EARTH-LIFE
SCIENCE
INSTITUTE

Eric Smith

The many faces of the nature of life

1
00:00:00,160 --> 00:00:14,470
[Music]

2
00:00:19,189 --> 00:00:17,029
okay thank you everybody yeah it's an

3
00:00:20,779 --> 00:00:19,199
amazing room I promise you that at 25

4
00:00:24,500 --> 00:00:20,789
minutes I will turn yellow and then at

5
00:00:26,509 --> 00:00:24,510
30 minutes I will turn red since the

6
00:00:28,160 --> 00:00:26,519
topic of the symposium was expanding

7
00:00:31,030 --> 00:00:28,170
views on the emergence of the biosphere

8
00:00:33,530 --> 00:00:31,040
I thought I would talk about plurality

9
00:00:35,690 --> 00:00:33,540
for the origin of life we have many

10
00:00:37,700 --> 00:00:35,700
bodies of evidence all complicated that

11
00:00:39,590 --> 00:00:37,710
are relevant to understand and it's

12
00:00:41,270 --> 00:00:39,600
possible to put together many possible

13
00:00:42,860 --> 00:00:41,280

scenarios for emergence that either

14
00:00:45,260 --> 00:00:42,870
emphasize different bodies of evidence

15
00:00:47,569 --> 00:00:45,270
or that interpret the same evidence in

16
00:00:51,139 --> 00:00:47,579
different ways so then the question is

17
00:00:53,479 --> 00:00:51,149
how do we want to get beyond the

18
00:00:55,400 --> 00:00:53,489
spinning of scenarios to a notion of

19
00:00:59,000 --> 00:00:55,410
cause and how can we learn to think

20
00:01:00,560 --> 00:00:59,010
systematically about these problems so a

21
00:01:02,479 --> 00:01:00,570
lot of times when people want to

22
00:01:04,700 --> 00:01:02,489
organize a diverse body of evidence of

23
00:01:05,990 --> 00:01:04,710
starting point is defination so I

24
00:01:07,940 --> 00:01:06,000
thought I would open with a good strong

25
00:01:09,980 --> 00:01:07,950
statement by Jack szostak about how well

26
00:01:12,050 --> 00:01:09,990
that seems to be working in his opinion

27
00:01:14,359 --> 00:01:12,060
for the origin of life Jack says

28
00:01:16,880 --> 00:01:14,369
attempts to define life do not help to

29
00:01:19,780 --> 00:01:16,890
understand the origin of life no on him

30
00:01:22,520 --> 00:01:19,790
no ambiguity there so his argument is

31
00:01:25,249 --> 00:01:22,530
you know as with all things from Shostak

32
00:01:28,910 --> 00:01:25,259
deeply empirical and very concerned with

33
00:01:30,710 --> 00:01:28,920
getting the details right he says that

34
00:01:32,179 --> 00:01:30,720
there's a huge number of transitions

35
00:01:34,370 --> 00:01:32,189
that are qualitatively of different

36
00:01:36,920 --> 00:01:34,380
kinds that make up the emergence of a

37
00:01:38,990 --> 00:01:36,930
biosphere and for people to artificially

38
00:01:41,719 --> 00:01:39,000

put a dichotomy in that and say that is

39
00:01:45,590 --> 00:01:41,729
not life this is that was before life

40
00:01:47,450 --> 00:01:45,600
this is is actually not faithful to the

41
00:01:49,310 --> 00:01:47,460
nature of the evidence and what we

42
00:01:50,840 --> 00:01:49,320
should do instead is just do careful

43
00:01:52,940 --> 00:01:50,850
science about the collection of diverse

44
00:01:56,060 --> 00:01:52,950
problems that we have to deal with as

45
00:01:58,490 --> 00:01:56,070
far as that goes absolutely and it's an

46
00:02:00,289 --> 00:01:58,500
important voice of discipline in what

47
00:02:02,480 --> 00:02:00,299
can sometimes be an undisciplined field

48
00:02:04,819 --> 00:02:02,490
and yet on the other hand the notion

49
00:02:07,130 --> 00:02:04,829
since antiquity that there is a unity of

50
00:02:09,199 --> 00:02:07,140
living things in the world is still

51
00:02:11,839 --> 00:02:09,209
correct and it is still scientifically

52
00:02:13,730 --> 00:02:11,849
relevant and the forest of life is more

53
00:02:16,030 --> 00:02:13,740
than the arbitrary sequence of tree

54
00:02:18,470 --> 00:02:16,040
that we happen to have chosen to study

55
00:02:19,730 --> 00:02:18,480
and that's an it's particularly

56
00:02:22,430 --> 00:02:19,740
important if we want to learn how to

57
00:02:24,650 --> 00:02:22,440
reason in the absence of evidence which

58
00:02:26,660 --> 00:02:24,660
is important because what we don't know

59
00:02:29,150 --> 00:02:26,670
that's necessary is more important or is

60
00:02:30,620 --> 00:02:29,160
larger than what we do so the question

61
00:02:32,930 --> 00:02:30,630
is how do we understand both the

62
00:02:35,390 --> 00:02:32,940
multiplicity and the unity that's sort

63
00:02:38,060 --> 00:02:35,400

of this notion of a pluribus unum out of

64
00:02:40,460 --> 00:02:38,070
many things that remain many when do

65
00:02:45,860 --> 00:02:40,470
they become an interdependent one while

66
00:02:47,930 --> 00:02:45,870
not losing their men enos so here are

67
00:02:49,640 --> 00:02:47,940
two examples of trying to create

68
00:02:50,960 --> 00:02:49,650
definitions of life that come from

69
00:02:54,200 --> 00:02:50,970
different perspectives and emphasize

70
00:02:55,630 --> 00:02:54,210
different things one is often cited as

71
00:02:58,040 --> 00:02:55,640
the working definition of NASA

72
00:03:00,880 --> 00:02:58,050
attributed to a working group that Gerry

73
00:03:02,660 --> 00:03:00,890
Joyce was in or chair of a

74
00:03:05,330 --> 00:03:02,670
self-maintaining chemical system capable

75
00:03:07,040 --> 00:03:05,340
of Darwinian evolution good features of

76
00:03:08,900 --> 00:03:07,050
this definition are it acknowledges the

77
00:03:11,090 --> 00:03:08,910
central role of chemistry though without

78
00:03:13,850 --> 00:03:11,100
necessarily explaining why it should be

79
00:03:16,190 --> 00:03:13,860
central the negative part is that it

80
00:03:18,740 --> 00:03:16,200
entails a lot of very complex concepts

81
00:03:20,750 --> 00:03:18,750
in that word Darwinian evolution and in

82
00:03:22,280 --> 00:03:20,760
my opinion others could disagree it

83
00:03:24,740 --> 00:03:22,290
under emphasizes how hard it is to

84
00:03:26,750 --> 00:03:24,750
explain why those concept concepts

85
00:03:29,750 --> 00:03:26,760
should be necessary to explain the

86
00:03:32,120 --> 00:03:29,760
structure of real matter Pete hood one

87
00:03:34,010 --> 00:03:32,130
of the founding PI's of LC takes a

88
00:03:35,600 --> 00:03:34,020

completely different approach on this he

89
00:03:37,250 --> 00:03:35,610
wants to say that the origin of life is

90
00:03:39,320 --> 00:03:37,260
the emergence the spontaneous of

91
00:03:41,900 --> 00:03:39,330
emergent emergence of autonomous agents

92
00:03:44,750 --> 00:03:41,910
in a complex system the plus side of

93
00:03:46,520 --> 00:03:44,760
that is that it gives specific names to

94
00:03:48,260 --> 00:03:46,530
a lot of aspects of architecture that

95
00:03:50,810 --> 00:03:48,270
are fundamental to the biosphere and

96
00:03:52,490 --> 00:03:50,820
that precede evolution so you need them

97
00:03:55,030 --> 00:03:52,500
to talk about where the Darwinian world

98
