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1
00:00:05,990 --> 00:00:05,430
we know a lot about the biological tree

2
00:00:07,510 --> 00:00:06,000
of life

3
00:00:09,350 --> 00:00:07,520
and can trace life's evolutionary

4
00:00:11,910 --> 00:00:09,360
history all the way back to a last

5
00:00:13,350 --> 00:00:11,920
universal common ancestor

6
00:00:14,870 --> 00:00:13,360
but for all that we understand about the

7
00:00:16,630 --> 00:00:14,880
tree of life there's still a great deal

8
00:00:18,550 --> 00:00:16,640
that we don't understand about its root

9
00:00:20,390 --> 00:00:18,560
system

10
00:00:22,550 --> 00:00:20,400
research on the origin of life can focus

11
00:00:24,790 --> 00:00:22,560
on any of a number of stages in life's

12
00:00:26,790 --> 00:00:24,800
emergence

13
00:00:28,070 --> 00:00:26,800

some origins of life research takes a

14
00:00:30,150 --> 00:00:28,080
top-down approach

15
00:00:32,310 --> 00:00:30,160
looking at the proximate ancestors to

16
00:00:34,229 --> 00:00:32,320
the last universal common ancestor

17
00:00:35,750 --> 00:00:34,239
with all of the historical contingencies

18
00:00:38,630 --> 00:00:35,760
they may have picked up along the way in

19
00:00:42,310 --> 00:00:40,389
alternatively one can take more of a

20
00:00:44,549 --> 00:00:42,320
bottom-up approach investigating the

21
00:00:46,229 --> 00:00:44,559
earliest stages of life's emergence

22
00:00:47,590 --> 00:00:46,239
when it only has the first intimations

23
00:00:50,069 --> 00:00:47,600
of lifelike behavior

24
00:00:53,830 --> 00:00:50,079
and when few significant historical

25
00:00:57,830 --> 00:00:55,590
auto catalytic cycles may have been an

26
00:00:59,990 --> 00:00:57,840
important part of life's chemical roots

27
00:01:00,790 --> 00:01:00,000
providing a means by which chemicals can

28
00:01:03,430 --> 00:01:00,800
collectively

29
00:01:05,189 --> 00:01:03,440
self-propagate the chemicals involved in

30
00:01:07,510 --> 00:01:05,199
auto-catalytic cycles

31
00:01:10,230 --> 00:01:07,520
can be split into three categories food

32
00:01:11,830 --> 00:01:10,240
species which only show up as reactants

33
00:01:13,750 --> 00:01:11,840
waste species that only show up as

34
00:01:15,990 --> 00:01:13,760
products and member species which show

35
00:01:17,749 --> 00:01:16,000
up as both products and reactants

36
00:01:20,390 --> 00:01:17,759
and whose abundance grow with each turn

37
00:01:21,990 --> 00:01:20,400
of the cycle

38
00:01:23,910 --> 00:01:22,000

here we have a simple toy model for an

39
00:01:25,429 --> 00:01:23,920
auto catalytic cycle consisting of two

40
00:01:26,710 --> 00:01:25,439
reversible reactions

41
00:01:28,469 --> 00:01:26,720
the first of which produces an

42
00:01:30,069 --> 00:01:28,479
intermediary member species and the

43
00:01:31,830 --> 00:01:30,079
second of which produces two of the

44
00:01:33,830 --> 00:01:31,840
original member species

45
00:01:36,469 --> 00:01:33,840
this provides a stoichiometric asymmetry

46
00:01:38,390 --> 00:01:36,479
that allows the cycle to grow and spread

47
00:01:40,149 --> 00:01:38,400
we simulate auto catalytic cycles in

48
00:01:41,670 --> 00:01:40,159
flow reactor environments where food

49
00:01:43,030 --> 00:01:41,680
flows in from a source to drive the

50
00:01:44,710 --> 00:01:43,040
system out of equilibrium

51
00:01:46,870 --> 00:01:44,720
