
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:11,940 --> 00:00:09,260
[Applause]

3
00:00:14,280 --> 00:00:11,950
thank you all for coming there are seats

4
00:00:16,380 --> 00:00:14,290
up front and I want to thank those who

5
00:00:18,870 --> 00:00:16,390
invited me to give this talk which I

6
00:00:21,330 --> 00:00:18,880
cannot give alone as indicated on this

7
00:00:24,240 --> 00:00:21,340
slide so I want to acknowledge at least

8
00:00:26,279 --> 00:00:24,250
some of the people who have helped

9
00:00:29,660 --> 00:00:26,289
educate me so that I can give this talk

10
00:00:33,630 --> 00:00:29,670
and in particular with regards to

11
00:00:36,960 --> 00:00:33,640
virology which is not my training I want

12
00:00:39,060 --> 00:00:36,970
to thank Barry Bloomberg for making it

13
00:00:42,150 --> 00:00:39,070

possible to think about viruses in an

14
00:00:44,430 --> 00:00:42,160
astrobiological context I want to thank

15
00:00:47,220 --> 00:00:44,440
John Barris who might be known for other

16
00:00:49,380 --> 00:00:47,230
things but his dissertation research was

17
00:00:51,180 --> 00:00:49,390
on bacteria phage and genetic exchange

18
00:00:54,240 --> 00:00:51,190
in the cold marine environment which I

19
00:00:55,830 --> 00:00:54,250
found inspirational lead Wells was a

20
00:00:57,600 --> 00:00:55,840
former graduate student of mine who

21
00:00:59,970 --> 00:00:57,610
taught me more about viruses than

22
00:01:02,250 --> 00:00:59,980
anybody and who pushed a lot of lower

23
00:01:05,520 --> 00:01:02,260
temperature and salt limits for viral

24
00:01:07,380 --> 00:01:05,530
production Matt Sullivan is a current

25
00:01:11,760 --> 00:01:07,390
collaborator who keeps me

26
00:01:15,719 --> 00:01:11,770
state-of-the-art I helped to launch the

27
00:01:18,330 --> 00:01:15,729
UW astrobiology program I sit in

28
00:01:19,410 --> 00:01:18,340
oceanography but what grabbed my

29
00:01:21,660 --> 00:01:19,420
attention the most

30
00:01:23,609 --> 00:01:21,670
about this field was that the sites we

31
00:01:25,500 --> 00:01:23,619
have to explore for life are all very

32
00:01:27,899 --> 00:01:25,510
cold and I thought perhaps I could

33
00:01:30,240 --> 00:01:27,909
contribute to this discussion my lab

34
00:01:33,560 --> 00:01:30,250
could contribute through the study of

35
00:01:36,690 --> 00:01:33,570
how microbial life manages in cold ice

36
00:01:38,999 --> 00:01:36,700
today we know or we can think of the

37
00:01:41,039 --> 00:01:39,009
solar system as overflowing with liquid

38
00:01:44,999 --> 00:01:41,049

water because we now know of multiple

39
00:01:48,060 --> 00:01:45,009
oceans in the solar system and so

40
00:01:50,460 --> 00:01:48,070
following the NAI mantra I have been

41
00:01:53,370 --> 00:01:50,470
following the water for most of my

42
00:01:56,730 --> 00:01:53,380
career even before Nai you see a

43
00:01:58,890 --> 00:01:56,740
temperature scale here today I am or in

44
00:02:01,020 --> 00:01:58,900
the last 20 years I have been working on

45
00:02:04,380 --> 00:02:01,030
the lower end of the temperature scale

46
00:02:08,280 --> 00:02:04,390
where salt keeps water from freezing at

47
00:02:09,900 --> 00:02:08,290
lower temperatures I've also been

48
00:02:12,390 --> 00:02:09,910
listening to the Inuit in the north

49
00:02:15,090 --> 00:02:12,400
where I work who I believe are the

50
00:02:17,370 --> 00:02:15,100
original astrobiologists who understand

51
00:02:21,570 --> 00:02:17,380
that ice is actually the natural state

52
00:02:25,560 --> 00:02:23,310
so in fact I've been following the ice

53
00:02:29,130 --> 00:02:25,570
and trying hard at that since we're

54
00:02:31,230 --> 00:02:29,140
losing it on this planet so I tried very

55
00:02:33,330 --> 00:02:31,240
hard always to get funding to go into

56
00:02:35,430 --> 00:02:33,340
the Arctic in the dead of winter which

57
00:02:37,770 --> 00:02:35,440
made me a lonely character with a few

58
00:02:40,440 --> 00:02:37,780
other people helping me but one of the

59
00:02:42,960 --> 00:02:40,450
reasons for this is that saline ice can

60
00:02:45,990 --> 00:02:42,970
get very cold and still have a liquid

61
00:02:48,030 --> 00:02:46,000
habitable environment within it so these

62
00:02:50,010 --> 00:02:48,040
are a series of panels I'm going to show

63
00:02:52,290 --> 00:02:50,020

you a little primer on sea ice if you

64
00:02:54,630 --> 00:02:52,300
haven't thought about it very much 30

65
00:02:56,850 --> 00:02:54,640
millimeter panels here the black area

66
00:03:05,370 --> 00:02:56,860
that you see is the liquid fraction of

67
00:03:07,620 --> 00:03:05,380
the ice with a 20% porosity so 20

68
00:03:10,560 --> 00:03:07,630
percent of this ice is liquid habitable

69
00:03:12,270 --> 00:03:10,570
space and an average pore is over 2

70
00:03:16,140 --> 00:03:12,280
millimeters in size so this is a

71
00:03:17,820 --> 00:03:16,150
Waterworld for microbes but you just

72
00:03:19,980 --> 00:03:17,830
have to chill the ice down a little bit

73
00:03:22,470 --> 00:03:19,990
before you begin to narrow up these

74
00:03:26,460 --> 00:03:22,480
spaces and when you get to wintertime

75
00:03:30,449 --> 00:03:26,470
ice you close up considerably and in the

76
00:03:32,850 --> 00:03:30,459
process concentrate the salt that was

77
00:03:38,670 --> 00:03:32,860
present in the source waters so at minus

78
00:03:40,740 --> 00:03:38,680
30 degrees woops sorry at minus 30

79
00:03:44,940 --> 00:03:40,750
degrees you have very small pore space

80
00:03:46,740 --> 00:03:44,950
2% liquid volume in here 24 percent salt

81
00:03:48,240 --> 00:03:46,750
in those brines conditions that would

82
00:03:50,699 --> 00:03:48,250
normally we would think would shut down

83
00:03:54,510 --> 00:03:50,709
