
AbSciCon
2019

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

2
00:00:12,340 --> 00:00:09,240
[Applause]

3
00:00:16,450 --> 00:00:12,350
so today I'm gonna try make the case

4
00:00:19,150 --> 00:00:16,460
that the the earliest adaptively

5
00:00:22,330 --> 00:00:19,160
evolving systems were surface limited

6
00:00:25,450 --> 00:00:22,340
metabolisms which we call slimes and

7
00:00:27,429 --> 00:00:25,460
that thinking through this the existence

8
00:00:29,499 --> 00:00:27,439
of slide provides some suggestions for

9
00:00:32,380 --> 00:00:29,509
some interesting sort of empirical

10
00:00:34,360 --> 00:00:32,390
approaches so to get us started let's

11
00:00:37,090 --> 00:00:34,370
just define the core problem the core

12
00:00:39,280 --> 00:00:37,100
problem as I see it is that the first

13
00:00:42,700 --> 00:00:39,290

adaptive the evolving system had to had

14
00:00:44,410 --> 00:00:42,710
to be self propagating also that system

15
00:00:46,780 --> 00:00:44,420
that was both self-propagating and

16
00:00:50,290 --> 00:00:46,790
adaptively evolvable by definition had

17
00:00:51,970 --> 00:00:50,300
to arrive arise without the help of any

18
00:00:55,030 --> 00:00:51,980
prior adaptive process it had this

19
00:00:56,800 --> 00:00:55,040
bringing to existence spontaneously and

20
00:00:59,410 --> 00:00:56,810
therefore whatever it is has to pass

21
00:01:00,130 --> 00:00:59,420
what we might call the junkyard tornado

22
00:01:01,990 --> 00:01:00,140
test

23
00:01:04,420 --> 00:01:02,000
so there's many of you will know that

24
00:01:06,580 --> 00:01:04,430
Hoyle you know pointed out that we don't

25
00:01:08,440 --> 00:01:06,590
really expect a tornado to be able to

26
00:01:12,250 --> 00:01:08,450
blow through a junkyard and blow

27
00:01:14,440 --> 00:01:12,260
together an airplane in a 747 and by

28
00:01:18,010 --> 00:01:14,450
similar reasoning even the simplest

29
00:01:19,960 --> 00:01:18,020
living cell is too complicated to

30
00:01:23,320 --> 00:01:19,970
imagine that without an adapted process

31
00:01:25,300 --> 00:01:23,330
that you could a prebiotic soup given

32
00:01:27,640 --> 00:01:25,310
some chance and time could spontaneously

33
00:01:30,670 --> 00:01:27,650
form a cell so we need something

34
00:01:32,830 --> 00:01:30,680
significantly simpler than a cell now

35
00:01:34,960 --> 00:01:32,840
one alternative that has been thrown

36
00:01:38,110 --> 00:01:34,970
around in the field is the idea that the

37
00:01:40,300 --> 00:01:38,120
initial starting place might be a single

38
00:01:42,370 --> 00:01:40,310

molecule with the ability to replicate

39
00:01:45,520 --> 00:01:42,380
itself and people usually think about

40
00:01:47,530 --> 00:01:45,530
RNA so the idea here is is that you have

41
00:01:50,440 --> 00:01:47,540
prebiotic soup it gives rise to an RNA

42
00:01:52,750 --> 00:01:50,450
that RNA can self propagate and the

43
00:01:55,390 --> 00:01:52,760
nature of propagation in RNAs makes it

44
00:01:57,190 --> 00:01:55,400
intrinsically evolvable however I think

45
00:01:57,910 --> 00:01:57,200
I won't have to convince many of you in

46
00:02:00,399 --> 00:01:57,920
the room that there are a lot of

47
00:02:02,860 --> 00:02:00,409
problems with this idea firstly long

48
00:02:04,690 --> 00:02:02,870
rnas are very unlikely secondly we have

49
00:02:06,460 --> 00:02:04,700
the whole error threshold problem that

50
00:02:08,619 --> 00:02:06,470
it would be even harder to get one that

51
00:02:12,190 --> 00:02:08,629
could self replicate itself accurately

52
00:02:13,479 --> 00:02:12,200
enough and and finally we have the whole

53
00:02:15,849 --> 00:02:13,489
problem they would need to be able to

54
00:02:19,869 --> 00:02:15,859
make its own monomers so I put a not

55
00:02:21,250 --> 00:02:19,879
