Panelists

Attendees (7)

- Hosts (1)
  - Mike Toillion
- Presenters (3)
  - Andy Burnett
  - Eric Boyd
  - Eric Smith
- Participants (3)
  - David Des Marais
  - Lee Bebout
  - Lindsay Hays

Open Chat (Everyone)

--------- (11/21/2013 10:56) ---------

Mike Toillion: Good afternoon, everyone! Please feel free to chat here in this window. If you have any questions or comments for the presenters, you can type them here, or ask them over the telecon line listed below. Thanks!

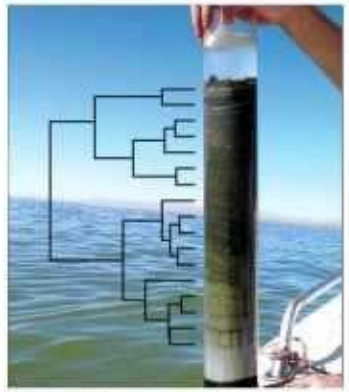
Teleconference Instructions (Parti...

Teleconference Line: 866-692-3158
Passcode: 9109668#
Please use *6 to MUTE your phone's mic when not speaking.
More info: https://astrobiologyfuture.org

Space for Time.pptx

Full Screen

How can we substitute space for time to better understand geochemical and co-evolutionary dynamics?



Swan, 2010.

Eric S. Boyd (Montana State University), Everett L. Shock (Arizona State University), Eric Smith (Santa Fe Institute)