00:03:57,320 --> 00:03:55,040
enters and some of them are importantly

99
00:03:59,450 --> 00:03:57,330
independently of it and yet still

100
00:04:01,250 --> 00:03:59,460
fundamental to the nature of life the

101
00:04:03,440 --> 00:04:01,260
negative side is that it's about

102
00:04:05,330 --> 00:04:03,450
high-level structure and it doesn't

103
00:04:07,010 --> 00:04:05,340
actually give a place to the conceptual

104
00:04:09,110 --> 00:04:07,020
role of chemistry so you could argue

105
00:04:11,350 --> 00:04:09,120
that these are two complementary views

106
00:04:14,510 --> 00:04:11,360
of the element elephant that cover

107
00:04:17,449 --> 00:04:14,520
different things now when you put up a

108
00:04:18,349 --> 00:04:17,459
definition like this you can ask we try

109
00:04:19,910 --> 00:04:18,359
to find things

110
00:04:21,950 --> 00:04:19,920
according to attributes that other

111
00:04:24,260 --> 00:04:21,960
things don't share but if we want a

112
00:04:26,050 --> 00:04:24,270
notion of cause we need to get beyond

113
00:04:28,240 --> 00:04:26,060

just attributes to essence

114
00:04:31,030 --> 00:04:28,250
things from which other things follow

115
00:04:32,860 --> 00:04:31,040
and so we asked in either of these

116
00:04:34,629 --> 00:04:32,870
definitions are we just looking at

117
00:04:36,700 --> 00:04:34,639
attributes that are useful to

118
00:04:38,710 --> 00:04:36,710
distinguish life or are we looking at

119
00:04:41,530 --> 00:04:38,720
essences that are good starting points

120
00:04:43,300 --> 00:04:41,540
in a theory of cause so one way people

121
00:04:45,340 --> 00:04:43,310
try to get at what is a starting point

122
00:04:47,500 --> 00:04:45,350
in a complicated world is to make

123
00:04:49,659 --> 00:04:47,510
dichotomies to take things that they

124
00:04:51,400 --> 00:04:49,669
think are alternatives and say can we

125
00:04:52,990 --> 00:04:51,410
cut one of them out and say that the

126
00:04:54,940 --> 00:04:53,000
essence of life were of the origin of

127
00:04:57,930 --> 00:04:54,950
life is found in the other so I'll give

128
00:05:00,250 --> 00:04:57,940
you three dichotomies and I'll give you

129
00:05:02,260 --> 00:05:00,260
what was in the abstract to this talk

130
00:05:03,760 --> 00:05:02,270
the argument that both sides seem to be

131
00:05:07,150 --> 00:05:03,770
fundamental and the dichotomy is not a

132
00:05:09,700 --> 00:05:07,160
cut at all so geochemical continuity or

133
00:05:11,320 --> 00:05:09,710
biochemical innovation is life

134
00:05:13,210 --> 00:05:11,330
fundamentally a chemical system or

135
00:05:16,180 --> 00:05:13,220
fundamentally an informational system

136
00:05:18,130 --> 00:05:16,190
and what should we think of as the unit

137
00:05:21,370 --> 00:05:18,140
of memory and persistence in the system

138
00:05:23,680 --> 00:05:21,380

organism ecosystem something else so

139
00:05:25,719 --> 00:05:23,690
first question is it an extension of

140
00:05:28,390 --> 00:05:25,729
geochemistry or an innovative departure

141
00:05:30,670 --> 00:05:28,400
this is a from a paper by George Cooper

142
00:05:32,409 --> 00:05:30,680
looking at the volatile content of

143
00:05:34,690 --> 00:05:32,419
organics and carbonaceous meteorites

144
00:05:37,480 --> 00:05:34,700
Cooper estimates that from the sample

145
00:05:39,159 --> 00:05:37,490
there are at least 50,000 probably

146
00:05:41,890 --> 00:05:39,169
correcting four sample blind spots

147
00:05:44,380 --> 00:05:41,900
closer to a half a million just volatile

148
00:05:46,810 --> 00:05:44,390
compounds in characteristic carbonaceous

149
00:05:49,600 --> 00:05:46,820
meteorite samples now if you look at the

150
00:05:51,100 --> 00:05:49,610
GC spectra of these you notice first of

151
00:05:53,020 --> 00:05:51,110
all that they are not uniform they're

152
00:05:54,940 --> 00:05:53,030
not mud and second that they have a

153
00:05:57,550 --> 00:05:54,950
significant overlap with compounds that

154
00:05:59,770 --> 00:05:57,560
are very central to actual biochemistry

155
00:06:01,750 --> 00:05:59,780
on the other hand a half a million

156
00:06:03,159 --> 00:06:01,760
compounds is considerably larger and

157
00:06:05,740 --> 00:06:03,169
considerably less discipline than

158
00:06:07,570 --> 00:06:05,750
biochemistry now Cooper I apologize for

159
00:06:09,279 --> 00:06:07,580
the rendering of this slide puts

160
00:06:10,930 --> 00:06:09,289
together a system in which he would say

161
00:06:13,060 --> 00:06:10,940
that pyruvate is the crucial non

162
00:06:16,570 --> 00:06:13,070
equilibrium compound that can actually

163
00:06:18,130 --> 00:06:16,580

be driving all of this so I should have

164
00:06:20,200 --> 00:06:18,140
mentioned at the beginning the question

165
00:06:22,510 --> 00:06:20,210
of extending geochemistry or innovating

166
00:06:24,370 --> 00:06:22,520
away from it is sort of the main point

167
00:06:26,740 --> 00:06:24,380
that distinguishes people who want early

168
00:06:28,420 --> 00:06:26,750
metabolism to be a foundation versus

169
00:06:31,690 --> 00:06:28,430
people who want some sort of RNA

170
00:06:34,149 --> 00:06:31,700
mediated central dogma type control to

171
00:06:35,710 --> 00:06:34,159
be the start so this is meteoritic

172
00:06:38,589 --> 00:06:35,720
carbon not so different from

173
00:06:39,380 --> 00:06:38,599
biochemistry contrast that with this

174
00:06:41,210 --> 00:06:39,390
this is a paper

175
00:06:43,460 --> 00:06:41,220
by Vijay Srinivasan and Harold Moore

176
00:06:45,580 --> 00:06:43,470
wits from a few years ago starting from

177
00:06:47,420 --> 00:06:45,590
the sequence genomes of aquifer Kaylee's

178
00:06:50,030 --> 00:06:47,430
reductive citric acid cycle

179
00:06:52,550 --> 00:06:50,040
autotrophs and saying can we distill

180
00:06:54,830 --> 00:06:52,560
from these complete genomes and then

181
00:06:57,260 --> 00:06:54,840
comparative analysis of alternatives in

182
00:06:59,390 --> 00:06:57,270
enzyme databases a kind of minimal

183
00:07:02,300 --> 00:06:59,400
metabolism that is both universal across

184
00:07:04,670 --> 00:07:02,310
the biosphere and also sufficient to

185
00:07:07,400 --> 00:07:04,680
create any living system and they say

186
00:07:10,130 --> 00:07:07,410
you can cut this down to about 125

187
00:07:11,810 --> 00:07:10,140
monomers and small metabolites and out

188
00:07:13,790 --> 00:07:11,820

of this you build everything in the

189
00:07:17,480 --> 00:07:13,800
world so we're down from a half a

190
00:07:19,130 --> 00:07:17,490
million to 125 so this says that the

191
00:07:22,010 --> 00:07:19,140
distinction in biochemistry that is

192
00:07:24,320 --> 00:07:22,020
conservative of geochemistry consists

193
00:07:26,000 --> 00:07:24,330
mostly of pruning but that accounts from

194
00:07:28,250 --> 00:07:26,010
maybe a third of the compounds in this

195
00:07:32,210 --> 00:07:28,260
diagram and the other two-thirds are

