AB GRAD CON23

1
00:00:04,230 --> 00:00:11,169
[Music]

2
00:00:16,310 --> 00:00:14,150
hi there I'm Alex Plum my talk is on

3
00:00:18,650 --> 00:00:16,320
auto catalytic chemical ecosystems in

4
00:00:20,090 --> 00:00:18,660
spatial settings uh

5
00:00:22,490 --> 00:00:20,100
so I wanted to start with this quote

6
00:00:24,230 --> 00:00:22,500
from the French naturalist George cuvier

7
00:00:26,150 --> 00:00:24,240
I don't think it's a good definition of

8
00:00:28,009 --> 00:00:26,160
life but I think it captures one feature

9
00:00:29,269 --> 00:00:28,019
of life that's very important uh

10
00:00:30,950 --> 00:00:29,279
specifically this feature of

11
00:00:33,709 --> 00:00:30,960
autocatalysis which I think is the

12
00:00:35,090 --> 00:00:33,719
central Motif for self-propagation that

13
00:00:36,410 --> 00:00:35,100

we see kind of all across life and it

14
00:00:38,690 --> 00:00:36,420
may have been relevant in life's

15
00:00:40,850 --> 00:00:38,700
earliest stages so we say that a process

16
00:00:42,889 --> 00:00:40,860
is auto catalytic if the products of

17
00:00:44,750 --> 00:00:42,899
that process catalyze the process itself

18
00:00:46,670 --> 00:00:44,760
here I'm going to be talking about Auto

19
00:00:48,590 --> 00:00:46,680
catalytic Cycles where you have a

20
00:00:50,510 --> 00:00:48,600
sequence of reactions that form a cycle

21
00:00:52,790 --> 00:00:50,520
such that with every turn of the cycle

22
00:00:54,590 --> 00:00:52,800
you get a stoichiometric increase in the

23
00:00:56,869 --> 00:00:54,600
number of some set of chemicals that

24
00:00:58,549 --> 00:00:56,879
we'll call member chemicals you can take

25
00:01:00,470 --> 00:00:58,559
all of the chemicals involved in an auto

26
00:01:03,410 --> 00:01:00,480
catalytic cycle and partition them into

27
00:01:04,850 --> 00:01:03,420
food chemicals into member chemicals and

28
00:01:06,530 --> 00:01:04,860
into waste chemicals based on which

29
00:01:08,270 --> 00:01:06,540
sides of the reactions they show up in

30
00:01:10,490 --> 00:01:08,280
and so here's a simple example where you

31
00:01:13,010 --> 00:01:10,500
just have two reversible reactions you

32
00:01:15,050 --> 00:01:13,020
have two member chemicals M1 and M2 you

33
00:01:18,050 --> 00:01:15,060
have one food that's being used for both

34
00:01:19,490 --> 00:01:18,060
reactions and waste chemical and in

35
00:01:22,010 --> 00:01:19,500
principle these can be be irreversible

36
00:01:24,469 --> 00:01:22,020
here I've drawn them as reversible and

37
00:01:26,990 --> 00:01:24,479
because they're reversible you can drive

38
00:01:28,550 --> 00:01:27,000

them in either direction if you have an

39
00:01:30,050 --> 00:01:28,560
abundance of food they can be driven in

40
00:01:31,789 --> 00:01:30,060
the productive direction that provides

41
00:01:32,929 --> 00:01:31,799
the stoichiometric increase in the

42
00:01:34,910 --> 00:01:32,939
member chemicals allowing them to

43
00:01:36,890 --> 00:01:34,920
self-propagate but if instead you have

44
00:01:38,450 --> 00:01:36,900
an accumulation of waste it can kind of

45
00:01:40,010 --> 00:01:38,460
wind down in the other direction and you

46
00:01:43,429 --> 00:01:40,020
can get a stoichiometric decrease in the

47
00:01:45,890 --> 00:01:43,439
number of member chemicals as well

48
00:01:47,929 --> 00:01:45,900
so we've analogized these Auto catalytic

49
00:01:49,249 --> 00:01:47,939
Cycles to biological species in part

50
00:01:50,749 --> 00:01:49,259
because they're consuming food they're

51
00:01:52,370 --> 00:01:50,759
producing waste and self-propagating

52
00:01:55,010 --> 00:01:52,380
themselves and we've demonstrated that

53
00:01:57,410 --> 00:01:55,020
they can exhibit logistic growth

54
00:01:59,030 --> 00:01:57,420
if you put them in a closed reactor some

55
00:02:00,469 --> 00:01:59,040
amount of food available some seed

56
00:02:02,389 --> 00:02:00,479
member species

57
00:02:04,670 --> 00:02:02,399
they can start growing and they can

58
00:02:06,289 --> 00:02:04,680
reach equilibrium concentrations but

59
00:02:07,789 --> 00:02:06,299
this isn't of great interest in an

60
00:02:09,529 --> 00:02:07,799
origins of Life context because life

61
00:02:11,270 --> 00:02:09,539
isn't out of equilibrium process so in

62
00:02:13,910 --> 00:02:11,280
practice we typically simulate these

63
00:02:16,309 --> 00:02:13,920

cycles and chemostats when you have an

64
00:02:18,050 --> 00:02:16,319
inflow of food from a source that drives

65
00:02:20,030 --> 00:02:18,060