equal sign there to indicate that we

56
00:02:24,369 --> 00:02:21,260
don't consider this

57
00:02:27,009 --> 00:02:24,379
plausible hypothesis for the first

58
00:02:29,470 --> 00:02:27,019
Evolver so if it's not a single molecule

59
00:02:31,630 --> 00:02:29,480
it has to be an ecosystem of molecules

60
00:02:33,729 --> 00:02:31,640
it has to be a set of interacting

61
00:02:37,780 --> 00:02:33,739
molecules with the collective property

62
00:02:42,759 --> 00:02:37,790
that they all facilitate and achieve one

63
00:02:45,009 --> 00:02:42,769

another's production now it it this

64
00:02:49,030 --> 00:02:45,019
general idea and I actually can't find

65
00:02:52,899 --> 00:02:49,040
the pointer yes and this general idea of

66
00:02:55,300 --> 00:02:52,909
auto catalytic systems or eco systems as

67
00:02:56,860 --> 00:02:55,310
I prefer to call them it's first I want

68
00:02:59,199 --> 00:02:56,870
to point out this is chemically agnostic

69
00:03:01,360 --> 00:02:59,209
the players in these ecosystems could be

70
00:03:03,970 --> 00:03:01,370
RNA molecules they could be metabolites

71
00:03:06,099 --> 00:03:03,980
and there's no indication or requirement

72
00:03:08,979 --> 00:03:06,109
that there be specific catalysis because

73
00:03:10,869 --> 00:03:08,989
branch networks such as this loop here

74
00:03:12,759 --> 00:03:10,879
because every time you go around it

75
00:03:15,460 --> 00:03:12,769
makes two ways the system would self

76
00:03:18,099 --> 00:03:15,470
propagate even though it doesn't have

77
00:03:20,050 --> 00:03:18,109
any specific catalysis and it also

78
00:03:21,670 --> 00:03:20,060
doesn't but it doesn't but it doesn't

79
00:03:25,030 --> 00:03:21,680
require 50 calories but it does require

80
00:03:26,890 --> 00:03:25,040
any such system would require a constant

81
00:03:28,629 --> 00:03:26,900
replenishing source of food and energy

82
00:03:30,039 --> 00:03:28,639
because it's going to be dissipating

83
00:03:34,210 --> 00:03:30,049
energy in this in the after

84
00:03:37,270 --> 00:03:34,220
self-propagating so the challenge then

85
00:03:39,939 --> 00:03:37,280
that causes is that we have a set of

86
00:03:42,430 --> 00:03:39,949
cooperating species in this ecosystem

87
00:03:44,379 --> 00:03:42,440
but which need to be maintained in

88
00:03:47,199 --> 00:03:44,389

physical proximity in order to cooperate

89
00:03:49,720 --> 00:03:47,209
and make more of one another in in that

90
00:03:51,610 --> 00:03:49,730
neighborhood and but they at the same

91
00:03:54,789 --> 00:03:51,620
time they need to have access to

92
00:03:58,089 --> 00:03:54,799
continuing flux of food and energy so

93
00:04:01,000 --> 00:03:58,099
how did they be spatially localized so

94
00:04:03,520 --> 00:04:01,010
one popular view is that the initial

95
00:04:07,119 --> 00:04:03,530
system was a spontaneously formed

96
00:04:09,879 --> 00:04:07,129
protocell and I think many people would

97
00:04:11,949 --> 00:04:09,889
acknowledge that given a lot of

98
00:04:13,720 --> 00:04:11,959
amphiphilic molecules in a aqueous

99
00:04:16,390 --> 00:04:13,730
solution you can imagine the spontaneous

100
00:04:18,210 --> 00:04:16,400
formation of a protocell and maybe once

101
00:04:21,719 --> 00:04:18,220
in a while it could trap within it a

102
00:04:24,550 --> 00:04:21,729
chemical ecosystem with this ability to

103
00:04:26,740 --> 00:04:24,560
wherever for every member of that set to

104
00:04:29,649 --> 00:04:26,750
be cooperate to make one or to make one

105
00:04:31,839 --> 00:04:29,659
another however we would like to suggest

106
00:04:34,000 --> 00:04:31,849
that although this is at some point life

107
00:04:35,050 --> 00:04:34,010
likely went through such a stage we

108
00:04:37,780 --> 00:04:35,060
can't we don't believe this

109
