
AbSciCon
2019

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

2
00:00:12,299 --> 00:00:09,259
[Applause]

3
00:00:13,799 --> 00:00:12,309
I've had problems with this Absalom's in

4
00:00:17,150 --> 00:00:13,809
the past which I was just telling Nadia

5
00:00:19,409 --> 00:00:17,160
about so in the interest of

6
00:00:22,380 --> 00:00:19,419
interdisciplinarity I tried to go with a

7
00:00:23,640 --> 00:00:22,390
simpler more general title and I'm going

8
00:00:26,609 --> 00:00:23,650
to give rather than the talk I

9
00:00:28,980 --> 00:00:26,619
originally originally planned a more of

10
00:00:30,630 --> 00:00:28,990
an overview of the research program that

11
00:00:33,330 --> 00:00:30,640
we're trying to develop at Georgia Tech

12
00:00:34,890 --> 00:00:33,340
and so my new title will be stabilizing

13
00:00:37,460 --> 00:00:34,900

the evolutionary transition to

14
00:00:40,229 --> 00:00:37,470
multicellularity against reversion and

15
00:00:43,140 --> 00:00:40,239
so the evolution of multicellularity is

16
00:00:45,000 --> 00:00:43,150
one of a very small number of events in

17
00:00:48,600 --> 00:00:45,010
the history of life in which the

18
00:00:51,149 --> 00:00:48,610
hierarchical complexity of biological

19
00:00:55,170 --> 00:00:51,159
systems has increased and so the others

20
00:00:57,689 --> 00:00:55,180
in this very simplified diagram are so

21
00:00:59,939 --> 00:00:57,699
the origin of life may be considered as

22
00:01:02,520 --> 00:00:59,949
one or the origin of chromosomes the

23
00:01:04,229 --> 00:01:02,530
origin of the prokaryotic cell eukaryote

24
00:01:07,980 --> 00:01:04,239
Genesis then the evolution of

25
00:01:11,130 --> 00:01:07,990
multicellularity and later in some cases

26
00:01:14,060 --> 00:01:11,140
the evolution of eusociality and so

27
00:01:16,289 --> 00:01:14,070
multicellularity is quite unique in that

28
00:01:19,200 --> 00:01:16,299
unlike many of the other transitions

29
00:01:21,330 --> 00:01:19,210
like eukaryote genesis which we know has

30
00:01:23,789 --> 00:01:21,340
which we only know has occurred at least

31
00:01:26,660 --> 00:01:23,799
once multicellularity has evolved

32
00:01:29,730 --> 00:01:26,670
independently across multiple lineages

33
00:01:32,249 --> 00:01:29,740
here in the eukaryotes it's thought to

34
00:01:35,310 --> 00:01:32,259
have occurred at least 25 times and I

35
00:01:38,190 --> 00:01:35,320
think the big question for us in the

36
00:01:41,039 --> 00:01:38,200
field of multicellularity research now

37
00:01:43,730 --> 00:01:41,049
that Frank rosensweig set up very nicely

38
00:01:46,800 --> 00:01:43,740

is how do you go from a unicellular

39
00:01:50,130 --> 00:01:46,810
ancestor of say metazoan all metazoans

40
00:01:52,160 --> 00:01:50,140
to something like a kangaroo and so I've

41
00:01:57,179 --> 00:01:52,170
simplified that process in this

42
00:01:59,249 --> 00:01:57,189
three-part diagram so our understanding

43
00:02:01,559 --> 00:01:59,259
of multicellularity is sort of in its

44
00:02:04,129 --> 00:02:01,569
infancy in terms of the process that

45
00:02:06,359 --> 00:02:04,139
generates something like a kangaroo from

46
00:02:09,150 --> 00:02:06,369
something that may resemble a coin of

47
00:02:10,559 --> 00:02:09,160
flageolet so first we think there are

48
00:02:13,230 --> 00:02:10,569
it's necessary that you have external

49
00:02:15,890 --> 00:02:13,240
drivers that create the benefit to you

50
00:02:19,410 --> 00:02:15,900
forming a simple social group of cells

51
00:02:22,050 --> 00:02:19,420
so that that drives the increased group

52
00:02:23,430 --> 00:02:22,060
size from one to many

53
00:02:26,130 --> 00:02:23,440
and then later there are subsequent

54
00:02:28,500 --> 00:02:26,140
social changes associated with the

55
00:02:31,080 --> 00:02:28,510
transformation of simple groups to more

56
00:02:33,030 --> 00:02:31,090
