
AbSciCon
2019

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

2
00:00:11,250 --> 00:00:09,080
[Applause]

3
00:00:13,440 --> 00:00:11,260
I've been looking forward to sharing

4
00:00:15,839 --> 00:00:13,450
with you some recent work that I hope

5
00:00:18,269 --> 00:00:15,849
provides a different perspective on the

6
00:00:19,769 --> 00:00:18,279
origin of cellularity and those of you

7
00:00:21,450 --> 00:00:19,779
who know me know that my lab usually

8
00:00:24,420 --> 00:00:21,460
doesn't work on the subject but rather

9
00:00:25,650 --> 00:00:24,430
on evolutionary history at or around the

10
00:00:27,660 --> 00:00:25,660
time of the last Universal common

11
00:00:30,150 --> 00:00:27,670
ancestor and we know a number of things

12
00:00:32,070 --> 00:00:30,160
about that ancestor one thing we know

13
00:00:34,200 --> 00:00:32,080

that's relevant to this talk is that

14
00:00:37,259 --> 00:00:34,210
that ancestor was most likely cellular

15
00:00:39,990 --> 00:00:37,269
we think that's the case because it had

16
00:00:43,110 --> 00:00:40,000
a signal recognition particle system

17
00:00:45,719 --> 00:00:43,120
which is used for delivering proteins to

18
00:00:47,430 --> 00:00:45,729
the cell membrane and other secreting

19
00:00:49,380 --> 00:00:47,440
proteins out of the membrane or

20
00:00:52,590 --> 00:00:49,390
embedding them within the membrane I

21
00:00:54,539 --> 00:00:52,600
know it says ER lumen here and that's

22
00:00:57,350 --> 00:00:54,549
true for eukaryotes but in prokaryotes

23
00:01:01,320 --> 00:00:57,360
this system occurs on the cell membrane

24
00:01:03,090 --> 00:01:01,330
one of those proteins that was very

25
00:01:04,770 --> 00:01:03,100
likely embedded in the cell membrane of

26
00:01:06,899 --> 00:01:04,780
the last Universal common ancestor was

27
00:01:08,969 --> 00:01:06,909
this ATP synthase motor which is one of

28
00:01:13,410 --> 00:01:08,979
my favorite proteins and it's

29
00:01:16,020 --> 00:01:13,420
responsible for forming ATP from ADP and

30
00:01:21,029 --> 00:01:16,030
phosphate by way of a proton motive

31
00:01:22,679 --> 00:01:21,039
force that is that is created by a

32
00:01:25,469 --> 00:01:22,689
proton or sometimes sodium gradient

33
00:01:28,739 --> 00:01:25,479
that's stabilized by in the case of

34
00:01:32,819 --> 00:01:28,749
prokaryotes a cell membrane but when we

35
00:01:34,889 --> 00:01:32,829
think about the origin of life we don't

36
00:01:36,599 --> 00:01:34,899
know how it happened I'm agnostic about

37
00:01:38,550 --> 00:01:36,609
how it happened myself because I tend to

38
00:01:39,809 --> 00:01:38,560

study things that happen much later but

39
00:01:41,580 --> 00:01:39,819
I hope we can agree that it wasn't the

40
00:01:45,330 --> 00:01:41,590
type of cellular organism that we see in

41
00:01:47,219 --> 00:01:45,340
modern life today and in several of the

42
00:01:49,230 --> 00:01:47,229
most you know popular hypotheses for

43
00:01:51,510 --> 00:01:49,240
what the simple genetic replicators were

44
00:01:53,719 --> 00:01:51,520
that led to the origin of life they

45
00:01:57,690 --> 00:01:53,729
didn't really require cellularity at all

46
00:02:00,239 --> 00:01:57,700
now that's not to say that the

47
00:02:02,340 --> 00:02:00,249
environment itself didn't provide some

48
00:02:03,989 --> 00:02:02,350
of the benefits of cellularity we've

49
00:02:09,029 --> 00:02:03,999
heard a lot about concentration both of

50
00:02:13,140 --> 00:02:09,039
this session and at the morning session

51
00:02:15,930 --> 00:02:13,150
and so these simple replicators likely

52
00:02:18,590 --> 00:02:15,940