life I'm here to tell you that is not

84
00:03:56,430 --> 00:03:54,520
the case but one important factor here

85
00:03:58,800 --> 00:03:56,440
or the important factor here is the

86
00:04:01,080 --> 00:03:58,810
brine concentrating factor whatever

87
00:04:03,240 --> 00:04:01,090
salts were in the source fluid get

88
00:04:05,790 --> 00:04:03,250

concentrated in these small spaces as a

89
00:04:07,500 --> 00:04:05,800
function of temperature and anything

90
00:04:11,210 --> 00:04:07,510
else that was in that source water also

91
00:04:12,870 --> 00:04:11,220
gets concentrated to demonstrate this

92
00:04:14,850 --> 00:04:12,880
concentration effect which is

93
00:04:17,880 --> 00:04:14,860
temperature driven I'm going to show you

94
00:04:19,920 --> 00:04:17,890
the temperature range across sea ice so

95
00:04:21,840 --> 00:04:19,930
here is an ice core that has just been

96
00:04:24,630 --> 00:04:21,850
pulled out onto the surface of the ice

97
00:04:26,820 --> 00:04:24,640
and the next slide shows you an infrared

98
00:04:29,909 --> 00:04:26,830
camera image of this so you can actually

99
00:04:32,100 --> 00:04:29,919
see the temperature gradient so here's

100
00:04:33,270 --> 00:04:32,110
the very cold ice at the top that was

101
00:04:35,700 --> 00:04:33,280
exposed to the

102
00:04:39,060 --> 00:04:35,710
Monsieur and the warm ice at the bottom

103
00:04:41,070 --> 00:04:39,070
that's bathed by ocean water so sea ice

104
00:04:43,980 --> 00:04:41,080
functions as a wonderful natural

105
00:04:45,870 --> 00:04:43,990
laboratory for all sorts of gradients in

106
00:04:49,170 --> 00:04:45,880
the cockle lab it would be multiple

107
00:04:50,970 --> 00:04:49,180
extremes all at once so here's the

108
00:04:54,510 --> 00:04:50,980
temperature range getting to the

109
00:04:56,220 --> 00:04:54,520
eutectic of seawater where all of the

110
00:05:00,629 --> 00:04:56,230
salt precipitates out and you no longer

111
00:05:03,360 --> 00:05:00,639
have liquid the salinity range here goes

112
00:05:05,490 --> 00:05:03,370
to very high until all the salts are

113
00:05:08,070 --> 00:05:05,500

precipitated out the liquid volume

114
00:05:10,650 --> 00:05:08,080
fraction reduces to zero under those

115
00:05:13,290 --> 00:05:10,660
extreme conditions but most importantly

116
00:05:16,050 --> 00:05:13,300
for this talk is that the colder the ice

117
00:05:17,790 --> 00:05:16,060
the higher the contact rate between

118
00:05:22,050 --> 00:05:17,800
particles or anything that's

119
00:05:24,570 --> 00:05:22,060
concentrated in those pockets so that

120
00:05:27,680 --> 00:05:24,580
includes microbial life and viral life

121
00:05:31,500 --> 00:05:27,690
or viruses depending on your definition

122
00:05:33,780 --> 00:05:31,510
so generally in this gradient here you

123
00:05:36,090 --> 00:05:33,790
can think about microbial growth easily

124
00:05:38,219 --> 00:05:36,100
happening under these conditions then

125
00:05:40,170 --> 00:05:38,229
reducing to metabolism and finally the

126
00:05:43,950 --> 00:05:40,180
strategies have to be about surviving

127
00:05:46,409 --> 00:05:43,960
and enzymes and quorum signaling signals

128
00:05:49,500 --> 00:05:46,419
like we just heard about or involved in

129
00:05:52,440 --> 00:05:49,510
all of this at these high contact rates

130
00:05:56,279 --> 00:05:52,450
we have lots of free DNA and phage and

131
00:05:58,590 --> 00:05:56,289
this is where I'll focus coming along XO

132
00:06:00,779 --> 00:05:58,600
polymers are central to the whole story

133
00:06:03,450 --> 00:06:00,789
I'll talk a bit more about that please

134
00:06:05,460 --> 00:06:03,460
go see max show Walters poster this

135
00:06:08,250 --> 00:06:05,470
evening he can tell you a lot more about

136
00:06:09,930 --> 00:06:08,260
this side of the story and Zac Cooper in

137
00:06:12,240 --> 00:06:09,940
a poster tonight can tell you all about

138
00:06:15,600 --> 00:06:12,250

the hosts that we are finding in these

139
00:06:17,490 --> 00:06:15,610
extreme environments the first thing we

140
00:06:20,760 --> 00:06:17,500
had to do was to figure out how to look

141
00:06:23,400 --> 00:06:20,770
into unfrozen sea ice so what you're

142
00:06:25,740 --> 00:06:23,410
seeing here with no stain is a brine

143
00:06:28,170 --> 00:06:25,750
pocket this is solid ice crystal maestra

144
00:06:31,020 --> 00:06:28,180
matrix around it you can see a few

145
00:06:32,370 --> 00:06:31,030
diatoms here with a DNA stain you can

146
00:06:36,330 --> 00:06:32,380
see all of the bacteria that are

147
00:06:38,670 --> 00:06:36,340
concentrated in there with another stain

148
00:06:40,500 --> 00:06:38,680
you can see these EXO polymers as we

149
00:06:42,230 --> 00:06:40,510
call them they're polysaccharides that

150
00:06:44,960 --> 00:06:42,240
function

151
00:06:46,640 --> 00:06:44,970
anti-freeze for these organisms and you

152
00:06:49,400 --> 00:06:46,650
don't even need a stain to see the goo

153
00:06:53,690 --> 00:06:49,410
penis of of them because they fill every

154
00:06:55,610 --> 00:06:53,700
pore in sea-ice you can grow artificial

155
00:06:58,490 --> 00:06:55,620
sea ice from seawater with and without

156
00:06:59,900 --> 00:06:58,500
this EXO polymeric material and you get

157
00:07:02,390 --> 00:06:59,910
a completely different physical

158
00:07:04,070 --> 00:07:02,400
structure you get Euclidean pores here

159
00:07:06,290 --> 00:07:04,080
which are disconnected from each other

160
00:07:08,180 --> 00:07:06,300
you get fractal pores here that are

161
00:07:10,910 --> 00:07:08,190
connected very important for the life

162
00:07:13,880 --> 00:07:10,920
living in there and you can increase the

163
00:07:17,540 --> 00:07:13,890

porosity you can increase the habitable