1
00:00:12,830 --> 00:00:10,520
thank you well welcome everyone to the

2
00:00:15,279 --> 00:00:12,840
next in our series of webinars this one

3
00:00:18,410 --> 00:00:15,289
is about substituting space for time

4
00:00:21,260 --> 00:00:18,420
just a couple of quick announcements the

5
00:00:24,200 --> 00:00:21,270
slides to this if you happen to be only

6
00:00:26,960 --> 00:00:24,210
connecting an audio are linked directly

7
00:00:30,830 --> 00:00:26,970
from the event notice on the front of

8
00:00:33,650 --> 00:00:30,840
the screen there will be a video up on

9
00:00:36,709 --> 00:00:33,660
this recording this probably women the

10
00:00:38,750 --> 00:00:36,719
next day and just reiterating what like

11
00:00:41,060 --> 00:00:38,760
it said this event is being recorded and

12
00:00:42,410 --> 00:00:41,070
will be publicly available such as John

13
00:00:49,100 --> 00:00:42,420

Denver like to say if you're going to

14
00:00:52,580 --> 00:00:49,110
sing along seem good with that Eric well

15
00:00:54,200 --> 00:00:52,590
okay um so this is a topic that was I

16
00:00:56,240 --> 00:00:54,210
think originally proposed by Everett

17
00:01:02,150 --> 00:00:56,250
shock and then put together by Everett

18
00:01:04,520 --> 00:01:02,160
and Eric Boyd and me um but ever it was

19
00:01:06,770 --> 00:01:04,530
the one to originate the title I think

20
00:01:08,300 --> 00:01:06,780
how can we substitute space for time to

21
00:01:12,590 --> 00:01:08,310
better understand geochemical & Co

22
00:01:13,730 --> 00:01:12,600
evolutionary dynamics on the space for

23
00:01:17,359 --> 00:01:13,740
time refers to something that's

24
00:01:19,969 --> 00:01:17,369
essentially of well known a lot of what

25
00:01:21,440 --> 00:01:19,979
happens in geochemistry and evolutionary

26
00:01:23,270 --> 00:01:21,450
dynamics and the coupling between the

27
00:01:26,690 --> 00:01:23,280
two occurs on time scales that are not

28
00:01:28,460 --> 00:01:26,700
accessible to us experimentally usually

29
00:01:30,469 --> 00:01:28,470
you would want the control of

30
00:01:31,969 --> 00:01:30,479
experiments to do things like infer

31
00:01:34,880 --> 00:01:31,979
out-of-sample which is relevant for

32
00:01:36,890 --> 00:01:34,890
detecting preferred places to look for

33
00:01:38,539 --> 00:01:36,900
life outside the earth and also

34
00:01:41,420 --> 00:01:38,549
understanding cause because without a

35
00:01:43,160 --> 00:01:41,430
model you can't simply infer from a

36
00:01:47,929 --> 00:01:43,170
sample what happens outside the sample

37
00:01:51,020 --> 00:01:47,939
condition the problem when you have no

38
00:01:53,210 --> 00:01:51,030

direct access to deep time is that you

39
00:01:55,219 --> 00:01:53,220
may have variation in the present but

40
00:01:58,039 --> 00:01:55,229
simple sample comparison of diversity

41
00:02:00,709 --> 00:01:58,049
does not directly get you at causation

42
00:02:03,260 --> 00:02:00,719
or at out-of-sample inference so then

43
00:02:06,109 --> 00:02:03,270
the question is what can we do to make

44
00:02:08,990 --> 00:02:06,119
how can we in a principled way use

45
00:02:11,089 --> 00:02:09,000
variation in the present to provide

46
00:02:11,620 --> 00:02:11,099
access to the things about the past that

47
00:02:14,470 --> 00:02:11,630
are needed

48
00:02:17,440 --> 00:02:14,480
for inference and for the deduction of

49
00:02:19,090 --> 00:02:17,450
cause three obvious ways this can be

50
00:02:21,430 --> 00:02:19,100
done which are not limited to biology

51
00:02:23,710 --> 00:02:21,440
they occur also in geology and many

52
00:02:25,570 --> 00:02:23,720
other areas if you have processes that

53
00:02:27,760 --> 00:02:25,580
are continuously reinitiated you can

54
00:02:30,640 --> 00:02:27,770
catch them at different stages and so

55
00:02:32,590 --> 00:02:30,650
you can substitute of synchronic

56
00:02:35,440 --> 00:02:32,600
comparisons for diachronic comparison in

57
00:02:37,210 --> 00:02:35,450
that way when there are accidental

58
00:02:40,210 --> 00:02:37,220
components or historically contingent

59
00:02:42,070 --> 00:02:40,220
components in the production of

60
00:02:43,990 --> 00:02:42,080
diversity you can use those to

61
00:02:47,200 --> 00:02:44,000
reconstruct history with phylogenetic

62
00:02:49,660 --> 00:02:47,210
methods and by then filling in the

63
00:02:51,310 --> 00:02:49,670

events of the past you can try to use

64
00:02:52,810 --> 00:02:51,320
those events to correct the things like

65
00:02:54,970 --> 00:02:52,820
Galton's problem to understand

66
00:02:56,860 --> 00:02:54,980
likelihood or context for the changes

67
00:02:59,530 --> 00:02:56,870
rather than simply looking at the

68
00:03:02,080 --> 00:02:59,540
diversity as it occurs now and this

69
00:03:04,050 --> 00:03:02,090
particularly for us this will be of

70
00:03:07,270 --> 00:03:04,060
interest for the relation between

71
00:03:09,490 --> 00:03:07,280
metabolic phenotypes and ways of living

72
00:03:12,130 --> 00:03:09,500
and the geological context where they

73
00:03:13,750 --> 00:03:12,140
occur and then of course the other thing

74
00:03:15,900 --> 00:03:13,760
that goes together with reconstructing

75
00:03:18,340 --> 00:03:15,910
accidental parts of the past is

76
00:03:19,870 --> 00:03:18,350
inferring a process model for what the

77
00:03:23,560 --> 00:03:19,880
laws are that have been active in

78
00:03:26,410 --> 00:03:23,570
evolution over that time so why is this

79
00:03:28,840 --> 00:03:26,420
a a thing that clearly there's a lot we

80
00:03:30,760 --> 00:03:28,850
can do with the biosphere is enormously

81
00:03:33,160 --> 00:03:30,770
diverse its diverse in its gene

82
00:03:35,530 --> 00:03:33,170
inventory it's diverse and the way genes

83
00:03:37,780 --> 00:03:35,540
are gathered in two genomes it's diverse

84
00:03:40,390 --> 00:03:37,790
in the way organisms anto genetically or

85
00:03:42,220 --> 00:03:40,400
developmentally produce phenotype from a

86
00:03:44,890 --> 00:03:42,230
combination of genes and environment and

87
00:03:47,410 --> 00:03:44,900
its diverse an ecological assembly and a

88
00:03:49,930 --> 00:03:47,420

lot of the diversity in ontogeny or

89
00:03:52,900 --> 00:03:49,940
development in ecology is coupled to the

90
00:03:54,430 --> 00:03:52,910
types of geochemical environments and

91
00:03:55,420 --> 00:03:54,440
thermodynamic environments that

92
00:04:00,610 --> 00:03:55,430
different organisms and their

93
00:04:03,940 --> 00:04:00,620
communities can inhabit so working from

94
00:04:06,640 --> 00:04:03,950
that what are the guiding questions in

95
00:04:08,980 --> 00:04:06,650
making use of the rich data record that

96
00:04:12,340 --> 00:04:08,990
while of genomic diversity makes

97
00:04:15,580 --> 00:04:12,350
available to us okay most basic question

98
00:04:18,640 --> 00:04:15,590
of life how did it originate and then

99
00:04:22,110 --> 00:04:18,650
how how and why was the diversity of

100
00:04:24,650 --> 00:04:22,120
life on earth produced as it was

101
00:04:26,510 --> 00:04:24,660
particularly with application to

102
00:04:28,250 --> 00:04:26,520
herbalism what are the metabolic

103
00:04:31,250 --> 00:04:28,260
features that we can reconstruct for

104
00:04:35,360 --> 00:04:31,260
early life and how do they give us a

105
00:04:36,830 --> 00:04:35,370
principled way to choose places to

106
00:04:39,980 --> 00:04:36,840
investigate and also modes of

107
00:04:41,480 --> 00:04:39,990
Investigation for astrobiology with

108
00:04:43,190 --> 00:04:41,490
regard to the question of whether or not

109
00:04:45,470 --> 00:04:43,200
there are time independent processes

110
00:04:47,330 --> 00:04:45,480
that can be inferred the sorts of things

111
00:04:48,890 --> 00:04:47,340
for which we already have some evidence

112
00:04:51,530 --> 00:04:48,900
but we would like a more systematic

113
00:04:53,870 --> 00:04:51,540

understanding are some environments more

114
00:04:55,820 --> 00:04:53,880
conservative both geologically and in

115
00:04:58,460 --> 00:04:55,830
the mode and tempo of evolution that

116
00:05:00,230 --> 00:04:58,470
they induce than others are can we say

117
00:05:03,730 --> 00:05:00,240
something about which types of

118
00:05:06,740 --> 00:05:03,740
environments are which when organisms

119
00:05:08,780 --> 00:05:06,750
diversify some of that may come from the

120
00:05:11,030 --> 00:05:08,790
bottlenecks of evolutionary discovery

121
00:05:12,890 --> 00:05:11,040
but some of it may also come from strict

122
00:05:14,780 --> 00:05:12,900
limits that are imposed geologically

123
00:05:17,380 --> 00:05:14,790
either on the organism or on the

124
00:05:19,910 --> 00:05:17,390
community structure of the organism um

125
00:05:22,100 --> 00:05:19,920
sometimes the limitations on community

126
00:05:24,560 --> 00:05:22,110
structure may come from limitations in

127
00:05:26,570 --> 00:05:24,570
one individual species can do other

128
00:05:28,340 --> 00:05:26,580
times the limits on community structure

129
00:05:31,010 --> 00:05:28,350
may be more fundamental to the community

130
00:05:33,260 --> 00:05:31,020
than they are to the individual and it's

131
00:05:35,420 --> 00:05:33,270
worth noting in all of these that all

132
00:05:37,730 --> 00:05:35,430
evolution essentially is coevolution

133
00:05:39,590 --> 00:05:37,740
it's a very rare geological environment

134
00:05:41,300 --> 00:05:39,600
that can be inhabited by only one

135
00:05:43,130 --> 00:05:41,310
species that's not affected by the

136
00:05:45,380 --> 00:05:43,140
dynamics of other species that share it

137
00:05:47,930 --> 00:05:45,390
and in everything from phylogenetic

138
00:05:51,470 --> 00:05:47,940

reconstruction understanding evidence

139
00:05:53,870 --> 00:05:51,480
about species interactions in genomic

140