complex ones and this could be anything

57
00:02:35,490 --> 00:02:33,040
and this is the part that we really

58
00:02:38,699 --> 00:02:35,500
don't quite understand so I would argue

59
00:02:41,960 --> 00:02:38,709
that our our understanding of these

60
00:02:45,479 --> 00:02:41,970
external drivers and their role is

61
00:02:47,699 --> 00:02:45,489
fairly well-established we have good

62
00:02:49,440 --> 00:02:47,709
theoretical and empirical results to

63
00:02:51,809 --> 00:02:49,450

support things like increased stress

64
00:02:54,920 --> 00:02:51,819
tolerance protection from predation and

65
00:02:57,600 --> 00:02:54,930
improved utilization of public goods as

66
00:03:00,900 --> 00:02:57,610
good drivers that might favor the

67
00:03:02,520 --> 00:03:00,910
evolution of simple social groups but

68
00:03:06,150 --> 00:03:02,530
what we really don't understand are

69
00:03:08,280 --> 00:03:06,160
these social changes but are associated

70
00:03:12,180 --> 00:03:08,290
with increases in the complexity of

71
00:03:13,979 --> 00:03:12,190
those simple groups and so as I may not

72
00:03:16,830 --> 00:03:13,989
have mentioned I work in the field of

73
00:03:18,809 --> 00:03:16,840
experimental evolution and actually

74
00:03:21,690 --> 00:03:18,819
there have been research groups evolving

75
00:03:26,100 --> 00:03:21,700
simple multicellular organisms in the

76
00:03:29,160 --> 00:03:26,110
laboratory for about 25 years and this

77
00:03:31,350 --> 00:03:29,170
is just a small sampling maybe I've

78
00:03:33,600 --> 00:03:31,360
captured about half of the instances of

79
00:03:37,680 --> 00:03:33,610
this happening in the field there have

80
00:03:40,470 --> 00:03:37,690
been multiple works with algae both this

81
00:03:42,420 --> 00:03:40,480
chlorella vulgaris in the middle and two

82
00:03:45,410 --> 00:03:42,430
experiments with different selective

83
00:03:48,509 --> 00:03:45,420
pressures with commit aluminium bonus

84
00:03:51,630 --> 00:03:48,519
there's also been work done in bacterial

85
00:03:54,960 --> 00:03:51,640
systems as well as different yeast model

86
00:03:57,060 --> 00:03:54,970
organisms and so there's just two

87
00:04:00,780 --> 00:03:57,070
lessons I want to summarize across these

88
00:04:02,970 --> 00:04:00,790

25 years of history of this emerging

89
00:04:05,400 --> 00:04:02,980
discipline so first simple

90
00:04:08,610 --> 00:04:05,410
multicellularity seems to evolve quite

91
00:04:11,520 --> 00:04:08,620
rapidly under the right conditions so

92
00:04:13,890 --> 00:04:11,530
all the experiments that I summarized

93
00:04:16,860 --> 00:04:13,900
here in the slide saw the evolution of

94
00:04:18,990 --> 00:04:16,870
multicellular genotypes over the course

95
00:04:21,870 --> 00:04:19,000
of a few hundred generations or less and

96
00:04:24,659 --> 00:04:21,880
this suggests that the genetic barriers

97
00:04:26,520 --> 00:04:24,669
to making this transition this first

98
00:04:30,029 --> 00:04:26,530
step of the transition at least are

99
00:04:32,370 --> 00:04:30,039
quite minimal the second lesson from

100
00:04:34,440 --> 00:04:32,380
experimental evolution is that simple

101
00:04:35,640 --> 00:04:34,450
multicellularity seems to be costly in

102
00:04:38,700 --> 00:04:35,650
the absence of these

103
00:04:41,280 --> 00:04:38,710
kernel drivers so just to pull out two

104
00:04:44,520 --> 00:04:41,290
examples in the yeast in the yeast

105
00:04:47,520 --> 00:04:44,530
picture on top right there was a ten

106
00:04:50,790 --> 00:04:47,530
percent cost measured by Ratcliffe a

107
00:04:52,770 --> 00:04:50,800
Talon twenty twelve when their snowflake

108
00:04:55,020 --> 00:04:52,780
yeast system was grown in liquid medium

109
00:04:56,879 --> 00:04:55,030
without the external driver in their

110
00:04:59,219 --> 00:04:56,889
case which was selection for rapid

111
00:05:01,409 --> 00:04:59,229
sedimentation and in the bacteria

