> 00:27:44,820
ionizing radiation like gamma rays

685
00:27:51,409 --> 00:27:48,900
x-rays that dosage is relatively benign

686
00:27:53,870 --> 00:27:51,419
from the standpoint of bacterial

687
00:27:56,570 --> 00:27:53,880
survival based on Earth bacterial

688
00:27:58,190 --> 00:27:56,580

survival under various intensities of

689
00:28:02,110 --> 00:27:58,200
ionizing radiation

690
00:28:05,630 --> 00:28:02,120
so I think the radiation environment for

691
00:28:07,010 --> 00:28:05,640
inactivation on the surface is this UV

692
00:28:09,649 --> 00:28:07,020
irradiation

693
00:28:12,470 --> 00:28:09,659
the hard radiation or ionizing radiation

694
00:28:14,269 --> 00:28:12,480
is probably only a minor Factor unless

695
00:28:15,470 --> 00:28:14,279
you're talking about geological time

696
00:28:17,210 --> 00:28:15,480
periods

697
00:28:18,590 --> 00:28:17,220
intriguing yeah that's really good to

698
00:28:20,390 --> 00:28:18,600
know and a good reminder for our

699
00:28:22,610 --> 00:28:20,400
audience too about the processes that

700
00:28:25,310 --> 00:28:22,620
affect you know living things on Mars as

701
00:28:26,930 --> 00:28:25,320
well as possible things like Organics

702
00:28:28,850 --> 00:28:26,940
um and so we I do want to jump to our

703
00:28:30,590 --> 00:28:28,860
audience uh questions here as soon as I

704
00:28:31,610 --> 00:28:30,600
can but there are two more quick things

705
00:28:33,710 --> 00:28:31,620
I do want to bring up about your

706
00:28:36,470 --> 00:28:33,720
research that you've been working on uh

707
00:28:39,169 --> 00:28:36,480
either now or in the past and one has to

708
00:28:41,570 --> 00:28:39,179
do with with UV on the surface of Mars

709
00:28:44,029 --> 00:28:41,580
you've been doing some work recently on

710
00:28:46,789 --> 00:28:44,039
studying the processes of forming and

711
00:28:48,409 --> 00:28:46,799
breaking down methane at the surface of

712
00:28:49,789 --> 00:28:48,419
Mars and you know for those who are

713
00:28:51,350 --> 00:28:49,799

watching they might be aware that you

714
00:28:53,930 --> 00:28:51,360
know some years ago we had the first

715
00:28:56,510 --> 00:28:53,940
potential detections of methane in large

716
00:28:58,070 --> 00:28:56,520
plumes the the Martian surface and now

717
00:29:00,110 --> 00:28:58,080
more recently we've had more

718
00:29:01,430 --> 00:29:00,120
confirmation of methane at the surface

719
00:29:03,470 --> 00:29:01,440
of Mars

720
00:29:04,909 --> 00:29:03,480
um so so what has your research been in

721
00:29:06,350 --> 00:29:04,919
looking at this production and

722
00:29:07,610 --> 00:29:06,360
destructive process when it comes to

723
00:29:10,190 --> 00:29:07,620
methane

724
00:29:12,350 --> 00:29:10,200
all right so a number of years ago I

725
00:29:15,909 --> 00:29:12,360
worked with several other scientists to

726
00:29:18,169 --> 00:29:15,919
explore how the ultraviolet irradiation

727
00:29:19,130 --> 00:29:18,179
environment that hits the surface of

728
00:29:21,409 --> 00:29:19,140
Mars

729
00:29:25,010 --> 00:29:21,419
can't is it energetic enough does it

730
00:29:28,330 --> 00:29:25,020
have enough energy per photon to break

731
00:29:30,350 --> 00:29:28,340
Bonds in a methane in a organic compound

732
00:29:33,950 --> 00:29:30,360
releasing methane

733
00:29:37,010 --> 00:29:33,960
and it turns out that it does uh the

734
00:29:40,310 --> 00:29:37,020
exact mechanism uh if for which that

735
00:29:44,389 --> 00:29:40,320
that process occurs is not really worked

736
00:29:48,590 --> 00:29:44,399
out but it clearly our research clearly

737
00:29:51,730 --> 00:29:48,600
demonstrated uh that the ultraviolet

738
00:29:55,010 --> 00:29:51,740

irradiation that reaches the surface can

739
00:29:56,389 --> 00:29:55,020
cleave or break down Organics in the

740
00:29:59,330 --> 00:29:56,399
surface environment and in the

741
00:30:02,570 --> 00:29:59,340
atmosphere releasing methane what's

742
00:30:06,950 --> 00:30:02,580
intriguing is that the Curiosity Rover

743
00:30:10,490 --> 00:30:06,960
with the uh an instrument called the MSL

744
00:30:13,430 --> 00:30:10,500
um I'm sorry called Sam Dash TLS which

745
00:30:16,310 --> 00:30:13,440
is an organic detection instrument with

746
00:30:18,590 --> 00:30:16,320
a specific tunable laser that it can

747
00:30:22,130 --> 00:30:18,600
detect methane very very small levels of

748
00:30:23,990 --> 00:30:22,140
methane it had a has had there's a

749
00:30:26,149 --> 00:30:24,000
number of papers published with this

750
00:30:28,450 --> 00:30:26,159
detection down in the parts per billion

751
00:30:32,049 --> 00:30:28,460
range so

752
00:30:35,450 --> 00:30:32,059
2017 15 years ago we had data from Earth

753
00:30:37,850 --> 00:30:35,460
telescopes of large plumes of methane in

754
00:30:41,029 --> 00:30:37,860
the Martian atmosphere followed with

755
00:30:43,789 --> 00:30:41,039
some skepticism by the community then

756
00:30:46,789 --> 00:30:43,799
the MSL rover Curiosity started

757
00:30:51,110 --> 00:30:46,799
detecting it and showing spikes in it in

758
00:30:53,750 --> 00:30:51,120
methane but then the trace gas Orbiter

759
00:30:58,430 --> 00:30:53,760
which is an Esa instrument or a

760
00:31:00,830 --> 00:30:58,440
spacecraft it is now completely gone

761
00:31:03,610 --> 00:31:00,840
negative on that methane story it cannot

762
00:31:06,350 --> 00:31:03,620
detect it and it's setting extremely low

763
00:31:09,190 --> 00:31:06,360

levels for methane in the bulk mesh and

764
00:31:11,350 --> 00:31:09,200
atmosphere so what I think is happening

765
00:31:14,630 --> 00:31:11,360
based on just the literature available

766
00:31:17,990 --> 00:31:14,640
is that the methane concentrations that

767
00:31:20,450 --> 00:31:18,000
are being detected by the Mars rover

768
00:31:23,690 --> 00:31:20,460
Curiosity could be very close to the

769
00:31:26,330 --> 00:31:23,700
ground maybe only up to a few tens of

770
00:31:27,830 --> 00:31:26,340
meters to a few hundreds of meters and

771
00:31:30,830 --> 00:31:27,840
then those are dissipated through the

772
00:31:33,430 --> 00:31:30,840
day and when the methane is diluted out

773
00:31:35,930 --> 00:31:33,440
in the bulk atmosphere

774
00:31:38,990 --> 00:31:35,940
then the trace gas Orbiter is having

775
00:31:41,630 --> 00:31:39,000
trouble seeing that methane now that's

776
00:31:43,970 --> 00:31:41,640
an open area of study but if we can

777
00:31:47,029 --> 00:31:43,980
confirm that methane exists

778
00:31:50,889 --> 00:31:47,039
we it has to constantly be resupplied

779
00:31:53,990 --> 00:31:50,899
because the solar UV

780
00:31:56,690 --> 00:31:54,000
breaks down methane which is what my

781
00:31:59,210 --> 00:31:56,700
research and others have shown uh so

782
00:32:01,190 --> 00:31:59,220
it's a very interesting topic because if

783
00:32:03,470 --> 00:32:01,200
it's there and we can confirm it it

784
00:32:06,430 --> 00:32:03,480
could be a biogenic signature or bio

785
00:32:10,130 --> 00:32:06,440
signature of some Subterranean

786
00:32:12,590 --> 00:32:10,140
methanogenic Community it might be three

787
00:32:16,549 --> 00:32:12,600
four kilometers down into the crust of

788
00:32:19,070 --> 00:32:16,559

Mars uh but if it's present it'll those

789
00:32:21,230 --> 00:32:19,080
those will seep out eventually and and

790
00:32:23,029 --> 00:32:21,240
that's what we might be seeing but I'm

791
00:32:25,250 --> 00:32:23,039
starting to get into speculation here so

792
00:32:27,529 --> 00:32:25,260
sticking with just the data we have

793
00:32:29,510 --> 00:32:27,539
these versus big plumes that are local

794
00:32:31,610 --> 00:32:29,520
detection now the trace gas Orbiter is

795
00:32:33,049 --> 00:32:31,620