them in the productive or autocatalytic

66
00:02:22,850 --> 00:02:20,040
Direction and where everything is

67
00:02:24,650 --> 00:02:22,860
diluted out of the system and this has

68
00:02:26,390 --> 00:02:24,660
two implications one it helps to offload

69
00:02:28,369 --> 00:02:26,400
the waste to kind of keep it from being

70
00:02:30,229 --> 00:02:28,379
driven in the other direction and it

71
00:02:32,089 --> 00:02:30,239
also provides a selective pressure so

72
00:02:33,830 --> 00:02:32,099
that now if the cycle doesn't replicate

73
00:02:35,809 --> 00:02:33,840
or propagate its member species quickly

74
00:02:37,369 --> 00:02:35,819
enough they'll just be diluted out of

75
00:02:38,809 --> 00:02:37,379
the reactor so it's not trivial that

76
00:02:41,110 --> 00:02:38,819
these Cycles are going to persist

77
00:02:43,009 --> 00:02:41,120
anymore persistence becomes a problem

78
00:02:44,030 --> 00:02:43,019
something that they have to kind of

79
00:02:45,650 --> 00:02:44,040
achieve

80
00:02:47,210 --> 00:02:45,660
so when you simulate these you can get

81
00:02:48,410 --> 00:02:47,220
time series that looks like this plot

82
00:02:49,850 --> 00:02:48,420
over here

83
00:02:51,530 --> 00:02:49,860
where you have a depletion of food

84
00:02:53,030 --> 00:02:51,540
through time you have logistic growth in

85
00:02:54,949 --> 00:02:53,040
the concentrations of member chemicals

86
00:02:56,330 --> 00:02:54,959
here in blue and you also have a buildup

87
00:02:58,369 --> 00:02:56,340
of waste

88
00:03:00,050 --> 00:02:58,379

you can choose to simulate them using

89
00:03:01,790 --> 00:03:00,060
ordinary differential equations if

90
00:03:03,229 --> 00:03:01,800
you're in a well-mixed reactor

91
00:03:04,670 --> 00:03:03,239
and that assumes that you have large

92
00:03:06,770 --> 00:03:04,680
enough quantities that you can treat

93
00:03:08,570 --> 00:03:06,780
continuous concentrations of chemicals

94
00:03:10,369 --> 00:03:08,580
the other approach is to simulate things

95
00:03:12,229 --> 00:03:10,379
stochastically and in kind of the large

96
00:03:14,210 --> 00:03:12,239
and limit this looks very similar to The

97
00:03:15,949 --> 00:03:14,220
Continuous case but as you go to smaller

98
00:03:17,869 --> 00:03:15,959
and smaller numbers of chemicals things

99
00:03:19,490 --> 00:03:17,879
look a lot noisier and you can start to

100
00:03:21,470 --> 00:03:19,500
have more contingency in the Dynamics

101
00:03:23,509 --> 00:03:21,480
where you can have the stochastic loss

102
00:03:25,430 --> 00:03:23,519
of a single chemical or the stochastic

103
00:03:27,830 --> 00:03:25,440
dispersal of a single chemical in a new

104
00:03:30,050 --> 00:03:27,840
location changing the dynamic somewhere

105
00:03:31,430 --> 00:03:30,060
else and so in everything I show here

106
00:03:33,589 --> 00:03:31,440
I'll be taking this to catch a

107
00:03:35,330 --> 00:03:33,599
stochastic approach

108
00:03:37,790 --> 00:03:35,340
so that's all the Dynamics for a single

109
00:03:39,770 --> 00:03:37,800
cycle we're ultimately interested in

110
00:03:42,710 --> 00:03:39,780
combining different cycles and seeing

111
00:03:44,630 --> 00:03:42,720
how they interact ecologically so here I

112
00:03:47,030 --> 00:03:44,640
show the the member chemical

113
00:03:49,850 --> 00:03:47,040

concentrations over time or counts over

114
00:03:51,830 --> 00:03:49,860
time for the different Auto catalytic

115
00:03:53,449 --> 00:03:51,840
Cycles shown on the left here they can

116
00:03:55,430 --> 00:03:53,459
exhibit competitive exclusion

117
00:03:57,530 --> 00:03:55,440
competitive coexistence when they share

118
00:03:59,690 --> 00:03:57,540
a common food source they can also

119
00:04:01,550 --> 00:03:59,700
exhibit mutualisms wherein the food or

120
00:04:03,830 --> 00:04:01,560
the waste of one chemical serves as food

121
00:04:06,530 --> 00:04:03,840
for another Auto catalytic cycle

122
00:04:08,270 --> 00:04:06,540
they can also exhibit predation where in

123
00:04:10,070 --> 00:04:08,280
the member chemicals of one cycle serve

124
00:04:11,630 --> 00:04:10,080
as the food for another cycle and the

125
00:04:13,250 --> 00:04:11,640
Dynamics resemble those that you get in

126
00:04:15,170 --> 00:04:13,260
the lack of Altera equations in ecology

127
00:04:17,449 --> 00:04:15,180
where you can get both stable and damped

128
00:04:19,490 --> 00:04:17,459
oscillations predator or prey dominance

129
00:04:21,949 --> 00:04:19,500
or coexistence of the the predator and