00:05:56,120 --> 00:05:53,880
records what you would like is to be

141
00:05:57,860 --> 00:05:56,130
able to calibrate mode and tempo of

142
00:06:01,310 --> 00:05:57,870
evolution to figure out what's happening

143
00:06:04,159 --> 00:06:01,320
in the same places at the same time so

144
00:06:07,550 --> 00:06:04,169
why is this not an easy thing to do a

145
00:06:09,860 --> 00:06:07,560
lot of time has expired the geological

146
00:06:12,380 --> 00:06:09,870
intervals that are given names are to

147
00:06:14,300 --> 00:06:12,390
some extent historical but in many

148
00:06:18,620 --> 00:06:14,310
respects they have to do with actually

149
00:06:21,200 --> 00:06:18,630
of different chemistry different Rock

150
00:06:23,060 --> 00:06:21,210
dynamics and different behavior of the

151
00:06:25,430 --> 00:06:23,070
atmosphere and oceans and also different

152
00:06:27,710 --> 00:06:25,440
phases of life and feedbacks of life on

153
00:06:30,320 --> 00:06:27,720
the geochemical environment and we have

154
00:06:31,820 --> 00:06:30,330
to look back through all of that in

155
00:06:32,820 --> 00:06:31,830
order to correctly interpret the

156
00:06:37,050 --> 00:06:32,830
diversity that we find

157
00:06:38,760 --> 00:06:37,060
the record today as just one example you

158
00:06:41,100 --> 00:06:38,770
know so life or life's origins are

159
00:06:43,620 --> 00:06:41,110
somewhere in the murky area between the

160
00:06:45,330 --> 00:06:43,630
Hadean the hidden era and the early

161
00:06:46,650 --> 00:06:45,340
Archaean where we have some ability to

162
00:06:51,000 --> 00:06:46,660
start talking about the chemistry of

163
00:06:52,320 --> 00:06:51,010

rockland oceans between then and now we

164
00:06:57,210 --> 00:06:52,330
have a whole sequence of major

165
00:06:58,980 --> 00:06:57,220
transitions and as an example you know

166
00:07:00,780 --> 00:06:58,990
many of the major transitions in life

167
00:07:03,390 --> 00:07:00,790
were actually major transitions of the

168
00:07:05,490 --> 00:07:03,400
biogeochemical environment all jointly

169
00:07:08,520 --> 00:07:05,500
this is a slide from ariel on bar

170
00:07:11,420 --> 00:07:08,530
science paper in 2008 which just tracks

171
00:07:14,700 --> 00:07:11,430
elemental abundances in the ocean

172
00:07:17,190 --> 00:07:14,710
jointly with the rise of oxygen as its

173
00:07:19,500 --> 00:07:17,200
approximately afford to invert today and

174
00:07:21,780 --> 00:07:19,510
both through direct interactions with

175
00:07:23,550 --> 00:07:21,790
molecular oxygen and particularly

176
00:07:26,880 --> 00:07:23,560
through things like the oxidation states

177
00:07:29,100 --> 00:07:26,890
of sulfur and what that makes soluble or

178
00:07:32,130 --> 00:07:29,110
insoluble you see that you have many

179
00:07:33,780 --> 00:07:32,140
orders of magnitude change especially in

180
00:07:36,660 --> 00:07:33,790
transition metals that are fundamental

181
00:07:38,600 --> 00:07:36,670
to biochemical functions and these

182
00:07:40,950 --> 00:07:38,610
determine both what it was

183
00:07:43,320 --> 00:07:40,960
thermodynamically affordable to do and

184
00:07:45,090 --> 00:07:43,330
to some extent they may have affected

185
00:07:47,220 --> 00:07:45,100
the partitioning of the way elements

186
00:07:49,550 --> 00:07:47,230
occur in different organisms so for

187
00:07:52,050 --> 00:07:49,560
instance you see the zinc and copper are

188
00:07:54,420 --> 00:07:52,060

extremely low concentration in anoxic

189
00:07:56,160 --> 00:07:54,430
oceans and then with the rise of oxygen

190
00:07:57,930 --> 00:07:56,170
at the same time as iron molybdenum

191
00:08:00,930 --> 00:07:57,940
cobalt nickel or driven out of solution

192
00:08:02,370 --> 00:08:00,940
zinc and copper come into solution so

193
00:08:04,740 --> 00:08:02,380
there can be different eras in

194
00:08:06,390 --> 00:08:04,750
evolutionary innovation that are coupled

195
00:08:08,700 --> 00:08:06,400
to just what's available and of course

196
00:08:11,610 --> 00:08:08,710
life is feeding back it was organism

197
00:08:13,320 --> 00:08:11,620
dynamics that created this so the

198
00:08:16,680 --> 00:08:13,330
sequence of the next several slides have

199
00:08:18,570 --> 00:08:16,690
to do with particular areas where we can

200
00:08:20,910 --> 00:08:18,580
say something about what's in the genome

201
00:08:22,830 --> 00:08:20,920
inventory how it couples within the

202
00:08:24,750 --> 00:08:22,840
ecosystem and also to the geochemistry

203
00:08:27,030 --> 00:08:24,760
there are sort of examples of how

204
00:08:28,950 --> 00:08:27,040
problems of this kind can be solved so

205
00:08:37,250 --> 00:08:28,960
I'll switch off at this point and

206
00:08:41,340 --> 00:08:37,260
transfer Eric void to do them okay so

207
00:08:43,740 --> 00:08:41,350
Eric did a nice job of outlining some of

208
00:08:46,710 --> 00:08:43,750
the barriers to these kind of studies

209
00:08:49,499 --> 00:08:46,720
and really outlined

210
00:08:51,269 --> 00:08:49,509
why we think that these kind of studies

211
00:08:54,329 --> 00:08:51,279
are necessary to understand why we have

212
00:08:56,550 --> 00:08:54,339
the diversification of life that that

213
00:08:58,129 --> 00:08:56,560

that we have today and really trying to

214
00:09:01,170 --> 00:08:58,139
understand how we got there and so

215
00:09:04,079 --> 00:09:01,180
there's a critical feature of microbial

216
00:09:05,939 --> 00:09:04,089
life that that we believe makes these

217
00:09:09,139 --> 00:09:05,949
kind of studies tractable and that is

218
00:09:12,329 --> 00:09:09,149
that they that life tends to inherit

219
00:09:15,749 --> 00:09:12,339
their genotypes or their genomes and

220
00:09:19,199 --> 00:09:15,759
thus their phenotypes from their

221
00:09:21,420 --> 00:09:19,209
ancestors okay and so the extent that in

222
00:09:23,220 --> 00:09:21,430
ecology of an organism so the

223
00:09:26,910 --> 00:09:23,230
environment that an organism tends to

224
00:09:30,030 --> 00:09:26,920
inhabit is related to what they can do

225
00:09:32,869 --> 00:09:30,040
or their their phenotype there should be

226
00:09:35,670 --> 00:09:32,879
a positive relationship there and so

227
00:09:38,040 --> 00:09:35,680
really guiding this word from here for

228
00:09:40,619 --> 00:09:38,050
it is is the tenant that genomes are a

229
00:09:42,150 --> 00:09:40,629
data rich historical record of the

230
00:09:44,579 --> 00:09:42,160
interactions between life and its

231
00:09:46,740 --> 00:09:44,589
environment and it's a data-rich record

232
00:09:49,590 --> 00:09:46,750
that we believe far exceeds the

233
00:09:51,269 --> 00:09:49,600
geological records so much as half

234
00:09:54,329 --> 00:09:51,279
there's many gas in the geological

235
00:09:57,840 --> 00:09:54,339
record there's there's really large

236
00:10:00,780 --> 00:09:57,850
barriers to understanding what what the

237
00:10:02,400 --> 00:10:00,790
environment might have been like say two

238
00:10:05,460 --> 00:10:02,410

billion years ago or whatnot and we

239
00:10:08,280 --> 00:10:05,470
think that we can actually mine this

240
00:10:12,900 --> 00:10:08,290
information out of existing genomes and

241
00:10:15,509 --> 00:10:12,910
so as we start down this path I just put

242
00:10:17,819 --> 00:10:15,519
this plot in here to illustrate this

243
00:10:22,199 --> 00:10:17,829
this basic tenet of microbiology and

244
00:10:24,929 --> 00:10:22,209
that is as a species diversifies as it

245
00:10:28,040 --> 00:10:24,939
increases its phylogenetic distance from

246
00:10:30,299 --> 00:10:28,050
its ancestor what you tend to see is a

247
00:10:32,189 --> 00:10:30,309
corresponding increase in the metabolic

248
00:10:35,939 --> 00:10:32,199
dissimilarity of those organisms and so

249
00:10:39,720 --> 00:10:35,949
this is taking 1800 genomes comprising

250
00:10:43,319 --> 00:10:39,730
both bacteria and archaea defining what

251
00:10:45,030 --> 00:10:43,329
their metabolic capacity is using a

252
00:10:47,850 --> 00:10:45,040
series of statistical and bioinformatic

253
00:10:50,730 --> 00:10:47,860
tools that I won't go into here and just

254
00:10:52,860 --> 00:10:50,740
simply creating a matrix to describe how

255
00:10:55,079 --> 00:10:52,870
similar those organisms are

256
00:10:56,910 --> 00:10:55,089
at a metabolic level and then relating

257
00:10:59,940 --> 00:10:56,920
that to a matrix describing how

258
00:11:01,950 --> 00:10:59,950
evolutionarily related those organisms

259
00:11:05,360 --> 00:11:01,960
are and so what you can see from that is

260
00:11:08,600 --> 00:11:05,370
that there is a correspondence so as you

261
00:11:10,769 --> 00:11:08,610
evolve new metabolic traits or new

262
00:11:14,340 --> 00:11:10,779
combinations of metabolic trades there's

263
00:11:16,590 --> 00:11:14,350

a corresponding diversification at an

264
00:11:18,900 --> 00:11:16,600
evolutionary level and so the question

265
00:11:22,170 --> 00:11:18,910
is is what drove the development of this

266
00:11:23,880 --> 00:11:22,180
phenotypic diversity so to the extent

267
00:11:26,280 --> 00:11:23,890
that environment or inter species

268
00:11:28,829 --> 00:11:26,290
interactions are driving or providing

269
00:11:30,990 --> 00:11:28,839
new ecological niches how did that

270
00:11:35,940 --> 00:11:31,000
select for new metabolic properties of

271
00:11:37,800 --> 00:11:35,950
these organisms and so just to simplify

272
00:11:39,030 --> 00:11:37,810
a little bit and take us a step back two

273
00:11:41,910 --> 00:11:39,040
things that I think most of us

274
00:11:44,579 --> 00:11:41,920
understand we can go back to Darwin's

275
00:11:46,620 --> 00:11:44,589
work back in the 1800s and you know

276
00:11:49,400 --> 00:11:46,630
Darwin without the benefit of genomics

277
00:11:52,050 --> 00:11:49,410