saying well not so fast maybe it's not

796
00:32:35,090 --> 00:32:33,059
there

797
00:32:36,409 --> 00:32:35,100
yeah it's rather incredible and you know

798
00:32:37,909 --> 00:32:36,419
your career you've done so many

799
00:32:40,909 --> 00:32:37,919
different things and I love that about

800
00:32:42,610 --> 00:32:40,919
astrobiology you know myself everyone I

801
00:32:44,990 --> 00:32:42,620
speak to in the realm of astrobiology

802
00:32:47,029 --> 00:32:45,000
hasn't just focused on one individual

803
00:32:49,010 --> 00:32:47,039
topic we've you know kind of touched all

804
00:32:50,750 --> 00:32:49,020
these different areas

805
00:32:52,370 --> 00:32:50,760
um and an astrobiology itself you know

806
00:32:55,070 --> 00:32:52,380
that's kind of crucial when it comes to

807
00:32:57,049 --> 00:32:55,080
understanding the nature of life and and

808
00:32:58,669 --> 00:32:57,059
one thing you worked on in the past was

809
00:33:01,250 --> 00:32:58,679
this thing called Dart uh the dust

810
00:33:02,690 --> 00:33:01,260
atmospheric recovery technology

811
00:33:04,669 --> 00:33:02,700
um for kind of looking at plant and

812
00:33:07,430 --> 00:33:04,679
human pathogens in dust plumes coming

813
00:33:09,110 --> 00:33:07,440

from Africa coming across the world and

814
00:33:11,269 --> 00:33:09,120
kind of coming here and that really

815
00:33:12,889 --> 00:33:11,279
sparked my own interests a lot I've been

816
00:33:14,450 --> 00:33:12,899
involved in the past

817
00:33:17,389 --> 00:33:14,460
um with some undergraduate level

818
00:33:19,669 --> 00:33:17,399
research and looking at uh aerobiology

819
00:33:22,070 --> 00:33:19,679
and how organisms are lofted into the

820
00:33:25,490 --> 00:33:22,080
atmosphere and move around a very good

821
00:33:27,529 --> 00:33:25,500
friend of mine David Smith NASA Ames he

822
00:33:29,750 --> 00:33:27,539
did research during his PhD looking at

823
00:33:31,549 --> 00:33:29,760
organisms being lofted from the Gobi

824
00:33:32,990 --> 00:33:31,559
desert and for eight days making their

825
00:33:34,789 --> 00:33:33,000
way across the world and kind of variety

826
00:33:37,190 --> 00:33:34,799
driving you know through the atmosphere

827
00:33:38,990 --> 00:33:37,200
to California and then you know we've

828
00:33:41,210 --> 00:33:39,000
now learned that the way the Amazon

829
00:33:44,330 --> 00:33:41,220
rainforest is being fertilized with

830
00:33:46,190 --> 00:33:44,340
phosphorus is from dust from the Saharan

831
00:33:48,169 --> 00:33:46,200
region of Africa being lofted and coming

832
00:33:51,710 --> 00:33:48,179
over here and it shows this beautiful

833
00:33:52,730 --> 00:33:51,720
connection of life on Earth but then you

834
00:33:53,630 --> 00:33:52,740
know you were also involved in this

835
00:33:55,789 --> 00:33:53,640
realm of kind of thinking about

836
00:33:57,889 --> 00:33:55,799
pathogens for plants and humans being

837
00:33:59,690 --> 00:33:57,899
lofted up as well I wonder if you could

838
00:34:01,549 --> 00:33:59,700

speak about you know that research what

839
00:34:03,769 --> 00:34:01,559
intrigued you about it and maybe kind of

840
00:34:05,330 --> 00:34:03,779
your vision for these things moving

841
00:34:10,669 --> 00:34:05,340
around the planet and this connectivity

842
00:34:13,550 --> 00:34:10,679
of Life yeah exactly the the planet uh

843
00:34:17,149 --> 00:34:13,560
the planet's atmosphere circulates

844
00:34:18,950 --> 00:34:17,159
pretty much everywhere so if in theory

845
00:34:21,290 --> 00:34:18,960
something is present in the Saharan

846
00:34:23,210 --> 00:34:21,300
Desert that will eventually be

847
00:34:25,970 --> 00:34:23,220
recirculated all over the planet

848
00:34:28,310 --> 00:34:25,980
eventually dropping or depositing out in

849
00:34:31,010 --> 00:34:28,320
the Arctic regions and the equatorial

850
00:34:34,490 --> 00:34:31,020
regions and the amount of dust being

851
00:34:36,829 --> 00:34:34,500
moved from the Sahara to North America

852
00:34:39,710 --> 00:34:36,839
is quite dramatic just in Florida every

853
00:34:42,829 --> 00:34:39,720
year 50 million metric tons of dust

854
00:34:44,690 --> 00:34:42,839
comes from Africa usually in the months

855
00:34:47,149 --> 00:34:44,700
of July middle of July through the

856
00:34:48,649 --> 00:34:47,159
middle of September but over in the

857
00:34:50,930 --> 00:34:48,659
Northwest this would be Northern

858
00:34:53,270 --> 00:34:50,940
California Oregon and Washington State

859
00:34:56,210 --> 00:34:53,280
up into British Columbia uh they're

860
00:34:58,550 --> 00:34:56,220
getting about another 60 or 70 million

861
00:35:01,730 --> 00:34:58,560
metric tons of dust coming from the

862
00:35:03,589 --> 00:35:01,740
Chinese the Gobi desert in China so

863
00:35:05,570 --> 00:35:03,599

there's a large volume of it bringing a

864
00:35:07,790 --> 00:35:05,580
lot of nutrients most of the fertility

865
00:35:10,130 --> 00:35:07,800
not only in the Amazon but in the

866
00:35:12,950 --> 00:35:10,140
islands in the Caribbean are due from

867
00:35:15,290 --> 00:35:12,960
the minerals that are coming from over

868
00:35:18,170 --> 00:35:15,300
geological time have come from the

869
00:35:21,109 --> 00:35:18,180
Saharan Desert So This Global movement

870
00:35:23,890 --> 00:35:21,119
is very interesting and there's a

871
00:35:26,569 --> 00:35:23,900
concept called emerging pathogens

872
00:35:29,329 --> 00:35:26,579
and there are a lot of institutes that

873
00:35:31,970 --> 00:35:29,339
study emerging pathogens a pathogen that

874
00:35:34,670 --> 00:35:31,980
was not present in one area suddenly

875
00:35:36,890 --> 00:35:34,680
becomes very active it could be a plant

876
00:35:39,410 --> 00:35:36,900
pathogen it could be an animal pathogen

877
00:35:41,210 --> 00:35:39,420
it could be a pathogen to fish or

878
00:35:43,609 --> 00:35:41,220
aquatic ecosystems or it could be a

879
00:35:45,109 --> 00:35:43,619
human pathogen so I just became as a

880
00:35:47,390 --> 00:35:45,119
plant pathologist I became very

881
00:35:49,250 --> 00:35:47,400
intrigued on whether or not plant

882
00:35:51,349 --> 00:35:49,260
pathogens were being moved around in

883
00:35:53,390 --> 00:35:51,359
these dust storms and the evidence

884
00:35:55,069 --> 00:35:53,400
pretty much supports that they are but

885
00:35:57,230 --> 00:35:55,079
we don't have it really kind of well

886
00:35:59,690 --> 00:35:57,240
characterized with the volume of those

887
00:36:02,450 --> 00:35:59,700
plant pathogens are and how much impact

888
00:36:04,250 --> 00:36:02,460

if any the plant pathogens are doing to

889
00:36:05,750 --> 00:36:04,260
the agricultural systems in these

890
00:36:07,730 --> 00:36:05,760
regions

891
00:36:09,290 --> 00:36:07,740
wow yeah and so for any of our audience

892
00:36:10,730 --> 00:36:09,300
who are watching who are interested in

893
00:36:13,130 --> 00:36:10,740
in this realm of research and

894
00:36:15,230 --> 00:36:13,140
microbiology and plant pathogens you

895
00:36:16,130 --> 00:36:15,240
know plant how plants function in

896
00:36:17,329 --> 00:36:16,140
general

897
00:36:18,829 --> 00:36:17,339
um there's so much to take from this

898
00:36:20,329 --> 00:36:18,839
that you can be an astrobiologist and

899
00:36:21,770 --> 00:36:20,339
work on so many of these different kinds

900
00:36:23,270 --> 00:36:21,780
of topics

901
00:36:24,349 --> 00:36:23,280
um I do want to move now I know that

902
00:36:25,910 --> 00:36:24,359
we're running out of time and so I want

903
00:36:28,130 --> 00:36:25,920
to move now to our faster than light

904
00:36:30,290 --> 00:36:28,140
segment this is where we just have some

905
00:36:31,670 --> 00:36:30,300
rapid fire questions

906
00:36:33,170 --> 00:36:31,680