required a rich geochemical environment

53
00:02:20,230 --> 00:02:18,600
whatever that environment may be that

54
00:02:22,330 --> 00:02:20,240
provided them

55
00:02:26,470 --> 00:02:22,340
with the kinds of compound some source

56
00:02:30,070 --> 00:02:26,480
of chemical potential energy and and

57
00:02:31,900 --> 00:02:30,080
also mechanisms for concentrating those

58
00:02:33,250 --> 00:02:31,910
compounds and making reactions

59
00:02:37,000 --> 00:02:33,260
thermodynamically are kinetically

60
00:02:39,160 --> 00:02:37,010
favorable but if the last Universal

61
00:02:41,850 --> 00:02:39,170
common ancestor was cellular and the

62
00:02:44,650 --> 00:02:41,860
origin of life was non cellular than

63
00:02:48,250 --> 00:02:44,660

that suggests that cellularity arose in

64
00:02:51,040 --> 00:02:48,260
between these two stages and maybe

65
00:02:53,110 --> 00:02:51,050
evolved because it's an adaptive trait

66
00:02:54,790 --> 00:02:53,120
and if it's an adaptive trait then there

67
00:02:58,120 --> 00:02:54,800
may have been some selective pressure

68
00:02:59,970 --> 00:02:58,130
that guided that evolutionary process

69
00:03:04,300 --> 00:02:59,980
and we were interested in understanding

70
00:03:07,030 --> 00:03:04,310
what those selective pressures selection

71
00:03:08,800 --> 00:03:07,040
pressures might be and so we designed

72
00:03:11,040 --> 00:03:08,810
what's called a digital life simulation

73
00:03:16,480 --> 00:03:11,050
where we kind of abstract some of the

74
00:03:18,790 --> 00:03:16,490
activities of organisms and which allows

75
00:03:20,860 --> 00:03:18,800
us to test hypotheses that we couldn't

76
00:03:25,600 --> 00:03:20,870
otherwise test in a laboratory setting

77
00:03:29,550 --> 00:03:25,610
or using phylogenetic analysis and so in

78
00:03:33,610 --> 00:03:29,560
our digital life system there are

79
00:03:35,860 --> 00:03:33,620
populations of organisms and they live

80
00:03:38,020 --> 00:03:35,870
in an environment with a shared food

81
00:03:41,260 --> 00:03:38,030
stock and some predetermined fixed

82
00:03:44,650 --> 00:03:41,270
population capacity each organism has a

83
00:03:47,530 --> 00:03:44,660
genome that has both metabolic genes and

84
00:03:49,810 --> 00:03:47,540
cellularity genes I'm not going to talk

85
00:03:51,190 --> 00:03:49,820
about how the metabolism works because I

86
00:03:52,600 --> 00:03:51,200
tried it over and over again I couldn't

87
00:03:55,540 --> 00:03:52,610
get it under five minutes so you can ask

88
00:03:59,950 --> 00:03:55,550

me questions about it later but in

89
00:04:02,020 --> 00:03:59,960
general the metabolism allows organisms

90
00:04:04,210 --> 00:04:02,030
to process the food particles and then

91
00:04:06,760 --> 00:04:04,220
received some energy reward for how well

92
00:04:09,400 --> 00:04:06,770
they process the food particles that

93
00:04:11,290 --> 00:04:09,410
energy is required to continue to tick

94
00:04:13,840 --> 00:04:11,300
through the genome and every time step

95
00:04:17,440 --> 00:04:13,850
in the simulation costs one each

96
00:04:20,349 --> 00:04:17,450
organism one energy unit once the

97
00:04:22,150 --> 00:04:20,359
organisms have accumulated an amount of

98
00:04:25,000 --> 00:04:22,160
energy that's equivalent to two times

99
00:04:26,590 --> 00:04:25,010
their initial allotment at the beginning

100
00:04:29,110 --> 00:04:26,600
of the simulation they automatically

101
00:04:32,770 --> 00:04:29,120
divide and that energy is split between

102
00:04:33,940 --> 00:04:32,780
the two resulting organisms I do want to

103
00:04:36,700 --> 00:04:33,950