and without the benefit of phylogenetics

278
00:11:55,740 --> 00:11:52,060
started to notice is pattered in beat

279
00:11:58,079 --> 00:11:55,750
morphology of these finches and found a

280
00:12:01,199 --> 00:11:58,089
tight correlation between the morphology

281
00:12:03,900 --> 00:12:01,209
of these Finch beaks and the lifestyle

282
00:12:06,600 --> 00:12:03,910
strategies that these finches lived and

283
00:12:09,750 --> 00:12:06,610
that is what kind of foraging habit

284
00:12:12,290 --> 00:12:09,760
habits do they have what kind of food

285
00:12:16,290 --> 00:12:12,300
resources did they use and noticed a

286
00:12:18,120 --> 00:12:16,300
correspondence in the beat morphology of

287
00:12:19,949 --> 00:12:18,130
these organisms and their local

288
00:12:21,600 --> 00:12:19,959

environment okay and so here we're not

289
00:12:23,579 --> 00:12:21,610
necessarily talking about a chemical

290
00:12:25,680 --> 00:12:23,589
environment we're talking about a food

291
00:12:28,079 --> 00:12:25,690
resource but you know let's think back

292
00:12:30,690 --> 00:12:28,089
to microbes and their food resource at

293
00:12:34,350 --> 00:12:30,700
least in most systems are our chemicals

294
00:12:36,810 --> 00:12:34,360
and so just using this as an analogy and

295
00:12:40,860 --> 00:12:36,820
and and what was particularly striking

296
00:12:43,769 --> 00:12:40,870
to me is this work by sato back in 1999

297
00:12:46,829 --> 00:12:43,779
I took these finches and actually

298
00:12:49,980 --> 00:12:46,839
subjected those these Finch populations

299
00:12:52,890 --> 00:12:49,990
to phylogenetic reconstruction and show

300
00:12:55,019 --> 00:12:52,900
that lifestyle strategy or their

301
00:12:57,060 --> 00:12:55,029
phenotypes tracked very nicely with

302
00:12:58,500 --> 00:12:57,070
their evolutionary history which is

303
00:13:00,930 --> 00:12:58,510
exactly what you would expect if

304
00:13:03,240 --> 00:13:00,940
metabolic innovation is driving

305
00:13:06,210 --> 00:13:03,250
taxonomic diversification

306
00:13:08,190 --> 00:13:06,220
and so the essence of these slides is

307
00:13:09,600 --> 00:13:08,200
that we believe that you can begin to

308
00:13:12,660 --> 00:13:09,610
understand the role of environment

309
00:13:14,340 --> 00:13:12,670
shaping biodiversity by examining

310
00:13:19,860 --> 00:13:14,350
patterns in the distribution of species

311
00:13:23,880 --> 00:13:19,870
and their functions okay and so a

312
00:13:26,550 --> 00:13:23,890
framework that we've used in moving this

313
00:13:28,980 --> 00:13:26,560

research forward is really could be

314
00:13:33,420 --> 00:13:28,990
summed up by this Venn diagram here

315
00:13:37,410 --> 00:13:33,430
where we have ecological interactions by

316
00:13:38,820 --> 00:13:37,420
this I mean in organisms ability to

317
00:13:41,760 --> 00:13:38,830
interact with its environment its

318
00:13:43,230 --> 00:13:41,770
environmental tolerances biological

319
00:13:46,980 --> 00:13:43,240
interactions these get a little bit more

320
00:13:50,610 --> 00:13:46,990
difficult to decipher when we're looking

321
00:13:54,050 --> 00:13:50,620
back in time and then we have evolution

322
00:13:56,340 --> 00:13:54,060
so these two interactions are together

323
00:13:58,260 --> 00:13:56,350
converging to drive an evolutionary

324
00:14:00,330 --> 00:13:58,270
phenomena and the way to really think

325
00:14:03,210 --> 00:14:00,340
about this is at the level of the

326
00:14:06,350 --> 00:14:03,220
ecological niche which is simply the

327
00:14:08,579 --> 00:14:06,360
multiplicity of a chemical physical and

328
00:14:10,950 --> 00:14:08,589
importantly biological parameters that

329
00:14:13,920 --> 00:14:10,960
characterize a local habitat and so that

330
00:14:16,829 --> 00:14:13,930
biology through mutagenesis every time a

331
00:14:18,870 --> 00:14:16,839
cell replicates mutations are introduced

332
00:14:22,320 --> 00:14:18,880
into the genome creating new

333
00:14:25,110 --> 00:14:22,330
opportunities to evolve new phenotypic

334
00:14:27,180 --> 00:14:25,120
traits or trait variants that enable

335
00:14:29,670 --> 00:14:27,190
that population to successfully compete

336
00:14:33,300 --> 00:14:29,680
and proliferate potentially in a new

337
00:14:38,000 --> 00:14:33,310
ecological niche ok and so interactions

338
00:14:40,530 --> 00:14:38,010

then in that newly expanded upon niche

339
00:14:42,480 --> 00:14:40,540
ultimately dictate the success of these

340
00:14:44,160 --> 00:14:42,490
diversification of entities you do and

341
00:14:45,750 --> 00:14:44,170
so it's a fairly simple framework and

342
00:14:50,670 --> 00:14:45,760
obviously you can get more complicated

343
00:14:53,340 --> 00:14:50,680
with it but I think it leads you to ask

344
00:14:56,700 --> 00:14:53,350
a couple of fairly simple questions of

345
00:14:58,800 --> 00:14:56,710
biological data so evolutionary history

346
00:15:02,220 --> 00:14:58,810
is informative okay so what was the role

347
00:15:04,680 --> 00:15:02,230
of analyte X so this can be whatever

348
00:15:06,750 --> 00:15:04,690
your favorite compound is in driving the

349
00:15:07,920 --> 00:15:06,760
diversification of lineage wide again

350
00:15:10,110 --> 00:15:07,930
that can be whatever your favorite

351
00:15:12,930 --> 00:15:10,120
lineage is and so you can ask these

352
00:15:15,630 --> 00:15:12,940
questions and any number of combinations

353
00:15:16,090 --> 00:15:15,640
and ask about how the evolutionary

354
00:15:19,360 --> 00:15:16,100
history

355
00:15:24,280 --> 00:15:19,370
of these populations or communities even

356
00:15:26,050 --> 00:15:24,290
was shaped by environmental variation we

357
00:15:29,350 --> 00:15:26,060
also believe that the distribution of

358
00:15:30,910 --> 00:15:29,360
lineages is import informative so what

359
00:15:32,910 --> 00:15:30,920
environment types harbor the earliest

360
00:15:35,280 --> 00:15:32,920
branching lineage is for example

361
00:15:40,600 --> 00:15:35,290
focusing in on some of the major

362
00:15:42,220 --> 00:15:40,610
transitions and in life on earth such as

363
00:15:45,639 --> 00:15:42,230

photosynthesis what kind of environment

364
00:15:51,370 --> 00:15:45,649
types dictate the distribution of that

365
00:15:54,009 --> 00:15:51,380
those kind of processes okay so how do

366
00:15:57,160 --> 00:15:54,019
we go about answering these questions so

367
00:15:59,889 --> 00:15:57,170
going back to Eric slide number two you

368
00:16:02,410 --> 00:15:59,899
know how can we actually use space to

369
00:16:05,829 --> 00:16:02,420
substitute that for or for time and so

370
00:16:08,680 --> 00:16:05,839
we believe again that the genomes of

371
00:16:11,710 --> 00:16:08,690
extant organisms are a data-rich record

372
00:16:14,530 --> 00:16:11,720
by which we can mine that we can mine at

373
00:16:16,749 --> 00:16:14,540
a phylogenetic level to understand how

374
00:16:19,300 --> 00:16:16,759
environmental gradients that have played

375
00:16:21,400 --> 00:16:19,310
out over over geological time have

376
00:16:23,800 --> 00:16:21,410
dictated the expat distribution of life

377
00:16:27,610 --> 00:16:23,810
and so what kind of a system would would

378
00:16:31,600 --> 00:16:27,620
serve us well for such studies and of

379
00:16:33,370 --> 00:16:31,610
course my work with Everett takes us to

380
00:16:36,309 --> 00:16:33,380
Yellowstone often to ask these kind of

381
00:16:39,040 --> 00:16:36,319
questions and the reason why is here's

382
00:16:41,499 --> 00:16:39,050
just a plot of I think 14 hundred

383
00:16:43,150 --> 00:16:41,509
springs in Yellowstone as a function of

384
00:16:46,569 --> 00:16:43,160
their pH and temperature space and you

385
00:16:48,420 --> 00:16:46,579
can see that you can sample any gradient

386
00:16:51,639 --> 00:16:48,430
of pH and temperature combinations

387
00:16:55,030 --> 00:16:51,649
combinations you can expand on this to

388
00:16:57,280 --> 00:16:55,040

virtually any analyte of interest aside

389
00:17:00,550 --> 00:16:57,290
from pressure and maybe salinity and you

390
00:17:03,220 --> 00:17:00,560
can sample orders of magnitude gradient

391
00:17:05,380 --> 00:17:03,230
spatial gradients in these and these

392
00:17:07,179 --> 00:17:05,390
analytes and so then you can take and

393
00:17:10,090 --> 00:17:07,189
you can sample microbial communities

394
00:17:12,069 --> 00:17:10,100
across these gradients eject them to

395
00:17:14,860 --> 00:17:12,079
phylogenetic analysis or a series of

396
00:17:20,439 --> 00:17:14,870
analyses and ask you know what the

397
00:17:22,149 --> 00:17:20,449
historical pattern is there so when we

398
00:17:25,149 --> 00:17:22,159
do this with something like

399
00:17:27,159 --> 00:17:25,159
photosynthesis so we call this the

400
00:17:28,060 --> 00:17:27,169
transition to photosynthesis I don't

401
00:17:29,860 --> 00:17:28,070
know if you can see Mike

402
00:17:32,650 --> 00:17:29,870
here on the screen but so starting in

403
00:17:37,360 --> 00:17:32,660
the center of this panel on the Left we

404
00:17:39,670 --> 00:17:37,370
have an acidic hot spring in Yellowstone

405
00:17:41,350 --> 00:17:39,680
the source is up near the top there

406
00:17:44,020 --> 00:17:41,360
where you see that yellow that's

407
00:17:46,450 --> 00:17:44,030
elemental sulfur and as that spring

408
00:17:48,910 --> 00:17:46,460
emanates outward from the source it

409
00:17:52,360 --> 00:17:48,920
cools forms a gradient and ultimately

410
00:17:54,160 --> 00:17:52,370
you can see green and purple life forms

411
00:17:56,620 --> 00:17:54,170
of fear up here well those are those are

412
00:17:59,710 --> 00:17:56,630
photo tropes and so there's something

413
00:18:00,820 --> 00:17:59,720

about the the source fluid of this

414
00:18:03,100 --> 00:18:00,830