um and so I just have a few that I want

907
00:36:34,609 --> 00:36:33,180
to ask you

908
00:36:36,530 --> 00:36:34,619
um to bring up some of these topics that

909
00:36:37,790 --> 00:36:36,540
are relevant to astrobiology and a lot

910
00:36:40,250 --> 00:36:37,800
of us kind of want to know from all the

911
00:36:43,430 --> 00:36:40,260
astrobiologists we speak to

912
00:36:44,930 --> 00:36:43,440
so the first question comes from Enrico

913
00:36:47,089 --> 00:36:44,940

Fermi when he when he first asked you

914
00:36:49,310 --> 00:36:47,099
know like where are they out there uh

915
00:36:51,410 --> 00:36:49,320
what is your favorite answer to fermi's

916
00:36:54,470 --> 00:36:51,420
question where are they

917
00:36:57,349 --> 00:36:54,480
oh fascinating I just read a book called

918
00:36:59,329 --> 00:36:57,359
where is everybody

919
00:37:02,690 --> 00:36:59,339
um and it's about trying to solve the

920
00:37:05,510 --> 00:37:02,700
Drake equation which was developed in an

921
00:37:06,410 --> 00:37:05,520
attempt to answer Enrico fermi's uh

922
00:37:09,230 --> 00:37:06,420
question

923
00:37:11,210 --> 00:37:09,240
and they gave 50 reasons why aliens

924
00:37:14,210 --> 00:37:11,220
haven't been in contact 50 plausible

925
00:37:18,290 --> 00:37:14,220
hypotheses of all of those I think the

926
00:37:21,829 --> 00:37:18,300
most reasonable is that the astronomical

927
00:37:25,430 --> 00:37:21,839
distance between Star systems are so

928
00:37:29,030 --> 00:37:25,440
incredibly huge that it is fundamentally

929
00:37:33,109 --> 00:37:29,040
impractical for aliens to travel between

930
00:37:35,270 --> 00:37:33,119
Star systems and just as an example uh

931
00:37:37,190 --> 00:37:35,280
Alpha Satori which is a cluster of three

932
00:37:38,829 --> 00:37:37,200
stars sort of in this very really

933
00:37:40,450 --> 00:37:38,839
incredible dance going on

934
00:37:44,990 --> 00:37:40,460
three-dimensional

935
00:37:48,710 --> 00:37:45,000
orbits that's 4.2 4.26 light years away

936
00:37:51,470 --> 00:37:48,720
current rocketry would take like 80 000

937
00:37:54,170 --> 00:37:51,480
years to have a spaceship reach the

938
00:37:57,109 --> 00:37:54,180

closest star so that I think is the best

939
00:37:59,109 --> 00:37:57,119
solution the distances are just way too

940
00:38:02,030 --> 00:37:59,119
big to have this easily happen

941
00:38:03,950 --> 00:38:02,040
absolutely I mean there are you know

942
00:38:06,170 --> 00:38:03,960
crazy vast distances in space that kind

943
00:38:08,630 --> 00:38:06,180
of bend the human mind but I'm glad you

944
00:38:11,690 --> 00:38:08,640
mentioned book our next question is is

945
00:38:13,849 --> 00:38:11,700
what stories have inspired you to want

946
00:38:15,770 --> 00:38:13,859
to pursue your career and learn more

947
00:38:17,930 --> 00:38:15,780
about life in the universe

948
00:38:20,390 --> 00:38:17,940
well I got to tell you uh it goes back

949
00:38:22,250 --> 00:38:20,400
to fourth grade uh it's I won't tell you

950
00:38:23,990 --> 00:38:22,260
the whole story because it's got more

951
00:38:25,609 --> 00:38:24,000
complicated but fundamentally I was

952
00:38:28,670 --> 00:38:25,619
struggling in fourth grade I didn't like

953
00:38:31,250 --> 00:38:28,680
to read I was bored I was a class clown

954
00:38:33,650 --> 00:38:31,260
in the back you know causing trouble and

955
00:38:35,870 --> 00:38:33,660
we had to buy a book from a book club so

956
00:38:37,910 --> 00:38:35,880
I brought in my 50 cents plopped it down

957
00:38:40,730 --> 00:38:37,920
and I was looking around you know you

958
00:38:43,010 --> 00:38:40,740
can imagine a little kid oh this is so

959
00:38:46,069 --> 00:38:43,020
boring oh and then I came across a title

960
00:38:49,130 --> 00:38:46,079
that said Mission to Mars

961
00:38:50,990 --> 00:38:49,140
and I said huh that sounded like fun so

962
00:38:53,930 --> 00:38:51,000
I bought this book it was about a family

963
00:38:56,089 --> 00:38:53,940

going to Mars and they meet martians the

964
00:38:57,890 --> 00:38:56,099
Martians helped them to survive because

965
00:39:01,609 --> 00:38:57,900
their life support system wasn't working

966
00:39:05,089 --> 00:39:01,619
right and so it's really been fun now to

967
00:39:07,970 --> 00:39:05,099
work and it closes the circle I had a

968
00:39:11,210 --> 00:39:07,980
new spark in fourth grade to think about

969
00:39:12,530 --> 00:39:11,220
outer space and mooc and flying to other

970
00:39:15,010 --> 00:39:12,540
planets

971
00:39:17,270 --> 00:39:15,020
and that came from that one single book

972
00:39:18,829 --> 00:39:17,280
uh and now I'm working on Mars

973
00:39:20,150 --> 00:39:18,839
astrobiology I think that's a really

974
00:39:21,890 --> 00:39:20,160
cool Circle

975
00:39:23,510 --> 00:39:21,900
that is really cool you know you're

976
00:39:24,770 --> 00:39:23,520
speaking to that young kid in me he used

977
00:39:26,569 --> 00:39:24,780
to go to the Scholastic Book Fair and

978
00:39:28,430 --> 00:39:26,579
buy a bunch of books for you know a

979
00:39:30,170 --> 00:39:28,440
nickel or a dime each and then you know

980
00:39:31,609 --> 00:39:30,180
get nerding out over the science and

981
00:39:33,770 --> 00:39:31,619
then then the culture and the history

982
00:39:35,569 --> 00:39:33,780
and all these things exactly um you know

983
00:39:37,130 --> 00:39:35,579
and now in your career it's been quite a

984
00:39:39,770 --> 00:39:37,140
while since fourth grade you've done so

985
00:39:42,470 --> 00:39:39,780
many cool things in your career

986
00:39:44,690 --> 00:39:42,480
if you could though go back to the very

987
00:39:47,329 --> 00:39:44,700
beginning of your career and give

988
00:39:48,950 --> 00:39:47,339

yourself some advice what advice would

989
00:39:51,170 --> 00:39:48,960
you give yourself

990
00:39:54,290 --> 00:39:51,180
wow uh

991
00:39:57,589 --> 00:39:54,300
get done with your graduate work as fast

992
00:40:00,190 --> 00:39:57,599
as possible but doing excellent work

993
00:40:03,410 --> 00:40:00,200
don't dwell on stuff

994
00:40:04,849 --> 00:40:03,420
and get out into the the academic

995
00:40:07,670 --> 00:40:04,859
environment if that's where you want to

996
00:40:12,349 --> 00:40:07,680
go research in Academia or at Nasa

997
00:40:14,750 --> 00:40:12,359
centers or or other National Labs get

998
00:40:17,690 --> 00:40:14,760
your graduate work done quick get out

999
00:40:19,310 --> 00:40:17,700
and start making uh making a name for

1000
00:40:22,790 --> 00:40:19,320
yourself and doing some fun work and the

1001
00:40:25,010 --> 00:40:22,800
second advice is pick really cool field

1002
00:40:28,430 --> 00:40:25,020
work field sites

1003
00:40:30,770 --> 00:40:28,440
so uh doing that Dart that dust

1004
00:40:34,370 --> 00:40:30,780
collection system I was able to fly in a

1005
00:40:35,990 --> 00:40:34,380
f-104 star fighter jet something I've

1006
00:40:39,950 --> 00:40:36,000
wanted to do my whole life since I was

1007
00:40:42,589 --> 00:40:39,960
just a little kid so uh you know just

1008
00:40:44,750 --> 00:40:42,599
have fun and but get to it

1009
00:40:46,069 --> 00:40:44,760
love it so much well let's talk about

1010
00:40:47,210 --> 00:40:46,079
the things that excite you then you know

1011
00:40:49,970 --> 00:40:47,220
when you were a kid you were excited by

1012
00:40:51,530 --> 00:40:49,980
this this f-104 Starfighter

1013
00:40:53,450 --> 00:40:51,540

um but right now you know not just in

1014
00:40:56,030 --> 00:40:53,460
your career and the research you've done

1015
00:40:58,790 --> 00:40:56,040
but just in general what excites you

1016
00:41:02,329 --> 00:40:58,800
about the future

1017
00:41:05,510 --> 00:41:02,339