196
00:07:33,860 --> 00:07:32,220
innovation so so far both and of course

197
00:07:35,630 --> 00:07:33,870
the attempt to make a dichotomy gets

198
00:07:38,630 --> 00:07:35,640
worse when you realize that the

199
00:07:40,580 --> 00:07:38,640
trajectory of geology once a biosphere

200
00:07:42,860 --> 00:07:40,590
has emerged it can no longer be

201
00:07:45,140 --> 00:07:42,870
understood without the biosphere so for

202
00:07:48,350 --> 00:07:45,150
instance we have Bob Hazen's analysis

203
00:07:50,120 --> 00:07:48,360
both in the empirical record and then by

204
00:07:52,100 --> 00:07:50,130
looking at mineral formation conditions

205
00:07:54,020 --> 00:07:52,110
of the fact that the mineral inventory

206
00:07:56,690 --> 00:07:54,030
on earth has changed cattle

207
00:07:58,580 --> 00:07:56,700
categorically between the earliest

208
00:08:00,800 --> 00:07:58,590
record in the Archaean into the

209
00:08:03,230 --> 00:08:00,810
Proterozoic this is an index of the

210
00:08:05,510 --> 00:08:03,240
diversity of boron minerals versus time

211
00:08:06,680 --> 00:08:05,520
but bob has similar tables for barium

212
00:08:09,650 --> 00:08:06,690
minerals in a variety of other things

213
00:08:12,020 --> 00:08:09,660

and a lot of this is due to feedbacks

214
00:08:13,610 --> 00:08:12,030
from seeding the environment with oxygen

215
00:08:16,280 --> 00:08:13,620
some of it is due to microbial

216
00:08:19,940 --> 00:08:16,290
precipitation so geology is no longer an

217
00:08:22,340 --> 00:08:19,950
abiotic concept once life exists one can

218
00:08:25,010 --> 00:08:22,350
go even further there's a fascinating

219
00:08:26,990 --> 00:08:25,020
argument I don't know how strong it is

220
00:08:28,700 --> 00:08:27,000
Minik rosen and then two of our guests

221
00:08:31,820 --> 00:08:28,710
last year norm sleep and fluency

222
00:08:34,070 --> 00:08:31,830
elbaradei our authors on this they argue

223
00:08:36,310 --> 00:08:34,080
that something as remarkable as the

224
00:08:39,219 --> 00:08:36,320
innovation of photosynthesis by driving

225
00:08:41,510 --> 00:08:39,229
geochemical cycles through the biosphere

226
00:08:43,610 --> 00:08:41,520
actually change the rate of granite

227
00:08:45,650 --> 00:08:43,620
formation and hence the accretion of

228
00:08:48,410 --> 00:08:45,660
continents and the formation of tectonic

229
00:08:49,790 --> 00:08:48,420
cycles that of course affects the rate

230
00:08:51,860 --> 00:08:49,800
of cooling through the upper mantle

231
00:08:53,780 --> 00:08:51,870
which then has implications for the

232
00:08:55,250 --> 00:08:53,790
maintenance of the geodynamo

233
00:08:58,220 --> 00:08:55,260
and the magnetic field and the

234
00:09:00,710 --> 00:08:58,230
conditions of the atmosphere so the

235
00:09:02,930 --> 00:09:00,720
whole notion of making a dichotomy

236
00:09:04,910 --> 00:09:02,940
between the abiotic earth and the

237
00:09:07,820 --> 00:09:04,920
biosphere looks like it's becoming a

238
00:09:09,860 --> 00:09:07,830

real mess okay how about the second one

239
00:09:12,290 --> 00:09:09,870
is life fundamentally chemical or is it

240
00:09:13,820 --> 00:09:12,300
fundamentally informational a lot of

241
00:09:15,950 --> 00:09:13,830
times when people say informational

242
00:09:18,650 --> 00:09:15,960
they're asking about the combinatorics

243
00:09:20,600 --> 00:09:18,660
of sequences there are a lot of places I

244
00:09:22,190 --> 00:09:20,610
could approach this but let me do one in

245
00:09:24,050 --> 00:09:22,200
particular from the genetic code that

246
00:09:26,540 --> 00:09:24,060
allows me to illustrate the contrast

247
00:09:28,220 --> 00:09:26,550
when we think about the combinatorial

248
00:09:30,530 --> 00:09:28,230
information in the genetic code that

249
00:09:33,050 --> 00:09:30,540
might reflect the action of selection we

250
00:09:34,490 --> 00:09:33,060
think of taking the amino acids as given

251
00:09:36,500 --> 00:09:34,500
that's somebody else's problem and

252
00:09:38,900 --> 00:09:36,510
taking the number of times each one

253
00:09:40,520 --> 00:09:38,910
appears just how many different shuffles

254
00:09:42,860 --> 00:09:40,530
could there be through the adapter

255
00:09:44,870 --> 00:09:42,870
apparatus of the genetic code that would

256
00:09:46,820 --> 00:09:44,880
still function and you can do the

257
00:09:49,910 --> 00:09:46,830
combinatorics and you say okay there's

258
00:09:51,650 --> 00:09:49,920
about 230 bits of information that look

259
00:09:53,540 --> 00:09:51,660
like they were selected to produce this

260
00:09:55,790 --> 00:09:53,550
code out of anything with the same

261
00:09:57,980 --> 00:09:55,800
number of amino acids but what if you

262
00:10:00,560 --> 00:09:57,990
said let's not take the amino acid

263
00:10:02,630 --> 00:10:00,570

inventory as given let's ask out of the

264
00:10:05,120 --> 00:10:02,640
carbonaceous inventory how did that

265
00:10:06,740 --> 00:10:05,130
amino acid inventory get selected now

266
00:10:08,930 --> 00:10:06,750
you might argue that that's a separate

267
00:10:09,440 --> 00:10:08,940
problem of pruning that doesn't belong

268
00:10:11,810 --> 00:10:09,450
here

269
00:10:16,160 --> 00:10:11,820
except that and that's the content of

270
00:10:18,590 --> 00:10:16,170
this paper here the particular way the

271
00:10:22,220 --> 00:10:18,600
amino acid assignments are made in the

272
00:10:24,950 --> 00:10:22,230
genetic code is threw out based on the

273
00:10:27,230 --> 00:10:24,960
biosynthetic sequence of the amino acids

274
00:10:30,230 --> 00:10:27,240
not just their terminal properties but

275
00:10:32,060 --> 00:10:30,240
how they're made so that argues that the

276
00:10:34,280 --> 00:10:32,070
identification of the amino acid

277
00:10:36,680 --> 00:10:34,290
inventory all the way from coming off of

278
00:10:38,960 --> 00:10:36,690
the citric acid cycle compounds to the

279
00:10:41,030 --> 00:10:38,970
first position on the codons and many

280
00:10:42,980 --> 00:10:41,040
other regularities through here was

281
00:10:44,690 --> 00:10:42,990
actually being done at the same time as

282
00:10:47,570 --> 00:10:44,700
at least the later stage of these

283
00:10:49,670 --> 00:10:47,580
assignments were being made so I want to

284
00:10:52,220 --> 00:10:49,680
introduce the concept of embodied

285
00:10:54,680 --> 00:10:52,230
information not merely combinatorial

286
00:10:56,680 --> 00:10:54,690
shuffling information but the idea that

287
00:10:59,360 --> 00:10:56,690
inherent in the chemistry and the

288
00:11:01,520 --> 00:10:59,370

limitations in chemical pathways to get

289
00:11:04,280 --> 00:11:01,530
somewhere is much of the information

290
00:11:07,460 --> 00:11:04,290
that we think of as essential to the

291
00:11:10,310 --> 00:11:07,470
nature of the only life we know

292
00:11:12,680 --> 00:11:10,320
and we can go beyond just the code we

293
00:11:14,060 --> 00:11:12,690