164
00:07:20,660 --> 00:07:17,550
space of this ice in the presence of

165
00:07:22,730 --> 00:07:20,670
these organic polymers so to emphasize

166
00:07:25,250 --> 00:07:22,740
to you that these little pore spaces in

167
00:07:28,280 --> 00:07:25,260
here under extreme conditions are not

168
00:07:30,290 --> 00:07:28,290
dead spaces here is our model organism

169
00:07:32,590 --> 00:07:30,300
happily swimming away at minus 10

170
00:07:35,090 --> 00:07:32,600
degrees in an EXO polymer rich solution

171
00:07:38,000 --> 00:07:35,100
we've also demonstrated this in the

172
00:07:39,890 --> 00:07:38,010
field using a digital holographic

173
00:07:42,650 --> 00:07:39,900
microscope but I don't have time to show

174
00:07:44,840 --> 00:07:42,660
you that so we've emerged from years of

175
00:07:48,350 --> 00:07:44,850
work with this image of what's going on

176
00:07:50,480 --> 00:07:48,360
in a sea ice pour the microbial

177
00:07:53,390 --> 00:07:50,490
ecosystem that lives there and this is

178
00:07:56,540 --> 00:07:53,400
all based on quantitative data so you

179
00:07:58,760 --> 00:07:56,550
see lots of viruses in here and we had

180
00:08:01,160 --> 00:07:58,770
the question do EXO polymers protect

181
00:08:03,620 --> 00:08:01,170
against viral infection in the biology

182
00:08:05,990 --> 00:08:03,630
world there's this war terminology about

183
00:08:08,810 --> 00:08:06,000
winners and losers those that infect and

184
00:08:10,970 --> 00:08:08,820
kill and lyse and so we were in that

185
00:08:13,490 --> 00:08:10,980
mode do EXO polymers protect against

186
00:08:15,440 --> 00:08:13,500
this we don't have a totally clear

187
00:08:18,560 --> 00:08:15,450
answer to that except that the high

188
00:08:21,680 --> 00:08:18,570

numbers of viruses do suggest production

189
00:08:23,650 --> 00:08:21,690
of viruses though again Max's poster

190
00:08:27,410 --> 00:08:23,660
this evening can tell you more

191
00:08:29,150 --> 00:08:27,420
eloquently about that the more important

192
00:08:33,500 --> 00:08:29,160
or profound question I've come to

193
00:08:35,810 --> 00:08:33,510
understand is do microbes benefit from

194
00:08:38,959 --> 00:08:35,820
gene exchange that they experience as a

195
00:08:41,719 --> 00:08:38,969
result of interaction with viruses and

196
00:08:44,780 --> 00:08:41,729
can this account for their adaptability

197
00:08:46,940 --> 00:08:44,790
to these extreme conditions so we have a

198
00:08:49,880 --> 00:08:46,950
new project or we're in the midst of it

199
00:08:52,550 --> 00:08:49,890
supported by the Moore Foundation to

200
00:08:55,040 --> 00:08:52,560
study gene flow in sub-zero brines and

201
00:08:56,840 --> 00:08:55,050
we're comparing gene flow in

202
00:08:58,490 --> 00:08:56,850
sea-ice a modern contemporary

203
00:09:01,010 --> 00:08:58,500
environment that i've already talked

204
00:09:04,520 --> 00:09:01,020
with you about and cryo pegs which

205
00:09:06,170 --> 00:09:04,530
represent ancient brines so we can

206
00:09:10,160 --> 00:09:06,180
access both of these environments from

207
00:09:13,000 --> 00:09:10,170
Vik Alaska we can go out onto this onto

208
00:09:19,970 --> 00:09:13,010
the frozen ocean for the sea ice and

209
00:09:23,210 --> 00:09:19,980
going too fast here we can access cryo

210
00:09:25,490 --> 00:09:23,220
pegs through this permafrost tunnel

211
00:09:28,910 --> 00:09:25,500
which is just a box in the middle of a

212
00:09:30,680 --> 00:09:28,920
frozen field and when we first opened it

213
00:09:32,780 --> 00:09:30,690

up to see what we were encountering is a

214
00:09:34,850 --> 00:09:32,790
little bit daunting as well as exciting

215
00:09:36,740 --> 00:09:34,860
if you've been in an elven dive before

216
00:09:39,530 --> 00:09:36,750
this is like diving into the frozen

217
00:09:42,650 --> 00:09:39,540
bowels of the earth so we had to climb

218
00:09:47,420 --> 00:09:42,660
down into this tunnel which is excavated

219
00:09:50,720 --> 00:09:47,430
from ice and permafrost so it's 66

220
00:09:53,390 --> 00:09:50,730
meters or so deep tunnel in here and

221
00:09:56,270 --> 00:09:53,400
through bore holes from the floor of the

222
00:09:59,390 --> 00:09:56,280
tunnel we can access marine sediments

223
00:10:02,270 --> 00:09:59,400
that are saturated with salt with liquid

224
00:10:04,790 --> 00:10:02,280
brine and this is what's called cryo peg

225
00:10:09,200 --> 00:10:04,800
by the Russians who have first studied

226
00:10:13,250 --> 00:10:09,210
these cryo peg grinds so the brine is at

227
00:10:15,260 --> 00:10:13,260
-6 - -8 degrees 115 to 140 parts per

228
00:10:19,400 --> 00:10:15,270
thousand so I think that's an extreme

229
00:10:22,910 --> 00:10:19,410
environment and these are ancient relic

230
00:10:25,610 --> 00:10:22,920
seawater brines the permafrost around

231
00:10:28,880 --> 00:10:25,620
here is dated at about 50 thousand years

232
00:10:32,180 --> 00:10:28,890
c14 dating puts a minimum at 11,000

233
00:10:35,660 --> 00:10:32,190
years so we will call this ancient sea

234
00:10:37,790 --> 00:10:35,670
water brine the Russians have already

235
00:10:39,680 --> 00:10:37,800
projected this as an analogue for the

236
00:10:44,000 --> 00:10:39,690
Mars subsurface so we're thinking along

237
00:10:47,870 --> 00:10:44,010
those lines as well here we are in our

238
00:10:49,910 --> 00:10:47,880

frozen cave and when we finally

239
00:10:52,790 --> 00:10:49,920
collected this golden solution from

240
00:10:56,150 --> 00:10:52,800
below the floor we had some surprises in

241
00:10:58,600 --> 00:10:56,160
store for us we actually have an organic

242
00:11:01,280 --> 00:10:58,610
soup under these very extreme conditions

243
00:11:03,710 --> 00:11:01,290