well I am just totally Blown Away to be

1018
00:41:06,890 --> 00:41:05,520
basically just amazed on the natural

1019
00:41:09,890 --> 00:41:06,900
world

1020
00:41:11,930 --> 00:41:09,900
uh the the big bang happened 3.8 billion

1021
00:41:15,050 --> 00:41:11,940
years ago we started with primarily

1022
00:41:18,109 --> 00:41:15,060
hydrogen and now we have every

1023
00:41:20,990 --> 00:41:18,119
everything that we have uh and there is

1024
00:41:23,390 --> 00:41:21,000
a very logical rational process from

1025
00:41:25,670 --> 00:41:23,400
going from hydrogen gas in the early

1026
00:41:28,010 --> 00:41:25,680
Universe all the way up to complex

1027
00:41:32,750 --> 00:41:28,020
medicine animals like humans and

1028
00:41:34,910 --> 00:41:32,760
giraffes and uh penguins and that that

1029
00:41:38,089 --> 00:41:34,920
whole wide range on how soil chemistry

1030
00:41:39,829 --> 00:41:38,099
played into it evolution of stars Jed

1031
00:41:43,849 --> 00:41:39,839
there's different populations of stars

1032
00:41:46,790 --> 00:41:43,859
metal Rich Stars metal poor Stars uh all

1033
00:41:49,370 --> 00:41:46,800
of that comes together and there's just

1034
00:41:52,150 --> 00:41:49,380
this amazing Universe out there and I

1035
00:41:55,190 --> 00:41:52,160
I'm Blown Away by by some of the

1036
00:41:57,589 --> 00:41:55,200
documentaries that are on TV and in in

1037
00:42:00,589 --> 00:41:57,599
you know broadcast YouTubes and things

1038
00:42:02,450 --> 00:42:00,599

like that it's just wonderful

1039
00:42:04,130 --> 00:42:02,460
yeah definitely and I I was you know I

1040
00:42:05,390 --> 00:42:04,140
was a young kid I would watch like the

1041
00:42:06,890 --> 00:42:05,400
Discovery Channel and The Learning

1042
00:42:08,930 --> 00:42:06,900
Channel back when they had actual

1043
00:42:10,849 --> 00:42:08,940
science content and I would get so like

1044
00:42:11,990 --> 00:42:10,859
just amazed by these documentaries and

1045
00:42:13,970 --> 00:42:12,000
things I remember one from the 90s

1046
00:42:15,650 --> 00:42:13,980
called solar Empire that just like it

1047
00:42:18,470 --> 00:42:15,660
blew my mind thinking about what we were

1048
00:42:20,510 --> 00:42:18,480
learning about science and that brings

1049
00:42:22,970 --> 00:42:20,520
me to my last question in this faster

1050
00:42:25,670 --> 00:42:22,980
than light segment what is a science

1051
00:42:27,710 --> 00:42:25,680
fact that maybe you still find

1052
00:42:29,329 --> 00:42:27,720
unbelievable or that still blows your

1053
00:42:31,490 --> 00:42:29,339
mind

1054
00:42:34,150 --> 00:42:31,500
that we are here

1055
00:42:36,950 --> 00:42:34,160
this can be stated that simply

1056
00:42:40,609 --> 00:42:36,960
uh the big Banks we know when the Big

1057
00:42:43,310 --> 00:42:40,619
Bang started 3.88 billion years ago

1058
00:42:44,810 --> 00:42:43,320
but what's the trigger where'd that

1059
00:42:47,089 --> 00:42:44,820
energy come from

1060
00:42:49,190 --> 00:42:47,099
uh and the fact that again we went from

1061
00:42:51,470 --> 00:42:49,200
hydrogen gas

1062
00:42:52,990 --> 00:42:51,480
through seller Evolution planetary

1063
00:42:56,510 --> 00:42:53,000

1064
00:42:58,730 --> 00:42:56,520
biological evolution and here we are a

1065
00:43:00,770 --> 00:42:58,740
species capable of thinking about all of

1066
00:43:03,170 --> 00:43:00,780
that that that's what really sort of

1067
00:43:05,450 --> 00:43:03,180
blows my mind that's beautiful yeah you

1068
00:43:06,829 --> 00:43:05,460
know it kind of blows my mind too

1069
00:43:09,950 --> 00:43:06,839
um just the fact that we get to exist

1070
00:43:11,450 --> 00:43:09,960
for even a short window each of us uh in

1071
00:43:13,430 --> 00:43:11,460
this world this universe you know this

1072
00:43:16,309 --> 00:43:13,440
Cosmos and some of us get to explore it

1073
00:43:17,990 --> 00:43:16,319
together and learn more about our place

1074
00:43:19,010 --> 00:43:18,000
um I really appreciate that so much from

1075
00:43:20,329 --> 00:43:19,020
you

1076
00:43:22,309 --> 00:43:20,339
um I'm going to open it now for our

1077
00:43:24,050 --> 00:43:22,319
audience q a I know we have a bunch of

1078
00:43:26,210 --> 00:43:24,060
questions coming in from YouTube in the

1079
00:43:28,069 --> 00:43:26,220
live chat uh and so let's just get

1080
00:43:29,210 --> 00:43:28,079
started and see what everyone wants to

1081
00:43:31,609 --> 00:43:29,220
ask

1082
00:43:34,250 --> 00:43:31,619
um first starting off uh user at

1083
00:43:36,109 --> 00:43:34,260
rendering reality on Twitter has said

1084
00:43:38,870 --> 00:43:36,119
friendly bacteria like strains of

1085
00:43:41,750 --> 00:43:38,880
bacillus subtilis used for watering or

1086
00:43:44,150 --> 00:43:41,760
foliar feeding make organic farming a

1087
00:43:46,490 --> 00:43:44,160
near closed-loop system is there any

1088
00:43:48,470 --> 00:43:46,500

research using uh good bacteria or

1089
00:43:50,329 --> 00:43:48,480
bacteria from Earth on making an organic

1090
00:43:51,470 --> 00:43:50,339
closed loose loop system for Martian

1091
00:43:54,410 --> 00:43:51,480
farming

1092
00:43:57,950 --> 00:43:54,420
there is actually research in that topic

1093
00:44:00,770 --> 00:43:57,960
uh both in Academia as well as in NASA

1094
00:44:05,829 --> 00:44:00,780
uh these these growth promoting

1095
00:44:07,630 --> 00:44:05,839
beneficial bacteria fungi prokarya

1096
00:44:09,829 --> 00:44:07,640
amoeba

1097
00:44:12,370 --> 00:44:09,839
algae a whole diversity of

1098
00:44:15,890 --> 00:44:12,380
microorganisms are going to be present

1099
00:44:18,829 --> 00:44:15,900
in any lunar biogenerative life support

1100
00:44:21,950 --> 00:44:18,839
system or Mrs bioregenerative life

1101
00:44:23,510 --> 00:44:21,960
support system and we have we have got

1102
00:44:25,910 --> 00:44:23,520
to understand how those beneficial

1103
00:44:27,829 --> 00:44:25,920
organisms are going to interplay with

1104
00:44:30,170 --> 00:44:27,839
the plants and with the humans in these

1105
00:44:32,450 --> 00:44:30,180
closed environments and so because

1106
00:44:36,170 --> 00:44:32,460
humans are will be in so much more

1107
00:44:39,530 --> 00:44:36,180
intimate contact with the life support

1108
00:44:41,510 --> 00:44:39,540
systems and on mars or on the moon uh we

1109
00:44:43,970 --> 00:44:41,520
have there's more to understand on how

1110
00:44:46,550 --> 00:44:43,980
beneficial organisms interact with our

1111
00:44:48,650 --> 00:44:46,560
own microbiomes so there is research

1112
00:44:52,069 --> 00:44:48,660
underway and it's a really exciting area

1113
00:44:54,589 --> 00:44:52,079

of future work for the space program

1114
00:44:58,250 --> 00:44:54,599
wonderful our next question comes from

1115
00:45:00,349 --> 00:44:58,260
Roshan bukhari on YouTube Roshan has

1116
00:45:02,270 --> 00:45:00,359
basically asked what role do you think

1117
00:45:04,309 --> 00:45:02,280
AI will play when it comes to Future

1118
00:45:05,510 --> 00:45:04,319
robotic explorers looking for Life on

1119
00:45:08,270 --> 00:45:05,520
Mars

1120
00:45:10,930 --> 00:45:08,280
oh AI well I'm worried about AI because

1121
00:45:15,770 --> 00:45:10,940
I saw this documentary called Terminator

1122
00:45:18,829 --> 00:45:15,780
and just kidding just kidding uh no AI

1123
00:45:22,670 --> 00:45:18,839
is a very important uh scientific area

1124
00:45:24,650 --> 00:45:22,680
of study and it's so

1125
00:45:27,470 --> 00:45:24,660
um I don't know how to predict how it's

1126
00:45:29,390 --> 00:45:27,480
going to really play out uh so I I

1127
00:45:31,790 --> 00:45:29,400
almost have to say I had no comment on

1128
00:45:35,030 --> 00:45:31,800
this simply because it could be so

1129
00:45:37,730 --> 00:45:35,040