130
00:04:23,930 --> 00:04:21,959
prey and you can also get priority

131
00:04:26,030 --> 00:04:23,940
effects wherein two cycles might

132
00:04:28,969 --> 00:04:26,040
mutually inhibit one another so that it

133
00:04:31,010 --> 00:04:28,979
matters if one cycle gets seated in a

134
00:04:32,390 --> 00:04:31,020
location first versus the other since

135
00:04:34,189 --> 00:04:32,400
they'll suppress the growth of the other

136
00:04:35,930 --> 00:04:34,199
cycle

137
00:04:38,749 --> 00:04:35,940
so why is this relevant to the origin of

138
00:04:40,850 --> 00:04:38,759

life we think that these Auto catalytic

139
00:04:43,730 --> 00:04:40,860
Cycles provide one of the simplest ways

140
00:04:46,070 --> 00:04:43,740
in the absence of needing compartments

141
00:04:47,390 --> 00:04:46,080
or polymer genetics to get this sort of

142
00:04:48,469 --> 00:04:47,400
self-propagation that you see in

143
00:04:50,510 --> 00:04:48,479
metabolism

144
00:04:51,770 --> 00:04:50,520
and we think that they can provide an

145
00:04:54,050 --> 00:04:51,780
Avenue for the accumulation of

146
00:04:56,210 --> 00:04:54,060
complexity to ultimately serve as

147
00:04:58,010 --> 00:04:56,220
precursors or scaffolds for later stages

148
00:04:59,629 --> 00:04:58,020
in the origin of life so as an Avenue

149
00:05:01,730 --> 00:04:59,639
for kind of increasing the chemical

150
00:05:03,469 --> 00:05:01,740
diversity that you might need to achieve

151
00:05:05,150 --> 00:05:03,479
later stages and we think that you can

152
00:05:06,590 --> 00:05:05,160
do that by taking individual Cycles

153
00:05:08,930 --> 00:05:06,600
composing them through various

154
00:05:10,310 --> 00:05:08,940
ecological interactions and then using

155
00:05:11,689 --> 00:05:10,320
the sorts of avenues that we see in

156
00:05:12,830 --> 00:05:11,699
ecology for the accumulation of

157
00:05:16,909 --> 00:05:12,840
complexity

158
00:05:19,249 --> 00:05:16,919
ecology one way is through ecological

159
00:05:21,170 --> 00:05:19,259
succession wherein you have some species

160
00:05:23,029 --> 00:05:21,180
that lay the groundwork for others to

161
00:05:24,830 --> 00:05:23,039
later succeed them you can imagine this

162
00:05:26,689 --> 00:05:24,840
in a Chemical Context where the waste or

163
00:05:28,430 --> 00:05:26,699

member chemicals enable the activation

164
00:05:30,290 --> 00:05:28,440
of new Cycles they couldn't have been

165
00:05:32,629 --> 00:05:30,300
activated into those first Cycles were

166
00:05:34,610 --> 00:05:32,639
activated you also have ideas on ecology

167
00:05:36,050 --> 00:05:34,620
about how to maximize biodiversity for

168
00:05:38,270 --> 00:05:36,060
example through the intermediate

169
00:05:39,890 --> 00:05:38,280
disturbance hypothesis and finally you

170
00:05:41,330 --> 00:05:39,900
have ideas about how spatial structure

171
00:05:43,430 --> 00:05:41,340
can be relevant to the accumulation of

172
00:05:45,409 --> 00:05:43,440
complexity in ecosystems where you have

173
00:05:47,689 --> 00:05:45,419
meta ecosystems and diversity among them

174
00:05:49,370 --> 00:05:47,699
and migration between them that allows

175
00:05:51,409 --> 00:05:49,380
for recombination in the formation of

176
00:05:53,270 --> 00:05:51,419
new ecological States

177
00:05:54,409 --> 00:05:53,280
so in an origins of Life context we

178
00:05:56,990 --> 00:05:54,419
often think about these chemical

179
00:05:58,670 --> 00:05:57,000
ecosystems as persisting and spatially

180
00:06:02,029 --> 00:05:58,680
structured environment like adsorbitive

181
00:06:03,230 --> 00:06:02,039
mineral surfaces uh moving across those

182
00:06:04,670 --> 00:06:03,240
surfaces where they're effectively

183
00:06:07,070 --> 00:06:04,680
concentrated where their diffusion is

184
00:06:09,050 --> 00:06:07,080
effectively lowered and those different

185
00:06:11,029 --> 00:06:09,060
ecosystems might interact

186
00:06:12,650 --> 00:06:11,039
when they interact they might annihilate

187
00:06:14,990 --> 00:06:12,660
they might continue to coexist they

188
00:06:18,710 --> 00:06:15,000

might fuse and modify one another and so

189
00:06:20,870 --> 00:06:18,720
we wanted to understand how uh these

190
00:06:22,490 --> 00:06:20,880
chemical ecosystems behave in space so

191
00:06:23,689 --> 00:06:22,500
the earlier kind of ecological time

192
00:06:25,670 --> 00:06:23,699
series that I showed you were all in

193
00:06:27,770 --> 00:06:25,680
well-mixed reactors now we're going to

194