00:04:39,970 --> 00:04:37,790
being the first Evolver and the reason

110
00:04:42,250 --> 00:04:39,980
is if the wireless achieves the goal of

111
00:04:44,409 --> 00:04:42,260
keeping the co-operative enclosed and

112
00:04:46,480 --> 00:04:44,419
spatially proximate to one another so

113
00:04:48,879 --> 00:04:46,490

that they can make one another and it

114
00:04:50,530 --> 00:04:48,889
also builds a barrier between them and

115
00:04:52,650 --> 00:04:50,540
the food and energy that they need in

116
00:04:55,210 --> 00:04:52,660
order to be able to propagate themselves

117
00:04:56,950 --> 00:04:55,220
so it's actually making life harder by

118
00:05:00,400 --> 00:04:56,960
separating them from that energy and

119
00:05:02,170 --> 00:05:00,410
food the other issue is because you have

120
00:05:04,240 --> 00:05:02,180
now two components they have to somehow

121
00:05:07,150 --> 00:05:04,250
miraculously without any prior adaptive

122
00:05:09,969 --> 00:05:07,160
process be coordinated so that they can

123
00:05:11,770 --> 00:05:09,979
actually grow without either the the the

124
00:05:16,690 --> 00:05:11,780
lumen contents getting diluted to

125
00:05:18,909 --> 00:05:16,700
non-existence or the membrane popping so

126
00:05:20,670 --> 00:05:18,919
we don't think this is a plausible model

127
00:05:24,640 --> 00:05:20,680
and so we want something simpler

128
00:05:27,040 --> 00:05:24,650
now one idea just to put there is we

129
00:05:28,840 --> 00:05:27,050
would say viable is the idea of a drop

130
00:05:34,450 --> 00:05:28,850
litter or coacervate so this is similar

131
00:05:36,610 --> 00:05:34,460
to a protocell except you only have one

132
00:05:40,180 --> 00:05:36,620
phase so you have some sort of maybe

133
00:05:42,490 --> 00:05:40,190
it's a set of an fulfilling molecules

134
00:05:44,620 --> 00:05:42,500
are formed some sort of droplet if the

135
00:05:46,480 --> 00:05:44,630
droplet is small those molecules do

136
00:05:48,040 --> 00:05:46,490
still have access to the external

137
00:05:50,830 --> 00:05:48,050
environment where the food and energy

138
00:05:52,570 --> 00:05:50,840

have to come from and so this is a

139
00:05:56,380 --> 00:05:52,580
perfectly viable we think modeling

140
00:05:58,719 --> 00:05:56,390
principle and may well have been the

141
00:06:01,180 --> 00:05:58,729
path by which lifelike system evolved in

142
00:06:04,270 --> 00:06:01,190
some places and in the solar system or

143
00:06:06,010 --> 00:06:04,280
the other the universe but we don't

144
00:06:08,409 --> 00:06:06,020
think it's a good model for a precursor

145
00:06:09,909 --> 00:06:08,419
to cellular life because once you have a

146
00:06:12,010 --> 00:06:09,919
droplet it's very hard to see how you

147
00:06:15,969 --> 00:06:12,020
can go to a cell how you can generate

148
00:06:21,370 --> 00:06:15,979
now a hydrophilic bubble within a

149
00:06:23,320 --> 00:06:21,380
hydrophobic droplet so I'm going to set

150
00:06:24,879 --> 00:06:23,330
that aside and instead tell you about

151
00:06:27,490 --> 00:06:24,889
the one that we do think is the most

152
00:06:29,529 --> 00:06:27,500
plausible way to think about this which

153
00:06:32,500 --> 00:06:29,539
was originally proposed by vectors

154
00:06:35,080 --> 00:06:32,510
Houser in a form so the idea here is is

155
00:06:37,500 --> 00:06:35,090
again you start with a prebiotic soup it

156
00:06:40,260 --> 00:06:37,510
interacts with a mineral surface and

157
00:06:42,460 --> 00:06:40,270
spontaneously you get a small set of

158
00:06:45,070 --> 00:06:42,470
cooperating molecules an ecosystem

159
00:06:47,810 --> 00:06:45,080
nucleates on that surface and can grow

160
00:06:50,000 --> 00:06:47,820
and spread can self propagate

161
00:06:51,740 --> 00:06:50,010
and so just to give an example and help