amazing and then yet maybe it doesn't

1130
00:45:40,849 --> 00:45:37,740
really reach the full potential that we

1131
00:45:43,010 --> 00:45:40,859
think it might be able to reach so uh I

1132
00:45:46,910 --> 00:45:43,020
think Advanced Computing is absolutely

1133
00:45:49,089 --> 00:45:46,920
key to successful missions to Mars and

1134
00:45:51,770 --> 00:45:49,099
to the surface of of the Moon

1135
00:45:55,370 --> 00:45:51,780
uh and every time I struggle to get my

1136
00:45:58,010 --> 00:45:55,380
little iPhone to work or or on my TV

1137
00:45:59,990 --> 00:45:58,020
programmed I think golly uh we're gonna

1138
00:46:02,210 --> 00:46:00,000

have trouble going to Mars but AI is

1139
00:46:03,530 --> 00:46:02,220
going to help us solve that

1140
00:46:05,270 --> 00:46:03,540
um that's about all I can say really

1141
00:46:07,490 --> 00:46:05,280
yeah absolutely there's a lot of

1142
00:46:09,470 --> 00:46:07,500
Advanced Technologies not just around

1143
00:46:11,390 --> 00:46:09,480
the corner or coming up tomorrow they're

1144
00:46:13,430 --> 00:46:11,400
here now you know we are using a lot of

1145
00:46:15,530 --> 00:46:13,440
Advanced Technologies and so our next

1146
00:46:16,670 --> 00:46:15,540
question from user tessellated on

1147
00:46:18,650 --> 00:46:16,680
YouTube

1148
00:46:21,050 --> 00:46:18,660
um is about not an advanced technology

1149
00:46:23,030 --> 00:46:21,060
necessarily but one about using tissue

1150
00:46:25,609 --> 00:46:23,040
culture and whether we can apply tissue

1151
00:46:27,650 --> 00:46:25,619
culture to astrobotomy I think for

1152
00:46:29,329 --> 00:46:27,660
myself first I will say you know I've

1153
00:46:30,589 --> 00:46:29,339
talked to people out there who are you

1154
00:46:32,630 --> 00:46:30,599
know in the process of developing

1155
00:46:33,770 --> 00:46:32,640
companies to do things like lab grown

1156
00:46:37,609 --> 00:46:33,780
meat

1157
00:46:39,770 --> 00:46:37,619
making a sushi grade tuna in the

1158
00:46:41,809 --> 00:46:39,780
laboratory or making beef hamburgers in

1159
00:46:43,430 --> 00:46:41,819
the laboratory I do think eventually

1160
00:46:45,309 --> 00:46:43,440
we're going to see people who are

1161
00:46:47,510 --> 00:46:45,319
learning now how to do tissue culture

1162
00:46:49,609 --> 00:46:47,520
we'll be going out with their friends

1163
00:46:51,849 --> 00:46:49,619

who are organic chemists and things like

1164
00:46:54,349 --> 00:46:51,859
this and learning how to develop

1165
00:46:56,030 --> 00:46:54,359
lab-grown Meats for the space station

1166
00:46:57,770 --> 00:46:56,040
and Mars

1167
00:47:00,849 --> 00:46:57,780
um but Dr sugar what do you think of

1168
00:47:03,290 --> 00:47:00,859
using tissue culture in astrobotomy

1169
00:47:04,730 --> 00:47:03,300
well there are many different types of

1170
00:47:06,530 --> 00:47:04,740
tissue culture which you just mentioned

1171
00:47:09,770 --> 00:47:06,540
there's tissue cultures have produced

1172
00:47:11,870 --> 00:47:09,780
pathogen free plantlets that would be

1173
00:47:13,910 --> 00:47:11,880
then propagated into your biogenerative

1174
00:47:16,490 --> 00:47:13,920
life support system I think that's a

1175
00:47:21,010 --> 00:47:16,500
done deal that will be used uh there's

1176
00:47:24,309 --> 00:47:21,020
tissue culture to create uh perhaps

1177
00:47:26,930 --> 00:47:24,319
genetically modified crops that have

1178
00:47:28,730 --> 00:47:26,940
vitamins added in that might not

1179
00:47:31,069 --> 00:47:28,740
normally be there one of the big

1180
00:47:33,290 --> 00:47:31,079
concerns with humans going to Mars is a

1181
00:47:36,530 --> 00:47:33,300
long period of time are we going to be

1182
00:47:38,750 --> 00:47:36,540
able to preserve vitamins you know in

1183
00:47:40,970 --> 00:47:38,760
the normal little pills they begin to

1184
00:47:42,770 --> 00:47:40,980
degrade over a release and reasonable

1185
00:47:45,410 --> 00:47:42,780
short periods of time so we might need

1186
00:47:47,450 --> 00:47:45,420
to grow plants that have vitamin C in

1187
00:47:49,849 --> 00:47:47,460
them that are genetically engineered for

1188
00:47:53,450 --> 00:47:49,859

vitamin C and tissue culture has a role

1189
00:47:56,930 --> 00:47:53,460
to play in that uh having the astronauts

1190
00:47:58,930 --> 00:47:56,940
eat artificial fish and artificial Meats

1191
00:48:02,030 --> 00:47:58,940
that's very very

1192
00:48:05,750 --> 00:48:02,040
scenario although well I'd really hate

1193
00:48:08,569 --> 00:48:05,760
not having a nice rib eye bone-in rib

1194
00:48:11,150 --> 00:48:08,579
eye over cooked over the Barbie so but

1195
00:48:13,730 --> 00:48:11,160
but the technology will be a part of

1196
00:48:15,530 --> 00:48:13,740
these space exploration efforts

1197
00:48:17,089 --> 00:48:15,540
absolutely

1198
00:48:19,609 --> 00:48:17,099
um our next question comes from user

1199
00:48:21,109 --> 00:48:19,619
Haley Monaco on YouTube and it's an

1200
00:48:23,990 --> 00:48:21,119
interesting one um how could we

1201
00:48:26,150 --> 00:48:24,000
differentiate between geological methane

1202
00:48:28,790 --> 00:48:26,160
and biologically produced methane on

1203
00:48:31,790 --> 00:48:28,800
Mars is there a way for us given current

1204
00:48:35,030 --> 00:48:31,800
technology to differentiate

1205
00:48:37,010 --> 00:48:35,040
yeah we can do that now on Earth uh and

1206
00:48:40,430 --> 00:48:37,020
it's really due to the isotopic

1207
00:48:43,849 --> 00:48:40,440
fractionation it's called Uh carbon 12

1208
00:48:46,430 --> 00:48:43,859
is the primary carbon atom that makes

1209
00:48:48,829 --> 00:48:46,440
all of us uh there's a small amount of

1210
00:48:51,470 --> 00:48:48,839
carbon 13 which has one extra Neutron

1211
00:48:52,510 --> 00:48:51,480
and then even a smaller amount of carbon

1212
00:48:55,150 --> 00:48:52,520
14

1213
00:48:59,089 --> 00:48:55,160

and biological

1214
00:49:03,130 --> 00:48:59,099
methane has a different carbon 12 to 13

1215
00:49:06,250 --> 00:49:03,140
to 14 ratio then

1216
00:49:09,890 --> 00:49:06,260
abiogenic methane generally speaking

1217
00:49:12,770 --> 00:49:09,900
abiogenic methane will not be enriched

1218
00:49:15,890 --> 00:49:12,780
in carbon 13 or carbon 14 it'll be sort

1219
00:49:19,790 --> 00:49:15,900
of a straight ratio of you know I think

1220
00:49:22,430 --> 00:49:19,800
it's I think it's 98 carbon 12. 1.9

1221
00:49:25,250 --> 00:49:22,440
percent carbon 13 and then 0.1 percent

1222
00:49:27,829 --> 00:49:25,260
carbon 14. but biology has the ability

1223
00:49:29,930 --> 00:49:27,839
to enrich some of those those Isotopes

1224
00:49:32,089 --> 00:49:29,940
and so that's one way to tell the

1225
00:49:34,250 --> 00:49:32,099
difference between biogenic methane and

1226
00:49:36,349 --> 00:49:34,260
abiogenic methane

1227
00:49:38,270 --> 00:49:36,359
yeah absolutely then that's important

1228
00:49:40,309 --> 00:49:38,280
it's also important to know the source

1229
00:49:42,170 --> 00:49:40,319
of the the carbon isotope reservoirs

1230
00:49:43,970 --> 00:49:42,180
that we might have on Mars and so that

1231
00:49:45,410 --> 00:49:43,980
will require a lot of work too figuring

1232
00:49:48,530 --> 00:49:45,420
out you know what are we starting with

1233
00:49:49,849 --> 00:49:48,540
for isotopic uh abundances on Mars when

1234
00:49:51,349 --> 00:49:49,859
we have a sample the methane's coming

1235
00:49:54,230 --> 00:49:51,359
from

1236
00:49:57,230 --> 00:49:54,240
um now we do have a user Mark Lumsden on

1237
00:49:59,270 --> 00:49:57,240
Twitter has asked a question if we have

1238
00:50:01,430 --> 00:49:59,280

any evidence of Life possibly being

1239
00:50:02,990 --> 00:50:01,440
based on different chemistry