00:06:29,450 --> 00:06:27,780
consider these systems in space so

195
00:06:30,710 --> 00:06:29,460
here's an example where a cycle is

196
00:06:32,330 --> 00:06:30,720
seated in the center and diffuses

197
00:06:34,070 --> 00:06:32,340
outwards kind of spreading to new

198
00:06:35,570 --> 00:06:34,080
sources of food and of course we know

199
00:06:37,309 --> 00:06:35,580
that spatial Dynamics are important for

200
00:06:38,990 --> 00:06:37,319
auto catalytic chemical systems we have

201
00:06:40,670 --> 00:06:39,000
classic examples like the belazov's

202
00:06:42,110 --> 00:06:40,680
abatinsky reaction it's out of

203
00:06:44,510 --> 00:06:42,120
equilibrium process we know that they

204
00:06:47,090 --> 00:06:44,520
can form stable patterns

205
00:06:48,710 --> 00:06:47,100
so I want to consider cases where Cycles

206
00:06:50,809 --> 00:06:48,720
mutually inhibit one another because

207
00:06:52,309 --> 00:06:50,819
getting more complex ecosystems is easy

208
00:06:53,870 --> 00:06:52,319
when there are mutualisms between the

209
00:06:55,730 --> 00:06:53,880
Cycles it's hard when you have

210
00:06:57,290 --> 00:06:55,740
inhibition between them and there are

211
00:06:58,730 --> 00:06:57,300
various ways that Cycles can inhibit one

212
00:07:00,290 --> 00:06:58,740
another for example you can have the

213
00:07:01,969 --> 00:07:00,300

waste of one cycle interfere with the

214
00:07:03,650 --> 00:07:01,979
food of another cycle or you can have

215
00:07:04,969 --> 00:07:03,660
their member species annihilate a much

216
00:07:06,290 --> 00:07:04,979
simpler example that I show in the

217
00:07:08,629 --> 00:07:06,300
bottom this is the one that I'm going to

218
00:07:10,249 --> 00:07:08,639
be working with in the subsequent slides

219
00:07:12,409 --> 00:07:10,259
so you can put these in space here I

220
00:07:14,090 --> 00:07:12,419
have a hexagonal lattice with chemicals

221
00:07:15,529 --> 00:07:14,100
reacting within each site and diffusing

222
00:07:17,390 --> 00:07:15,539
between sites

223
00:07:19,070 --> 00:07:17,400
and I'm coloring them according to the

224
00:07:20,629 --> 00:07:19,080
fraction of member species that belong

225
00:07:23,390 --> 00:07:20,639
to one of these two mutually inhibiting

226
00:07:26,870 --> 00:07:23,400
Cycles red for cycle a B for are blue

227
00:07:28,730 --> 00:07:26,880
for cycle B and with slow diffusion they

228
00:07:30,890 --> 00:07:28,740
stop interacting and just form these

229
00:07:32,809 --> 00:07:30,900
stable patches with much higher

230
00:07:34,790 --> 00:07:32,819
diffusion you can see one cycle starts

231
00:07:36,110 --> 00:07:34,800
to crowd the other out globally and we

232
00:07:38,029 --> 00:07:36,120
can look at this more systematically

233
00:07:40,070 --> 00:07:38,039
varying the diffusion of all the

234
00:07:42,890 --> 00:07:40,080
chemicals involved kind of gradually

235
00:07:45,350 --> 00:07:42,900
increasing in the low case low diffusion

236
00:07:47,870 --> 00:07:45,360
case you end up with pretty randomly

237
00:07:49,189 --> 00:07:47,880
distributed ecological outcomes and the

238
00:07:51,170 --> 00:07:49,199

very high case you end up with one

239
00:07:53,510 --> 00:07:51,180
Global winner one cycle Drive in the

240
00:07:57,230 --> 00:07:53,520
other extinct and you can look at the

241
00:07:59,210 --> 00:07:57,240
heterogeneity of chemicals across this

242
00:08:02,089 --> 00:07:59,220
hexagonal lattice and what we find is

243
00:08:04,490 --> 00:08:02,099
that an intermediate diffusion regimes

244
00:08:06,170 --> 00:08:04,500
this heterogeneity is maximized

245
00:08:07,550 --> 00:08:06,180
and insofar as these Cycles are

246
00:08:08,870 --> 00:08:07,560
inhibiting one another through these

247
00:08:11,809 --> 00:08:08,880
reactions that might produce other

248
00:08:13,309 --> 00:08:11,819
chemicals that could help to provide

249
00:08:14,390 --> 00:08:13,319
support for the activation of future

250
00:08:16,010 --> 00:08:14,400
Cycles

251
00:08:17,689 --> 00:08:16,020
you don't have that sort of interaction

252
00:08:19,010 --> 00:08:17,699
in the very very low diffusion case and

253
00:08:21,050 --> 00:08:19,020
you also lose it in the height of each

254
00:08:22,730 --> 00:08:21,060
in case when one cycle is driven extinct

255
00:08:24,890 --> 00:08:22,740
and so this suggests that some

256
00:08:26,990 --> 00:08:24,900
intermediate diffusion regimes are the

257
00:08:29,150 --> 00:08:27,000
most favorable to uh kind of this

258
00:08:31,610 --> 00:08:29,160