can think of RNA and DNA they are often

294
00:11:16,460 --> 00:11:14,070
thought of as the ultimate things

295
00:11:19,210 --> 00:11:16,470
selected to be carriers of any sequence

296
00:11:21,680 --> 00:11:19,220
but if you think about the biochemical

297
00:11:24,680 --> 00:11:21,690
synthetic networks of for instance

298
00:11:27,230 --> 00:11:24,690
purine RNA the embodied information in

299
00:11:30,020 --> 00:11:27,240
that is all information about crucial

300
00:11:32,150 --> 00:11:30,030
cofactors whether you consider histidine

301
00:11:34,130 --> 00:11:32,160
a cofactor or not we can talk about that

302
00:11:36,140 --> 00:11:34,140
but these things are essential in

303
00:11:37,970 --> 00:11:36,150
catalysis they aren't essential in one

304
00:11:39,800 --> 00:11:37,980
carbon transport and they're crucial

305
00:11:42,110 --> 00:11:39,810
cofactors in oxidation-reduction

306
00:11:44,630 --> 00:11:42,120
chemistry which are central to all of

307
00:11:47,870 --> 00:11:44,640
biochemistry and so I don't think you

308
00:11:49,900 --> 00:11:47,880
understand the biotic position and maybe

309
00:11:52,430 --> 00:11:49,910
not the abiotic position of RNA and DNA

310
00:11:55,130 --> 00:11:52,440
until you have understood the embodied

311
00:11:57,560 --> 00:11:55,140
information in this chemical Network

312
00:12:00,770 --> 00:11:57,570
that's preserved today in the cofactor

313
00:12:03,890 --> 00:12:00,780

world organism or eco system our third

314
00:12:05,120 --> 00:12:03,900
dichotomy Steve Gould in the structure

315
00:12:07,640 --> 00:12:05,130
of evolutionary theory makes the

316
00:12:10,250 --> 00:12:07,650
argument that Darwin was very focused on

317
00:12:12,530 --> 00:12:10,260
the organism as the unit of memory even

318
00:12:15,740 --> 00:12:12,540
though he was a consummate ecologist and

319
00:12:17,450 --> 00:12:15,750
from 1859 with the origin through the

320
00:12:19,160 --> 00:12:17,460
modern synthesis in the 30s with its

321
00:12:21,170 --> 00:12:19,170
emphasis on what we can say about the

322
00:12:23,330 --> 00:12:21,180
statistics of genomes to then the

323
00:12:25,310 --> 00:12:23,340
Williams Dawkins emphasis in the 60s on

324
00:12:29,030 --> 00:12:25,320
the gene is the building block of memory

325
00:12:31,670 --> 00:12:29,040
we have become progressively I would say

326
00:12:34,640 --> 00:12:31,680
narrower and harder in what we allow to

327
00:12:36,620 --> 00:12:34,650
be an evolutionary entity but I think

328
00:12:38,780 --> 00:12:36,630
this is an intellectual mistake because

329
00:12:42,080 --> 00:12:38,790
it increasingly takes the entities for

330
00:12:43,900 --> 00:12:42,090
granted and not explains why they exist

331
00:12:46,310 --> 00:12:43,910
and its ruling out the role of

332
00:12:48,530 --> 00:12:46,320
informational or relational variables as

333
00:12:50,330 --> 00:12:48,540
carriers of information now I won't talk

334
00:12:52,010 --> 00:12:50,340
about it today it's not like everyone

335
00:12:54,260 --> 00:12:52,020
has forgotten relations there is good

336
00:12:56,720 --> 00:12:54,270
pushback within science on what the

337
00:12:58,520 --> 00:12:56,730
relational variables carry but the

338
00:13:00,770 --> 00:12:58,530

important point is that in our formal

339
00:13:03,320 --> 00:13:00,780
theory of evolutionary memory population

340
00:13:06,050 --> 00:13:03,330
genetics the non entities become bean

341
00:13:10,910 --> 00:13:06,060
bags or communities the genome or the

342
00:13:12,620 --> 00:13:10,920
ecosystem and so they leave out the role

343
00:13:14,270 --> 00:13:12,630
of the relational variables what I want

344
00:13:16,520 --> 00:13:14,280
to show you in the next couple slides is

345
00:13:19,220 --> 00:13:16,530
that that narrow evolutionary view of

346
00:13:21,049 --> 00:13:19,230
entities does not actually say anything

347
00:13:23,059 --> 00:13:21,059
about the particularity of the bio

348
00:13:25,039 --> 00:13:23,069
chemistry I just showed you meaning that

349
00:13:26,629 --> 00:13:25,049
had the biochemistry been different we

350
00:13:29,029 --> 00:13:26,639
would tell exactly the same story about

351
00:13:31,309 --> 00:13:29,039
genes genomes and Darwinism which means

352
00:13:32,389 --> 00:13:31,319
that by being correct for everything

353
00:13:37,009 --> 00:13:32,399
they explained nothing

354
00:13:40,069 --> 00:13:37,019
so the embodied information I would say

355
00:13:42,919 --> 00:13:40,079
we have in these population level things

356
00:13:44,899 --> 00:13:42,929
takes the form of topologies how is it

357
00:13:47,989 --> 00:13:44,909
possible and how is it not possible to

358
00:13:50,719 --> 00:13:47,999
form a cell or an organism evolutionary

359
00:13:53,179 --> 00:13:50,729
change happens within the typology of

360
00:13:55,369 --> 00:13:53,189
the possible now for organisms the two

361
00:13:57,559 --> 00:13:55,379
most basic I would argue typological

362
00:13:59,899 --> 00:13:57,569
questions are is it autotrophic or

363
00:14:01,429 --> 00:13:59,909

heterotrophic so is it metabolically

364
00:14:03,619 --> 00:14:01,439
self-sufficient or can you not

365
00:14:05,359 --> 00:14:03,629
understand its metabolism except in the

366
00:14:08,239 --> 00:14:05,369
context of the ecosystem it depends on

367
00:14:10,609 --> 00:14:08,249
and is it an anaerobic or an aerobic

368
00:14:12,559 --> 00:14:10,619
metabolism fundamentally so are its

369
00:14:15,319 --> 00:14:12,569
energy sources more reduced or more

370
00:14:17,119 --> 00:14:15,329
oxidized than the net biological carbon

371
00:14:19,579 --> 00:14:17,129
now the interesting thing is that the

372
00:14:22,249 --> 00:14:19,589
anaerobic aerobic variable is also a

373
00:14:24,469 --> 00:14:22,259
type variable for ecosystems the auto

374
00:14:27,199 --> 00:14:24,479
hetero distinction requires the

375
00:14:29,749 --> 00:14:27,209
emergence of organisms to even become a

376
00:14:31,759 --> 00:14:29,759
meaningful thing to say whereas the

377
00:14:33,499 --> 00:14:31,769
arrow of anaerobe distinction does not

378
00:14:35,869 --> 00:14:33,509
and I'm going to argue that that's more

379
00:14:37,729 --> 00:14:35,879
fundamental and in particular that it is

380
00:14:39,619 --> 00:14:37,739
more closely connected to what I will

381
00:14:42,849 --> 00:14:39,629
say is the most universal feature in the

382
00:14:46,099 --> 00:14:42,859
biosphere and that's the following

383
00:14:48,019 --> 00:14:46,109
everything that you synthesize to make a

384
00:14:49,609 --> 00:14:48,029
living organism has its original

385
00:14:50,839 --> 00:14:49,619
starting point in one of four or five

386
00:14:52,269 --> 00:14:50,849
compounds that happen to be

387
00:14:54,409 --> 00:14:52,279
intermediates in the citric acid cycle

388
00:14:56,269 --> 00:14:54,419

there can be a lot of twists and turns

389
00:14:59,149 --> 00:14:56,279