system that's constraining

415
00:18:05,800 --> 00:18:03,110
photosynthesis not allowing it to

416
00:18:08,410 --> 00:18:05,810
compete in that environment and here's

417
00:18:12,690 --> 00:18:08,420
an environment here on the right this is

418
00:18:15,280 --> 00:18:12,700
roadside spring another spring close to

419
00:18:16,990 --> 00:18:15,290
norris geyser basin has a different p

420
00:18:19,810 --> 00:18:17,000
agent temperature regime and we can see

421
00:18:23,230 --> 00:18:19,820
that that that transition from a largely

422
00:18:25,360 --> 00:18:23,240
chemosynthetic community to one that

423
00:18:29,740 --> 00:18:25,370
photosynthetic occurs at a different ph

424
00:18:32,920 --> 00:18:29,750
and temperature issue okay so we took

425
00:18:37,720 --> 00:18:32,930
and we mapped the distribution of

426
00:18:39,790 --> 00:18:37,730
photosynthesis and I think roughly 450

427
00:18:42,010 --> 00:18:39,800
different hotspur 440 hot springs in

428
00:18:43,480 --> 00:18:42,020
Yellowstone and and this is just three

429
00:18:45,880 --> 00:18:43,490
analytes that we've measured we measured

430
00:18:48,250 --> 00:18:45,890
temperature pH and sulfide we just

431
00:18:51,120 --> 00:18:48,260
simply ask the question where do we find

432
00:18:53,260 --> 00:18:51,130
photosynthesis evidence for genetic or

433
00:18:55,480 --> 00:18:53,270
biochemical evidence for photosynthesis

434
00:18:57,820 --> 00:18:55,490
and where do we not and the first thing

435
00:18:59,500 --> 00:18:57,830
I'd like to point your attention to is

436
00:19:01,270 --> 00:18:59,510
this panel on the left now this is the

437
00:19:04,300 --> 00:19:01,280
distribution of photosynthesis as a

438
00:19:08,160 --> 00:19:04,310

function of temperature and pH and what

439
00:19:12,520 --> 00:19:08,170
we see well we see kind of a stepwise

440
00:19:15,220 --> 00:19:12,530
function there we're at ph 5 you see

441
00:19:17,560 --> 00:19:15,230
photosynthesis and the systems with ph

442
00:19:18,970 --> 00:19:17,570
greater than 5 we see photosynthesis all

443
00:19:24,400 --> 00:19:18,980
the way up is about 73 degrees

444
00:19:26,860 --> 00:19:24,410
centigrade and below this ph realm more

445
00:19:29,470 --> 00:19:26,870
acidic systems we see photosynthesis

446
00:19:30,790 --> 00:19:29,480
more constrained to lower lower

447
00:19:34,090 --> 00:19:30,800
temperature environments and so what is

448
00:19:35,860 --> 00:19:34,100
this telling us well we think that this

449
00:19:38,410 --> 00:19:35,870
is telling us that photosynthesis it's

450
00:19:39,549 --> 00:19:38,420
very unlikely photosynthesis originated

451
00:19:42,489 --> 00:19:39,559
in the hot spring with the 10

452
00:19:43,779 --> 00:19:42,499
greater than 72 degrees centigrade we

453
00:19:46,539 --> 00:19:43,789
think that there's something very unique

454
00:19:49,539 --> 00:19:46,549
about this 73 degrees centigrade upper

455
00:19:51,369 --> 00:19:49,549
temperature limit that is keeping

456
00:19:53,230 --> 00:19:51,379
photosynthesis from diversifying into

457
00:19:54,220 --> 00:19:53,240
those into those environmental realms

458
00:19:56,639 --> 00:19:54,230
and I actually had a very nice

459
00:19:59,230 --> 00:19:56,649
discussion with with Eric my

460
00:20:01,180 --> 00:19:59,240
co-presenter hear about what this what

461
00:20:04,869 --> 00:20:01,190
might be defining the supper temperature

462
00:20:06,159 --> 00:20:04,879
limit we started really well we spent

463
00:20:07,539 --> 00:20:06,169

about 30 minutes that we should been

464
00:20:09,310 --> 00:20:07,549
using to prepare for this presentation

465
00:20:11,590 --> 00:20:09,320
talking about what what this might

466
00:20:13,230 --> 00:20:11,600
reflect and it got very interesting

467
00:20:16,149 --> 00:20:13,240
talking about inorganic carbon

468
00:20:19,659 --> 00:20:16,159
availability potentially the constraints

469
00:20:22,299 --> 00:20:19,669
at that place is on the ability for

470
00:20:24,940 --> 00:20:22,309
these organisms to get rid of reducing

471
00:20:26,529 --> 00:20:24,950
equivalents or electrons that their

472
00:20:27,879 --> 00:20:26,539
chatter that they generate through

473
00:20:30,850 --> 00:20:27,889
photosynthesis they can't really

474
00:20:32,470 --> 00:20:30,860
regulate photosynthesis and their

475
00:20:34,840 --> 00:20:32,480
inability to get rid of those electrons

476
00:20:36,940 --> 00:20:34,850
so at this 73 degree temperature limit

477
00:20:39,430 --> 00:20:36,950
perhaps they're there they're just

478
00:20:42,039 --> 00:20:39,440
burning up with energy what about this

479
00:20:44,859 --> 00:20:42,049
this this step function that occurs here

480
00:20:46,950 --> 00:20:44,869
at about ph 5 well that turns out to be

481
00:20:49,029 --> 00:20:46,960
a strip demarcation between

482
00:20:51,989 --> 00:20:49,039
cyanobacterial dominated systems at

483
00:20:56,169 --> 00:20:51,999
about between ph 4 and 5 and above

484
00:20:59,799 --> 00:20:56,179
versus algal dominated systems below

485
00:21:03,789 --> 00:20:59,809
below this ph realm so if we now

486
00:21:05,769 --> 00:21:03,799
transition over to panel B we have math

487
00:21:08,259 --> 00:21:05,779
to the distribution of photosynthesis as

488
00:21:09,519 --> 00:21:08,269

a function of temperature and sulfide we

489
00:21:11,200 --> 00:21:09,529
can see that there appears to be an

490
00:21:14,080 --> 00:21:11,210
upper temperature or an upper sulphide

491
00:21:15,940 --> 00:21:14,090
limit for for most of these photo tropes

492
00:21:18,690 --> 00:21:15,950
and I should mention that this is

493
00:21:21,159 --> 00:21:18,700
probably Yellowstone specific as there's

494
00:21:22,960 --> 00:21:21,169
known to be some cyanobacteria that

495
00:21:24,879 --> 00:21:22,970
tolerate much higher concentrations of

496
00:21:26,440 --> 00:21:24,889
sulfides of this and so for whatever

497
00:21:29,980 --> 00:21:26,450
reason is those organisms aren't

498
00:21:32,739 --> 00:21:29,990
successful in Yellowstone but anyway so

499
00:21:34,359 --> 00:21:32,749
we saw this data and we decided well

500
00:21:36,159 --> 00:21:34,369
this is interesting let's see if we

501
00:21:38,950 --> 00:21:36,169
can't understand what the effect of

502
00:21:41,259 --> 00:21:38,960
sulfide is on photosynthetic activities

503
00:21:42,999 --> 00:21:41,269
we picked a couple algal dominated

504
00:21:44,379 --> 00:21:43,009
systems and a couple of cyanobacterial

505
00:21:46,389 --> 00:21:44,389
dominated systems and we showed that

506
00:21:49,509 --> 00:21:46,399
cyanobacteria don't seem to be sensitive

507
00:21:53,940 --> 00:21:49,519
to sulfide okay but the algal

508
00:21:57,460 --> 00:21:53,950
populations co2 fixation systematically

509
00:22:00,550 --> 00:21:57,470
goes down with increasing sulfide

510
00:22:03,120 --> 00:22:00,560
concentration suggesting that something

511
00:22:07,990 --> 00:22:03,130
may perhaps sulfide gradients might have

512
00:22:11,170 --> 00:22:08,000
impacted the evolution of algae and how

513
00:22:15,550 --> 00:22:11,180

the ability for eukaryotes to perform

514
00:22:19,030 --> 00:22:15,560
photosynthesis and this final slide I'm

515
00:22:21,970 --> 00:22:19,040
just going to cut to the chase here this

516
00:22:23,620 --> 00:22:21,980
is about thirty thirty communities in

517
00:22:25,530 --> 00:22:23,630
the Yellowstone that we generated meta

518
00:22:30,010 --> 00:22:25,540
genomic sequence data so that is

519
00:22:32,710 --> 00:22:30,020
randomly sequence total genomic DNA from

520
00:22:36,610 --> 00:22:32,720
these communities through a series of

521
00:22:38,830 --> 00:22:36,620
bioinformatics tools that get a little

522
00:22:41,680 --> 00:22:38,840
complex we generate a comparative

523
00:22:42,850 --> 00:22:41,690
analysis of the metabolic composition of

524
00:22:44,860 --> 00:22:42,860
these communities or the genetic

525
00:22:46,960 --> 00:22:44,870
composition of these communities so

526
00:22:49,210 --> 00:22:46,970
those communities that are separated by

527
00:22:51,550 --> 00:22:49,220
a short branch links here are more

528
00:22:53,830 --> 00:22:51,560
similar metabolically than those that

529
00:22:58,120 --> 00:22:53,840
are separated by longer branch links and

530
00:23:00,790 --> 00:22:58,130
what you can see here very simply is

531
00:23:03,340 --> 00:23:00,800
this B mark ation between photosynthetic

532
00:23:06,310 --> 00:23:03,350
and chemosynthetic ecosystems and if we

533
00:23:09,850 --> 00:23:06,320
think back to this transition that we

534
00:23:11,980 --> 00:23:09,860
noted in our distribution analysis you

535
00:23:15,250 --> 00:23:11,990
can pretty much overlay that right here

536
00:23:17,650 --> 00:23:15,260
so as we transition from kemah trophic

537
00:23:19,690 --> 00:23:17,660
communities to phototrophic communities

538
00:23:23,010 --> 00:23:19,700

you know whatever that was 2.8 million

539
00:23:25,440 --> 00:23:23,020
years ago all hell broke loose

540
00:23:29,020 --> 00:23:25,450
metabolically all kinds of news

541
00:23:30,460 --> 00:23:29,030
metabolic innovations the second thing I

542
00:23:32,500 --> 00:23:30,470
want to point out on this flight I don't

543
00:23:35,770 --> 00:23:32,510
have it clearly delineated here but

544
00:23:38,260 --> 00:23:35,780
within that kima trophic cluster there's

545
00:23:41,430 --> 00:23:38,270
two there's two primary clusters sub

546
00:23:43,930 --> 00:23:41,440
clusters one of these is comprises

547
00:23:45,990 --> 00:23:43,940
communities that inhabit circum neutral

548
00:23:48,700 --> 00:23:46,000
to alkaline systems and the other

549
00:23:51,310 --> 00:23:48,710
comprises communities that have it

550
00:23:54,010 --> 00:23:51,320
acidic systems and that demarcation is

551
00:23:57,150 --> 00:23:54,020
right there at about ph 5 and so there's