here is plotted dissolved organic matter

244
00:11:05,660 --> 00:11:03,720
which is orders of magnitude higher than

245
00:11:08,450 --> 00:11:05,670
anything in sea ice or sea water

246
00:11:11,300 --> 00:11:08,460
most of it is accounted for as XO

247
00:11:13,430 --> 00:11:11,310
marek material when we just put a drop

248
00:11:16,519 --> 00:11:13,440
of this liquid under the microscope it's

249
00:11:20,480 --> 00:11:16,529
jam-packed with microorganisms 10 to the

250
00:11:23,180 --> 00:11:20,490
8th per mil we were totally surprised by

251
00:11:25,880 --> 00:11:23,190
this so now we're launched into a

252
00:11:28,730 --> 00:11:25,890
complete omics analysis of what we found

253
00:11:31,699 --> 00:11:28,740
so we don't have the low biomass problem

254
00:11:33,440 --> 00:11:31,709
here however the bots the brine has

255
00:11:35,660 --> 00:11:33,450
presented us with some extraction

256
00:11:37,760 --> 00:11:35,670
problems but in any case we're moving

257
00:11:41,120 --> 00:11:37,770
forward with our omics discussions here

258
00:11:42,230 --> 00:11:41,130
am i doing two minutes ok to get to the

259
00:11:44,900 --> 00:11:42,240
heart of the matter here

260
00:11:47,090 --> 00:11:44,910
okay so Josie rap is my postdoc who's

261
00:11:49,790 --> 00:11:47,100
not here right now but she's put

262
00:11:52,790 --> 00:11:49,800
together a comparative slide here of

263
00:11:54,829 --> 00:11:52,800

cryopak brine and sea ice brine these

264
00:11:58,250 --> 00:11:54,839
are all the functional gene categories

265
00:12:00,050 --> 00:11:58,260
that exist in our current databases to

266
00:12:02,540 --> 00:12:00,060
tell you all the different functions of

267
00:12:04,730 --> 00:12:02,550
cellular life of microbial cellular life

268
00:12:08,329 --> 00:12:04,740
I just want to draw your attention to

269
00:12:11,480 --> 00:12:08,339
defense mechanisms or evidence of phage

270
00:12:13,730 --> 00:12:11,490
host interactions so in the cryo peg

271
00:12:16,070 --> 00:12:13,740
brine we have a greater relative

272
00:12:18,199 --> 00:12:16,080
abundance of those genes than we do in

273
00:12:20,510 --> 00:12:18,209
the sea ice brines this was unexpected

274
00:12:22,760 --> 00:12:20,520
because sea ice is a fluctuating

275
00:12:25,190 --> 00:12:22,770
environment I was expecting more

276
00:12:27,650 --> 00:12:25,200
interactions with viruses there than in

277
00:12:30,650 --> 00:12:27,660
the ancient cryo peg brines which have

278
00:12:33,650 --> 00:12:30,660
been stable geologically isolated in the

279
00:12:36,050 --> 00:12:33,660
dark for 50,000 years instead we have

280
00:12:38,090 --> 00:12:36,060
more var evidence of more viral

281
00:12:40,490 --> 00:12:38,100
interaction and this is just a visual

282
00:12:42,949 --> 00:12:40,500
depiction to convince you showing you

283
00:12:45,340 --> 00:12:42,959
all of the genes that the cryo peg brine

284
00:12:48,110 --> 00:12:45,350
is very different from the sea ice brine

285
00:12:50,900 --> 00:12:48,120
if I just pull out or if Josie just

286
00:12:53,210 --> 00:12:50,910
pulls out a set of genes that indicate

287
00:12:55,370 --> 00:12:53,220
phage hosts interaction CRISPR genes I'm

288
00:12:57,230 --> 00:12:55,380

sure some of you are aware of these you

289
00:12:59,810 --> 00:12:57,240
can see the higher abundance in the cryo

290
00:13:02,210 --> 00:12:59,820
peg versus sea ice and just to pull out

291
00:13:06,410 --> 00:13:02,220
one example its orders of magnitude

292
00:13:08,480 --> 00:13:06,420
higher and here is a co assembly of the

293
00:13:10,910 --> 00:13:08,490
cryo peg brine samples for genome

294
00:13:13,069 --> 00:13:10,920
beaming so if you're not familiar with

295
00:13:16,069 --> 00:13:13,079
these the thing to realize is that these

296
00:13:18,019 --> 00:13:16,079
gray layers here are our cryo peg brine

297
00:13:19,579 --> 00:13:18,029
samples these are all the genes that

298
00:13:21,610 --> 00:13:19,589
were present in those brines

299
00:13:24,040 --> 00:13:21,620
here are the bacterial hos

300
00:13:26,320 --> 00:13:24,050
that we can identify and importantly

301
00:13:29,040 --> 00:13:26,330
here are the viral genes that we're

302
00:13:33,100 --> 00:13:29,050
picking up throughout these metagenomes

303
00:13:35,829 --> 00:13:33,110
these viral signals 927 of these pieces

304
00:13:39,190 --> 00:13:35,839
of DNA these contexts which corresponds

305
00:13:41,560 --> 00:13:39,200
to over 20,000 gene calls for viruses in

306
00:13:44,440 --> 00:13:41,570
existing databases so we're not

307
00:13:48,570 --> 00:13:44,450
accounting for anything unknown yet or

308
00:13:51,329 --> 00:13:48,580
if we can ever and of these 915

309
00:13:53,860 --> 00:13:51,339
correspond to auxilary metabolic genes

310
00:13:57,160 --> 00:13:53,870
AMJ so if you're not familiar with those

311
00:13:59,200 --> 00:13:57,170
those are genes delivered by viruses to

312
00:14:00,730 --> 00:13:59,210
the host cell that improved the

313
00:14:03,430 --> 00:14:00,740

condition of the host cell its

314
00:14:07,600 --> 00:14:03,440
metabolism so here is clear evidence

315
00:14:09,850 --> 00:14:07,610
that viruses are helping these microbes

316
00:14:12,220 --> 00:14:09,860
to succeed in their environments or I

317
00:14:14,140 --> 00:14:12,230
would suggest it's clear evidence and

318
00:14:18,850 --> 00:14:14,150
just zooming in a little closer here

319
00:14:24,190 --> 00:14:18,860
these are the viral context here which

320
00:14:26,769 --> 00:14:24,200
we can link to their microbial hosts so

321
00:14:28,269 --> 00:14:26,779
that we can put together specific phage

322
00:14:30,850 --> 00:14:28,279
hose interactions that have happened

323
00:14:33,310 --> 00:14:30,860
gene transfers that have happened if not