talk briefly about the cellular

104
00:04:39,880 --> 00:04:36,710
Jeanne's so the cellularity of an

105
00:04:43,410 --> 00:04:39,890
organism is some number between zero and

106
00:04:45,790 --> 00:04:43,420
one that's defined by the number of

107
00:04:48,850 --> 00:04:45,800
cellularity genes that follows this

108
00:04:50,770 --> 00:04:48,860
equation here and a low level of

109
00:04:53,890 --> 00:04:50,780
cellularity has the consequence that the

110
00:04:57,280 --> 00:04:53,900
organism is essentially leakier so a low

111
00:04:59,320 --> 00:04:57,290
level a low cellularity organism will be

112
00:05:01,540 --> 00:04:59,330
more likely to lose genetic material to

113
00:05:02,740 --> 00:05:01,550

the environment but also receive genetic

114
00:05:04,840 --> 00:05:02,750
material that's floating around in the

115
00:05:08,350 --> 00:05:04,850
environment it will also be more likely

116
00:05:11,950 --> 00:05:08,360
to lose energy rewards that it got from

117
00:05:15,160 --> 00:05:11,960
metabolism but also receive energy that

118
00:05:19,450 --> 00:05:15,170
is floating around in the environment in

119
00:05:21,850 --> 00:05:19,460
addition to the mutations that a cell or

120
00:05:23,680 --> 00:05:21,860
an organism might have due to this

121
00:05:26,500 --> 00:05:23,690
random horizontal gene transfer that's a

122
00:05:31,480 --> 00:05:26,510
consequence of low cellularity the

123
00:05:34,080 --> 00:05:31,490
organisms are also regularly are their

124
00:05:37,770 --> 00:05:34,090
genomes are regularly mutated through

125
00:05:41,590 --> 00:05:37,780
insertions of any of these genomic

126
00:05:44,370 --> 00:05:41,600
instruction types deletions of those

127
00:05:46,690 --> 00:05:44,380
genomic instructions or small

128
00:05:49,180 --> 00:05:46,700
reconfigurations of the metabolic

129
00:05:54,940 --> 00:05:49,190
network that they use to process food

130
00:05:56,500 --> 00:05:54,950
particles and after we had created this

131
00:05:58,540 --> 00:05:56,510
digital life simulation we were kind of

132
00:06:01,810 --> 00:05:58,550
looking through the different parameter

133
00:06:03,970 --> 00:06:01,820
definable parameter spaces and trying to

134
00:06:05,950 --> 00:06:03,980
determine what would be a good area to

135
00:06:08,350 --> 00:06:05,960
investigate for selection pressures and

136
00:06:11,050 --> 00:06:08,360
one thing that we noticed was when we

137
00:06:14,230 --> 00:06:11,060
made the energy reward from processing

138
00:06:17,050 --> 00:06:14,240

food very generous we would always see

139
00:06:18,640 --> 00:06:17,060
an evolution of non cellularity and what

140
00:06:20,260 --> 00:06:18,650
we thought might have been happening is

141
00:06:22,480 --> 00:06:20,270
that organisms were starting off with

142
00:06:24,550 --> 00:06:22,490
zero cellularity it didn't take much

143
00:06:27,550 --> 00:06:24,560
metabolism basically the metabolism of a

144
00:06:29,050 --> 00:06:27,560
randomized genome to get a lot of energy

145
00:06:31,660 --> 00:06:29,060
and then that energy was leaking out

146
00:06:34,690 --> 00:06:31,670
into the environment and it behooved

147
00:06:36,760 --> 00:06:34,700
organisms to maintain a low cellularity

148
00:06:38,560 --> 00:06:36,770
so that well that's not the right way to

149
00:06:41,530 --> 00:06:38,570
talk about evolutionary processes it's

150
00:06:43,660 --> 00:06:41,540
selected for organisms that had a low

151
00:06:45,550 --> 00:06:43,670
level of cellularity because those

152
00:06:47,559 --> 00:06:45,560
organisms were able to take advantage of

153