552
00:23:59,290 --> 00:23:57,160
something about systems that are

553
00:24:01,450 --> 00:23:59,300
alkaline or circum neutral that select

554
00:24:05,670 --> 00:24:01,460
for different metabolic functions than

555
00:24:08,550 --> 00:24:05,680
those that are acidic now this analysis

556
00:24:10,710 --> 00:24:08,560
is interesting as it might be is not

557
00:24:12,900 --> 00:24:10,720
where Eric and I would like to see that

558
00:24:15,180 --> 00:24:12,910
and what we would really like to do and

559
00:24:18,690 --> 00:24:15,190
what we're really proposing here in this

560
00:24:21,120 --> 00:24:18,700
light paper is to take this data to take

561
00:24:23,580 --> 00:24:21,130
this data that we already have and turn

562
00:24:26,160 --> 00:24:23,590
it and really analyze it within a

563
00:24:28,020 --> 00:24:26,170

phylogenetic framework so the problem

564
00:24:30,510 --> 00:24:28,030
with this data set as it exists we can't

565
00:24:32,250 --> 00:24:30,520
establish trajectory okay we can map

566
00:24:36,480 --> 00:24:32,260
geochemical gradients on this very

567
00:24:39,600 --> 00:24:36,490
easily but we can't map trajectory so to

568
00:24:42,180 --> 00:24:39,610
really link this this space for time

569
00:24:44,700 --> 00:24:42,190
argument and make use of it right we

570
00:24:47,310 --> 00:24:44,710
want to feed this into a phylogenetic

571
00:24:49,620 --> 00:24:47,320
context or a phylogenetic context and

572
00:24:53,430 --> 00:24:49,630
then at that point really start looking

573
00:24:55,860 --> 00:24:53,440
at specific metabolic pathways how they

574
00:24:57,360 --> 00:24:55,870
evolved when they evolved in what kind

575
00:25:00,390 --> 00:24:57,370
of environment types seem to have

576
00:25:06,960 --> 00:25:00,400
selected for or the innovation of those

577
00:25:09,000 --> 00:25:06,970
of those metabolisms and then finally if

578
00:25:11,970 --> 00:25:09,010
we're able to get that far in our

579
00:25:13,590 --> 00:25:11,980
analyses what we really think should be

580
00:25:15,360 --> 00:25:13,600
done is we think that we should

581
00:25:17,760 --> 00:25:15,370
integrate reaction kinetics into these

582
00:25:21,030 --> 00:25:17,770
models and so you can make the argument

583
00:25:24,120 --> 00:25:21,040
that that geochemistry is extremely

584
00:25:26,340 --> 00:25:24,130
important in the diversification of life

585
00:25:27,900 --> 00:25:26,350
without a doubt that was the case but

586
00:25:29,130 --> 00:25:27,910
something that's very difficult to

587
00:25:32,550 --> 00:25:29,140
incorporate into those kind of

588
00:25:36,440 --> 00:25:32,560

considerations is the fact that some

589
00:25:39,240 --> 00:25:36,450
reactions have huge kinetic barriers to

590
00:25:41,750 --> 00:25:39,250
biology and maybe they don't have such

591
00:25:45,870 --> 00:25:41,760
high kinetic barriers to abiotic

592
00:25:49,470 --> 00:25:45,880
reactions and so the example that that I

593
00:25:51,480 --> 00:25:49,480
like to use is so we've we've all heard

594
00:25:55,230 --> 00:25:51,490
of these these really interesting Oh

595
00:25:56,790 --> 00:25:55,240
flight systems such as lost city where

596
00:26:00,060 --> 00:25:56,800
they're generating massive quantities of

597
00:26:02,010 --> 00:26:00,070
hydrogen abiotic Lee well if you're a

598
00:26:04,020 --> 00:26:02,020
fervent eighth of organism you're an

599
00:26:05,340 --> 00:26:04,030
organism that's fermenting for made or

600
00:26:08,400 --> 00:26:05,350
you're fermenting whatever your favorite

601
00:26:11,100 --> 00:26:08,410
organic molecule is and you critically

602
00:26:15,360 --> 00:26:11,110
depend on low partial pressures of

603
00:26:17,190 --> 00:26:15,370
hydrogen to run that reaction forward to

604
00:26:18,770 --> 00:26:17,200
take that reaction forward now that's

605
00:26:21,350 --> 00:26:18,780
not going to be a great place for you to

606
00:26:23,740 --> 00:26:21,360
to be catalyzing these processes you can

607
00:26:26,000 --> 00:26:23,750
also think about this as you have these

608
00:26:27,910 --> 00:26:26,010
ophiolite sequences that are cat

609
00:26:30,530 --> 00:26:27,920
catalyzing the reduction of co2

610
00:26:34,520 --> 00:26:30,540
producing formate as an intermediate on

611
00:26:36,950 --> 00:26:34,530
its way to methane if you are an

612
00:26:40,550 --> 00:26:36,960
organism that wants to squeak out a

613
00:26:43,490 --> 00:26:40,560

living i'm using a form 8 as an electron

614
00:26:46,040 --> 00:26:43,500
or carbon source and that abiotic

615
00:26:48,140 --> 00:26:46,050
reaction that abiotic reduction of

616
00:26:51,350 --> 00:26:48,150
formate to methane is too fast for you

617
00:26:55,460 --> 00:26:51,360
to keep up you're at a lot right there's

618
00:26:57,530 --> 00:26:55,470
no energy we have for you and so ideally

619
00:26:59,060 --> 00:26:57,540
you know focusing on a couple of

620
00:27:01,220 --> 00:26:59,070
reactions that we think are important

621
00:27:03,590 --> 00:27:01,230
for early life now we might be able to

622
00:27:05,090 --> 00:27:03,600
get at this these kind of questions and

623
00:27:08,240 --> 00:27:05,100
integrate this greater consideration

624
00:27:13,460 --> 00:27:08,250
into these models that we would hope

625
00:27:16,220 --> 00:27:13,470
would be developed and I guess just to

626
00:27:18,590 --> 00:27:16,230
summarize the point here is is how can

627
00:27:21,110 --> 00:27:18,600
we take advantage of expanders

628
00:27:23,720 --> 00:27:21,120
distributions of life and their

629
00:27:25,330 --> 00:27:23,730
metabolic strategies the guide our

630
00:27:27,950 --> 00:27:25,340
understanding of what early life

631
00:27:30,800 --> 00:27:27,960
metabolic strategies were and how they

632
00:27:32,660 --> 00:27:30,810
diversified okay and so really trying to

633
00:27:35,480 --> 00:27:32,670
understand what the role of environment

634
00:27:38,450 --> 00:27:35,490
an environmental variation is in those

635
00:27:40,880 --> 00:27:38,460
events how can we integrate a biotic

636
00:27:42,860 --> 00:27:40,890
reaction kinetics into these models this

637
00:27:44,330 --> 00:27:42,870
is something that that has been avoided

638
00:27:45,950 --> 00:27:44,340

and probably with good reason because

639
00:27:49,730 --> 00:27:45,960
it's not easy to do these kind of

640
00:27:53,690 --> 00:27:49,740
experiments or integrate those into your

641
00:27:57,620 --> 00:27:53,700
models but how can we use abiotic

642
00:28:00,710 --> 00:27:57,630
reaction reaction kinetic kinetics to

643
00:28:03,440 --> 00:28:00,720
further our understanding of what early

644
00:28:04,820 --> 00:28:03,450
life might have been up against we

645
00:28:07,310 --> 00:28:04,830
didn't talk much about the role of inter

646
00:28:09,260 --> 00:28:07,320
species interactions but certainly as

647
00:28:12,410 --> 00:28:09,270
Eric mentioned there's very few

648
00:28:15,020 --> 00:28:12,420
environments that are mono species

649
00:28:16,670 --> 00:28:15,030
environments typically you have a very

650
00:28:19,910 --> 00:28:16,680
complex community and so you can't

651
00:28:21,950 --> 00:28:19,920
neglect the role of interspecies

652
00:28:25,870 --> 00:28:21,960
interactions in dictating

653
00:28:27,800 --> 00:28:25,880
co-evolutionary dynamics and I guess

654
00:28:30,380 --> 00:28:27,810
finally you know why would any

655
00:28:32,100 --> 00:28:30,390
astrobiologist care you know how can we

656
00:28:34,799 --> 00:28:32,110
use the information that we would gain

657
00:28:38,730 --> 00:28:34,809
came from such a these analyses to guide

658
00:28:42,090 --> 00:28:38,740
or improve guiding a site selection for

659
00:28:44,460 --> 00:28:42,100
four missions and Eric and I both think

660
00:28:48,299 --> 00:28:44,470
that by focusing on these early early

661
00:28:51,660 --> 00:28:48,309
life sustaining metabolisms exploitation

662
00:28:53,549 --> 00:28:51,670
of small energetic gradients that those

663
00:28:57,330 --> 00:28:53,559

are the kind of metabolisms that we most

664
00:29:00,330 --> 00:28:57,340
likely see on another planet and that

665
00:29:02,610 --> 00:29:00,340
could provide some new insight in that

666
00:29:04,770 --> 00:29:02,620
regard and so with that that's the end

667
00:29:07,500 --> 00:29:04,780
of our presentation I'd be great to open

668
00:29:11,400 --> 00:29:07,510
this up for any discussion that people

669
00:29:14,669 --> 00:29:11,410
might have Thanks great thank you very

670
00:29:17,430 --> 00:29:14,679
much um just while you're doing the

671
00:29:21,930 --> 00:29:17,440
presentation we switched the document so

672
00:29:23,520 --> 00:29:21,940
it's now open for adding comments I can

673
00:29:26,880 --> 00:29:23,530
see there are several people in here

674
00:29:29,490 --> 00:29:26,890
it's helpful if you can actually log in

675
00:29:32,460 --> 00:29:29,500
with your google ID just so the authors

676
00:29:34,590 --> 00:29:32,470
can see who's writing what so if you're

677
00:29:38,340 --> 00:29:34,600
logged in and you know you are anonymous

678
00:29:40,110 --> 00:29:38,350
narwhal or anonymous wombat as Google

679
00:29:41,760 --> 00:29:40,120
likes to give you these names it's great

680
00:29:44,310 --> 00:29:41,770
if before you add your comments you

681
00:29:45,960 --> 00:29:44,320
could just authenticate if for some

682
00:29:48,659 --> 00:29:45,970
reason that doesn't work then it's worth

683
00:29:52,110 --> 00:29:48,669
sticking your name in when you add your

684
00:29:54,960 --> 00:29:52,120
virtual post-it notes so um at this

685
00:29:58,260 --> 00:29:54,970
point where i can see dave is is typing

686
00:30:00,990 --> 00:29:58,270
comments already but the audio lines are

687
00:30:03,180 --> 00:30:01,000
now open Jennifer I've noticed that

688
00:30:04,860 --> 00:30:03,190