and where all chemicals flow out of the

52
00:01:48,630 --> 00:01:46,880
reactor such that if a cycle doesn't

53
00:01:49,350 --> 00:01:48,640
propagate itself fast enough it will go

54
00:01:51,350 --> 00:01:49,360
extinct

55
00:01:52,789 --> 00:01:51,360
these simulations can be performed using

56
00:01:54,870 --> 00:01:52,799
mass action kinetics in which case

57
00:01:56,709 --> 00:01:54,880
chemical concentrations are continuous

58
00:01:58,389 --> 00:01:56,719
and the simulations are deterministic

59
00:02:00,389 --> 00:01:58,399
we're using the gillespie algorithm in

60
00:02:02,550 --> 00:02:00,399
which case chemical counts are discrete

61
00:02:04,149 --> 00:02:02,560
and the simulations are stochastic we

62
00:02:04,870 --> 00:02:04,159
use the gillespie algorithm in this

63
00:02:06,469 --> 00:02:04,880

presentation

64
00:02:08,229 --> 00:02:06,479
an example is on the right you can see

65
00:02:11,110 --> 00:02:08,239
the logistic growth of member species

66
00:02:12,949 --> 00:02:11,120
and waste species as food is depleted

67
00:02:14,309 --> 00:02:12,959
in 2020 we published a paper

68
00:02:15,750 --> 00:02:14,319
investigating the different types of

69
00:02:17,670 --> 00:02:15,760
ecological interactions that auto

70
00:02:19,589 --> 00:02:17,680
catalytic cycles might exhibit

71
00:02:22,710 --> 00:02:19,599
extending the analogy of auto catalytic

72
00:02:24,710 --> 00:02:22,720
cycles as species in an ecosystem

73
00:02:26,390 --> 00:02:24,720
we showed that auto catalytic cycles can

74
00:02:27,910 --> 00:02:26,400
compete for food sources

75
00:02:29,990 --> 00:02:27,920
exhibit facultative and obligate

76
00:02:32,630 --> 00:02:30,000
mutualisms with the waste of one

77
00:02:34,550 --> 00:02:32,640
serving as the food for another that the

78
00:02:36,150 --> 00:02:34,560
one cycle can prey on the member species

79
00:02:38,070 --> 00:02:36,160
of another cycle and that cycles can

80
00:02:40,710 --> 00:02:38,080
mutually inhibit one another

81
00:02:42,630 --> 00:02:40,720
the idea is that different ecological

82
00:02:44,390 --> 00:02:42,640
interactions can be composed to form

83
00:02:45,509 --> 00:02:44,400
stable ecosystems of increasing

84
00:02:47,110 --> 00:02:45,519
complexity

85
00:02:49,750 --> 00:02:47,120
to provide the scaffolding for later

86
00:02:51,830 --> 00:02:49,760
stages in the emergence of

87
00:02:53,830 --> 00:02:51,840
this previous work limited its analysis

88
00:02:54,790 --> 00:02:53,840

to auto catalytic cycles in well-mixed

89
00:02:56,390 --> 00:02:54,800
environments

90
00:02:58,470 --> 00:02:56,400
but the ecological possibilities for

91
00:03:00,470 --> 00:02:58,480
chemical ecosystems might be expanded if

92
00:03:02,390 --> 00:03:00,480
we consider different types of spatially

93
00:03:04,550 --> 00:03:02,400
structured environments instead

94
00:03:06,390 --> 00:03:04,560
for example reaction diffusion systems

95
00:03:08,630 --> 00:03:06,400
where cycles can spread

96
00:03:10,149 --> 00:03:08,640
to occupy new locations and thereby gain

97
00:03:11,990 --> 00:03:10,159
access to new food

98
00:03:14,470 --> 00:03:12,000
these will be the primary focus of this

99
00:03:15,910 --> 00:03:14,480
presentation

100
00:03:17,110 --> 00:03:15,920
there are several reasons the spatial

101
00:03:19,350 --> 00:03:17,120
structure might be important to the

102