biodiversity so to speak of these

259
00:08:34,190 --> 00:08:31,620
chemical ecosystems

260
00:08:35,510 --> 00:08:34,200
that's all with keeping these Cycles on

261
00:08:36,949 --> 00:08:35,520
an equal playing field where they have

262
00:08:38,750 --> 00:08:36,959
the same reaction kinetics and the same

263
00:08:40,850 --> 00:08:38,760

diffusion properties what I want to show

264
00:08:43,070 --> 00:08:40,860
next is when you vary the properties of

265
00:08:45,590 --> 00:08:43,080
these two cycles asymmetrically so I'm

266
00:08:47,630 --> 00:08:45,600
showing time series here on the right of

267
00:08:49,670 --> 00:08:47,640
both Cycles being seated in some Central

268
00:08:52,970 --> 00:08:49,680
site in a three by three array and they

269
00:08:55,550 --> 00:08:52,980
can diffuse outwards I make cycle a in

270
00:08:58,190 --> 00:08:55,560
Red fiercer so that it consumes

271
00:08:59,750 --> 00:08:58,200
food more quickly than cycle B and

272
00:09:01,430 --> 00:08:59,760
because of that it starts to drive cycle

273
00:09:03,889 --> 00:09:01,440
B extinct initially

274
00:09:05,509 --> 00:09:03,899
but cycle B is made faster than cycle a

275
00:09:07,250 --> 00:09:05,519
meaning that it can diffuse outward more

276
00:09:09,410 --> 00:09:07,260
quickly and access new sources of food

277
00:09:11,750 --> 00:09:09,420
and so despite initially being driven

278
00:09:14,630 --> 00:09:11,760
down it manages to dominate in these

279
00:09:16,070 --> 00:09:14,640
outer sites and eventually reinvade so

280
00:09:18,829 --> 00:09:16,080
that in the long term it ends up driving

281
00:09:20,930 --> 00:09:18,839
cycle a extinct

282
00:09:22,310 --> 00:09:20,940
and you can kind of vary these

283
00:09:24,290 --> 00:09:22,320
properties systematically and construct

284
00:09:25,970 --> 00:09:24,300
a phase diagram here I vary the relative

285
00:09:28,370 --> 00:09:25,980
fierceness and relative fastness of the

286
00:09:29,870 --> 00:09:28,380
two cycles and you find regimes in which

287
00:09:31,970 --> 00:09:29,880
either of the Cycles can be favored

288
00:09:33,650 --> 00:09:31,980

suggesting that spatial environments can

289
00:09:35,030 --> 00:09:33,660
select for new types of traits such as

290
00:09:37,009 --> 00:09:35,040
the diffusivity of these member

291
00:09:38,750 --> 00:09:37,019
chemicals once you put them in a spatial

292
00:09:40,449 --> 00:09:38,760
environment a well-mixed reactor would

293
00:09:43,009 --> 00:09:40,459
be blind to these sorts of traits

294
00:09:44,930 --> 00:09:43,019
notably you can also look at other types

295
00:09:46,790 --> 00:09:44,940
of inhibition that don't involve

296
00:09:48,470 --> 00:09:46,800
explicit chemistry you can look at

297
00:09:50,509 --> 00:09:48,480
competition for absorption sites on

298
00:09:52,670 --> 00:09:50,519
Mineral surfaces and there we find very

299
00:09:54,889 --> 00:09:52,680
similar Dynamics and I think that this

300
00:09:56,449 --> 00:09:54,899
is suggestive that something like the

301
00:09:58,130 --> 00:09:56,459
Intermediate disturbance hypothesis

302
00:10:00,470 --> 00:09:58,140
might hold even for these chemical

303
00:10:01,670 --> 00:10:00,480
ecosystems and of course in an origins

304
00:10:03,290 --> 00:10:01,680
of Life context there are lots of

305
00:10:05,870 --> 00:10:03,300
different types of disturbances that you

306
00:10:06,949 --> 00:10:05,880
could have the noise of the spatially

307
00:10:09,110 --> 00:10:06,959
structured environment that you have

308
00:10:11,509 --> 00:10:09,120
different impacts

309
00:10:13,970 --> 00:10:11,519
and so with that I'd like to acknowledge

310
00:10:15,350 --> 00:10:13,980
David Baum my undergraduate advisor at

311
00:10:16,790 --> 00:10:15,360
the University of Wisconsin-Madison and

312
00:10:18,650 --> 00:10:16,800
Chris campus my mentor and collaborator

313
00:10:20,269 --> 00:10:18,660

at the Santa Fe Institute some excellent

314
00:10:21,829 --> 00:10:20,279
grad students and postdocs including

315
00:10:23,810 --> 00:10:21,839
profile who just defended this thesis

316
00:10:25,009 --> 00:10:23,820
last week and some excellent undergrads

317
00:10:27,410 --> 00:10:25,019
that I've had the opportunity to work

318
00:10:29,090 --> 00:10:27,420
with including Gage actually you should

319
00:10:30,710 --> 00:10:29,100
be on here

320
00:10:31,970 --> 00:10:30,720
all right with that I'll take any

321
00:10:38,780 --> 00:10:31,980
questions

322
00:10:38,790 --> 00:10:48,190
[Music]