162
00:06:53,180 --> 00:06:51,750
you visualize this where this little

163
00:06:55,370 --> 00:06:53,190

network I showed you before little

164
00:06:58,040 --> 00:06:55,380
branch Network and we're imagining that

165
00:07:00,080 --> 00:06:58,050
the capital letters denote species that

166
00:07:01,850 --> 00:07:00,090
are the co-operators and they all stick

167
00:07:04,910 --> 00:07:01,860
to this membrane but are not present in

168
00:07:06,710 --> 00:07:04,920
the soup and the lowercase letters are

169
00:07:08,330 --> 00:07:06,720
food energy sources that are in the

170
00:07:11,480 --> 00:07:08,340
environment and are being constantly

171
00:07:14,990 --> 00:07:11,490
replenished and so the notion is is that

172
00:07:17,960 --> 00:07:15,000
if some rare side reaction generates one

173
00:07:20,120 --> 00:07:17,970
member of this set and it would stick to

174
00:07:22,790 --> 00:07:20,130
the surface and it will then nucleate a

175
00:07:25,130 --> 00:07:22,800
system or whereby these would grow out

176
00:07:28,130 --> 00:07:25,140
and propagate laterally to cover that

177
00:07:31,130 --> 00:07:28,140
surface eventually so that's what we

178
00:07:34,220 --> 00:07:31,140
mean by a slime but you might wonder

179
00:07:36,020 --> 00:07:34,230
well could a slime be evolvable in the

180
00:07:38,450 --> 00:07:36,030
absence of any kind of genetic encoding

181
00:07:40,310 --> 00:07:38,460
system well in principle there's good

182
00:07:43,130 --> 00:07:40,320
theory to suggest the answer is yes

183
00:07:45,550 --> 00:07:43,140
because there isn't in the totality of

184
00:07:47,990 --> 00:07:45,560
chemistry one or the catalytic loop

185
00:07:51,140 --> 00:07:48,000
system but real chemistry has lots of

186
00:07:54,050 --> 00:07:51,150
loops lots of potential autocatalytic

187
00:07:55,640 --> 00:07:54,060
networks such that once you have one

188
00:07:57,140 --> 00:07:55,650

network like in this case so here we

189
00:07:59,450 --> 00:07:57,150
have one one loop that I showed you

190
00:08:02,270 --> 00:07:59,460
before this loop can feed on waste on

191
00:08:05,300 --> 00:08:02,280
this loop so once that one has covered a

192
00:08:08,540 --> 00:08:05,310
surface you can imagine again a

193
00:08:10,100 --> 00:08:08,550
spontaneous reaction rare one giving

194
00:08:12,890 --> 00:08:10,110
rise to there's some member of the red

195
00:08:14,900 --> 00:08:12,900
set like that H that maybe you little

196
00:08:18,140 --> 00:08:14,910
didn't see and then and now these

197
00:08:20,180 --> 00:08:18,150
molecules can be added to this slime to

198
00:08:22,720 --> 00:08:20,190
this system so what that means is is

199
00:08:25,280 --> 00:08:22,730
that slimes can exist in multiple

200
00:08:28,190 --> 00:08:25,290
metastable States that can be found by

201
00:08:30,950 --> 00:08:28,200
rare side reactions the analog version

202
00:08:32,620 --> 00:08:30,960
of mutation and as a result of that

203
00:08:35,360 --> 00:08:32,630
these slimes would not only be

204
00:08:37,880 --> 00:08:35,370
self-propagating but there would be sort

205
00:08:39,320 --> 00:08:37,890
of communities of these systems that

206
00:08:40,730 --> 00:08:39,330
would be where there could be some of

207
00:08:44,390 --> 00:08:40,740
the competitive interaction and the

208
00:08:46,640 --> 00:08:44,400
potential for selection among them now

209
00:08:48,230 --> 00:08:46,650
it's not the main focus of the talk so

210
00:08:50,570 --> 00:08:48,240
I'm going to be very brief but one thing

211
00:08:54,920 --> 00:08:50,580
this does offer is a very natural path

212
00:08:58,910 --> 00:08:54,930
to a cell because once you have a blind

213
00:09:01,370 --> 00:08:58,920

on a surface the one of the they're

214
00:09:03,050 --> 00:09:01,380
going to be limited to their surface