00:06:49,329 --> 00:06:47,569
the energy pool in the environment

154
00:06:54,939 --> 00:06:49,339
so that led us to a more formal

155
00:06:56,439 --> 00:06:54,949
hypothesis that under in environments

156
00:06:59,260 --> 00:06:56,449
where there was a high level of not just

157
00:07:01,809 --> 00:06:59,270
food but the energy that is a reward

158
00:07:03,339 --> 00:07:01,819
from processing food so if we give them

159
00:07:04,719 --> 00:07:03,349
freely available energy in the

160
00:07:06,669 --> 00:07:04,729
environment that will actually select

161
00:07:08,409 --> 00:07:06,679
for non cellularity and it's only when

162
00:07:11,379 --> 00:07:08,419
we limit that energy in the environment

163
00:07:13,239 --> 00:07:11,389

that it will select for cellularity so

164
00:07:15,790 --> 00:07:13,249
we set up a series of experiments to

165
00:07:18,489 --> 00:07:15,800
test this hypothesis half of those

166
00:07:21,489 --> 00:07:18,499
experiments had simulations where

167
00:07:23,499 --> 00:07:21,499
organisms began with 0% cellularity and

168
00:07:25,209 --> 00:07:23,509
we either gave them unlimited food and

169
00:07:27,040 --> 00:07:25,219
energy in the environment or we gave

170
00:07:28,209 --> 00:07:27,050
them unlimited food but limited the

171
00:07:31,089 --> 00:07:28,219
amount of energy that was in the

172
00:07:32,980 --> 00:07:31,099
environment the other half so that we

173
00:07:35,709 --> 00:07:32,990
could assign a direction of selection

174
00:07:38,019 --> 00:07:35,719
here the other half began with a

175
00:07:39,399 --> 00:07:38,029
cellularity value of eighty seven and a

176
00:07:41,799 --> 00:07:39,409
half percent which is equivalent to

177
00:07:44,679 --> 00:07:41,809
three cellularity jeans and then again

178
00:07:47,469 --> 00:07:44,689
they either had unlimited food and

179
00:07:49,209 --> 00:07:47,479
energy in the environment or unlimited

180
00:07:51,129 --> 00:07:49,219
food but limited energy in the

181
00:07:53,589 --> 00:07:51,139
environment and we ran each of these

182
00:07:55,989 --> 00:07:53,599
different experiments under three

183
00:07:58,239 --> 00:07:55,999
different maximum population capacities

184
00:08:00,730 --> 00:07:58,249
to see whether population pressure

185
00:08:02,439 --> 00:08:00,740
played any role and then we ran each of

186
00:08:03,689 --> 00:08:02,449
those simulations three times so each of

187
00:08:06,639 --> 00:08:03,699
these experiments has nine different

188
00:08:08,350 --> 00:08:06,649

simulations and all of the results of

189
00:08:12,399 --> 00:08:08,360
those were pretty similar so I want to

190
00:08:14,920 --> 00:08:12,409
direct your attention to panel B here in

191
00:08:17,499 --> 00:08:14,930
which the organisms begin with a

192
00:08:19,059 --> 00:08:17,509
cellularity of zero percent but we limit

193
00:08:21,129 --> 00:08:19,069
the amount of energy in the environment

194
00:08:23,109 --> 00:08:21,139
and as our hypothesis would predict we

195
00:08:25,689 --> 00:08:23,119
see an evolution toward cellularity

196
00:08:27,790 --> 00:08:25,699
these are population averages of the

197
00:08:30,759 --> 00:08:27,800
cellularity across all of the organisms

198
00:08:36,879 --> 00:08:30,769
in the simulation and the cellularity

199
00:08:38,819 --> 00:08:36,889
reaches near 100% I also want to direct

200
00:08:41,379 --> 00:08:38,829
your attention to this panel where we

201
00:08:44,110 --> 00:08:41,389
where the organisms begin with a high

202
00:08:46,629 --> 00:08:44,120
level of cellularity but we give them

203
00:08:49,120 --> 00:08:46,639
both unlimited food and unlimited energy