324
00:14:37,960 --> 00:14:33,320
favored have enabled life in these

325
00:14:44,470 --> 00:14:37,970
extreme environments okay want me to

326
00:14:47,650 --> 00:14:44,480
zoom forward here and conclude we have

327
00:14:50,050 --> 00:14:47,660
evidence of viral AMG's for EXO polymer

328
00:14:51,820 --> 00:14:50,060
production for cryo tolerance Osmo

329
00:14:53,350 --> 00:14:51,830
tolerance membrane fluidity so we're

330
00:14:55,570 --> 00:14:53,360
getting very close to supporting our

331
00:14:58,540 --> 00:14:55,580
hypothesis and I would just end by

332
00:15:00,970 --> 00:14:58,550
saying that as we search for microbial

333
00:15:04,030 --> 00:15:00,980
life as we know it what we're really

334
00:15:06,850 --> 00:15:04,040
searching for is this Co evolving pair

335
00:15:09,400 --> 00:15:06,860
or sets of on the spectrum of life

336
00:15:11,350 --> 00:15:09,410
between microbes and viruses which is

337
00:15:17,980 --> 00:15:11,360
going to complicate our search but make

338
00:15:23,090 --> 00:15:21,379

all right Thank You Jody so let's start

339
00:15:25,340 --> 00:15:23,100
off with a couple of quick questions for

340
00:15:26,930 --> 00:15:25,350
Jody and by the way for anybody who just

341
00:15:28,790 --> 00:15:26,940
came in here we're gonna spend the next

342
00:15:30,860 --> 00:15:28,800
15 minutes it's kind of a break time so

343
00:15:32,329 --> 00:15:30,870
we'll have questions for Jody and also

344
00:15:34,879 --> 00:15:32,339
for Rebecca for the first talk of the

345
00:15:36,620 --> 00:15:34,889
session yeah I'm Charlie lineweaver from

346
00:15:38,000 --> 00:15:36,630
the Australian National University it

347
00:15:39,470 --> 00:15:38,010
seems to me that the environment that

348
00:15:41,480 --> 00:15:39,480
you're investigating here is one of the

349
00:15:43,759 --> 00:15:41,490
few places on earth where you have I

350
00:15:46,790 --> 00:15:43,769
mean I've been told by many people that

351
00:15:48,920 --> 00:15:46,800
the ice caps go away and for most life

352
00:15:50,569 --> 00:15:48,930
of the earth that they haven't had ice

353
00:15:52,310 --> 00:15:50,579
caps so you're an environment which you

354
00:15:53,660 --> 00:15:52,320
have ice caps on you don't you have and

355
00:15:56,960 --> 00:15:53,670
you don't I would have thought that that

356
00:15:58,759 --> 00:15:56,970
would but you talk about cryo tolerance

357
00:16:00,889 --> 00:15:58,769
and the genes for cryo tolerance I mean

358
00:16:02,389 --> 00:16:00,899
I'm not sure how soon we will lose our

359
00:16:03,860 --> 00:16:02,399
ice cap but when we do we'll all the

360
00:16:05,930 --> 00:16:03,870
organisms that you're studying go

361
00:16:07,639 --> 00:16:05,940
extinct or will they somehow try to

362
00:16:10,100 --> 00:16:07,649
adapt to go further south and then they

363
00:16:12,199 --> 00:16:10,110

will have to revolve cryo tolerance

364
00:16:13,879 --> 00:16:12,209
genes that you're analyzing here when we

365
00:16:15,350 --> 00:16:13,889
get another ice cap etc cos that are

366
00:16:17,060 --> 00:16:15,360
excited for thousands and thousands of

367
00:16:20,000 --> 00:16:17,070
times yeah no I understand your question

368
00:16:22,069 --> 00:16:20,010
if you all didn't get it it's how how do

369
00:16:24,110 --> 00:16:22,079
these cold adapted microbes survive

370
00:16:26,840 --> 00:16:24,120
between periods when we don't have ice

371
00:16:29,019 --> 00:16:26,850
on the planet so we don't have a clear

372
00:16:32,059 --> 00:16:29,029
answer on that but my view is that

373
00:16:34,040 --> 00:16:32,069
microorganisms retain the memories the

374
00:16:36,199 --> 00:16:34,050
genetic memories of where they have been

375
00:16:39,699 --> 00:16:36,209
before for very long periods of time as

376
00:16:41,960 --> 00:16:39,709
long as there's some minimally cold

377
00:16:44,150 --> 00:16:41,970
environmental refuge for them on the

378
00:16:45,860 --> 00:16:44,160
planet it could be in the deep sea at 15

379
00:16:48,199 --> 00:16:45,870
degrees you know it doesn't have to be

380
00:16:50,240 --> 00:16:48,209
frozen they can retain the genetic

381
00:16:53,870 --> 00:16:50,250
information they need and if they don't

382
00:16:56,689 --> 00:16:53,880
retain it the pool of viral the pan

383
00:16:58,579 --> 00:16:56,699
viral genome will retain it for them so

384
00:17:01,610 --> 00:16:58,589
you see evidence of trout tolerant genes

385
00:17:03,559 --> 00:17:01,620
that have that are older than multiple

386
00:17:05,900 --> 00:17:03,569
episodes of ice caps going away coming

387
00:17:08,720 --> 00:17:05,910
back going away coming back great

388
00:17:10,789 --> 00:17:08,730

question I'm gonna look at that I was

389
00:17:13,579 --> 00:17:10,799
gonna ask something similar could can

390
00:17:16,460 --> 00:17:13,589
you see differences in the mutation rate

391
00:17:18,470 --> 00:17:16,470
or the sequences of some of the

392
00:17:21,530 --> 00:17:18,480
auxiliary metabolic and and then a

393
00:17:24,020 --> 00:17:21,540
related question would be I just sort of

394
00:17:25,789 --> 00:17:24,030
CRISPR in terms of gain editing and the

395
00:17:27,590 --> 00:17:25,799
insertion of a CRISPR gene itself does

396
00:17:29,030 --> 00:17:27,600
that alter the flanking sequences that

397
00:17:33,530 --> 00:17:29,040
that will alter all

398
00:17:36,410 --> 00:17:33,540
we changed the nucleotide sequence that

399
00:17:38,540 --> 00:17:36,420
within the gene itself continue in other

400
00:17:42,230 --> 00:17:38,550
words can you can you sequence these

401
00:17:44,840 --> 00:17:42,240
Kings and see how they're evolving the

402
00:17:46,670 --> 00:17:44,850
same yes so I've now gotten involved in

403
00:17:51,130 --> 00:17:46,680