you're sort of coming in and out of the

689
00:30:06,690 --> 00:30:04,870
space oh and presumably a slight

690
00:30:10,039 --> 00:30:06,700
technical problems there but hopefully

691
00:30:12,990 --> 00:30:10,049
you're still with us on audio so

692
00:30:14,850 --> 00:30:13,000
questions observations what should the

693
00:30:38,320 --> 00:30:14,860
authors be thinking about and how can we

694
00:30:42,889 --> 00:30:41,180
actually won't dave is type in cleansing

695
00:30:45,490 --> 00:30:42,899
I know that just recently you've always

696
00:30:49,639 --> 00:30:45,500
wanted to ask questions with regards to

697
00:30:51,289 --> 00:30:49,649
where this would shape activities but I

698
00:30:55,430 --> 00:30:51,299
don't want to put words into your mouth

699
00:30:58,940 --> 00:30:55,440
so what is even normally asking hey the

700
00:31:00,680 --> 00:30:58,950
presenters to put cool yeah so I mean

701
00:31:02,600 --> 00:31:00,690
that this is this is sort of a question

702
00:31:05,060 --> 00:31:02,610
that we've been trying to move forward

703
00:31:08,389 --> 00:31:05,070
with and that sort of you know this I

704
00:31:09,769 --> 00:31:08,399
know this topic is I find this one very

705
00:31:12,440 --> 00:31:09,779
interesting and you know i think that

706
00:31:14,869 --> 00:31:12,450
there's there's certainly a in some ways

707
00:31:16,999 --> 00:31:14,879
this feels like a very long term view of

708
00:31:20,570 --> 00:31:17,009
how to view this but what specifically

709
00:31:21,950 --> 00:31:20,580
do you guys think is more what kind of

710
00:31:23,330 --> 00:31:21,960
things do you think are more likely to

711
00:31:25,940 --> 00:31:23,340
be you know what we're going to look at

712
00:31:34,159 --> 00:31:25,950
in the next 10 years rather than sort of

713
00:31:35,960 --> 00:31:34,169

set the very long view ah I guess I'll

714
00:31:38,840 --> 00:31:35,970
take the first crack at that I don't

715
00:31:43,159 --> 00:31:38,850
think that this is a very real long-term

716
00:31:45,399 --> 00:31:43,169
view at all I think with the expanse of

717
00:31:47,810 --> 00:31:45,409
genome sequence technology i mean it's

718
00:31:49,460 --> 00:31:47,820
absolutely crazy what you can generate a

719
00:31:53,029 --> 00:31:49,470
meta-genome for one hundred two hundred

720
00:31:57,289 --> 00:31:53,039
dollars these days you have the samples

721
00:32:01,279 --> 00:31:57,299
that span that 1440 geochemical very hot

722
00:32:02,840 --> 00:32:01,289
spring gradient that i showed you and we

723
00:32:04,009 --> 00:32:02,850
have the bio and traumatic tools to make

724
00:32:07,159 --> 00:32:04,019
this happen i'm sorry i'm having trouble

725
00:32:10,730 --> 00:32:07,169
with my light son just keeps moving on

726
00:32:13,549 --> 00:32:10,740
me um anyway I so I don't think it

727
00:32:16,399 --> 00:32:13,559
necessarily is at least on that first

728
00:32:20,419 --> 00:32:16,409
part the sense this is a very long term

729
00:32:21,889 --> 00:32:20,429
goal I think we can do this now you

730
00:32:23,269 --> 00:32:21,899
think that kind of thing is the kind of

731
00:32:26,120 --> 00:32:23,279
thing you're looking at in the next 10

732
00:32:31,919 --> 00:32:30,630
meta-genome you can act in it I think

733
00:32:33,360 --> 00:32:31,929
you can do it with metagenomes I think

734
00:32:35,039 --> 00:32:33,370
he can do it with meta transcriptomes

735
00:32:39,630 --> 00:32:35,049
which would even get more interesting

736
00:32:40,830 --> 00:32:39,640
right so you can start looking at you

737
00:32:43,049 --> 00:32:40,840
could even look at temporal dynamics

738
00:32:47,760 --> 00:32:43,059

within a system and how that's causing

739
00:32:49,500 --> 00:32:47,770
metabolic complexity to evolve but I you

740
00:32:52,380 --> 00:32:49,510
know this is all stuff that I think the

741
00:32:55,260 --> 00:32:52,390
the integrating abiotic reaction

742
00:32:58,110 --> 00:32:55,270
kinetics for even biological reaction

743
00:33:02,100 --> 00:32:58,120
kinetics into these models is where the

744
00:33:04,860 --> 00:33:02,110
challenges that's that to me is where we

745
00:33:07,110 --> 00:33:04,870
need to go but Eric I don't give

746
00:33:11,399 --> 00:33:07,120
anything to add yeah I'd like to pick up

747
00:33:13,770 --> 00:33:11,409
on that and of agreeing with you too to

748
00:33:18,480 --> 00:33:13,780
say some some more things of a similar

749
00:33:23,430 --> 00:33:18,490
sort and hi Lindsay you know it seems

750
00:33:25,169 --> 00:33:23,440
Eric here there are basic things about

751
00:33:27,810 --> 00:33:25,179
the notion of cause and the notion of

752
00:33:29,880 --> 00:33:27,820
regulation where we spend a lot of time

753
00:33:31,799 --> 00:33:29,890
taking for granted when in fact we have

754
00:33:35,490 --> 00:33:31,809
the data to actually try to understand

755
00:33:37,260 --> 00:33:35,500
instead too many things organism focused

756
00:33:39,419 --> 00:33:37,270
we're at the level of basically trying

757
00:33:42,180 --> 00:33:39,429
to model constraints like full

758
00:33:44,250 --> 00:33:42,190
metabolism models for organisms it still

759
00:33:46,020 --> 00:33:44,260
is just the leading edge to try to

760
00:33:48,240 --> 00:33:46,030
understand the regulation of metabolism

761
00:33:52,020 --> 00:33:48,250
within organisms but there's a lot of

762
00:33:53,820 --> 00:33:52,030
reason I would argue to say that a lot

763
00:33:56,760 --> 00:33:53,830

of constraint or causation or even

764
00:33:59,220 --> 00:33:56,770
regulation of chemical reaction input

765
00:34:00,840 --> 00:33:59,230
output systems is not controlled at the

766
00:34:02,820 --> 00:34:00,850
organism level it's controlled at the

767
00:34:07,200 --> 00:34:02,830
ecosystem level and it's mediated by

768
00:34:08,909 --> 00:34:07,210
organism dynamics but the the point Eric

769
00:34:11,119 --> 00:34:08,919
was making where you can do dendrograms

770
00:34:16,230 --> 00:34:11,129
and you can do similarity relations at

771
00:34:19,169 --> 00:34:16,240
the sort of ecosystem level metabolic

772
00:34:21,270 --> 00:34:19,179
competence level you would really like

773
00:34:23,849 --> 00:34:21,280
to pair that with an organism

774
00:34:25,829 --> 00:34:23,859
phylogenetic reconstruction because what

775
00:34:28,260 --> 00:34:25,839
you get from organism histories are two

776
00:34:29,909 --> 00:34:28,270
things one is the dependency sequence

777
00:34:31,649 --> 00:34:29,919
and then the other is the degree of

778
00:34:33,450 --> 00:34:31,659
Trina sort of articulation which gives

779
00:34:36,550 --> 00:34:33,460
you some sense of where you need to know

780
00:34:38,700 --> 00:34:36,560
or don't need to know ecological context

781
00:34:41,710 --> 00:34:38,710
what the determinants were of

782
00:34:43,450 --> 00:34:41,720
opportunities for innovation and I feel

783
00:34:45,730 --> 00:34:43,460
like this is a place to actually get

784
00:34:47,710 --> 00:34:45,740
conceptually at where cause and

785
00:34:50,980 --> 00:34:47,720
regulation are going on in biology it's

786
00:34:52,990 --> 00:34:50,990
it's not us I was going to say something

787
00:34:56,800 --> 00:34:53,000
that would get me in trouble but I think

788
00:34:59,200 --> 00:34:56,810

better of it it's not a particularly

789
00:35:01,420 --> 00:34:59,210
scientifically well defended point of

790
00:35:04,530 --> 00:35:01,430
view to just suppose that everything

791
00:35:07,750 --> 00:35:04,540
happens at the level of the organism and

792
00:35:09,580 --> 00:35:07,760
you know the the tools we have both for

793
00:35:11,320 --> 00:35:09,590
modeling and just for data analysis

794
00:35:13,120 --> 00:35:11,330
allow us to frame a lot of those

795
00:35:15,040 --> 00:35:13,130
questions in a less prejudiced way and I

796
00:35:22,780 --> 00:35:15,050
think that stuff we can do in in real

797
00:35:26,830 --> 00:35:22,790
time with what we already have gentlemen

798
00:35:29,470 --> 00:35:26,840
DC the the question that dave has 20

799
00:35:32,110 --> 00:35:29,480
into your chat window so i do i'm

800
00:35:34,390 --> 00:35:32,120
reading now nothing said to give you a

801
00:35:43,720 --> 00:35:34,400
million or so typical it was typing for

802
00:35:45,720 --> 00:35:43,730
so long oh yeah the the connectivity of

803
00:35:47,800 --> 00:35:45,730
extreme environments you know i

804
00:35:51,510 --> 00:35:47,810
absolutely you know our hot springs the

805
00:35:55,120 --> 00:35:51,520
best environment study origin of life

806
00:35:58,150 --> 00:35:55,130
type to nibhana probably not right i

807
00:36:02,340 --> 00:35:58,160
mean for the reasons that you indicate

808
00:36:06,130 --> 00:36:02,350
here also because they jet they you know

809
00:36:08,770 --> 00:36:06,140
a little known fact is that they get a

810
00:36:11,620 --> 00:36:08,780
lot of support from their external

811
00:36:13,450 --> 00:36:11,630
environment which is you know adjacent

812
00:36:15,850 --> 00:36:13,460
soils and so on and so forth so they're

813
00:36:17,590 --> 00:36:15,860

connected you're making the claim that

814
00:36:21,070 --> 00:36:17,600
maybe some of these organisms don't have

815
00:36:23,410 --> 00:36:21,080
actually a heritage in these systems and

816
00:36:27,040 --> 00:36:23,420
actually recently invaded these systems

817
00:36:29,620 --> 00:36:27,050
and and I think that's partially true

818
00:36:31,300 --> 00:36:29,630
for sub dominant players but the

819
00:36:34,660 --> 00:36:31,310
dominant players and all of the systems

820
00:36:37,980 --> 00:36:34,670
at least that I've ever looked at have a

821
00:36:42,820 --> 00:36:37,990
strong hydrothermal early life

822
00:36:46,170 --> 00:36:42,830
hydrothermal heritage where I where I

823
00:36:48,450 --> 00:36:46,180
think you know we're going to improve