building up and breaking down and

390
00:15:01,519 --> 00:14:59,159
shearing in ecosystems but this is true

391
00:15:03,709 --> 00:15:01,529
across everything that is preserved that

392
00:15:05,119 --> 00:15:03,719
we know of in the biosphere and as far

393
00:15:10,219 --> 00:15:05,129
as we know throughout the history of

394
00:15:13,249 --> 00:15:10,229
life now in order for that to be true

395
00:15:15,679 --> 00:15:13,259
that it's a biosynthetic Universal this

396
00:15:18,619 --> 00:15:15,689
is a picture of where it lies within a

397
00:15:20,689 --> 00:15:18,629
small network of 37 compounds which is

398
00:15:23,869 --> 00:15:20,699
the core of the core we can cut down the

399
00:15:26,479 --> 00:15:23,879
stree nevis on marwitz set of 125 small

400
00:15:29,479 --> 00:15:26,489
meta metabolites that are necessary and

401
00:15:32,179 --> 00:15:29,489
sufficient to this core which actually

402
00:15:34,070 --> 00:15:32,189
organizes them all in order for these to

403
00:15:36,470 --> 00:15:34,080
be the universal starting points in bio

404
00:15:38,270 --> 00:15:36,480
synthesis they must also have been the

405
00:15:40,940 --> 00:15:38,280
reference points for all subsequent

406
00:15:42,800 --> 00:15:40,950
evolutionary innovation so these are all

407
00:15:45,320 --> 00:15:42,810
of the other auto kettle auto catalytic

408
00:15:47,330 --> 00:15:45,330
loop feedback pathways drawn as a kind

409
00:15:49,130 --> 00:15:47,340
of a metro map with different pathways

410
00:15:50,930 --> 00:15:49,140
in different colors and the thing that

411
00:15:52,910 --> 00:15:50,940
you can see and it's a different talk to

412
00:15:55,820 --> 00:15:52,920
give you all the details on this is that

413
00:15:59,060 --> 00:15:55,830

they either reuse or re-enter or simply

414
00:16:01,430 --> 00:15:59,070
duplicate with some context change the

415
00:16:03,800 --> 00:16:01,440
arcs that are there in this core

416
00:16:06,620 --> 00:16:03,810
metabolism and all of this comes from

417
00:16:09,350 --> 00:16:06,630
the anaerobic world that is the core in

418
00:16:12,260 --> 00:16:09,360
both ecosystems or organisms so it's not

419
00:16:15,100 --> 00:16:12,270
a cellular property so the argument that

420
00:16:17,540 --> 00:16:15,110
I'll make is that the eco system is more

421
00:16:19,520 --> 00:16:17,550
fundamentally the explanatory unit for

422
00:16:22,700 --> 00:16:19,530
this Universal biochemistry than the

423
00:16:24,830 --> 00:16:22,710
organism is the reason being that the

424
00:16:26,990 --> 00:16:24,840
anchor status of the citric acid cycle

425
00:16:30,590 --> 00:16:27,000
or it's reductive version intermediate

426
00:16:32,300 --> 00:16:30,600
metabolites that can always be seen at

427
00:16:33,740 --> 00:16:32,310
the level of self-sufficient eco systems

428
00:16:35,060 --> 00:16:33,750
because they have to make everything we

429
00:16:37,100 --> 00:16:35,070
don't depend on carbon from space

430
00:16:39,950 --> 00:16:37,110
anymore if there was a time when we once

431
00:16:42,230 --> 00:16:39,960
did it happens that in the case for of

432
00:16:44,090 --> 00:16:42,240
autotrophic organisms you can see it at

433
00:16:45,710 --> 00:16:44,100
the level of the single organism but

434
00:16:48,260 --> 00:16:45,720
that's a question of how biochemistry

435
00:16:49,880 --> 00:16:48,270
comes under genomic control which is a

436
00:16:51,650 --> 00:16:49,890
higher-order organizational question

437
00:16:56,960 --> 00:16:51,660
it's not about the nature of what

438
00:16:59,180 --> 00:16:56,970

biochemistry must be so in evolutionary

439
00:17:01,160 --> 00:16:59,190
dynamics the embodied information about

440
00:17:04,130 --> 00:17:01,170
the precursors is carried not by

441
00:17:05,570 --> 00:17:04,140
individual descent lineages but by Co

442
00:17:08,030 --> 00:17:05,580
evolutionary dynamics where the

443
00:17:09,770 --> 00:17:08,040
ecosystem members affect each other

444
00:17:12,380 --> 00:17:09,780
now some of it can just reflect the

445
00:17:14,570 --> 00:17:12,390
environment passing through but the rest

446
00:17:16,640 --> 00:17:14,580
of it is frequency dependent fitness

447
00:17:18,110 --> 00:17:16,650
where completeness or compatibility is

448
00:17:20,420 --> 00:17:18,120
propagated through things like

449
00:17:21,980 --> 00:17:20,430
ecological stoichiometry to make sure

450
00:17:24,020 --> 00:17:21,990
that the members of the ecosystem do

451
00:17:26,180 --> 00:17:24,030
everything that needs to get done so

452
00:17:28,310 --> 00:17:26,190
coming back to Shostak subjection this

453
00:17:30,050 --> 00:17:28,320
looks very strong looking for life

454
00:17:31,520 --> 00:17:30,060
non-life categories in terms of these

455
00:17:35,690 --> 00:17:31,530
dichotomies doesn't seem to be working

456
00:17:37,880 --> 00:17:35,700
for us okay so why is that and what can

457
00:17:39,530 --> 00:17:37,890
we do is an alternative approach I would

458
00:17:42,020 --> 00:17:39,540
argue that the problem with this domain

459
00:17:43,670 --> 00:17:42,030
approach to starting is that every

460
00:17:45,680 --> 00:17:43,680
domain is carrying some features that

461
00:17:47,870 --> 00:17:45,690
are essential to life but for none of

462
00:17:51,020 --> 00:17:47,880
these do the features that that domain

463
00:17:52,880 --> 00:17:51,030

has seemed to pratima to account for all

464
00:17:56,150 --> 00:17:52,890
of the others that are also fundamental

465
00:17:58,790 --> 00:17:56,160
so instead of starting with domains can

466
00:18:01,310 --> 00:17:58,800
we make a kind of directed graph of the

467
00:18:04,010 --> 00:18:01,320
way information or constraint propagates

468
00:18:05,750 --> 00:18:04,020
from one domain to another and at the

469
00:18:08,510 --> 00:18:05,760
kind of beginning of that directed graph

470
00:18:10,130 --> 00:18:08,520
can we look for a starting point this is

471
00:18:12,230 --> 00:18:10,140
where the physicists have something to

472
00:18:13,460 --> 00:18:12,240
do that's not completely empty because

473
00:18:14,990 --> 00:18:13,470
this is a problem it's thoroughly

474
00:18:17,180 --> 00:18:15,000
understood for the hierarchy of matter

475
00:18:18,560 --> 00:18:17,190
this is the entire 20th century in

476
00:18:20,240 --> 00:18:18,570
physics and it's probably the best thing

477
00:18:23,060 --> 00:18:20,250
that's understood within the physical

478
00:18:24,860 --> 00:18:23,070
sciences it introduces a set of concepts

479
00:18:26,390 --> 00:18:24,870
that are readily applicable to life but

480
00:18:29,030 --> 00:18:26,400
that are not commonly used in biology

481
00:18:31,160 --> 00:18:29,040
and it's all about embodied information

482
00:18:32,930 --> 00:18:31,170
so let me give you some of this argument

483
00:18:38,600 --> 00:18:32,940
in a level of detail that I don't

484
00:18:40,670 --> 00:18:38,610
usually pursue in the simple physics of

485