00:03:20,869 --> 00:03:19,360
dynamics of chemical ecosystems

103
00:03:22,550 --> 00:03:20,879
first it might help to sustain more

104
00:03:24,229 --> 00:03:22,560
complex chemical ecosystems by

105
00:03:25,910 --> 00:03:24,239
permitting the coexistence of cycles

106
00:03:26,949 --> 00:03:25,920
that couldn't coexist in a well-mixed

107
00:03:30,630 --> 00:03:26,959
environment

108
00:03:32,070 --> 00:03:30,640
might select for spatial properties of

109
00:03:34,630 --> 00:03:32,080
auto catalytic cycles

110
00:03:36,630 --> 00:03:34,640
such as the permeability or diffusivity

111
00:03:39,030 --> 00:03:36,640
of their constituent chemicals

112
00:03:40,390 --> 00:03:39,040
and third spatial structure might create

113
00:03:42,309 --> 00:03:40,400

new levels of selection

114
00:03:43,430 --> 00:03:42,319
either favoring traits that couldn't be

115
00:03:45,910 --> 00:03:43,440
favored in the well-mixed

116
00:03:47,589 --> 00:03:45,920
environment analogous to group structure

117
00:03:48,949 --> 00:03:47,599
favoring different traits and biological

118
00:03:51,030 --> 00:03:48,959
populations

119
00:03:52,630 --> 00:03:51,040
or creating new units of selection

120
00:03:54,149 --> 00:03:52,640
altogether

121
00:03:56,149 --> 00:03:54,159
first i'm going to present a simple

122
00:03:57,589 --> 00:03:56,159
example where a spatially structured

123
00:03:59,589 --> 00:03:57,599
environment permits a more complex

124
00:04:01,030 --> 00:03:59,599
chemical ecosystem to be maintained

125
00:04:03,110 --> 00:04:01,040
then could otherwise be maintained in

126
00:04:05,190 --> 00:04:03,120
the well-mixed case this is going to be

127
00:04:07,429 --> 00:04:05,200
similar in spirit to the bz reaction

128
00:04:09,509 --> 00:04:07,439
which has auto catalytic mechanisms

129
00:04:11,110 --> 00:04:09,519
and which while oscillating between two

130
00:04:13,429 --> 00:04:11,120
states in the wellmix case

131
00:04:15,990 --> 00:04:13,439
exhibits stable and dynamic patterns and

132
00:04:17,909 --> 00:04:16,000
as a reaction diffusion system

133
00:04:19,749 --> 00:04:17,919
this example is going to consist of two

134
00:04:20,310 --> 00:04:19,759
mutually inhibiting auto catalytic

135
00:04:22,629 --> 00:04:20,320
cycles

136
00:04:23,830 --> 00:04:22,639
a and b which are colored red and blue

137
00:04:25,270 --> 00:04:23,840
respectively

138
00:04:26,629 --> 00:04:25,280

each cycle is supplied with an

139
00:04:29,189 --> 00:04:26,639
independent food source so that they're

140
00:04:30,870 --> 00:04:29,199
not directly competing for food

141
00:04:32,950 --> 00:04:30,880
each consists of two reversible

142
00:04:34,390 --> 00:04:32,960
reactions identical to the toy model i

143
00:04:36,629 --> 00:04:34,400
initially showed

144
00:04:37,990 --> 00:04:36,639
additionally we include two reversible

145
00:04:40,230 --> 00:04:38,000
inhibition reactions

146
00:04:42,469 --> 00:04:40,240
which react the waste of one cycle with

147
00:04:43,510 --> 00:04:42,479
the food of the other cycle to produce

148
00:04:46,150 --> 00:04:43,520
another species

149
00:04:47,270 --> 00:04:46,160
x or y that neither cycle can directly

150
00:04:49,270 --> 00:04:47,280
use

151
00:04:51,510 --> 00:04:49,280
the effect of this is that if one cycle

152
00:04:54,070 --> 00:04:51,520
increases its abundance more quickly

153
00:04:55,430 --> 00:04:54,080