204
00:08:52,120 --> 00:08:49,130
and in every one of these simulations

205
00:08:54,900 --> 00:08:52,130
the cellularity value of the average

206
00:08:57,939 --> 00:08:54,910
cellularity of the entire population

207
00:09:01,390 --> 00:08:57,949
settles at pretty close to 0%

208
00:09:04,020 --> 00:09:01,400
cellularity so

209
00:09:06,670 --> 00:09:04,030
our predictions were borne out by these

210
00:09:10,060 --> 00:09:06,680
experiments at the same time that we

211
00:09:12,280 --> 00:09:10,070
were measuring cellularity we were also

212
00:09:14,110 --> 00:09:12,290
measuring how good their metabolism was

213
00:09:16,750 --> 00:09:14,120

and we did that by pausing the

214
00:09:19,000 --> 00:09:16,760
simulation and giving the each organism

215
00:09:21,420 --> 00:09:19,010
1000 food particles that they would

216
00:09:24,330 --> 00:09:21,430
process and then we took the average

217
00:09:28,150 --> 00:09:24,340
quality of their solution to the food

218
00:09:29,950 --> 00:09:28,160
processing and then we averaged that

219
00:09:31,930 --> 00:09:29,960
across the whole population and we came

220
00:09:34,300 --> 00:09:31,940
up with a value of metabolic proficiency

221
00:09:36,880 --> 00:09:34,310
now a metabolic proficiency of zero

222
00:09:39,310 --> 00:09:36,890
means no metabolism is happening a

223
00:09:41,560 --> 00:09:39,320
metabolic proficiency of eight for

224
00:09:43,360 --> 00:09:41,570
reasons of how the metabolism works that

225
00:09:45,610 --> 00:09:43,370
I didn't discuss in this talk a

226
00:09:48,370 --> 00:09:45,620
metabolic proficiency of eight means a

227
00:09:50,110 --> 00:09:48,380
perfect metabolism and a randomized

228
00:09:53,170 --> 00:09:50,120
genome like the ones that they start

229
00:09:58,680 --> 00:09:53,180
with is equivalent to a little under

230
00:10:01,330 --> 00:09:58,690
four so in every scenario where we

231
00:10:03,940 --> 00:10:01,340
limited the amount of energy in the

232
00:10:07,870 --> 00:10:03,950
environment organisms had to process

233
00:10:11,140 --> 00:10:07,880
food to get energy that's panel B and E

234
00:10:13,870 --> 00:10:11,150
and in all of those cases the the

235
00:10:15,970 --> 00:10:13,880
metabolic proficiency increased over

236
00:10:21,090 --> 00:10:15,980
time but in every case where they gave

237
00:10:24,160 --> 00:10:21,100
them unlimited energy metabolism

238
00:10:26,080 --> 00:10:24,170

metabolic proficiency did not increase

239
00:10:28,870 --> 00:10:26,090
in the population so they settled at

240
00:10:33,460 --> 00:10:28,880
basically the random value R the value

241
00:10:35,710 --> 00:10:33,470
of a randomized genome so this shows

242
00:10:38,230 --> 00:10:35,720
that and these results aren't too

243
00:10:40,330 --> 00:10:38,240
surprising but taken together this shows

244
00:10:46,780 --> 00:10:40,340
that when there's energy in the

245
00:10:48,250 --> 00:10:46,790
environment that selection is that

246
00:10:50,320 --> 00:10:48,260
natural that the selection within our

247
00:10:52,810 --> 00:10:50,330
digital life simulation is selecting for

248
00:10:55,710 --> 00:10:52,820
populations of organisms that have both

249
00:10:58,090 --> 00:10:55,720
a low level of cellularity and a

250
00:11:00,520 --> 00:10:58,100
metabolic proficiency that's equivalent

251
00:11:02,860 --> 00:11:00,530
to a randomized genome when energy is

252
00:11:06,610 --> 00:11:02,870
limited in the environment organisms

253
00:11:09,280 --> 00:11:06,620
have to process food metabolically and

254
00:11:11,230 --> 00:11:09,290
so we see metabolites metabolic

255