824
00:36:50,520 --> 00:36:48,460
site selection for

825
00:36:53,480 --> 00:36:50,530
you know some of these these missions

826
00:36:56,220 --> 00:36:53,490
well what do we need to do well I think

827
00:37:00,570 --> 00:36:56,230
moving from surface hot spring type

828
00:37:03,780 --> 00:37:00,580
systems for surface living into the deep

829
00:37:08,579 --> 00:37:03,790
subsurface rate so drilling in a

830
00:37:11,280 --> 00:37:08,589
hydrothermal system looking at some of

831
00:37:13,530 --> 00:37:11,290
these subsurface ophiolites and

832
00:37:16,890 --> 00:37:13,540
understanding how those organisms are

833
00:37:22,740 --> 00:37:16,900
exploiting small energetic gradients and

834
00:37:24,780 --> 00:37:22,750
I think that to me is the key parameter

835
00:37:28,589 --> 00:37:24,790
to focus in on it's not the heat it's

836
00:37:31,099 --> 00:37:28,599
not the low pH of a high pH it's its

837
00:37:36,079 --> 00:37:31,109
energetic gradients that are small and

838
00:37:39,240 --> 00:37:36,089

how does white develop a strategy to

839
00:37:41,730 --> 00:37:39,250
support itself based on those small

840
00:37:45,690 --> 00:37:41,740
energetic gradients and are there this

841
00:37:48,359 --> 00:37:45,700
is key are there some unique biomarkers

842
00:37:51,950 --> 00:37:48,369
whether it be a gaseous biomarker a

843
00:37:54,540 --> 00:37:51,960
metabolic biomarker a biochemical marker

844
00:37:58,130 --> 00:37:54,550
for those kind of organisms that we can

845
00:38:03,810 --> 00:37:58,140
exploit in our search for life elsewhere

846
00:38:08,099 --> 00:38:03,820
that would be my comments on your your

847
00:38:10,470 --> 00:38:08,109
comment David yeah I just put it out

848
00:38:12,650 --> 00:38:10,480
mostly as a cautionary note about how

849
00:38:14,970 --> 00:38:12,660
far you can push final genetics in this

850
00:38:17,400 --> 00:38:14,980
because as you guys know much better

851
00:38:19,140 --> 00:38:17,410
than I that when organisms associate in

852
00:38:21,060 --> 00:38:19,150
communities that gene transfers and

853
00:38:23,070 --> 00:38:21,070
stuffed end over time to organize them

854
00:38:25,470 --> 00:38:23,080
some of the earliest evidence for the

855
00:38:29,370 --> 00:38:25,480
antiquity of photosynthesis is really it

856
00:38:32,370 --> 00:38:29,380
sort of functional space more than then

857
00:38:34,500 --> 00:38:32,380
you know what is with us that we don't

858
00:38:36,930 --> 00:38:34,510
want to talk about them sequence

859
00:38:40,020 --> 00:38:36,940
similarity in on some of the molecules

860
00:38:41,609 --> 00:38:40,030
that code for it so you know it's just

861
00:38:42,960 --> 00:38:41,619
that I think this is sort of like when

862
00:38:44,700 --> 00:38:42,970
you go to Mars looking for life you have

863
00:38:45,960 --> 00:38:44,710

to worry about terrestrial contamination

864
00:38:48,900 --> 00:38:45,970
when you do this you have to worry about

865
00:38:51,599 --> 00:38:48,910
quote contamination from things that are

866
00:38:53,040 --> 00:38:51,609
really not intrinsically intrinsic

867
00:38:55,230 --> 00:38:53,050
principles of living in an extreme

868
00:38:58,920 --> 00:38:55,240
environment so just just sort of a

869
00:39:02,500 --> 00:38:58,930
cautionary known about phylogeny yeah

870
00:39:04,480 --> 00:39:02,510
well I think I think that I I definitely

871
00:39:09,040 --> 00:39:04,490
what you're saying but I think the point

872
00:39:10,630 --> 00:39:09,050
is is that unless you have a heritage an

873
00:39:12,730 --> 00:39:10,640
evolutionary history that allows

874
00:39:15,190 --> 00:39:12,740
whatever function that is that you got

875
00:39:16,840 --> 00:39:15,200
you know so its ecology really defines

876
00:39:18,250 --> 00:39:16,850
the success of horizontal gene transfer

877
00:39:22,330 --> 00:39:18,260
you're not going to see genes

878
00:39:24,460 --> 00:39:22,340
transferred from organisms one from an

879
00:39:26,860 --> 00:39:24,470
acidifying went from an alkyl ofile very

880
00:39:28,450 --> 00:39:26,870
often right you see it often within an

881
00:39:31,240 --> 00:39:28,460
asst it of silt in an acid environment

882
00:39:34,630 --> 00:39:31,250
or an alkyl environment so there are

883
00:39:37,630 --> 00:39:34,640
environmental barriers to do gene

884
00:39:39,070 --> 00:39:37,640
transfer and because of that when you

885
00:39:41,520 --> 00:39:39,080
think about these systems at the

886
00:39:44,560 --> 00:39:41,530
ecosystem level like Eric just mentioned

887
00:39:48,730 --> 00:39:44,570
those kind of considerations become less

888
00:39:51,790 --> 00:39:48,740

of a concern you know what you're

889
00:39:54,730 --> 00:39:51,800
talking we yeah that that's that's all

890
00:39:56,650 --> 00:39:54,740
I'd have to say about that yeah I always

891
00:39:59,260 --> 00:39:56,660
worried more about comparisons of genes

892
00:40:00,730 --> 00:39:59,270
within a given environment where

893
00:40:03,640 --> 00:40:00,740
organism might have come from a variety

894
00:40:05,380 --> 00:40:03,650
of sources but you're right on i think

895
00:40:07,810 --> 00:40:05,390
it's the process that's required to

896
00:40:13,660 --> 00:40:07,820
survive in that environment that is is

897
00:40:15,910 --> 00:40:13,670
the key thing to keep in the front and

898
00:40:17,650 --> 00:40:15,920
this good thing to to keep in mind here

899
00:40:23,080 --> 00:40:17,660
which is the phylogenetic siz not an

900
00:40:26,500 --> 00:40:23,090
oracle phylogenetics is one indication

901
00:40:28,240 --> 00:40:26,510
of relatedness or dependency which winds

902
00:40:31,120 --> 00:40:28,250
up being used in a very multi-factor

903
00:40:35,380 --> 00:40:31,130
argument and at this point that Eric

904
00:40:37,690 --> 00:40:35,390
just made about the sort of not only

905
00:40:39,970 --> 00:40:37,700
species separation environment but

906
00:40:42,790 --> 00:40:39,980
entire phenotype genotype class

907
00:40:44,380 --> 00:40:42,800
separations the amazing thing is that

908
00:40:46,270 --> 00:40:44,390
you can see that in phylogenetic

909
00:40:48,520 --> 00:40:46,280
signatures exactly where you would most

910
00:40:50,710 --> 00:40:48,530
not expect to see it from a standpoint

911
00:40:53,740 --> 00:40:50,720
of gene transfer so you look at

912
00:40:56,170 --> 00:40:53,750
innovations in carbon fixation and not

913
00:40:59,350 --> 00:40:56,180

taking any historical perspective you

914
00:41:01,540 --> 00:40:59,360
can say how can one lay out all known

915
00:41:03,300 --> 00:41:01,550
innovations in carbon fixation just to

916
00:41:05,680 --> 00:41:03,310
see how they depend on each other and

917
00:41:07,870 --> 00:41:05,690
the thing the staggering is that they

918
00:41:10,270 --> 00:41:07,880
reconstruct as a tree much better than

919
00:41:11,440 --> 00:41:10,280
most of the protein families for most

920
00:41:13,810 --> 00:41:11,450
genes in the organ

921
00:41:15,460 --> 00:41:13,820
that use them reconstruct as a tree and

922
00:41:18,490 --> 00:41:15,470
you think that's crazy why would there

923
00:41:22,540 --> 00:41:18,500
be trina's at the deep layers when gene

924
00:41:24,760 --> 00:41:22,550
transfer is easiest and one possible

925
00:41:26,950 --> 00:41:24,770
explanation for that is that the

926
00:41:30,520 --> 00:41:26,960
environments are so strongly in training

927
00:41:35,230 --> 00:41:30,530
organisms can do essentially you can't

928
00:41:37,030 --> 00:41:35,240
for a certain gene inventory far outside

929
00:41:38,530 --> 00:41:37,040
the environment where it's well selected

930
00:41:40,870 --> 00:41:38,540
without the organisms just becoming

931
00:41:42,880 --> 00:41:40,880
non-viable and so you get these tree

932
00:41:44,740 --> 00:41:42,890
like dependencies that are not accidents

933
00:41:46,540 --> 00:41:44,750
of inheritance but just the fact that

934
00:41:50,050 --> 00:41:46,550
environments don't mix without in the

935
00:41:52,150 --> 00:41:50,060
course changing so I think that's great

936
00:41:53,800 --> 00:41:52,160
you know absolutely your point is very

937
00:41:56,680 --> 00:41:53,810
well taken that one must always be

938
00:41:59,500 --> 00:41:56,690

thinking and not using these tools in a

939
00:42:01,120 --> 00:41:59,510
kind of a mindless way but in a

940
00:42:06,730 --> 00:42:01,130
multi-factor argument I think there's a

941
00:42:11,050 --> 00:42:06,740
lot that we can do with care agreed

942
00:42:30,460 --> 00:42:11,060
other other questions or observations

943
00:42:38,089 --> 00:42:35,680
no okay the monkeys gentlemen thank you

944
00:42:40,220 --> 00:42:38,099
Eric Boyd I'd also like to think

945
00:42:42,560 --> 00:42:40,230
probably the graduate student who did

946
00:42:44,000 --> 00:42:42,570
some great photo bombing behind you just

947
00:42:47,450 --> 00:42:44,010
poking her head through the little

948
00:42:49,940 --> 00:42:47,460
window in the club yes you can get a

949
00:42:52,430 --> 00:42:49,950
hold of me and tell about two minutes

950
00:42:56,660 --> 00:42:52,440
before we started this so I've been

951
00:42:58,700 --> 00:42:56,670
hearing her knocking how's that oh well

952
00:43:01,849 --> 00:42:58,710
you can you can say she's contributed to

953
00:43:03,530 --> 00:43:01,859
a webinar on astrobiology probably site

954
00:43:07,700 --> 00:43:03,540
of although i'm not sure what formats

955
00:43:08,990 --> 00:43:07,710
are cycling that is okay so particularly

956
00:43:11,510 --> 00:43:09,000
if you're watching this recording

957
00:43:13,690 --> 00:43:11,520
afterwards also encourage you to go to

958
00:43:17,780 --> 00:43:13,700
the document it's open for comments arm

959
00:43:19,849 --> 00:43:17,790
and that is about it for now so

960
00:43:22,280 --> 00:43:19,859
gentlemen thank you very much and thank