00:18:43,160 --> 00:18:40,680
phase transitions the idea of embodiment

486
00:18:45,530 --> 00:18:43,170
means the structure of the state space

487
00:18:47,060 --> 00:18:45,540
this determines what information is

488
00:18:49,460 --> 00:18:47,070

available to be found when a phase

489
00:18:51,530 --> 00:18:49,470
transition happens Seth Lloyd in his

490
00:18:52,820 --> 00:18:51,540
book computing the universe likes to

491
00:18:55,160 --> 00:18:52,830
talk about hierarchies of phase

492
00:18:56,660 --> 00:18:55,170
transitions as creating information I'd

493
00:18:58,610 --> 00:18:56,670
rather say that the information is

494
00:19:00,560 --> 00:18:58,620
already there in the structure of the

495
00:19:03,080 --> 00:19:00,570
state space but when systems are

496
00:19:05,000 --> 00:19:03,090
amorphous they don't express it and when

497
00:19:08,030 --> 00:19:05,010
they freeze and become ordered that

498
00:19:09,650 --> 00:19:08,040
becomes expressed so the example is for

499
00:19:12,020 --> 00:19:09,660
instance a collection of spins that make

500
00:19:14,150 --> 00:19:12,030
up a magnet each of them might be up or

501
00:19:16,070 --> 00:19:14,160
down the state space is some hypercube

502
00:19:18,590 --> 00:19:16,080
whose dimension is how many spins there

503
00:19:20,030 --> 00:19:18,600
are there are lots of configurations

504
00:19:22,160 --> 00:19:20,040
where the number of up and down spins

505
00:19:24,470 --> 00:19:22,170
are about the same and if the magnet is

506
00:19:26,840 --> 00:19:24,480
hot you live in this domain of large

507
00:19:28,700 --> 00:19:26,850
numbers and you can't see that the up

508
00:19:30,920 --> 00:19:28,710
and the down are squeezed into little

509
00:19:34,250 --> 00:19:30,930
corners of the state space but as you

510
00:19:36,320 --> 00:19:34,260
freeze your actual system state gets

511
00:19:38,450 --> 00:19:36,330
stuck in one of these little corners and

512
00:19:39,860 --> 00:19:38,460
then the properties of the magnet start

513
00:19:41,780 --> 00:19:39,870

to display the properties of the

514
00:19:43,970 --> 00:19:41,790
squeezed corners of the state space and

515
00:19:46,280 --> 00:19:43,980
that formerly hidden information becomes

516
00:19:47,840 --> 00:19:46,290
available so I'm going to add a couple

517
00:19:50,020 --> 00:19:47,850
of other concepts to this and then argue

518
00:19:52,130 --> 00:19:50,030
that we can do this for life as well

519
00:19:54,470 --> 00:19:52,140
second concept that's brought into

520
00:19:55,970 --> 00:19:54,480
existence by phase transitions is what

521
00:19:57,080 --> 00:19:55,980
we'll call long-range order and this is

522
00:20:00,260 --> 00:19:57,090
where we're going to get directionality

523
00:20:01,560 --> 00:20:00,270
from the idea is the following when

524
00:20:03,510 --> 00:20:01,570
something freezes you

525
00:20:05,930 --> 00:20:03,520
a bunch of local degrees of freedom or

526
00:20:08,880 --> 00:20:05,940
building blocks that might have some

527
00:20:10,500 --> 00:20:08,890
group of configurations they can occupy

528
00:20:11,910 --> 00:20:10,510
and when they're melted the groups are

529
00:20:14,430 --> 00:20:11,920
all independent so we write it as a

530
00:20:16,500 --> 00:20:14,440
product but any product could also be

531
00:20:18,750 --> 00:20:16,510
written as a collective effect where

532
00:20:21,660 --> 00:20:18,760
they all do the same thing which is then

533
00:20:23,460 --> 00:20:21,670
this h1 and then the first difference

534
00:20:25,590 --> 00:20:23,470
where they deviate from doing the same

535
00:20:27,360 --> 00:20:25,600
thing that's h2 and we can go and we can

536
00:20:29,970 --> 00:20:27,370
fill out the same state space the same

537
00:20:31,830 --> 00:20:29,980
way when something freezes one of these

538
00:20:33,540 --> 00:20:31,840

collective things gets frozen and they

539
00:20:35,490 --> 00:20:33,550
get stuck in a corner of the state space

540
00:20:37,380 --> 00:20:35,500
and they can't sample everything anymore

541
00:20:40,200 --> 00:20:37,390
and it's only the remaining degrees of

542
00:20:42,780 --> 00:20:40,210
freedom that wind up free to vary this

543
00:20:44,880 --> 00:20:42,790
story of phase transitions turns out to

544
00:20:46,830 --> 00:20:44,890
be the entire modern theory of the

545
00:20:48,750 --> 00:20:46,840
hierarchy of matter and if you look at

546
00:20:51,030 --> 00:20:48,760
these iconic graphs going from the Big

547
00:20:53,250 --> 00:20:51,040
Bang to the modern world every one of

548
00:20:55,590 --> 00:20:53,260
these transitions is one of these

549
00:20:57,750 --> 00:20:55,600
freezing's the interesting reason

550
00:20:59,430 --> 00:20:57,760
there's directionality in this is that

551
00:21:02,190 --> 00:20:59,440
the more local the degrees of freedom

552
00:21:04,980 --> 00:21:02,200
are the ones that are easier to find the

553
00:21:07,290 --> 00:21:04,990
order in they make smaller building

554
00:21:09,090 --> 00:21:07,300
blocks and they're more rigid those

555
00:21:11,430 --> 00:21:09,100
rigid building blocks that assemble

556
00:21:14,700 --> 00:21:11,440
first act as constraints on what can be

557
00:21:16,950 --> 00:21:14,710
assembled later and because a constraint

558
00:21:19,290 --> 00:21:16,960
is a restriction on the available state

559
00:21:21,420 --> 00:21:19,300
space that propagates upward in the

560
00:21:23,250 --> 00:21:21,430
hierarchy of form as a kind of

561
00:21:26,970 --> 00:21:23,260
information and this is where I'm gonna

562
00:21:28,800 --> 00:21:26,980
argue embodied information comes from so

563
00:21:30,540 --> 00:21:28,810

here's an example where that argument

564
00:21:31,110 --> 00:21:30,550
was has been invoked explicitly in

565
00:21:33,840 --> 00:21:31,120
biology

566
00:21:35,880 --> 00:21:33,850
remember the genetic code what kind of

567
00:21:38,280 --> 00:21:35,890
information could be selected for in the

568
00:21:40,710 --> 00:21:38,290
genetic code you would think the genetic

569
00:21:42,510 --> 00:21:40,720
code could should be a firewall because

570
00:21:44,490 --> 00:21:42,520
there's all this inescapable structure

571
00:21:46,110 --> 00:21:44,500
and metabolism and you don't want that

572
00:21:48,060 --> 00:21:46,120
propagating through to your sequence

573
00:21:49,500 --> 00:21:48,070
world you want any sequence to be

574
00:21:51,600 --> 00:21:49,510
available so that proteins can be

575
00:21:54,150 --> 00:21:51,610
selected based on the phenotype the

576
00:21:56,790 --> 00:21:54,160
reason you can't that code should not be

577
00:21:59,160 --> 00:21:56,800
completely agnostic about structure is

578
00:22:00,690 --> 00:21:59,170
that translation doesn't always work

579
00:22:03,780 --> 00:22:00,700
perfectly and some of this structure

580
00:22:05,400 --> 00:22:03,790
leaks through so if the codons are

581
00:22:07,950 --> 00:22:05,410
arranged in such a way that they can