your second question mentally what was

404
00:17:55,610 --> 00:17:51,140
the first one just again are the genes

405
00:17:57,440 --> 00:17:55,620
themselves evolving can you see

406
00:17:59,570 --> 00:17:57,450
different oh okay so I don't have an

407
00:18:01,820 --> 00:17:59,580
answer for you but we definitely intend

408
00:18:03,620 --> 00:18:01,830
to look at that using whatever tools we

409
00:18:05,740 --> 00:18:03,630
have there'll be bioinformatic tools

410
00:18:08,120 --> 00:18:05,750
where we have to make assumptions about

411
00:18:10,220 --> 00:18:08,130
evolutionary rates but we'll definitely

412
00:18:12,080 --> 00:18:10,230
be looking at that so there are number

413
00:18:14,210 --> 00:18:12,090

of ways that they could be able there

414
00:18:18,860 --> 00:18:14,220
are a number of theoretical ways to look

415
00:18:22,250 --> 00:18:18,870
at that yep I have two questions one is

416
00:18:25,340 --> 00:18:22,260
I you alluded to it but never said it I

417
00:18:27,800 --> 00:18:25,350
think and that is that viruses play a

418
00:18:31,250 --> 00:18:27,810
role and actually turning on the genes

419
00:18:34,490 --> 00:18:31,260
for the extracellular polymer is that

420
00:18:37,640 --> 00:18:34,500
correct so I didn't get to show you that

421
00:18:38,450 --> 00:18:37,650
last slide very well we all we've done

422
00:18:40,790 --> 00:18:38,460
so far

423
00:18:44,030 --> 00:18:40,800
mind you we just received the sequences

424
00:18:46,520 --> 00:18:44,040
so we've pulled out this set of a dozen

425
00:18:49,910 --> 00:18:46,530
genes that are associated with EXO

426
00:18:52,280 --> 00:18:49,920
polymer production and they are virally

427
00:18:55,970 --> 00:18:52,290
associated genes they fall they are

428
00:18:58,250 --> 00:18:55,980
genes that are recorded in databases as

429
00:19:00,800 --> 00:18:58,260
having come from viruses so the actual

430
00:19:03,320 --> 00:19:00,810
regulatory mechanism I can't comment on

431
00:19:06,110 --> 00:19:03,330
with the metagenomics but we also have

432
00:19:08,240 --> 00:19:06,120
meta transcriptomic data which we've not

433
00:19:10,970 --> 00:19:08,250
examined yet so you have to stay tuned

434
00:19:14,930 --> 00:19:10,980
for that sorry the second question is

435
00:19:18,350 --> 00:19:14,940
the EPS is is an appreciable amount of

436
00:19:21,440 --> 00:19:18,360
that a polysaccharide and if so are the

437
00:19:23,780 --> 00:19:21,450
dominant sugars uronic acids like Laki

438
00:19:25,940 --> 00:19:23,790

Roenick acid and glucuronic acid like

439
00:19:30,200 --> 00:19:25,950
you find in other organisms other marine

440
00:19:32,390 --> 00:19:30,210
organisms like cyanobacteria I can't

441
00:19:34,820 --> 00:19:32,400
answer that question because the method

442
00:19:37,220 --> 00:19:34,830
we're using for extracting is the phenol

443
00:19:40,440 --> 00:19:37,230
sulfuric acid method if we were using an

444
00:19:42,239 --> 00:19:40,450
LC n' stain i could i could tell you yes

445
00:19:46,139 --> 00:19:42,249
I believe that they're similar they

446
00:19:47,489 --> 00:19:46,149
behave like our sea ice polymers do so I

447
00:19:51,299 --> 00:19:47,499
believe they're similar but we haven't

448
00:19:53,759 --> 00:19:51,309
done the chemical analysis Carl Pilcher

449
00:19:54,269 --> 00:19:53,769
of space blue marble space Institute of

450
00:19:56,639 --> 00:19:54,279
Science

451
00:19:58,710 --> 00:19:56,649
Jody great talk I don't have a question

452
00:20:01,619 --> 00:19:58,720
but I just had to make the comment that

453
00:20:03,299 --> 00:20:01,629
Barry Bloomberg would really really have

454
00:20:06,180 --> 00:20:03,309
liked this talk because as you know

455
00:20:08,430 --> 00:20:06,190
Barry emphasized that life is about

456
00:20:10,379 --> 00:20:08,440
cooperation more than it is about

457
00:20:12,509 --> 00:20:10,389
competition and you've just given us a

458
00:20:14,129 --> 00:20:12,519
beautiful example of that thank you for

459
00:20:17,220 --> 00:20:14,139
that I

460
00:20:20,519 --> 00:20:17,230
I do enjoy thinking about viral host

461
00:20:23,340 --> 00:20:20,529
interactions as altruism and not in the

462
00:20:25,229 --> 00:20:23,350
war terminology that infiltrates our

463
00:20:27,060 --> 00:20:25,239

literature I do believe that they are

464
00:20:29,389 --> 00:20:27,070
helping each other as they Co evolve

465
00:20:32,820 --> 00:20:29,399
it's all part of one collaborative

466
00:20:35,729 --> 00:20:32,830
evolutionary effort so I actually have

467
00:20:38,039 --> 00:20:35,739
two questions one I am actually

468
00:20:40,379 --> 00:20:38,049
wondering if you have looked at plasmids

469
00:20:42,389 --> 00:20:40,389
at all for in terms of conjugation and

470
00:20:46,200 --> 00:20:42,399
transformation as potentially being

471
00:20:48,599 --> 00:20:46,210
related to any any of these any of the

472
00:20:50,009 --> 00:20:48,609
HTT that's present in these samples I'm

473
00:20:53,310 --> 00:20:50,019
actually with the NASA gene lab

474
00:20:55,499 --> 00:20:53,320
developing a pipeline for performing

475
00:20:57,720 --> 00:20:55,509
first computationally deriving plasmid

476
00:21:00,090 --> 00:20:57,730
sequencing plasmid sequences from

477
00:21:02,399 --> 00:21:00,100
metagenomic sabbith and performing a

478
00:21:04,049 --> 00:21:02,409
gene ontology enrichment analysis so I

479
00:21:05,340 --> 00:21:04,059
would be happy to potentially

480
00:21:06,749 --> 00:21:05,350
collaborate with you if you were

481
00:21:11,450 --> 00:21:06,759
interested in said anyway I'm also in

482
00:21:13,440 --> 00:21:11,460
the market for a PhD program but

483
00:21:16,720 --> 00:21:13,450
incidentally I'm near retirement

484
00:21:19,060 --> 00:21:16,730
[Laughter]