112
00:05:03,050 --> 00:05:01,419
example there was a twenty percent cost

113
00:05:06,659 --> 00:05:03,060

measured in Pseudomonas fluorescens

114
00:05:08,310 --> 00:05:06,669
wrinkly spreaders when there was colony

115
00:05:12,510 --> 00:05:08,320
colonization of the air water interface

116
00:05:15,029 --> 00:05:12,520
was not necessary and so together these

117
00:05:18,540 --> 00:05:15,039
two lessons point towards a major

118
00:05:20,490 --> 00:05:18,550
problem for the increase subsequent

119
00:05:23,159 --> 00:05:20,500
increases in complexity for new

120
00:05:24,750 --> 00:05:23,169
multicellular forms which is that if you

121
00:05:28,800 --> 00:05:24,760
have something that's genetically labile

122
00:05:30,680 --> 00:05:28,810
and has high fitness costs when the

123
00:05:34,560 --> 00:05:30,690
external drivers are not present you

124
00:05:37,110 --> 00:05:34,570
should see the the reversion of back to

125
00:05:40,230 --> 00:05:37,120
unicellular t should the environment

126
00:05:42,900 --> 00:05:40,240
change and actually maria replicated

127
00:05:44,879 --> 00:05:42,910
gomez and mike travisano had a pair of

128
00:05:47,189 --> 00:05:44,889
great papers come out in the past year

129
00:05:49,790 --> 00:05:47,199
where they measured exactly this

130
00:05:54,149 --> 00:05:49,800
so using that snowflake yeast system

131
00:05:56,399 --> 00:05:54,159
they first show in a growth in liquid

132
00:05:58,200 --> 00:05:56,409
without settling selection that ten

133
00:06:00,480 --> 00:05:58,210
percent fitness costs they measure that

134
00:06:03,240 --> 00:06:00,490
i mentioned and they also demonstrated

135
00:06:05,610 --> 00:06:03,250
that when you do your selections on agar

136
00:06:08,580 --> 00:06:05,620
plates there's an even greater fitness

137
00:06:11,490 --> 00:06:08,590
cost for the multicellular forms so what

138
00:06:15,800 --> 00:06:11,500

they found really interestingly here we

139
00:06:18,510 --> 00:06:15,810
have a simple histograms of the area

140
00:06:21,540 --> 00:06:18,520
have these multicellular types that form

141
00:06:23,670 --> 00:06:21,550
a distribution of clump sizes over the

142
00:06:26,250 --> 00:06:23,680
course of 30 days when they're doing

143
00:06:29,189 --> 00:06:26,260
selection on plates you see rapidly

144
00:06:32,730 --> 00:06:29,199
going from the black distribution to the

145
00:06:34,890 --> 00:06:32,740
lighter ones you see size decrease quite

146
00:06:37,350 --> 00:06:34,900
rapidly but when you do your selections

147
00:06:39,839 --> 00:06:37,360
in liquid that size decreases both

148
00:06:43,350 --> 00:06:39,849
slower and less pronounced

149
00:06:46,080 --> 00:06:43,360
and so the cost associated with the

150
00:06:49,380 --> 00:06:46,090
simple multicellularity actually is a

151
00:06:53,040 --> 00:06:49,390
good predictor of how rapidly multi cell

152
00:06:56,420 --> 00:06:53,050
we'll be lost as well as the extent to

153
00:06:58,830 --> 00:06:56,430
which the phenotype will change and so

154
00:07:02,160 --> 00:06:58,840
we need at least one more arrow in my

155
00:07:04,020 --> 00:07:02,170
simple diagram which is that before you

156
00:07:06,680 --> 00:07:04,030
get locked into this positive feedback

157
00:07:09,600 --> 00:07:06,690
loop that produces things like kangaroos

158
00:07:11,430 --> 00:07:09,610
you might actually experience an

159
00:07:15,570 --> 00:07:11,440
environmental change that favors you

160
00:07:18,420 --> 00:07:15,580
exiting this simple this simple system

161
00:07:19,020 --> 00:07:18,430
and so the vicious cycle can't ever

162
00:07:20,940 --> 00:07:19,030
occur

163
00:07:23,490 --> 00:07:20,950

you'll never get increases in complexity

164
00:07:26,250 --> 00:07:23,500
and so this is this is just say that

165
00:07:27,840 --> 00:07:26,260
reversion may in fact be a major problem

166
00:07:32,580 --> 00:07:27,850