582
00:22:10,620 --> 00:22:07,960
mask the errors as much as possible you

583
00:22:12,300 --> 00:22:10,630
can get a flatter state space here than

584
00:22:13,760 --> 00:22:12,310
the structured state space of the

585
00:22:16,970 --> 00:22:13,770
chemistry that's leaking through

586
00:22:18,680 --> 00:22:16,980
in selecting what your molecules are so

587
00:22:20,930 --> 00:22:18,690
nitrile golden Feld and Colleen vets

588
00:22:22,910 --> 00:22:20,940

Egon and Carl was following up on some

589
00:22:26,540 --> 00:22:22,920
of Carl's ideas about the Darwinian

590
00:22:28,330 --> 00:22:26,550
threshold a few years ago asked is it

591
00:22:30,919 --> 00:22:28,340
realistic to think that codon

592
00:22:33,230 --> 00:22:30,929
rearrangements can actually get a

593
00:22:35,390 --> 00:22:33,240
genetic code that is as good at

594
00:22:38,360 --> 00:22:35,400
buffering as the code we actually see

595
00:22:40,460 --> 00:22:38,370
and their argument was after the

596
00:22:42,169 --> 00:22:40,470
Darwinian threshold when organisms have

597
00:22:44,330 --> 00:22:42,179
barriers against horizontal gene

598
00:22:46,760 --> 00:22:44,340
transfer and the components of the

599
00:22:49,790 --> 00:22:46,770
ribosome in different organisms are not

600
00:22:51,860 --> 00:22:49,800
permitted to be exchanged because that's

601
00:22:54,260 --> 00:22:51,870
too damaging to the fidelity of

602
00:22:56,919 --> 00:22:54,270
translation in such a world there is

603
00:23:00,290 --> 00:22:56,929
long-range order and you can't actually

604
00:23:02,600 --> 00:23:00,300
rearrange the codons well enough to get

605
00:23:04,790 --> 00:23:02,610
the degree of buffering we see it is

606
00:23:07,130 --> 00:23:04,800
only in a world of extensive horizontal

607
00:23:09,560 --> 00:23:07,140
gene transfer where you make the fitness

608
00:23:12,049 --> 00:23:09,570
of a gene local you evaluate it in the

609
00:23:14,600 --> 00:23:12,059
context of all other genes where it

610
00:23:17,180 --> 00:23:14,610
could occupy an organism and then you

611
00:23:19,250 --> 00:23:17,190
make your your proteins statistical so

612
00:23:21,650 --> 00:23:19,260
that they are robust against all the

613
00:23:23,900 --> 00:23:21,660

errors in that ugly world and therefore

614
00:23:26,419 --> 00:23:23,910
they're tolerant of exchange of coding

615
00:23:29,060 --> 00:23:26,429
positions only in that kind of a world

616
00:23:30,860 --> 00:23:29,070
can you actually optimize to the point

617
00:23:33,049 --> 00:23:30,870
where you get a code that is as good as

618
00:23:35,510 --> 00:23:33,059
the code we see so the mess the

619
00:23:38,299 --> 00:23:35,520
substance of their message is that this

620
00:23:40,250 --> 00:23:38,309
thermalization which then locks in the

621
00:23:42,620 --> 00:23:40,260
optimal genetic code when the ribosome

622
00:23:45,830 --> 00:23:42,630
becomes accurate and the Darwinian world

623
00:23:47,419 --> 00:23:45,840
of persistent lineages emerges only that

624
00:23:49,549 --> 00:23:47,429
thermalization was a kind of Vic in

625
00:23:51,860 --> 00:23:49,559
Stein's letter on which the biosphere

626
00:23:55,970 --> 00:23:51,870
could have climbed up with a solution

627
00:23:57,260 --> 00:23:55,980
that it currently has so the reason we

628
00:23:59,720 --> 00:23:57,270
can make use of some of this

629
00:24:02,000 --> 00:23:59,730
quantitatively is that the story I just

630
00:24:04,760 --> 00:24:02,010
told you has mathematical structure the

631
00:24:06,919 --> 00:24:04,770
important way to understand the origin

632
00:24:10,010 --> 00:24:06,929
of directionality is to recognize that

633
00:24:13,190 --> 00:24:10,020
robustness in phase transitions comes in

634
00:24:14,930 --> 00:24:13,200
classes the master formula for

635
00:24:16,460 --> 00:24:14,940
everything in fact I don't know if you

636
00:24:18,530 --> 00:24:16,470
realize there was a master formula for

637
00:24:20,660 --> 00:24:18,540
everything this is called the formula

638
00:24:23,659 --> 00:24:20,670

for large deviations scaling and it is

639
00:24:25,310 --> 00:24:23,669
the reason a macro world exists it says

640
00:24:27,200 --> 00:24:25,320
that when you have probability

641
00:24:27,980 --> 00:24:27,210
distributions for systems with a lot of

642
00:24:30,620 --> 00:24:27,990
component

643
00:24:33,289 --> 00:24:30,630
the only times you get a macro world is

644
00:24:36,769 --> 00:24:33,299
when the probability turns out to split

645
00:24:38,480 --> 00:24:36,779
into a term where the scale can vary in

646
00:24:40,960 --> 00:24:38,490
a way that doesn't have to be precise

647
00:24:44,029 --> 00:24:40,970
but the structure of the macro world

648
00:24:46,370 --> 00:24:44,039
remains well-defined across a whole

649
00:24:48,230 --> 00:24:46,380
variety of scales this is what you don't

650
00:24:50,299 --> 00:24:48,240
have in the micro world where it matters

651
00:24:52,460 --> 00:24:50,309
whether you have one two or three

652
00:24:54,440 --> 00:24:52,470
molecules but you do have in the world

653
00:24:57,380 --> 00:24:54,450
of a cat where it doesn't matter whether

654
00:25:00,529 --> 00:24:57,390
the cat has inhaled or exhaled more or

655
00:25:02,450 --> 00:25:00,539
fewer molecules of o2 or co2 and the

656
00:25:04,820 --> 00:25:02,460
place where phase transitions occur is

657
00:25:07,370 --> 00:25:04,830
when these structure factors factors

658
00:25:09,740 --> 00:25:07,380
change between one major domain and

659
00:25:11,659 --> 00:25:09,750
another the interesting thing is that

660
00:25:13,610 --> 00:25:11,669
the characteristics of structure are

661
00:25:16,340 --> 00:25:13,620
different in different classes of phase

662
00:25:18,889 --> 00:25:16,350
transitions so there are some for which

663
00:25:21,169 --> 00:25:18,899

there's only solution only one solution

664
00:25:23,269 --> 00:25:21,179
like an ideal gas this vial of chlorine

665
00:25:25,340 --> 00:25:23,279
you will always go to the same state

666
00:25:26,810 --> 00:25:25,350
there are others like the simple

667
00:25:30,409 --> 00:25:26,820
second-order phase transitions like

668
00:25:32,180 --> 00:25:30,419
Frost where the crystal magnitude will

669
00:25:34,580 --> 00:25:32,190
look the same but the direction is

670
00:25:36,649 --> 00:25:34,590
uncertain and these guys can drift over

671
00:25:38,149 --> 00:25:36,659
time but it's a closed-ended drift and I

672
00:25:39,980 --> 00:25:38,159
mean this in the sense of closed-ended

673
00:25:42,409 --> 00:25:39,990
evolution and then the furthest we've

674
00:25:44,419 --> 00:25:42,419
gotten in physics is to look at glasses

675
00:25:47,240 --> 00:25:44,429
where you now have a set of possible

676
00:25:49,279 --> 00:25:47,250
solutions that are indefinitely large as

677
00:25:51,950 --> 00:25:49,289
the system becomes big and they can

678
00:25:55,549 --> 00:25:51,960