485
00:21:22,030 --> 00:21:19,070
as far as I know we haven't looked at

486
00:21:24,490 --> 00:21:22,040
the plasmid question and anybody from my

487
00:21:48,770 --> 00:21:24,500
lab elaborate on this I don't think so I

488
00:21:53,100 --> 00:21:51,390

we have a whole list of questions that

489
00:21:55,320 --> 00:21:53,110
we can now address now that we're

490
00:21:57,060 --> 00:21:55,330
sitting on all this omics data and we're

491
00:21:58,400 --> 00:21:57,070
just at the start of it so forgive us

492
00:22:01,710 --> 00:21:58,410
that we haven't got all your answers

493
00:22:03,450 --> 00:22:01,720
wait the second question was so I saw

494
00:22:05,910 --> 00:22:03,460
that a lot of the genes I came up for

495
00:22:07,560 --> 00:22:05,920
CRISPR associated and I've heard that

496
00:22:09,170 --> 00:22:07,570
just you know I guess in extreme

497
00:22:12,180 --> 00:22:09,180
environments you tend to have very

498
00:22:14,340 --> 00:22:12,190
streamlined and very confined genetic

499
00:22:15,210 --> 00:22:14,350
Suites so I'm wondering if you know what

500
00:22:16,740 --> 00:22:15,220
you're seeing is that you're seeing

501
00:22:20,040 --> 00:22:16,750
CRISPR Association and implying

502
00:22:21,990 --> 00:22:20,050
microbial all you know microbial viral

503
00:22:26,310 --> 00:22:22,000
resistance genes right but also seeing

504
00:22:28,500 --> 00:22:26,320
these metabolic genes so it's a surprise

505
00:22:30,270 --> 00:22:28,510
isn't it I had gone into this thinking

506
00:22:32,340 --> 00:22:30,280
that at the low end of the temperature

507
00:22:34,470 --> 00:22:32,350
range we would see fewer and fewer

508
00:22:37,440 --> 00:22:34,480
crispers there's some literature that

509
00:22:39,510 --> 00:22:37,450
suggests that and so we haven't

510
00:22:41,610 --> 00:22:39,520
completed our comparative analyses of

511
00:22:42,930 --> 00:22:41,620
how many crispers in these extreme

512
00:22:45,020 --> 00:22:42,940
environments compared to other

513
00:22:48,570 --> 00:22:45,030

environments but it's looking

514
00:22:49,320 --> 00:22:48,580
surprisingly high I don't know how to

515
00:22:51,720 --> 00:22:49,330
explain that

516
00:22:54,000 --> 00:22:51,730
except that extreme environments are

517
00:22:55,830 --> 00:22:54,010
always presenting us with surprises and

518
00:23:09,810 --> 00:22:55,840
we need to keep an open mind about our

519
00:23:11,610 --> 00:23:09,820
mindsets involving if you could comment

520
00:23:14,490 --> 00:23:11,620
sort of on the competition because I

521
00:23:17,730 --> 00:23:14,500
thought that that's a shockingly really

522
00:23:19,860 --> 00:23:17,740
high biomass environment and so maybe

523
00:23:22,350 --> 00:23:19,870
you probably haven't looked at any of

524
00:23:25,020 --> 00:23:22,360
these antimicrobial compounds or genes

525
00:23:26,580 --> 00:23:25,030
or anything but if you were to kind of

526
00:23:29,550 --> 00:23:26,590
speculate what could you speculate about

527
00:23:31,800 --> 00:23:29,560
that you're right we haven't looked at

528
00:23:34,290 --> 00:23:31,810
those things yet we have other measures

529
00:23:36,510 --> 00:23:34,300
of activity going on in these samples we

530
00:23:39,000 --> 00:23:36,520
have measures of high extracellular

531
00:23:41,220 --> 00:23:39,010
enzyme activity or high for the

532
00:23:43,160 --> 00:23:41,230
conditions that they're under we have

533
00:23:45,720 --> 00:23:43,170
evidence of dividing cells we have

534
00:23:47,580 --> 00:23:45,730
evidence from bond cat which is a

535
00:23:52,950 --> 00:23:47,590
relatively new method that tells you

536
00:23:56,790 --> 00:23:52,960
that they're consuming amino acids we

537
00:23:58,470 --> 00:23:56,800
don't have any any anything that I can

538
00:23:59,440 --> 00:23:58,480

use to comment on the competition

539
00:24:03,100 --> 00:23:59,450
question other

540
00:24:06,039 --> 00:24:03,110
than the bacteria to virus ratio which

541
00:24:09,879 --> 00:24:06,049
is surprisingly low it's on the order of

542
00:24:12,039 --> 00:24:09,889
one or less in the cryo peg Bryon's it's

543
00:24:13,539 --> 00:24:12,049
higher in the sea-ice brines which is

544
00:24:16,570 --> 00:24:13,549
why i was expecting to see more

545
00:24:18,279 --> 00:24:16,580
infection and more crispers and more

546
00:24:20,110 --> 00:24:18,289
interaction at the competitive level

547
00:24:22,419 --> 00:24:20,120
they're at the lysis level how would

548
00:24:25,889 --> 00:24:22,429
that compare to like just outside soil

549
00:24:31,480 --> 00:24:25,899
environment beats me we'll have to look

550
00:24:33,340 --> 00:24:31,490
I'm an oceanographer thank you for a

551
00:24:36,759 --> 00:24:33,350
really wonderful talk Frank Rosen's why

552
00:24:38,620 --> 00:24:36,769
Georgia Tech a couple of related

553
00:24:40,659 --> 00:24:38,630
questions and questions that sort of

554
00:24:43,389 --> 00:24:40,669
feedback on to the an early question

555
00:24:45,909 --> 00:24:43,399
about mutation rate and that is you know

556