that we should consider in the evolution

167
00:07:35,000 --> 00:07:32,590
of multicellularity and so in my view

168
00:07:37,110 --> 00:07:35,010
there's probably two possible routes to

169
00:07:39,480 --> 00:07:37,120
stabilizing the evolution of

170
00:07:41,820 --> 00:07:39,490
multicellularity the first being you can

171
00:07:44,130 --> 00:07:41,830
reduce the number of potential reversion

172
00:07:46,650 --> 00:07:44,140
mutations so here I've drawn just a

173
00:07:49,500 --> 00:07:46,660
simplest distribution of fitness effects

174
00:07:54,930 --> 00:07:49,510
of reversion mutations that I could

175
00:07:59,370 --> 00:07:54,940
imagine so here you have this greyed out

176
00:08:01,140 --> 00:07:59,380
dashed you know modal distribution that

177
00:08:03,330 --> 00:08:01,150
represents all the possible mutations

178
00:08:04,500 --> 00:08:03,340
that will cause a reversion and the

179
00:08:06,240 --> 00:08:04,510
arrow is saying that through

180
00:08:08,730 --> 00:08:06,250
evolutionary time while you're in this

181
00:08:10,740 --> 00:08:08,740
positive feedback loop you may lose some

182
00:08:12,480 --> 00:08:10,750
of those potential routes back to

183
00:08:15,620 --> 00:08:12,490
unicellular T that's just a question

184
00:08:18,630 --> 00:08:15,630
about the availability of mutations

185
00:08:22,500 --> 00:08:18,640
another route would be to reduce the

186
00:08:25,920 --> 00:08:22,510
selective advantage to fixing one of

187
00:08:28,170 --> 00:08:25,930
those reversion mutations so if by

188
00:08:31,110 --> 00:08:28,180

further genetic interactions and

189
00:08:33,000 --> 00:08:31,120
mutations reversion is no longer

190
00:08:35,219 --> 00:08:33,010
beneficial even when you have

191
00:08:38,360 --> 00:08:35,229
environmental change then that should

192
00:08:44,070 --> 00:08:38,370
also prevent the exiting of this

193
00:08:46,170 --> 00:08:44,080
cyclical this cycle here that I had on

194
00:08:51,630 --> 00:08:46,180
the previous slide or of course you can

195
00:08:53,610 --> 00:08:51,640
do both and so we saw we our aim was to

196
00:08:55,260 --> 00:08:53,620
look for evidence of whether either of

197
00:08:58,020 --> 00:08:55,270
these two processes were happening in

198
00:09:00,210 --> 00:08:58,030
our laboratory experiments so we also

199
00:09:02,590 --> 00:09:00,220
are working with the sacrum icy service

200
00:09:05,620 --> 00:09:02,600
see a snowflake yeast system

201
00:09:07,749 --> 00:09:05,630
and what will Ratcliffe in my crevice on

202
00:09:09,400 --> 00:09:07,759
Oh and others did in this original

203
00:09:12,910 --> 00:09:09,410
experiment is they subjected a

204
00:09:15,189 --> 00:09:12,920
unicellular strain of baker's yeast to

205
00:09:18,759 --> 00:09:15,199
selection for rapid settling in liquid

206
00:09:21,519 --> 00:09:18,769
media and over the course of 60 days or

207
00:09:24,370 --> 00:09:21,529
fewer they got things that grew in this

208
00:09:26,620 --> 00:09:24,380
beautiful fractal like pattern and being

209
00:09:29,079 --> 00:09:26,630
from Minnesota as I already spoiled they

210
00:09:35,019 --> 00:09:29,089
called it snowflake yeast because that

211
00:09:38,319 --> 00:09:35,029
was familiar so the thing that really

212
00:09:40,800 --> 00:09:38,329
enables our present study is that the

213
00:09:43,180 --> 00:09:40,810

genetics of multicellularity are

214
00:09:46,210 --> 00:09:43,190
excessively simple in this system at

215
00:09:50,590 --> 00:09:46,220
least in five of the 10 original

216
00:09:52,749 --> 00:09:50,600
isolates the mutation was a single loss

217
00:09:55,180 --> 00:09:52,759
of function in a transcription factor

218
00:09:57,340 --> 00:09:55,190
called ace 2 that produced the

219
00:09:59,259 --> 00:09:57,350
multicellular growth form and the

220
00:10:04,240 --> 00:09:59,269
restoration of a functional copy of ace

221
00:10:06,519 --> 00:10:04,250