1240
00:50:05,089 --> 00:50:03,000
um people often often ask you know like

1241
00:50:07,190 --> 00:50:05,099
carbon based life versus silicon-based

1242
00:50:09,410 --> 00:50:07,200
life could there be other solvents out

1243
00:50:11,329 --> 00:50:09,420
there besides water I will personally

1244
00:50:13,430 --> 00:50:11,339
say an answer to Mark

1245
00:50:14,870 --> 00:50:13,440
um silicon-based life is a possibility

1246
00:50:17,630 --> 00:50:14,880
it might be that we actually create

1247
00:50:19,370 --> 00:50:17,640
maybe post biological life on Earth will

1248
00:50:20,690 --> 00:50:19,380
be silicon based because we've made it

1249
00:50:22,010 --> 00:50:20,700
that way

1250
00:50:24,410 --> 00:50:22,020
um it is worth looking into the

1251
00:50:25,730 --> 00:50:24,420
chemistry though silicon silicon bonds

1252
00:50:28,430 --> 00:50:25,740
are not nearly as strong as

1253
00:50:31,670 --> 00:50:28,440
carbon-carbon bonds and they're also not

1254
00:50:32,450 --> 00:50:31,680
super stable in water like carbon is and

1255
00:50:35,569 --> 00:50:32,460
so there might be a different

1256
00:50:36,890 --> 00:50:35,579
environment a product cryosolvins for

1257
00:50:38,750 --> 00:50:36,900
instance are a place where silicon

1258
00:50:40,790 --> 00:50:38,760
silicon bonds are much stronger and can

1259
00:50:42,530 --> 00:50:40,800
survive a lot better and so it's worth

1260
00:50:44,349 --> 00:50:42,540
looking into the chemistry if you're

1261
00:50:48,410 --> 00:50:44,359
really interested in this question mark

1262
00:50:50,510 --> 00:50:48,420
however Andrew for you our next user THM

1263
00:50:53,089 --> 00:50:50,520

on YouTube has said that they're

1264
00:50:55,670 --> 00:50:53,099
interested in inter researching microbes

1265
00:50:57,230 --> 00:50:55,680
living in lava tubes do you have any

1266
00:50:59,390 --> 00:50:57,240
recommendations for them of what they

1267
00:51:01,190 --> 00:50:59,400
might want to look into when it comes to

1268
00:51:04,549 --> 00:51:01,200
understanding how microbes would thrive

1269
00:51:06,829 --> 00:51:04,559
in a unique environment like that

1270
00:51:08,690 --> 00:51:06,839
wow that that's a very good topic I

1271
00:51:10,309 --> 00:51:08,700
sometimes think back on a discipline

1272
00:51:11,809 --> 00:51:10,319
that I wish I would have gone into from

1273
00:51:14,150 --> 00:51:11,819
a career standpoint and Cave

1274
00:51:16,849 --> 00:51:14,160
microbiology is one of that one of those

1275
00:51:19,910 --> 00:51:16,859
topics I've been into some caves in the

1276
00:51:22,190 --> 00:51:19,920
southwest of the United States that uh

1277
00:51:24,049 --> 00:51:22,200
on the outside of the cave there's it's

1278
00:51:27,530 --> 00:51:24,059
dry hot

1279
00:51:30,109 --> 00:51:27,540
of desert terrain desert ecosystems you

1280
00:51:32,510 --> 00:51:30,119
drop down into the cave and it there's

1281
00:51:35,150 --> 00:51:32,520
literally fog in the cave just just a

1282
00:51:37,190 --> 00:51:35,160
few tens of meters from The Cave opening

1283
00:51:39,530 --> 00:51:37,200
there's literally fog forming

1284
00:51:42,130 --> 00:51:39,540
condensation on the walls with an

1285
00:51:45,069 --> 00:51:42,140
incredible diversity of microbial

1286
00:51:48,349 --> 00:51:45,079
species on the walls and on the ceilings

1287
00:51:49,970 --> 00:51:48,359
uh when I first saw that you know 10

1288
00:51:52,250 --> 00:51:49,980

years ago on a field trip at a

1289
00:51:56,150 --> 00:51:52,260
conference it was like wow that's so

1290
00:51:58,849 --> 00:51:56,160
exciting uh how to get into it the best

1291
00:52:01,790 --> 00:51:58,859
thing to do on any discipline of how to

1292
00:52:04,970 --> 00:52:01,800
get into it is look into the literature

1293
00:52:07,010 --> 00:52:04,980
on who's publishing in the last few

1294
00:52:10,010 --> 00:52:07,020
years on your topic

1295
00:52:13,190 --> 00:52:10,020
so if you find papers of a scientist

1296
00:52:16,250 --> 00:52:13,200
that's published you know on the

1297
00:52:17,870 --> 00:52:16,260
Southwest lava tube caves in a variety

1298
00:52:19,549 --> 00:52:17,880
of locations

1299
00:52:23,750 --> 00:52:19,559
contact them

1300
00:52:25,970 --> 00:52:23,760
uh if they're if their literature is is

1301
00:52:28,609 --> 00:52:25,980
not in your topical area but it's in

1302
00:52:30,770 --> 00:52:28,619
cave microbiology and but what they're

1303
00:52:32,630 --> 00:52:30,780
doing is not that interesting contact

1304
00:52:35,270 --> 00:52:32,640
them and say this is what I'm interested

1305
00:52:38,089 --> 00:52:35,280
in doing who would you might recommend

1306
00:52:40,309 --> 00:52:38,099
that would be a different Professor uh

1307
00:52:43,670 --> 00:52:40,319
and so the best thing is just get into

1308
00:52:46,970 --> 00:52:43,680
it get find out what you're interested

1309
00:52:48,829 --> 00:52:46,980
in and write to the people and ask for a

1310
00:52:51,589 --> 00:52:48,839
little bit of advice they mostly will

1311
00:52:54,049 --> 00:52:51,599
will respond to you that's fantastic and

1312
00:52:55,910 --> 00:52:54,059
great advice one way to find really good

1313
00:52:57,290 --> 00:52:55,920

mentors and advisors out there is just

1314
00:52:58,309 --> 00:52:57,300
to reach out to people who are doing the

1315
00:52:59,390 --> 00:52:58,319
work

1316
00:53:01,130 --> 00:52:59,400
um but it's also a great way to make

1317
00:53:03,349 --> 00:53:01,140
those connections to find people who can

1318
00:53:04,430 --> 00:53:03,359
help you uh find the research and so I

1319
00:53:06,410 --> 00:53:04,440
really appreciate that as well it's

1320
00:53:07,910 --> 00:53:06,420
always advice that I love to hear given

1321
00:53:10,309 --> 00:53:07,920
to people

1322
00:53:12,770 --> 00:53:10,319
um our next question comes from astativa

1323
00:53:14,510 --> 00:53:12,780
arai on YouTube

1324
00:53:15,650 --> 00:53:14,520
um and I'm gonna change their question a

1325
00:53:17,750 --> 00:53:15,660
little bit they want they want to know

1326
00:53:20,089 --> 00:53:17,760
how important is the Criterion of

1327
00:53:24,109 --> 00:53:20,099
salinity in the Martian soil when it

1328
00:53:25,609 --> 00:53:24,119
comes to living things including growing

1329
00:53:27,230 --> 00:53:25,619
um and so for the Martian and we call it

1330
00:53:31,549 --> 00:53:27,240
regolith

1331
00:53:34,190 --> 00:53:31,559
know salinity but how important are the

1332
00:53:35,870 --> 00:53:34,200
actual salts themselves for instance I

1333
00:53:37,670 --> 00:53:35,880
know an astrobotonist who has pointed

1334
00:53:39,470 --> 00:53:37,680
out that you know in the Martian that

1335
00:53:40,549 --> 00:53:39,480
Mark Watney eating those potatoes would

1336
00:53:42,710 --> 00:53:40,559
have been in trouble because he didn't

1337
00:53:45,410 --> 00:53:42,720
clean the perchlorate salts out of the

1338
00:53:46,790 --> 00:53:45,420

Martian regalith first so I wonder uh Dr

1339
00:53:49,069 --> 00:53:46,800
sugar if you can speak to the Martian

1340
00:53:50,809 --> 00:53:49,079
regolith it's chemistry and maybe how

1341
00:53:53,809 --> 00:53:50,819
important some of these salts are

1342
00:53:55,970 --> 00:53:53,819
right uh boy that that could be a whole

1343
00:53:58,309 --> 00:53:55,980
topic an hour long topic just on the

1344
00:54:01,609 --> 00:53:58,319
geochemistry of the Martian regolith uh

1345
00:54:04,370 --> 00:54:01,619
the main thing is that the salts uh on

1346
00:54:07,430 --> 00:54:04,380
Mars the regolith is composed of ground

1347
00:54:10,670 --> 00:54:07,440
up basaltic material that's been

1348
00:54:14,930 --> 00:54:10,680
weathered or acted upon over geological

1349
00:54:18,109 --> 00:54:14,940