the waste that it produces can inhibit

154
00:04:57,670 --> 00:04:55,440
the growth of the other cycle

155
00:04:59,990 --> 00:04:57,680
ultimately driving it extinct and once

156
00:05:00,710 --> 00:05:00,000
again all chemicals will be constantly

157
00:05:03,189 --> 00:05:00,720
diluted

158
00:05:06,469 --> 00:05:03,199
creating a selective pressure for cycles

159
00:05:08,390 --> 00:05:06,479
that can propagate more quickly

160
00:05:09,670 --> 00:05:08,400
instead of simulating this chemical

161
00:05:11,830 --> 00:05:09,680
reaction network

162
00:05:13,909 --> 00:05:11,840
in a singular flow reactor will simulate

163
00:05:16,150 --> 00:05:13,919

it in a reaction diffusion system

164
00:05:18,230 --> 00:05:16,160
where each pixel has inflow from a

165
00:05:20,870 --> 00:05:18,240
source and outflow into a sink

166
00:05:24,870 --> 00:05:20,880
but also exchanges its chemical contents

167
00:05:27,110 --> 00:05:24,880
with neighboring pixels via diffusion

168
00:05:29,270 --> 00:05:27,120
more specifically we'll use a 5x5

169
00:05:31,029 --> 00:05:29,280
reaction diffusion system with periodic

170
00:05:33,510 --> 00:05:31,039
boundaries

171
00:05:34,390 --> 00:05:33,520
now if we were to seed every pixel in

172
00:05:37,590 --> 00:05:34,400
this system

173
00:05:38,550 --> 00:05:37,600
uniformly with equal amounts of cycles a

174
00:05:41,350 --> 00:05:38,560
and b

175
00:05:43,189 --> 00:05:41,360
but with no diffusion it would be

176
00:05:46,310 --> 00:05:43,199
possible to have an outcome like this

177
00:05:49,510 --> 00:05:46,320
in which cycles a and b dominate

178
00:05:51,270 --> 00:05:49,520
in adjacent pixels and stably coexist

179
00:05:53,749 --> 00:05:51,280
because there is no interaction between

180
00:05:54,310 --> 00:05:53,759
those pixels if we were to add diffusion

181
00:05:57,909 --> 00:05:54,320
in

182
00:05:59,990 --> 00:05:57,919
this sort of outcome would be unstable

183
00:06:01,510 --> 00:06:00,000
for example with any slight imbalance

184
00:06:03,270 --> 00:06:01,520
like blue coming to dominate in the

185
00:06:05,830 --> 00:06:03,280
center

186
00:06:07,749 --> 00:06:05,840
accumulated member species by cycle b in

187
00:06:09,909 --> 00:06:07,759
the center could diffuse outwards

188
00:06:13,510 --> 00:06:09,919

and strengthen the invasion of pixels

189
00:06:17,430 --> 00:06:15,430
and with high enough diffusion rates we

190
00:06:19,590 --> 00:06:17,440
would expect the whole system to reach

191
00:06:21,990 --> 00:06:19,600
one global outcome

192
00:06:23,510 --> 00:06:22,000
here we have stochastic simulations of

193
00:06:25,670 --> 00:06:23,520
the reaction diffusion system

194
00:06:26,550 --> 00:06:25,680
under three different conditions where

195
00:06:29,189 --> 00:06:26,560
we're varying

196
00:06:31,029 --> 00:06:29,199
the rate constant for the diffusion of

197
00:06:32,790 --> 00:06:31,039
all chemicals in the system

198
00:06:35,909 --> 00:06:32,800
we have a slow diffusion case a moderate

199
00:06:37,909 --> 00:06:35,919
diffusion case and a fast diffusion case

200
00:06:39,749 --> 00:06:37,919
here we have time series plots for the

201
00:06:40,790 --> 00:06:39,759
total number of member species belonging

202
00:06:42,710 --> 00:06:40,800
to each cycle

203
00:06:45,430 --> 00:06:42,720
and each pixel of the reaction diffusion

204
00:06:47,430 --> 00:06:45,440