2 can produce unicellular progeny so

222
00:10:09,340 --> 00:10:06,529
here's the original mutant here's a

223
00:10:12,040 --> 00:10:09,350
functional ace to put into that mutant

224
00:10:14,350 --> 00:10:12,050
and here if you knock out both copies of

225
00:10:17,319 --> 00:10:14,360
the ancestral type you recapitulate the

226
00:10:20,050 --> 00:10:17,329
snowflake yeast form and so we did this

227
00:10:23,860 --> 00:10:20,060
from the original 60 day evolution

228
00:10:26,889 --> 00:10:23,870
experiment and just at two-two intervals

229
00:10:29,530 --> 00:10:26,899
so and then we measured a competitive

230
00:10:31,300 --> 00:10:29,540
fitness of the unicellular riverton's

231
00:10:34,030 --> 00:10:31,310
that were derived from multicellular

232
00:10:36,340 --> 00:10:34,040
types against their ancestors and what

233
00:10:38,439 --> 00:10:36,350
we saw was really striking is that at

234
00:10:40,179 --> 00:10:38,449
the beginning their fitness is equal to

235
00:10:44,530 --> 00:10:40,189
their ancestor they haven't undergone

236
00:10:46,179 --> 00:10:44,540
any mutations but then by 30 transfers

237
00:10:47,679 --> 00:10:46,189
they were a bit lower which is the

238
00:10:51,249 --> 00:10:47,689

opposite of what you normally expect and

239
00:10:53,889 --> 00:10:51,259
then by 60 days there was about a 5%

240
00:10:56,470 --> 00:10:53,899
fitness cost associated with this

241
00:10:58,509 --> 00:10:56,480
reversion mutation so this is this is

242
00:11:02,559 --> 00:10:58,519
evidence of that second class of

243
00:11:05,679 --> 00:11:02,569
mutations potentially fixing and at

244
00:11:08,470 --> 00:11:05,689
least in the case of the transition the

245
00:11:10,960 --> 00:11:08,480
the difference between day 30 and day 60

246
00:11:13,329 --> 00:11:10,970
we had a few candidate traits that we

247
00:11:16,030 --> 00:11:13,339
thought might explain this decrease in

248
00:11:18,220 --> 00:11:16,040
unicellular Fitness so

249
00:11:20,370 --> 00:11:18,230
he's populate this particular population

250
00:11:23,130 --> 00:11:20,380
of all of dicks elevated rates of

251
00:11:26,380 --> 00:11:23,140
programmed cell death or apoptosis as

252
00:11:28,240 --> 00:11:26,390
well as increased cell size and we have

253
00:11:31,000 --> 00:11:28,250
these uh priori reasons to think that

254
00:11:33,220 --> 00:11:31,010
those traits might be costly in a

255
00:11:37,150 --> 00:11:33,230
unicellular background but beneficial

256
00:11:38,260 --> 00:11:37,160
for the multi cells so what we really

257
00:11:41,470 --> 00:11:38,270
want to know after getting this

258
00:11:43,240 --> 00:11:41,480
provocative first piece of data is what

259
00:11:46,780 --> 00:11:43,250
are the dynamics and the consequences of

260
00:11:50,110 --> 00:11:46,790
long-term selection on size and luckily

261
00:11:52,630 --> 00:11:50,120
for me and hopefully for other people we

262
00:11:55,000 --> 00:11:52,640
already had a fantastic postdoc that

263
00:11:56,350 --> 00:11:55,010

joined the lab years before me that was

264
00:11:59,110 --> 00:11:56,360
conducting a long term evolution

265
00:12:01,150 --> 00:11:59,120
experiment with settling selection and

266
00:12:03,940 --> 00:12:01,160
that is ozone buzz Doug who's here in

267
00:12:05,890 --> 00:12:03,950
the audience and later today he'll be

268
00:12:09,310 --> 00:12:05,900
giving a poster on this long term

269
00:12:11,770 --> 00:12:09,320
experiment and also talking a bit about

270
00:12:13,390 --> 00:12:11,780
the effects of high and low oxygen

271
00:12:15,730 --> 00:12:13,400
levels on the evolution of multicellular

272
00:12:19,480 --> 00:12:15,740
size so please check out his poster this

273
00:12:22,180 --> 00:12:19,490
evening but what we did is again take

274
00:12:24,190 --> 00:12:22,190
all of the isolates from this original

275
00:12:26,110 --> 00:12:24,200
experiment and perform these genetic