times with water water vapor

1350
00:54:21,290 --> 00:54:18,119
um and other uh energy sources like UV

1351
00:54:23,230 --> 00:54:21,300
irradiation with water vapor with mixing

1352
00:54:27,349 --> 00:54:23,240
of minerals so there is actual

1353
00:54:29,089 --> 00:54:27,359
weathering of the soils much more than

1354
00:54:31,250 --> 00:54:29,099
on the moon and here's a great example I

1355
00:54:35,089 --> 00:54:31,260
got to use my little my little show and

1356
00:54:38,569 --> 00:54:35,099
tell here in this hand is a gray lunar

1357
00:54:40,670 --> 00:54:38,579
simulant that I use in my lab this is a

1358
00:54:44,089 --> 00:54:40,680
primary mineral it's just like ground up

1359
00:54:46,609 --> 00:54:44,099
Basalt which is like lava okay this is

1360
00:54:49,250 --> 00:54:46,619
the Martian stimulant and it is

1361
00:54:50,750 --> 00:54:49,260
orange-like now the chemistries of these

1362
00:54:53,690 --> 00:54:50,760
two are very similar they're basic

1363
00:54:56,089 --> 00:54:53,700

chemistry this is basaltic this is

1364
00:54:58,030 --> 00:54:56,099
basaltic but what's happened here with

1365
00:55:02,089 --> 00:54:58,040
the Martian stimulant

1366
00:55:05,450 --> 00:55:02,099
is that water and oxygen have acted upon

1367
00:55:08,150 --> 00:55:05,460
this material over geological time and

1368
00:55:12,349 --> 00:55:08,160
have altered it such that it's more

1369
00:55:14,210 --> 00:55:12,359
complex in its geochemistry it is has a

1370
00:55:16,370 --> 00:55:14,220
lot more salts in it the salts are

1371
00:55:18,589 --> 00:55:16,380
forming and dissolving and forming and

1372
00:55:20,569 --> 00:55:18,599
changing because of this liquid water

1373
00:55:23,390 --> 00:55:20,579
environment that's hap that's been on

1374
00:55:26,270 --> 00:55:23,400
Mars in the past so these two little

1375
00:55:27,950 --> 00:55:26,280
soil samples are very different but yet

1376
00:55:32,569 --> 00:55:27,960
they started out at the same which is

1377
00:55:35,270 --> 00:55:32,579
basalt and so on Mars there is a problem

1378
00:55:38,650 --> 00:55:35,280
with some of these soils might have

1379
00:55:41,809 --> 00:55:38,660
salts that are too high a concentration

1380
00:55:44,510 --> 00:55:41,819
to use those soils immediately for

1381
00:55:47,150 --> 00:55:44,520
growing plants in so we might have to

1382
00:55:49,430 --> 00:55:47,160
figure out methods of leeching out the

1383
00:55:51,410 --> 00:55:49,440
salts or chemically extracting the salts

1384
00:55:53,690 --> 00:55:51,420
from the soils before they can be used

1385
00:55:55,849 --> 00:55:53,700
to grow plants on so that's one thing

1386
00:55:57,230 --> 00:55:55,859
the other thing is that the salts

1387
00:55:59,750 --> 00:55:57,240
themselves the little tiny micro

1388
00:56:01,430 --> 00:55:59,760

crystals of salts can land on a

1389
00:56:04,430 --> 00:56:01,440
spacecraft surface and if they come into

1390
00:56:06,770 --> 00:56:04,440
contact with a bacterial cell that

1391
00:56:08,150 --> 00:56:06,780
little super Crystal of salt can

1392
00:56:10,549 --> 00:56:08,160
actually kill a lot of different

1393
00:56:12,950 --> 00:56:10,559
bacterial cells just by contacting you

1394
00:56:16,250 --> 00:56:12,960
don't even need liquid water to have the

1395
00:56:17,990 --> 00:56:16,260
salt dissolve in so salts are one of

1396
00:56:20,630 --> 00:56:18,000
those biocidal factors that are on the

1397
00:56:24,049 --> 00:56:20,640
in the Martian regolith they can kill

1398
00:56:25,910 --> 00:56:24,059
bacteria and spacecraft surfaces and we

1399
00:56:28,190 --> 00:56:25,920
might have to learn how to remove the

1400
00:56:29,870 --> 00:56:28,200
salts before we can use the regulate for

1401
00:56:31,730 --> 00:56:29,880
growth and that's actually a really

1402
00:56:34,010 --> 00:56:31,740
important area of research that needs to

1403
00:56:35,270 --> 00:56:34,020
be done yeah absolutely it's so

1404
00:56:37,490 --> 00:56:35,280
important for us to know how we could

1405
00:56:39,470 --> 00:56:37,500
use that regolith to grow and to use as

1406
00:56:42,230 --> 00:56:39,480
a building material as well to you know

1407
00:56:44,150 --> 00:56:42,240
to reinforce our habitats to things like

1408
00:56:46,190 --> 00:56:44,160
that to build habitats

1409
00:56:47,990 --> 00:56:46,200
um there's so much to learn our next

1410
00:56:52,510 --> 00:56:48,000
question for you comes from Milton

1411
00:56:55,010 --> 00:56:52,520
mendocha Jr at Ms mendocha Jr on Twitter

1412
00:56:57,410 --> 00:56:55,020
uh they want to know that if there is

1413
00:56:59,930 --> 00:56:57,420

life on Mars Martian life not earth life

1414
00:57:02,270 --> 00:56:59,940
but it's not based on things like DNA

1415
00:57:04,010 --> 00:57:02,280
and proteins would there still be a way

1416
00:57:05,569 --> 00:57:04,020
for us to understand

1417
00:57:07,730 --> 00:57:05,579
um biological things like how the

1418
00:57:10,150 --> 00:57:07,740
resisting radiation salinity maybe even

1419
00:57:13,750 --> 00:57:10,160
if they're there

1420
00:57:16,970 --> 00:57:13,760
well uh I think the scientific Community

1421
00:57:18,770 --> 00:57:16,980
believes or uses the definition of life

1422
00:57:21,950 --> 00:57:18,780
that requires

1423
00:57:24,109 --> 00:57:21,960
a series of steps that leads to

1424
00:57:26,690 --> 00:57:24,119
Evolution adaptation

1425
00:57:29,270 --> 00:57:26,700
so life has to be able to take in

1426
00:57:32,510 --> 00:57:29,280
whatever liquid they're using as their

1427
00:57:35,270 --> 00:57:32,520
medium in our case it's water life has

1428
00:57:38,990 --> 00:57:35,280
to take in nutrients life has to have

1429
00:57:41,510 --> 00:57:39,000
the mechanisms within the cell or cells

1430
00:57:44,210 --> 00:57:41,520
to take those raw materials and make

1431
00:57:46,730 --> 00:57:44,220
whatever they need to make in order to

1432
00:57:48,609 --> 00:57:46,740
divide and then keep the process going

1433
00:57:51,670 --> 00:57:48,619
through multiple cycles

1434
00:57:54,890 --> 00:57:51,680
and that process

1435
00:57:56,710 --> 00:57:54,900
requires a road map a genetic road map

1436
00:57:59,390 --> 00:57:56,720
that could be DNA

1437
00:58:02,630 --> 00:57:59,400
uh well in our case it's DNA but it

1438
00:58:04,790 --> 00:58:02,640

could also be DNA on the surface of Mars

1439
00:58:08,089 --> 00:58:04,800
because there's our two planets of

1440
00:58:10,549 --> 00:58:08,099
exchanged Rock debris early in our in

1441
00:58:13,010 --> 00:58:10,559
our history and continue to this day so

1442
00:58:15,589 --> 00:58:13,020
if life was present on an early Earth it

1443
00:58:21,230 --> 00:58:15,599
could have been transported to Mars and

1444
00:58:23,750 --> 00:58:21,240
or vice versa uh so life requires this

1445
00:58:27,290 --> 00:58:23,760
process and at the end of that process

1446
00:58:30,109 --> 00:58:27,300
is evolution so if there is an extant

1447
00:58:32,630 --> 00:58:30,119
microbiota on the surface of Mars or in

1448
00:58:34,730 --> 00:58:32,640
the shallow subsurface it has to have

1449
00:58:37,370 --> 00:58:34,740
those ingredients it has to be able to

1450
00:58:39,770 --> 00:58:37,380
acquire nutrients which means we should

1451
00:58:41,930 --> 00:58:39,780
be able to figure out what it needs as a

1452
00:58:43,730 --> 00:58:41,940
set of nutrients it's going to be

1453
00:58:45,770 --> 00:58:43,740
sensitive to some things and not to

1454
00:58:47,630 --> 00:58:45,780
others and we should be able to figure

1455
00:58:51,950 --> 00:58:47,640
that out

1456
00:58:54,650 --> 00:58:51,960
um the real question is on Earth

1457
00:58:57,289 --> 00:58:54,660
greater than 99 of the microorganisms

1458
00:58:58,789 --> 00:58:57,299