system for each of the three cases

205
00:06:48,870 --> 00:06:47,440
on the left in the slow diffusion case

206
00:06:51,670 --> 00:06:48,880
we can see that each pixel

207
00:06:53,670 --> 00:06:51,680
quickly has one cycle dominate and that

208
00:06:55,110 --> 00:06:53,680
a low amount of material is exchanged

209
00:06:57,430 --> 00:06:55,120
between reactors

210
00:06:59,670 --> 00:06:57,440
such that each cycle struggles to invade

211
00:07:02,070 --> 00:06:59,680
adjacent pixels

212
00:07:03,830 --> 00:07:02,080
on the right we see the opposite extreme

213
00:07:05,990 --> 00:07:03,840

a large amount of chemicals are

214
00:07:07,909 --> 00:07:06,000
exchanged between adjacent pixels

215
00:07:10,070 --> 00:07:07,919
so that the plots tend to resemble one

216
00:07:10,550 --> 00:07:10,080
another and a global outcome is quickly

217
00:07:13,510 --> 00:07:10,560
reached

218
00:07:15,830 --> 00:07:13,520
approximating a well-mixed reactor in

219
00:07:17,830 --> 00:07:15,840
the moderate diffusion regime each pixel

220
00:07:18,469 --> 00:07:17,840
alternates between being dominated by

221
00:07:21,670 --> 00:07:18,479
cycle a

222
00:07:23,990 --> 00:07:21,680
and cycle b neither cycle wins globally

223
00:07:25,589 --> 00:07:24,000
and each shifts around its advantage

224
00:07:27,430 --> 00:07:25,599
forming patterns reminiscent

225
00:07:30,309 --> 00:07:27,440
of the spatial patterns of the bc

226
00:07:35,189 --> 00:07:30,319
reaction in a petri dish

227
00:07:39,670 --> 00:07:37,510
next i'll continue using the example of

228
00:07:40,790 --> 00:07:39,680
mutually inhibiting cycles in a reaction

229
00:07:42,550 --> 00:07:40,800
diffusion system

230
00:07:44,309 --> 00:07:42,560
to show a case where the spatial

231
00:07:46,550 --> 00:07:44,319
properties of auto catalytic cycles can

232
00:07:48,390 --> 00:07:46,560
be selected for

233
00:07:50,950 --> 00:07:48,400
we'll take the same two mutually

234
00:07:52,950 --> 00:07:50,960
inhibiting cycles that we had before

235
00:07:55,029 --> 00:07:52,960
but instead of making them identical to

236
00:07:57,510 --> 00:07:55,039
one another in their rate constants

237
00:07:58,950 --> 00:07:57,520
and the diffusion constants associated

238
00:08:01,270 --> 00:07:58,960

with their chemicals

239
00:08:02,150 --> 00:08:01,280
we're going to make them differ in two

240
00:08:04,550 --> 00:08:02,160
ways

241
00:08:06,070 --> 00:08:04,560
the red cycle is going to be fiercer in

242
00:08:08,390 --> 00:08:06,080
the sense that it's going to have

243
00:08:10,469 --> 00:08:08,400
reactions with higher rate constants

244
00:08:11,990 --> 00:08:10,479
but the blue cycle is going to be faster

245
00:08:16,550 --> 00:08:12,000
meaning that its member species are

246
00:08:20,710 --> 00:08:18,629
we are going to do this in a 3x3

247
00:08:21,670 --> 00:08:20,720
reaction diffusion system with periodic

248
00:08:24,150 --> 00:08:21,680
boundaries

249
00:08:25,110 --> 00:08:24,160
where both cycles are only seated in the

250
00:08:29,110 --> 00:08:25,120
center pixel

251
00:08:34,790 --> 00:08:32,230
the expectation is that cycle a in red

252
00:08:36,230 --> 00:08:34,800
being fiercer will tend to dominate in

253
00:08:39,110 --> 00:08:36,240
the central pixel

254
00:08:39,990 --> 00:08:39,120
whereas cycle b in blue being faster

255
00:08:42,230 --> 00:08:40,000
will tend to spread

256