276
00:12:28,930 --> 00:12:26,120
reversions on them and so on the next

277
00:12:31,870 --> 00:12:28,940
slide and I promised Frank it'll

278
00:12:34,210 --> 00:12:31,880
actually happen on the next slide will

279
00:12:37,720 --> 00:12:34,220
either these dots that are representing

280
00:12:40,240 --> 00:12:37,730
day 200 day 400 and day 600 isolates

281
00:12:42,730 --> 00:12:40,250
from two parallel experiments that ozone

282
00:12:45,730 --> 00:12:42,740
had run will sit tell you whether or not

283
00:12:48,880 --> 00:12:45,740
the transform ins with a functional h2

284
00:12:50,740 --> 00:12:48,890
are unicellular or multicellular and so

285
00:12:54,190 --> 00:12:50,750
unsurprisingly based on the way I set

286
00:12:56,020 --> 00:12:54,200
this up we have some some some of the

287
00:12:57,280 --> 00:12:56,030
populations have actually lost the

288
00:12:59,500 --> 00:12:57,290

ability to revert to you know

289
00:13:02,220 --> 00:12:59,510
cellularity when we put a functional ace

290
00:13:04,870 --> 00:13:02,230
2 back into them this was particularly

291
00:13:06,760 --> 00:13:04,880
validating for us because the two

292
00:13:09,660 --> 00:13:06,770
populations are actually the three

293
00:13:13,390 --> 00:13:09,670
populations at the bottom there that

294
00:13:16,690 --> 00:13:13,400
were unable to revert also exhibited the

295
00:13:18,430 --> 00:13:16,700
most pronounced phenotypic changes over

296
00:13:20,920 --> 00:13:18,440
the course of these 600 days of

297
00:13:23,470 --> 00:13:20,930
evolution and one of those really

298
00:13:25,120 --> 00:13:23,480
dramatic changes was that the site the

299
00:13:28,270 --> 00:13:25,130
average size of the snowflake yeast

300
00:13:29,230 --> 00:13:28,280
clusters increased from 50 microns in

301
00:13:36,759 --> 00:13:29,240
diameter

302
00:13:39,999 --> 00:13:36,769
so we did some genome sequencing of

303
00:13:42,129 --> 00:13:40,009
these large 600 transfer isolates those

304
00:13:45,220 --> 00:13:42,139
suggest further genes of interest that

305
00:13:46,720 --> 00:13:45,230
might be costly in a unicellular context

306
00:13:49,299 --> 00:13:46,730
but beneficial in a multicellular

307
00:13:51,249 --> 00:13:49,309
context and many of them are associated

308
00:13:53,489 --> 00:13:51,259
with the phenotypes that we think are

309
00:13:58,869 --> 00:13:53,499
enabling this extremely large size

310
00:14:03,009 --> 00:13:58,879
namely very elongated cells and both

311
00:14:05,049 --> 00:14:03,019
polar and side budding and so if you're

312
00:14:07,389 --> 00:14:05,059
interested in some of these new

313
00:14:09,489 --> 00:14:07,399

candidate genes and the interaction

314
00:14:11,679 --> 00:14:09,499
between those genes we have another

315
00:14:14,410 --> 00:14:11,689
postdoc here also giving a poster this

316
00:14:15,970 --> 00:14:14,420
evening Toni Bernette II and his poster

317
00:14:19,660 --> 00:14:15,980
will be in the Evergreen Ballroom as

318
00:14:22,569 --> 00:14:19,670
well and so in summary our results

319
00:14:25,660 --> 00:14:22,579
suggest this third model where both the

320
00:14:28,210 --> 00:14:25,670
Fitness effects of reversion mutations

321
00:14:31,030 --> 00:14:28,220
as well as the availability of reversion

322
00:14:32,319 --> 00:14:31,040
mutations is changing over evolutionary

323
00:14:35,109 --> 00:14:32,329
time at least for some of our

324
00:14:37,329 --> 00:14:35,119
populations the failure of the

325
00:14:40,059 --> 00:14:37,339
functional ASA to to restore unicellular

326
00:14:44,019 --> 00:14:40,069
T is associated with more dramatic

327
00:14:46,499 --> 00:14:44,029
phenotypic changes and we'll continue

328
00:14:50,859 --> 00:14:46,509
working on this and be doing some direct

329
00:14:52,749 --> 00:14:50,869
pairwise competitions with these more

330
00:14:54,640 --> 00:14:52,759
derived strains in the future so thank