that are in our environment are not a

1459
00:58:59,809 --> 00:58:58,799
we're not able to grow them in the

1460
00:59:02,270 --> 00:58:59,819
laboratory

1461
00:59:04,670 --> 00:59:02,280
uh so that creates quite a lot of

1462
00:59:07,549 --> 00:59:04,680
difficulty in looking at their basic

1463
00:59:09,829 --> 00:59:07,559

metabolism basic methods of evolution

1464
00:59:11,809 --> 00:59:09,839
and adaptation there are methods to

1465
00:59:15,410 --> 00:59:11,819
doing that and I think those same

1466
00:59:18,170 --> 00:59:15,420
methods can be applied to any microbes

1467
00:59:20,870 --> 00:59:18,180
on Mars that are not cultural but the

1468
00:59:24,230 --> 00:59:20,880
last point of this question is that like

1469
00:59:27,470 --> 00:59:24,240
Earth Mars if there's life has a series

1470
00:59:29,690 --> 00:59:27,480
of ecosystems it's not just a single

1471
00:59:32,210 --> 00:59:29,700
bacterium sitting on a rock saying hey I

1472
00:59:34,010 --> 00:59:32,220
hope I get sunlight today there's an

1473
00:59:36,289 --> 00:59:34,020
ecosystem there and there has to be

1474
00:59:38,770 --> 00:59:36,299
energy flow within that ecosystem and it

1475
00:59:41,329 --> 00:59:38,780
has to be chemical flow and

1476
00:59:44,329 --> 00:59:41,339
disequilibrium's uh creating the ability

1477
00:59:46,430 --> 00:59:44,339
to do work in that ecosystem that is

1478
00:59:48,650 --> 00:59:46,440
something that's really complex and it's

1479
00:59:51,829 --> 00:59:48,660
it's like we should be able to see that

1480
00:59:54,349 --> 00:59:51,839
if there's life then there's ecosystems

1481
00:59:57,170 --> 00:59:54,359
and we should be able to detect those I

1482
01:00:01,870 --> 00:59:57,180
believe without without invoking very

1483
01:00:04,490 --> 01:00:01,880
unusual exotic silly based life or

1484
01:00:07,130 --> 01:00:04,500
methane-based life at you know minus 300

1485
01:00:09,170 --> 01:00:07,140
degrees or whatever

1486
01:00:11,450 --> 01:00:09,180
that's awesome uh so I so much

1487
01:00:12,770 --> 01:00:11,460
appreciate your time and joining us here

1488
01:00:14,750 --> 01:00:12,780

um I apologize though it's been great

1489
01:00:16,789 --> 01:00:14,760
then you have so many more questions but

1490
01:00:18,109 --> 01:00:16,799
we are at the very top of the hour

1491
01:00:20,870 --> 01:00:18,119
um if I could just ask for a really

1492
01:00:22,309 --> 01:00:20,880
brief answer to one more question

1493
01:00:24,770 --> 01:00:22,319
um I saw one that I really liked from

1494
01:00:27,589 --> 01:00:24,780
kashish Gupta on YouTube

1495
01:00:29,690 --> 01:00:27,599
um so so kashish has asked Dr sugar if

1496
01:00:31,609 --> 01:00:29,700
you get to send a single microbial

1497
01:00:34,970 --> 01:00:31,619
species on a future Mission to Mars

1498
01:00:37,250 --> 01:00:34,980
which one would you pick

1499
01:00:39,589 --> 01:00:37,260
wow I don't want to send any microbes to

1500
01:00:40,430 --> 01:00:39,599
Mars

1501
01:00:48,530 --> 01:00:40,440
um

1502
01:00:49,789 --> 01:00:48,540
starting the process of terraforming the

1503
01:00:52,970 --> 01:00:49,799
planet

1504
01:00:55,190 --> 01:00:52,980
if I was if if we were if we understood

1505
01:00:58,150 --> 01:00:55,200
the environment on Mars enough and

1506
01:01:01,609 --> 01:00:58,160
humanity is ready to take the step

1507
01:01:04,370 --> 01:01:01,619
towards uh you know terraforming the

1508
01:01:07,069 --> 01:01:04,380
surface of Mars my first thought would

1509
01:01:08,630 --> 01:01:07,079
be to begin sending microbes I could

1510
01:01:11,150 --> 01:01:08,640
take carbon dioxide out of the air

1511
01:01:14,450 --> 01:01:11,160
produce oxygen maybe even utilize the

1512
01:01:15,890 --> 01:01:14,460
nitrogen uh so that that would be I

1513
01:01:18,109 --> 01:01:15,900

think the most intriguing but that's

1514
01:01:19,069 --> 01:01:18,119
tens of years away if not hundreds of

1515
01:01:21,289 --> 01:01:19,079
years away

1516
01:01:22,609 --> 01:01:21,299
absolutely yeah well thank you so much

1517
01:01:23,809 --> 01:01:22,619
for that answer

1518
01:01:25,250 --> 01:01:23,819
um to the rest of our audience I

1519
01:01:26,750 --> 01:01:25,260
apologize we couldn't get to all of your

1520
01:01:27,650 --> 01:01:26,760
questions there were so many good ones

1521
01:01:29,089 --> 01:01:27,660
there

1522
01:01:30,410 --> 01:01:29,099
um if you are interested uh you can

1523
01:01:32,329 --> 01:01:30,420
always ask your questions in the

1524
01:01:34,730 --> 01:01:32,339
comments section once we post the

1525
01:01:36,109 --> 01:01:34,740
recorded version of the YouTube uh video

1526
01:01:37,430 --> 01:01:36,119
as well

1527
01:01:38,930 --> 01:01:37,440
um for those of you out there who watch

1528
01:01:40,609 --> 01:01:38,940
the show and join in and ask us

1529
01:01:42,829 --> 01:01:40,619
questions please share the show with

1530
01:01:44,870 --> 01:01:42,839
your friends uh we love to always point

1531
01:01:46,970 --> 01:01:44,880
out an ambassador of the month for each

1532
01:01:48,650 --> 01:01:46,980
episode who's shared about the show

1533
01:01:50,990 --> 01:01:48,660
who's asked questions of our guests

1534
01:01:53,210 --> 01:01:51,000
who's really gotten engaged uh in this

1535
01:01:54,710 --> 01:01:53,220
whole thing of astrobiology we want to

1536
01:01:57,890 --> 01:01:54,720
give a special shout out this month for

1537
01:01:59,270 --> 01:01:57,900
instance to father karuya fafi is an

1538
01:02:01,490 --> 01:01:59,280

affiliate researcher at Blue Marble

1539
01:02:03,470 --> 01:02:01,500
space Institute of science as well as

1540
01:02:05,690 --> 01:02:03,480
being a researcher at NASA Ames and he

1541
01:02:08,690 --> 01:02:05,700
shared about our show so father we

1542
01:02:10,309 --> 01:02:08,700
really appreciate that uh Dr sugar thank

1543
01:02:12,109 --> 01:02:10,319
you so much for joining us for ask an

1544
01:02:13,549 --> 01:02:12,119
astrobiologist it's been a blast having

1545
01:02:15,530 --> 01:02:13,559
you it's been fun

1546
01:02:17,809 --> 01:02:15,540
this has been fun thanks

1547
01:02:19,490 --> 01:02:17,819
thank you so much I'm glad our audience

1548
01:02:21,109 --> 01:02:19,500
has so many great questions about your

1549
01:02:23,210 --> 01:02:21,119
research they might even reach out with

1550
01:02:25,190 --> 01:02:23,220
more questions so keep an eye out for

1551
01:02:26,870 --> 01:02:25,200
that uh for those of you tuning in and

1552
01:02:29,150 --> 01:02:26,880
joining us I hope you signed up already

1553
01:02:30,950 --> 01:02:29,160
for the NASA astrobiology mailing list

1554
01:02:33,289 --> 01:02:30,960
that way you can find out about new

1555
01:02:34,970 --> 01:02:33,299
episodes of ask an astrobiologist as

1556
01:02:36,530 --> 01:02:34,980
well as all of the other incredible

1557
01:02:39,230 --> 01:02:36,540
things going on through NASA

1558
01:02:41,990 --> 01:02:39,240
astrobiology including opportunities for

1559
01:02:43,789 --> 01:02:42,000
early career researchers missions new

1560
01:02:45,890 --> 01:02:43,799
articles on the website lots of cool

1561
01:02:48,170 --> 01:02:45,900
things going on there so please sign up

1562
01:02:50,150 --> 01:02:48,180
for the official mailing list uh thank

1563
01:02:52,910 --> 01:02:50,160

you Dr sugar for joining us thank you to

1564
01:02:57,470 --> 01:02:52,920
the audience for joining us uh and as

1565
01:03:00,010 --> 01:02:57,480
always everyone remember to stay curious

1566
01:03:14,340 --> 01:03:00,020
foreign

1567
01:03:15,450 --> 01:03:14,350
[Music]

1568
01:03:16,500 --> 01:03:15,460
[Applause]

1569
01:03:18,400 --> 01:03:16,510
[Music]

1570
01:03:27,549 --> 01:03:18,410
[Applause]

1571
01:03:39,970 --> 01:03:30,210
thank you