00:08:45,750 --> 00:08:42,240
more quickly to adjacent pixels and

257
00:08:48,710 --> 00:08:45,760
thereby access new food more quickly

258
00:08:49,750 --> 00:08:48,720
as cycle b continues to expand it might

259
00:08:51,110 --> 00:08:49,760
be able to build up

260
00:08:53,190 --> 00:08:51,120
enough of an advantage in the

261
00:08:54,150 --> 00:08:53,200
surrounding pixels to re-invade the

262
00:08:57,829 --> 00:08:54,160
central pixel

263
00:09:00,070 --> 00:08:57,839

and overcome cycle a here we have an

264
00:09:02,070 --> 00:09:00,080
animation of the unfolding of time

265
00:09:04,070 --> 00:09:02,080
series of the total number of member

266
00:09:07,190 --> 00:09:04,080
species for each cycle in each pixel of

267
00:09:10,470 --> 00:09:09,590
in the central pixel cycle a being

268
00:09:11,990 --> 00:09:10,480
fiercer

269
00:09:14,710 --> 00:09:12,000
drives cycle b to the brink of

270
00:09:17,030 --> 00:09:14,720
extinction but cycle b being faster

271
00:09:18,630 --> 00:09:17,040
is able to diffuse into adjacent sites

272
00:09:20,150 --> 00:09:18,640
and build up an advantage in those

273
00:09:22,230 --> 00:09:20,160
pixels more quickly

274
00:09:23,750 --> 00:09:22,240
so that it can suppress the growth of

275
00:09:26,230 --> 00:09:23,760
cycle a

276
00:09:27,829 --> 00:09:26,240
eventually cycle b is able to re-invade

277
00:09:29,590 --> 00:09:27,839
the central pixel

278
00:09:33,030 --> 00:09:29,600
to such an extent that it begins to

279
00:09:34,870 --> 00:09:33,040
drive cycle a towards extinction

280
00:09:36,870 --> 00:09:34,880
the outcome of this type of simulation

281
00:09:39,030 --> 00:09:36,880
largely depends on the relative fastness

282
00:09:40,870 --> 00:09:39,040
and fierceness of cycles a and b

283
00:09:43,110 --> 00:09:40,880
here we have a heat map in which we

284
00:09:45,829 --> 00:09:43,120
sweep over those parameters

285
00:09:48,470 --> 00:09:45,839
on the left we sweep over the diffusion

286
00:09:50,470 --> 00:09:48,480
constants for the chemicals of cycle b

287
00:09:52,230 --> 00:09:50,480
where as we go down cycle b gets

288
00:09:54,630 --> 00:09:52,240

increasingly fast

289
00:09:55,750 --> 00:09:54,640
on the bottom we sweep over the reaction

290
00:09:58,550 --> 00:09:55,760
rate constants

291
00:09:59,750 --> 00:09:58,560
for cycle b's reactions whereas we move

292
00:10:03,829 --> 00:09:59,760
from right to left

293
00:10:05,670 --> 00:10:03,839
cycle b gets increasingly less fierce

294
00:10:06,870 --> 00:10:05,680
the colors in the heat map encode the

295
00:10:09,430 --> 00:10:06,880
final frequency

296
00:10:10,230 --> 00:10:09,440
of member species for cycles a and b

297
00:10:13,430 --> 00:10:10,240
aggregated

298
00:10:15,509 --> 00:10:13,440
over the reaction diffusion system we

299
00:10:17,750 --> 00:10:15,519
find parameter combinations where

300
00:10:20,310 --> 00:10:17,760
fastness overcomes fierceness and where

301
00:10:22,069 --> 00:10:20,320
fierceness overcomes fastness

302
00:10:24,069 --> 00:10:22,079
meaning that either could be selected

303
00:10:26,150 --> 00:10:24,079
for

304
00:10:28,310 --> 00:10:26,160
additionally while it is always better

305
00:10:29,750 --> 00:10:28,320
to be fiercer it is not always better to

306
00:10:32,230 --> 00:10:29,760
be faster

307
00:10:33,190 --> 00:10:32,240
in the bottom left we see a region where

308