215
00:09:05,180 --> 00:09:03,060
but they're gonna be patches of surface

216
00:09:08,090 --> 00:09:05,190
elsewhere in the ocean selection would

217
00:09:10,040 --> 00:09:08,100
favor any variants that could bobble off

218
00:09:12,680 --> 00:09:10,050
little bits of itself into the water

219
00:09:15,200 --> 00:09:12,690
column to spread and colonize other

220
00:09:17,960 --> 00:09:15,210
surfaces furthermore those variants that

221
00:09:19,970 --> 00:09:17,970
could not only spread by youth energy in

222
00:09:21,560 --> 00:09:19,980
the water column to divide would be

223
00:09:23,870 --> 00:09:21,570
favored to the point where they no

224
00:09:25,190 --> 00:09:23,880
longer need the mineral surface and this

225
00:09:27,920 --> 00:09:25,200
was similar to what Festus Houser

226
00:09:30,290 --> 00:09:27,930
himself had proposed so we think that

227
00:09:32,930 --> 00:09:30,300
the the starting place is prebiotic soup

228
00:09:35,570 --> 00:09:32,940
that interacts with kinds of mineral

229
00:09:38,180 --> 00:09:35,580
surfaces and spontaneously gives rise to

230
00:09:40,690 --> 00:09:38,190
these adaptively evolving chemical

231
00:09:43,490 --> 00:09:40,700
systems on surfaces these slimes

232
00:09:46,370 --> 00:09:43,500
so we think is a promising approach and

233
00:09:49,070 --> 00:09:46,380
what's nice about it is it suggests an

234
00:09:52,160 --> 00:09:49,080
empirical approach to the origin of life

235
00:09:53,600 --> 00:09:52,170
which we think is somewhat overdue so

236
00:09:57,470 --> 00:09:53,610
the experiments have we've been doing in

237
00:09:59,570 --> 00:09:57,480
my lab as part of this nasa-funded group

238
00:10:01,490 --> 00:09:59,580

the conceal it chemical ecosystem

239
00:10:04,220 --> 00:10:01,500
selection paradigm for origin of life or

240
00:10:07,510 --> 00:10:04,230
cesspool is looking for slime very

241
00:10:10,160 --> 00:10:07,520
fitting by building little eaten

242
00:10:13,520 --> 00:10:10,170
microcosms of the prebiotic earth so

243
00:10:16,160 --> 00:10:13,530
little soup prebiotic soups minerals and

244
00:10:16,970 --> 00:10:16,170
atmosphere imagining that a slime might

245
00:10:19,430 --> 00:10:16,980
thank you

246
00:10:22,700 --> 00:10:19,440
when spontaneously emerge and then using

247
00:10:24,920 --> 00:10:22,710
a cereal transfer and dilute protocol to

248
00:10:27,380 --> 00:10:24,930
enrich for any slimes that might be

249
00:10:29,750 --> 00:10:27,390
present and to detect their presence

250
00:10:31,070 --> 00:10:29,760
using chemical proxy traits now

251
00:10:33,620 --> 00:10:31,080
obviously I was trying to tell you is

252
00:10:35,660 --> 00:10:33,630
the results but Lena Vincent my

253
00:10:37,820 --> 00:10:35,670
co-author and and student is going to be

254
00:10:39,800 --> 00:10:37,830
talking on Wednesday to give you the

255
00:10:42,050 --> 00:10:39,810
results but let me just say that this

256
00:10:44,480 --> 00:10:42,060
approach has found evidence of the

257
00:10:47,840 --> 00:10:44,490
spontaneous sort of accumulation of

258
00:10:50,900 --> 00:10:47,850
organic layers on pirate iron pyrite

259
00:10:53,050 --> 00:10:50,910
grains and at a macro scale we see a

260
00:10:55,910 --> 00:10:53,060
very interesting long term dynamic

261
00:10:58,490 --> 00:10:55,920
across these transfers that looks very

262
00:11:00,350 --> 00:10:58,500
ecological in structure with ecological

263
00:11:05,300 --> 00:11:00,360

will look like ecological booms and bust

264
00:11:06,620 --> 00:11:05,310
cycles so the conclusions I would help

265
00:11:08,780 --> 00:11:06,630
hope that you might take away is that

266
00:11:11,270 --> 00:11:08,790
first of all of us has to arise without

267
00:11:12,920 --> 00:11:11,280
any help from prior adapt ation meaning