323
00:10:52,190 --> 00:10:50,389
just wants to give you know their name

324
00:10:53,930 --> 00:10:52,200
and affiliation and ask a question

325
00:10:55,970 --> 00:10:53,940
that'd be great

326
00:10:58,310 --> 00:10:55,980
hi my name is George schaible I'm from

327
00:11:00,949 --> 00:10:58,320
Montana State University and I should

328
00:11:02,090 --> 00:11:00,959
preface I am a microbiologist so um but

329
00:11:04,250 --> 00:11:02,100
that was a great talk I thought you did

330
00:11:05,630 --> 00:11:04,260
a good job breaking down for us uh I'm

331
00:11:07,790 --> 00:11:05,640
just curious when diffusion happens

332
00:11:09,949 --> 00:11:07,800
that's I think of it in like a

333
00:11:11,630 --> 00:11:09,959
three-dimensional space so you were

334
00:11:12,650 --> 00:11:11,640
showing a lot of two-dimensional graphs

335
00:11:13,550 --> 00:11:12,660
so what does that look like in three

336
00:11:15,410 --> 00:11:13,560
dimensions

337
00:11:16,910 --> 00:11:15,420
yeah so I didn't do simulations in

338
00:11:19,190 --> 00:11:16,920

three-dimensional space in part because

339
00:11:21,230 --> 00:11:19,200
I think the most like origins of Life

340
00:11:22,730 --> 00:11:21,240
relevant spatial structures are going to

341
00:11:23,990 --> 00:11:22,740
be these two-dimensional environments I

342
00:11:25,730 --> 00:11:24,000
think the two-dimensional environments

343
00:11:27,230 --> 00:11:25,740
can help to constrain kind of the

344
00:11:30,050 --> 00:11:27,240
effective diffusion that you would have

345
00:11:31,370 --> 00:11:30,060
they can concentrate chemistry lots of

346
00:11:33,410 --> 00:11:31,380
origins of Life theories that look at

347
00:11:34,730 --> 00:11:33,420
adsorbed Mineral surfaces already so we

348
00:11:37,009 --> 00:11:34,740
were kind of committed to that sort of

349
00:11:38,810 --> 00:11:37,019
scenario and here the idea of

350
00:11:40,550 --> 00:11:38,820
intermediate diffusion being favorable

351
00:11:42,350 --> 00:11:40,560
for chemical diversity I think that

352
00:11:43,970 --> 00:11:42,360
that's further support that that's the

353
00:11:45,710 --> 00:11:43,980
type of scenario that might be important

354
00:11:47,630 --> 00:11:45,720
I think there's a quote from Gunter

355
00:11:49,910 --> 00:11:47,640
washer who kind of pioneered some of

356
00:11:51,170 --> 00:11:49,920
these ideas that we don't build planes

357
00:11:53,569 --> 00:11:51,180
in the sky we build them on the ground

358
00:11:55,130 --> 00:11:53,579
and that's for a reason

359
00:11:57,350 --> 00:11:55,140
um I just to follow up with that what

360
00:11:59,030 --> 00:11:57,360
what kind of mineral surface would would

361
00:12:00,829 --> 00:11:59,040
you like consider this yeah so that kind

362
00:12:02,870 --> 00:12:00,839
of the experimental side of my group in

363
00:12:03,949 --> 00:12:02,880

undergrad we um we were using pyrite

364
00:12:05,630 --> 00:12:03,959
surfaces

365
00:12:07,670 --> 00:12:05,640
um but here we're chemically agnostic

366
00:12:17,870 --> 00:12:07,680
and we're also agnostic to the exact

367
00:12:22,370 --> 00:12:20,810
hi I'm Ellie I'm from CU Boulder and I

368
00:12:24,530 --> 00:12:22,380
was wondering so I'm mainly a lab

369
00:12:27,829 --> 00:12:24,540
chemist and I was curious if you had any

370
00:12:29,930 --> 00:12:27,839
any like personal thoughts of how you

371
00:12:31,490 --> 00:12:29,940
would want a chemist to do some of this

372
00:12:33,230 --> 00:12:31,500
work or what kind of questions you would

373
00:12:35,030 --> 00:12:33,240
want a lab chemist to do to help ground

374