00:11:13,000 --> 00:11:11,240
proficiency increased but we also see

256
00:11:14,950 --> 00:11:13,010
cellularity increase across the

257
00:11:17,290 --> 00:11:14,960
population

258
00:11:21,190 --> 00:11:17,300
and between these two extremes we see

259
00:11:24,150 --> 00:11:21,200
that these two traits are linked and so

260
00:11:26,140 --> 00:11:24,160
this is just the experiment in which

261
00:11:28,960 --> 00:11:26,150
organism started with zero percent

262
00:11:31,570 --> 00:11:28,970
cellularity and we gave them unlimited

263
00:11:37,000 --> 00:11:31,580

food but we limited the amount of energy

264
00:11:39,280 --> 00:11:37,010
in the environment and as cellularity

265
00:11:43,510 --> 00:11:39,290
increased so did metabolic proficiency

266
00:11:45,520 --> 00:11:43,520
so these are the the data points for all

267
00:11:48,610 --> 00:11:45,530
of all nine of the simulations in this

268
00:11:50,800 --> 00:11:48,620
experiment and you see that they're very

269
00:11:52,780 --> 00:11:50,810
strongly correlated these two traits are

270
00:11:55,330 --> 00:11:52,790
very strongly correlated with one

271
00:11:57,490 --> 00:11:55,340
another as they are evolving and so we

272
00:11:59,370 --> 00:11:57,500
take this as evidence that within the

273
00:12:02,790 --> 00:11:59,380
context of our digital life simulation

274
00:12:05,320 --> 00:12:02,800
the cellular the cellular T and

275
00:12:07,660 --> 00:12:05,330
metabolism are actually Co evolving with

276
00:12:09,370 --> 00:12:07,670
one another and we think this is

277
00:12:11,800 --> 00:12:09,380
important for the context of the origin

278
00:12:15,760 --> 00:12:11,810
of life because if you consider the kind

279
00:12:17,980 --> 00:12:15,770
of geochemical environment that we'd all

280
00:12:19,750 --> 00:12:17,990
like to see as an origin of life setting

281
00:12:23,350 --> 00:12:19,760
one that was very rich that was

282
00:12:25,360 --> 00:12:23,360
providing the early simple replicators

283
00:12:27,700 --> 00:12:25,370
with all of the materials and energy

284
00:12:29,500 --> 00:12:27,710
that they would need to keep going it's

285
00:12:33,280 --> 00:12:29,510
not just the case that the simple

286
00:12:35,980 --> 00:12:33,290
replicators were non cellular when they

287
00:12:39,070 --> 00:12:35,990
first arose but that this environment

288
00:12:42,340 --> 00:12:39,080

would have strongly selected for non

289
00:12:45,780 --> 00:12:42,350
cellularity and it wasn't until a change

290
00:12:48,490 --> 00:12:45,790
occurred in that environment that

291
00:12:51,370 --> 00:12:48,500
cellularity and metabolism would have

292
00:12:52,570 --> 00:12:51,380
co-evolved I think for the interest of

293
00:12:55,390 --> 00:12:52,580
time because I'd like to take questions

294
00:12:58,930 --> 00:12:55,400
I'm going to skip some other experiments

295
00:13:03,190 --> 00:12:58,940
and just point out that there were

296
00:13:08,160 --> 00:13:03,200
several co-authors on this work unit

297
00:13:11,290 --> 00:13:08,170
ACOG II who's shown here in my lab circa

298
00:13:14,370 --> 00:13:11,300
2015 also sitting right there as yab

299
00:13:18,310 --> 00:13:14,380
nuyen who is sitting right there or here

300
00:13:20,230 --> 00:13:18,320
from my lab this year and then Tom

301
00:13:22,800 --> 00:13:20,240
Wexler is a colleague who was at Oberlin

302
00:13:25,780 --> 00:13:22,810
College but has since left for Google

303
00:13:27,550 --> 00:13:25,790
also some funding sources who made this

304
00:13:31,780 --> 00:13:27,560
work possible and thank you for your

305
00:13:31,790 --> 00:13:36,400
[Applause]