00:10:35,750 --> 00:10:33,200
cycle b

309
00:10:37,590 --> 00:10:35,760
being faster gives it a disadvantage to

310
00:10:40,310 --> 00:10:37,600
cycle a

311
00:10:41,910 --> 00:10:40,320
likely because its members diffuse so

312
00:10:43,829 --> 00:10:41,920
quickly that they can't stably

313
00:10:45,750 --> 00:10:43,839

accumulate

314
00:10:47,190 --> 00:10:45,760
in addition to simple reaction diffusion

315
00:10:48,870 --> 00:10:47,200
systems there are various other

316
00:10:50,550 --> 00:10:48,880
spatially structured environments that

317
00:10:52,310 --> 00:10:50,560
may be relevant to the origin of life

318
00:10:53,910 --> 00:10:52,320
and to the dynamics of auto catalytic

319
00:10:56,069 --> 00:10:53,920
chemical ecosystems

320
00:10:58,230 --> 00:10:56,079
for example mineral surfaces where

321
00:10:59,030 --> 00:10:58,240
chemicals can adsorb and desorb from a

322
00:11:03,430 --> 00:10:59,040
surface

323
00:11:05,269 --> 00:11:03,440
and also provide a new basis for

324
00:11:07,269 --> 00:11:05,279
competition between auto catalytic

325
00:11:08,710 --> 00:11:07,279
cycles as they compete for adsorption

326
00:11:10,710 --> 00:11:08,720
sites

327
00:11:12,310 --> 00:11:10,720
compartments are another important class

328
00:11:12,949 --> 00:11:12,320
of spatial structures that might affect

329
00:11:15,030 --> 00:11:12,959
the dynamic

330
00:11:16,870 --> 00:11:15,040
chemical ecosystems they might be

331
00:11:19,829 --> 00:11:16,880
semi-permeable or closed

332
00:11:21,430 --> 00:11:19,839
they might grow and or divide some

333
00:11:22,150 --> 00:11:21,440
examples of these in the origins of life

334
00:11:25,430 --> 00:11:22,160
literature

335
00:11:26,470 --> 00:11:25,440
are vesicles and coagulate some forms of

336
00:11:28,630 --> 00:11:26,480
spatial structure

337
00:11:30,710 --> 00:11:28,640
especially compartments provide the

338
00:11:32,550 --> 00:11:30,720

possibility of new levels of selection

339
00:11:34,310 --> 00:11:32,560
especially when the dynamics of the

340
00:11:36,230 --> 00:11:34,320
spatial structure become coupled to the

341
00:11:38,630 --> 00:11:36,240
chemistry itself

342
00:11:40,389 --> 00:11:38,640
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343
00:11:41,670 --> 00:11:40,399
david baum who i've been working with

344
00:11:43,190 --> 00:11:41,680
through the hildale undergraduate

345
00:11:44,870 --> 00:11:43,200
faculty research fellowship at the

346
00:11:46,630 --> 00:11:44,880
wisconsin institute for discovery

347
00:11:48,069 --> 00:11:46,640
and chris kemp is my mentor at the santa

348
00:11:50,230 --> 00:11:48,079
fe institute for the undergraduate

349
00:11:51,590 --> 00:11:50,240
complexity research program

350
00:11:53,030 --> 00:11:51,600
also the graduate students and

351
00:11:54,550 --> 00:11:53,040
post-doctoral students that i've been

352
00:11:55,750 --> 00:11:54,560
working with at the wisconsin institute

353
00:11:57,430 --> 00:11:55,760
for discovery

354
00:11:59,509 --> 00:11:57,440
and the other undergraduates in the bomb

355
00:12:01,030 --> 00:11:59,519
lab as well

356
00:12:02,790 --> 00:12:01,040
for additional reading you can check out

357
00:12:04,470 --> 00:12:02,800
our paper from last year in ecological

358
00:12:07,430 --> 00:12:04,480
framework for the analysis of prebiotic

359
00:12:08,790 --> 00:12:07,440
chemical reaction networks