00:24:49,210 --> 00:24:45,919
what are the you know what handle do you

557
00:24:51,759 --> 00:24:49,220
have on generation time in in the in the

558
00:24:55,330 --> 00:24:51,769
sea-ice versus the cryo pegs and then

559
00:24:58,240 --> 00:24:55,340
related to that question is you know

560
00:25:01,509 --> 00:24:58,250
what what are the sources of primary

561
00:25:04,180 --> 00:25:01,519
productivity and is that is that

562
00:25:07,120 --> 00:25:04,190
continuous and slow or is it episodic

563
00:25:10,600 --> 00:25:07,130

and again if you could contrast those

564
00:25:11,950 --> 00:25:10,610
two okay so in sea ice it depends on

565
00:25:13,960 --> 00:25:11,960
where you are in the ice but if you're

566
00:25:15,789 --> 00:25:13,970
at the bottom of the ice where light

567
00:25:17,620 --> 00:25:15,799
penetrates and nutrients are from below

568
00:25:20,259 --> 00:25:17,630
you have plenty of primary production

569
00:25:24,730 --> 00:25:20,269
through ice algae which Jody young will

570
00:25:27,009 --> 00:25:24,740
talk about shortly in the cryo peg it's

571
00:25:30,430 --> 00:25:27,019
totally dark and has been totally dark

572
00:25:31,659 --> 00:25:30,440
for 50,000 years we have some evidence I

573
00:25:32,350 --> 00:25:31,669
don't know if she's going to talk about

574
00:25:34,840 --> 00:25:32,360
this or not

575
00:25:38,310 --> 00:25:34,850
of Rubisco genes and there that could be

576
00:25:42,100 --> 00:25:38,320
utilized by chemoautotrophs

577
00:25:44,769 --> 00:25:42,110
but they would be a very rare in

578
00:25:47,049 --> 00:25:44,779
occurrence because our data is telling

579
00:25:50,379 --> 00:25:47,059
us that this swamp of bacteria are

580
00:25:52,060 --> 00:25:50,389
heterotrophic bacteria so it is a puzzle

581
00:25:54,159 --> 00:25:52,070
as to where all the carbon is coming

582
00:25:56,789 --> 00:25:54,169
from and we are definitely puzzling over

583
00:25:59,649 --> 00:25:56,799
that trying to get datings on things and

584
00:26:01,960 --> 00:25:59,659
sources of organics here and it's a it's

585
00:26:06,330 --> 00:26:01,970
a difficult question and I think I've

586
00:26:08,909 --> 00:26:06,340
probably forgotten your first really

587
00:26:10,440 --> 00:26:08,919
wonderful systems okay thank you it's a

588
00:26:12,269 --> 00:26:10,450

wonderful system but there are a lot of

589
00:26:15,630 --> 00:26:12,279
unknowns about it that and a lot of

590
00:26:17,370 --> 00:26:15,640
things we have to wrestle with hi Jodi

591
00:26:18,060 --> 00:26:17,380
sorry yeah I guess I'll be the last

592
00:26:19,860 --> 00:26:18,070
question

593
00:26:22,380 --> 00:26:19,870
yes and he's the one that invited me to

594
00:26:23,909 --> 00:26:22,390
do this oh thank you thank you so much

595
00:26:26,580 --> 00:26:23,919
for coming out it was a great talk it's

596
00:26:27,779 --> 00:26:26,590
exciting for the AMG's you know they can

597
00:26:29,909 --> 00:26:27,789
be hard to discover and now you guys are

598
00:26:31,620 --> 00:26:29,919
doing more work where there are other

599
00:26:33,690 --> 00:26:31,630
AMG's that you didn't talk about for the

600
00:26:35,130 --> 00:26:33,700
sake of time did you find anything for

601
00:26:37,710 --> 00:26:35,140
antifreeze proteins or anything else

602
00:26:40,139 --> 00:26:37,720
like that yeah yeah

603
00:26:40,950 --> 00:26:40,149
I haven't listed them out oh yes I was

604
00:26:44,460 --> 00:26:40,960
thinking these are all we have

605
00:26:47,039 --> 00:26:44,470
comparable tables for the cryo tolerance

606
00:26:49,279 --> 00:26:47,049
Osmo tolerance membrane fluidity out of

607
00:26:52,470 --> 00:26:49,289
Matt Sullivan's lab jeeping zong his

608
00:26:54,980 --> 00:26:52,480
postdoc has identified a lipid

609
00:26:57,889 --> 00:26:54,990
desaturates which keeps the membrane

610
00:27:02,310 --> 00:26:57,899
fluid under very extreme cold conditions

611
00:27:04,320 --> 00:27:02,320
that is an AMG virally transferred he's

612
00:27:08,430 --> 00:27:04,330
identified that in the virus from the

613
00:27:10,320 --> 00:27:08,440

cryo pegs so so yes we have some very

614
00:27:12,899 --> 00:27:10,330
clear evidence there I also wondered

615
00:27:14,940 --> 00:27:12,909
there's this idea of this art BGM system

616
00:27:17,430 --> 00:27:14,950
where it's virus communication via

617
00:27:19,289 --> 00:27:17,440
adapting the host quorum sensing if you

618
00:27:20,820 --> 00:27:19,299
think maybe here they're producing this

619
00:27:23,430 --> 00:27:20,830
eat they're helping the host produces

620
00:27:25,110 --> 00:27:23,440
EPS and maybe they're communicating to

621
00:27:26,460 --> 00:27:25,120
have these guided decisions of when to

622
00:27:28,649 --> 00:27:26,470
burst out of the host and when not to

623
00:27:33,090 --> 00:27:28,659
and that might affect the virus host

624
00:27:34,470 --> 00:27:33,100
abundance very cool idea yeah we don't

625
00:27:38,370 --> 00:27:34,480
we haven't measured quorum sensing

626
00:27:44,580 --> 00:27:38,380
compounds here we'd be happy to give her