306
00:13:42,050 --> 00:13:39,140
multiple the ability to do a metabolism

307
00:13:44,690 --> 00:13:42,060
is not the only benefit of a membrane

308
00:13:47,870 --> 00:13:44,700
for example a membrane protects yourself

309
00:13:50,090 --> 00:13:47,880
against molecular parasites and a

310
00:13:54,820 --> 00:13:50,100
membrane helps you to define yourself

311
00:13:57,860 --> 00:13:54,830
for evolution which means I think your

312
00:13:59,329 --> 00:13:57,870
your conclusion is right that once you

313
00:14:01,280 --> 00:13:59,339

need to have a metabolism you need a

314
00:14:03,710 --> 00:14:01,290
membrane but I would not make the other

315
00:14:06,290 --> 00:14:03,720
conclusion that without the necessity

316
00:14:07,730 --> 00:14:06,300
for metabolism you don't need a membrane

317
00:14:08,870 --> 00:14:07,740
actually you're absolutely right and I

318
00:14:12,190 --> 00:14:08,880
skipped over the experiment that

319
00:14:16,340 --> 00:14:12,200
demonstrates that so apologies for that

320
00:14:17,810 --> 00:14:16,350
so we actually turned off because it's a

321
00:14:19,670 --> 00:14:17,820
digital life simulation we can do that

322
00:14:22,600 --> 00:14:19,680
we turned off the consequences of

323
00:14:28,220 --> 00:14:22,610
randomized horizontal gene transfer and

324
00:14:29,690 --> 00:14:28,230
when when there is unlimited energy in

325
00:14:32,329 --> 00:14:29,700
the environment and organisms don't have

326
00:14:37,850 --> 00:14:32,339
to do metabolism we still see a strong

327
00:14:40,190 --> 00:14:37,860
selection for non cellularity but when

328
00:14:41,300 --> 00:14:40,200
there is limited energy in the

329
00:14:43,550 --> 00:14:41,310
environment and they have to do

330
00:14:46,010 --> 00:14:43,560
metabolism with horizontal gene transfer

331
00:14:47,870 --> 00:14:46,020
turned off it doesn't really settle the

332
00:14:49,010 --> 00:14:47,880
cellularity doesn't increase to a

333
00:14:50,570 --> 00:14:49,020
hundred percent or near a hundred

334
00:14:53,150 --> 00:14:50,580
percent it actually kind of fluctuates

335
00:14:56,390 --> 00:14:53,160
around and you can see we've extended

336
00:14:58,070 --> 00:14:56,400
the simulation how to ten to the fifth

337
00:15:02,410 --> 00:14:58,080
time steps and it's still fluctuating

338
00:15:06,320 --> 00:15:02,420

around and so we think that in the

339
00:15:08,630 --> 00:15:06,330
situation where there's unlimited energy

340
00:15:10,370 --> 00:15:08,640
there's selection for not having a very

341
00:15:13,070 --> 00:15:10,380
good metabolism or there's not selection

342
00:15:15,380 --> 00:15:13,080
at all for metabolism it seems to be the

343
00:15:16,610 --> 00:15:15,390
equivalent of a random randomized genome

344
00:15:19,280 --> 00:15:16,620
but there's selection for non

345
00:15:23,780 --> 00:15:19,290
cellularity to take advantage of the

346
00:15:25,850 --> 00:15:23,790
energy in the environment but when we

347
00:15:27,829 --> 00:15:25,860
limit the energy in the environment the

348
00:15:30,790 --> 00:15:27,839
selection is for having a proficient

349
00:15:34,100 --> 00:15:30,800
metabolism and cellularity just as you

350
00:15:35,960 --> 00:15:34,110
suggested is actually a mechanism for

351
00:15:38,810 --> 00:15:35,970
providing genetic fidelity to the

352
00:15:44,210 --> 00:15:41,500
a there's an interesting set of

353
00:15:45,290 --> 00:15:44,220
simulations now one of the things that

354
00:15:46,760 --> 00:15:45,300
you point out is that there's a

355
00:15:49,490 --> 00:15:46,770
selection pressure away from the

356
00:15:51,560 --> 00:15:49,500
cellularity and so my question is are

357
00:15:55,640 --> 00:15:51,570
there you know systems and modern

358
00:15:58,550 --> 00:15:55,650
biology high-energy lots of food that

359
00:16:00,530 --> 00:15:58,560
you can look to and see and it doesn't

360
00:16:03,890 --> 00:16:00,540
make sense to look at modern well you

361
00:16:06,980 --> 00:16:03,900
know I think viruses don't have to do

362
00:16:10,370 --> 00:16:06,990
their own metabolism and they need to

363
00:16:12,440 --> 00:16:10,380

have a little in a spacesuit to get from

364
00:16:14,260 --> 00:16:12,450
cell to cell but once they're in the

365
00:16:17,990 --> 00:16:14,270
cell they kind of become these non

366
00:16:19,700 --> 00:16:18,000
cellular entities within the cell and so

367
00:16:21,170 --> 00:16:19,710
that might be I can't think of any

368
00:16:23,900 --> 00:16:21,180
others off the top of my head but that

369
00:16:29,620 --> 00:16:23,910
might be a nice analogy to the kind of

370
00:16:31,140 --> 00:16:30,610
[Applause]