268
00:11:14,989 --> 00:11:12,930
there must be simple

269
00:11:17,600 --> 00:11:14,999
we would contend that that ruled out a

270
00:11:18,980 --> 00:11:17,610
single magic molecule and it also maybe

271
00:11:22,150 --> 00:11:18,990
more controversially rules out a

272
00:11:26,179 --> 00:11:22,160
protocell as the first Evolver slimes

273
00:11:27,619 --> 00:11:26,189
offer one alternative because their

274
00:11:30,259 --> 00:11:27,629
evolvable and there's a natural

275
00:11:32,480 --> 00:11:30,269
selective pass to a cell and that there

276
00:11:34,280 --> 00:11:32,490
are these early empirical studies seem

277
00:11:37,009 --> 00:11:34,290
to ask consistent with this basic

278
00:11:39,079 --> 00:11:37,019
approach so just to end I want to thank

279
00:11:42,079 --> 00:11:39,089
my entire lab but particularly Lena

280
00:11:44,929 --> 00:11:42,089
shown there collaborators at UW Madison

281
00:11:47,509 --> 00:11:44,939
we received funding from NASA and NSF

282
00:11:48,980 --> 00:11:47,519
and the University of Wisconsin and I

283
00:11:52,189 --> 00:11:48,990
also want to acknowledge other members

284
00:11:54,109 --> 00:11:52,199
of the cesspool consortium listed here

285
00:12:04,489 --> 00:11:54,119
some of whom are at this meeting so

286
00:12:13,590 --> 00:12:04,499
thank you David we have time for

287
00:12:13,600 --> 00:12:31,970
he was Speaker Peter I'll repeat it

288
00:12:37,290 --> 00:12:34,590

so the question was what the the the

289
00:12:38,520 --> 00:12:37,300
constraint is evolvability and so the

290
00:12:41,780 --> 00:12:38,530
example I gave with a particular

291
00:12:44,550 --> 00:12:41,790
hypothetical ABCD network sharing loops

292
00:12:48,120 --> 00:12:44,560
and the question was do we have specific

293
00:12:50,490 --> 00:12:48,130
ideas and no I wouldn't say we I mean I

294
00:12:51,750 --> 00:12:50,500
have some vague ideas of theirs and if

295
00:12:53,700 --> 00:12:51,760
you you know people looking core

296
00:12:57,420 --> 00:12:53,710
metabolism and finds hints of

297
00:12:59,730 --> 00:12:57,430
autocatalytic loops rather like this the

298
00:13:02,280 --> 00:12:59,740
basic loop looks like reverse TCA fit

299
00:13:03,030 --> 00:13:02,290
SATs for example but you need a second

300
00:13:04,710 --> 00:13:03,040
one and so forth

301
00:13:07,080 --> 00:13:04,720
and but that's sort of the approach

302
00:13:09,450 --> 00:13:07,090
we're taking is we give it the soup we

303
00:13:12,000 --> 00:13:09,460
see what emerges rather than trying to

304
00:13:13,860 --> 00:13:12,010
build the soup in order to generate a

305
00:13:16,470 --> 00:13:13,870
particular target or two catalytic

306
00:13:18,570 --> 00:13:16,480
system so we'll try to let do it in the

307
00:13:32,610 --> 00:13:18,580
rather more bottom-up approach and see

308
00:13:37,449 --> 00:13:35,470
yeah so our goal was to develop a

309
00:13:39,250 --> 00:13:37,459
protocol that could be used in a broad

310
00:13:41,800 --> 00:13:39,260
sweep by the whole community of

311
00:13:43,720 --> 00:13:41,810
different minerals different soups but

312
00:13:46,210 --> 00:13:43,730
we just decided give investors houses

313
00:13:47,819 --> 00:13:46,220

model to start with a soup well it's the

314
00:13:51,240 --> 00:13:47,829
ameliorate

315
00:13:54,269 --> 00:13:53,069
whew we tried and this one gave these

316
00:13:56,100 --> 00:13:54,279
interesting without so we've been

317
00:13:58,019 --> 00:13:56,110
sticking with it for the time being but

318
00:14:00,540 --> 00:13:58,029
eventually we should try many many other

319
00:14:02,850 --> 00:14:00,550
minerals and soup combinations including

320
00:14:06,119 --> 00:14:02,860
ones that are appropriate on two other

321
00:14:08,309 --> 00:14:06,129
planetary other worlds since there's no