00:12:36,590 --> 00:12:35,040
truth some of the modeling that you do

375
00:12:37,910 --> 00:12:36,600
because I work a lot of like mineral

376
00:12:39,650 --> 00:12:37,920
absorption and mineral facilitated

377
00:12:42,050 --> 00:12:39,660
chemistry and of course when we do a lot

378
00:12:43,850 --> 00:12:42,060
of this stuff it is an equilibrium

379
00:12:46,069 --> 00:12:43,860
reaction because you're kind of waiting

380
00:12:47,750 --> 00:12:46,079
for it to resolve to equilibrium we're

381
00:12:49,370 --> 00:12:47,760
basing our reactions on that so like how

382
00:12:52,129 --> 00:12:49,380
would you kind of design something like

383
00:12:54,110 --> 00:12:52,139
this or like theorize or like hope for

384
00:12:55,850 --> 00:12:54,120
something right so a lot of what I

385
00:12:57,110 --> 00:12:55,860
showed that in the well-mixed cases we

386
00:12:58,250 --> 00:12:57,120
were working with chemostats and

387
00:13:00,290 --> 00:12:58,260
certainly chemostats are an

388
00:13:02,090 --> 00:13:00,300

experimentally kind of realizable

389
00:13:04,250 --> 00:13:02,100
approach

390
00:13:05,870 --> 00:13:04,260
um there's another side to our group uh

391
00:13:08,389 --> 00:13:05,880
that looked for kind of real Auto

392
00:13:09,829 --> 00:13:08,399
catalytic cycles and known chemical

393
00:13:11,930 --> 00:13:09,839
reaction networks both biotic and

394
00:13:14,030 --> 00:13:11,940
abiotic and so I think one promising

395
00:13:15,710 --> 00:13:14,040
approach is to look at how these

396
00:13:17,329 --> 00:13:15,720
chemical ecosystems might explore that

397
00:13:19,310 --> 00:13:17,339
space where you seed with one chemical

398
00:13:21,050 --> 00:13:19,320
that activates maybe a single cycle or a

399
00:13:23,150 --> 00:13:21,060
small set of cycles and then through the

400
00:13:25,550 --> 00:13:23,160
addition of subsequent seeds you might

401
00:13:26,870 --> 00:13:25,560
activate kind of new cycles and so I

402
00:13:29,150 --> 00:13:26,880
think there are kind of experimental

403
00:13:30,650 --> 00:13:29,160
approaches that can be done there and I

404
00:13:33,490 --> 00:13:30,660
think people in our group are continuing

405
00:13:38,150 --> 00:13:35,990
okay hello we have a question from

406
00:13:40,190 --> 00:13:38,160
online actually so this comes from user

407
00:13:42,769 --> 00:13:40,200
Alex he's asking can you simulate

408
00:13:46,430 --> 00:13:42,779
tipping points hysteresis spatially with

409
00:13:49,310 --> 00:13:46,440
this method tipping points uh it's hard

410
00:13:51,230 --> 00:13:49,320
to ask for a clarification via Zoom okay

411
00:13:52,790 --> 00:13:51,240
Alex if you can hear this um please

412
00:14:05,389 --> 00:13:52,800
clarify our question and we'll come back

413
00:14:10,310 --> 00:14:08,150

hi I'm Jake from UCSD um can you clarify

414
00:14:12,530 --> 00:14:10,320
why you used a stochastic process to

415
00:14:15,530 --> 00:14:12,540
like just solving differential equations

416
00:14:17,329 --> 00:14:15,540
analytically yeah so you can have cases

417
00:14:19,550 --> 00:14:17,339
in these chemical ecosystems where

418
00:14:21,889 --> 00:14:19,560
there's kind of some unstable fixed

419
00:14:23,449 --> 00:14:21,899
point and those unstable fixed points

420
00:14:24,889 --> 00:14:23,459
you need some degree of stochasticity to

421
00:14:26,930 --> 00:14:24,899
break out of them so that's one reason

422
00:14:30,050 --> 00:14:26,940
if I just use deterministic simulations

423
00:14:32,269 --> 00:14:30,060
you could get stuck in those uh it's

424
00:14:34,490 --> 00:14:32,279
also the case that in ecology we're

425
00:14:35,990 --> 00:14:34,500
interested in lots of contingency and

426
00:14:37,430 --> 00:14:36,000
stochasticity and then doing lots of

427
00:14:40,069 --> 00:14:37,440
replicates allows you to explore all

428
00:14:42,829 --> 00:14:40,079
those contingent outcomes that's largely

429
00:14:42,839 --> 00:14:54,530
okay we return for one more question

430
00:14:59,689 --> 00:14:57,769
hi I'm Donna from Indiana University I'm

431
00:15:02,569 --> 00:14:59,699
an ecologist by training and it was

432
00:15:04,790 --> 00:15:02,579
really interesting to see all of those

433
00:15:06,530 --> 00:15:04,800
theories that I've been trained for in

434
00:15:09,790 --> 00:15:06,540
this context

435
00:15:12,710 --> 00:15:09,800
um as ecologist we abandoned

436
00:15:15,710 --> 00:15:12,720
intermediate disturbance hypothesis

437
00:15:19,069 --> 00:15:15,720
because we haven't observed in nature

438
00:15:23,210 --> 00:15:19,079

yeah for doing years I was wondering if

439
00:15:23,930 --> 00:15:23,220
there are ways to test experimentally

440
00:15:26,260 --> 00:15:23,940
um

441
00:15:27,530 --> 00:15:26,270
what do you think about that and also

442
00:15:30,310 --> 00:15:27,540
[Music]

443
00:15:33,829 --> 00:15:30,320
looking for tipping points I think

444
00:15:37,329 --> 00:15:33,839
the online person mentioned you can

445
00:15:39,889 --> 00:15:37,339
probably see the signals before

446
00:15:42,410 --> 00:15:39,899
transitions like time or talk increasing

447
00:15:44,650 --> 00:15:42,420
Time auto correlation

448
00:15:46,310 --> 00:15:44,660
um or coefficient of variation

449
00:15:47,870 --> 00:15:46,320
absolutely thank you for the question

450
00:15:49,730 --> 00:15:47,880
yeah so I think an ecology that

451
00:15:51,170 --> 00:15:49,740
intermediate disturbance hypothesis is

452
00:15:53,689 --> 00:15:51,180
controversial and many people have

453
00:15:55,550 --> 00:15:53,699
abandoned it I think in this kind of

454
00:15:57,650 --> 00:15:55,560
modeling context it's very easy to kind

455
00:16:01,189 --> 00:15:57,660
of look for it just because we're doing

456
00:16:02,870 --> 00:16:01,199
experiments in silico and

457
00:16:04,910 --> 00:16:02,880
I think that

458
00:16:06,470 --> 00:16:04,920
if it does hold in the biological case

459
00:16:08,509 --> 00:16:06,480
certainly it holds in the chemical case

460
00:16:09,949 --> 00:16:08,519
there's a possibility that it holds in

461
00:16:11,090 --> 00:16:09,959
the chemical case and not the biological

462
00:16:12,889 --> 00:16:11,100
case

463
00:16:14,030 --> 00:16:12,899

um I think the weak version of this is

464
00:16:15,290 --> 00:16:14,040
that there are certain types of

465
00:16:17,030 --> 00:16:15,300
disturbance regimes that can be

466
00:16:18,910 --> 00:16:17,040
beneficial for chemical diversity even

467
00:16:21,350 --> 00:16:18,920
if the intermediate disturbance

468
00:16:23,629 --> 00:16:21,360
hypothesis doesn't hold her at large to

469
00:16:25,910 --> 00:16:23,639
the Tipping points question I think you

470
00:16:28,009 --> 00:16:25,920
do see sort of kind of signs in the

471
00:16:29,810 --> 00:16:28,019
diffusion cases I kind of vary it you

472
00:16:31,310 --> 00:16:29,820
end up seeing sort of power loss scaling

473
00:16:32,750 --> 00:16:31,320
in the patch size

474
00:16:35,689 --> 00:16:32,760
um sort of like you would see in an

475
00:16:37,129 --> 00:16:35,699
icing model in physics and so the sort

476
00:16:39,769 --> 00:16:37,139
of theory that looks at tippling points

477
00:16:46,450 --> 00:16:39,779
there would also apply here