drift in an open-ended way in finite

679
00:25:57,799 --> 00:25:55,559
systems so does the biosphere have such

680
00:26:00,320 --> 00:25:57,809
closed and open-ended I would argue yes

681
00:26:01,940 --> 00:26:00,330
the biosphere contains chance and

682
00:26:04,279 --> 00:26:01,950
necessity and they are all equally

683
00:26:06,590 --> 00:26:04,289
fundamental aspects of life the small

684
00:26:08,750 --> 00:26:06,600
molecule world looks more like the

685
00:26:10,370 --> 00:26:08,760
necessary geochemical world than it

686
00:26:12,289 --> 00:26:10,380
looks like the world of the accidents of

687
00:26:14,330 --> 00:26:12,299
species and then many aspects of

688
00:26:18,139 --> 00:26:14,340

cellular architecture live somewhere

689
00:26:19,399 --> 00:26:18,149
along the spectrum between I'm very

690
00:26:20,419 --> 00:26:19,409
nearly out of time their stuff it won't

691
00:26:22,909 --> 00:26:20,429
be able to show you but I'll show you a

692
00:26:25,820 --> 00:26:22,919
couple more things the fascinating thing

693
00:26:27,919 --> 00:26:25,830
is that in the biosphere there is an

694
00:26:29,659 --> 00:26:27,929
inverse hierarchy you know they say

695
00:26:31,370 --> 00:26:29,669
diamonds are forever diamonds are not

696
00:26:33,139 --> 00:26:31,380
forever on the surface of the earth but

697
00:26:35,600 --> 00:26:33,149
they will last longer than the person

698
00:26:39,049 --> 00:26:35,610
you give them to and that's enough but

699
00:26:41,660 --> 00:26:39,059
in the world in the world of equilibrium

700
00:26:43,610 --> 00:26:41,670
physics the unit cell of the diamond is

701
00:26:45,980 --> 00:26:43,620
persistent because the diamond is hard

702
00:26:48,350 --> 00:26:45,990
and durable in the biosphere it's

703
00:26:50,720 --> 00:26:48,360
exactly the opposite the most durable

704
00:26:52,640 --> 00:26:50,730
patterns the the metabolic chart that I

705
00:26:54,740 --> 00:26:52,650
showed you are carried by the small

706
00:26:56,360 --> 00:26:54,750
metabolites that turn over on time

707
00:26:59,750 --> 00:26:56,370
scales from milliseconds to tens of

708
00:27:02,480 --> 00:26:59,760
seconds individual organisms last longer

709
00:27:05,660 --> 00:27:02,490
they can be twenty minutes to perhaps a

710
00:27:07,460 --> 00:27:05,670
hundred years species may have a tenure

711
00:27:09,070 --> 00:27:07,470
going up to a million years as a

712
00:27:11,660 --> 00:27:09,080
characteristic figure of Merit

713
00:27:13,790 --> 00:27:11,670

ecosystems can switch on a time scale

714
00:27:16,220 --> 00:27:13,800
from a month to the durations of

715
00:27:19,070 --> 00:27:16,230
keystone species in them the interesting

716
00:27:20,630 --> 00:27:19,080
thing is that the more durable the

717
00:27:22,820 --> 00:27:20,640
pattern we're talking about were the

718
00:27:25,250 --> 00:27:22,830
entities of that pattern the more

719
00:27:27,800 --> 00:27:25,260
arbitrary and the less stable in

720
00:27:29,540 --> 00:27:27,810
geological time that pattern is so I

721
00:27:31,640 --> 00:27:29,550
want to argue in the previous story

722
00:27:34,070 --> 00:27:31,650
about local things being robust things

723
00:27:37,460 --> 00:27:34,080
that it is precisely this smallness in

724
00:27:39,440 --> 00:27:37,470
space and short turnover in time that

725
00:27:43,520 --> 00:27:39,450
identifies the starting point for cause

726
00:27:46,280 --> 00:27:43,530
in the biosphere now the reason this

727
00:27:48,800 --> 00:27:46,290
subject has teeth is that everything we

728
00:27:51,500 --> 00:27:48,810
can do in equilibrium phase transitions

729
00:27:53,180 --> 00:27:51,510
can be mapped to dynamics and the

730
00:27:55,280 --> 00:27:53,190
fascinating thing is that when you do

731
00:27:58,040 --> 00:27:55,290
map it to dynamics you are in the world

732
00:28:00,140 --> 00:27:58,050
of dynamical error correction so this is

733
00:28:02,000 --> 00:28:00,150
the mapping we can come back and I can

734
00:28:04,010 --> 00:28:02,010
talk offline about all these particular

735
00:28:05,210 --> 00:28:04,020
things they're laid out here but the

736
00:28:07,700 --> 00:28:05,220
important point is there are new

737
00:28:10,280 --> 00:28:07,710
concepts that are introduced in optimal

738
00:28:12,590 --> 00:28:10,290

error correction that enable us I think

739
00:28:17,030 --> 00:28:12,600
to get better clarity on what we see in

740
00:28:20,660 --> 00:28:17,040
the biological world around us I can't

741
00:28:22,070 --> 00:28:20,670
do this so I'm gonna skip to something

742
00:28:25,400 --> 00:28:22,080
because this is a point that can be made

743
00:28:26,780 --> 00:28:25,410
simply in any error correcting system

744
00:28:29,480 --> 00:28:26,790
where you have only finitely many

745
00:28:31,880 --> 00:28:29,490
degrees of freedom that are used to look

746
00:28:35,690 --> 00:28:31,890
for errors through redundancy and to

747
00:28:38,990 --> 00:28:35,700
correct them anything finite will always

748
00:28:41,780 --> 00:28:39,000
with certainty eventually decode to the

749
00:28:43,970 --> 00:28:41,790
wrong answer the only thing that never

750
00:28:45,860 --> 00:28:43,980
decodes to the wrong answer is something

751
00:28:48,100 --> 00:28:45,870
like the ideal-gas that only has one

752
00:28:51,200 --> 00:28:48,110
answer so the code is not doing anything

753
00:28:53,180 --> 00:28:51,210
in the biological world the only thing

754
00:28:54,669 --> 00:28:53,190
that there's exactly one of is the

755
00:28:57,009 --> 00:28:54,679
universal format at

756
00:28:58,629 --> 00:28:57,019
all the rest of these guys are error

757
00:29:01,779 --> 00:28:58,639
messages that are carried with finite

758
00:29:06,370 --> 00:29:01,789
probability of error so I will stop in

759
00:29:08,139 --> 00:29:06,380
honor of time do you have another minute

760
00:29:09,460 --> 00:29:08,149
to wrap up and leave you with the

761
00:29:13,149 --> 00:29:09,470
summary comments there's other stuff

762
00:29:15,129 --> 00:29:13,159
that I'm happy to cover the main things

763
00:29:18,159 --> 00:29:15,139

that I want to take I want to give you

764
00:29:20,499 --> 00:29:18,169
to take from this are that when we take

765
00:29:22,149 --> 00:29:20,509
the mathematically founded concepts of

766
00:29:24,129 --> 00:29:22,159
phases that are understood well in

767
00:29:26,110 --> 00:29:24,139
equilibrium into the dynamical world

768
00:29:27,999 --> 00:29:26,120
that we need to understand biology they

769
00:29:30,549 --> 00:29:28,009
do not look like the physics of

770
00:29:32,649 --> 00:29:30,559
equilibrium except mathematically they

771
00:29:35,080 --> 00:29:32,659
become the theory of optimal error

772
00:29:37,529 --> 00:29:35,090
correction about which we have our own

773
00:29:39,909 --> 00:29:37,539
base of knowledge important thing

774
00:29:42,100 --> 00:29:39,919
comprehensive asymptotically reliable

775
00:29:44,560 --> 00:29:42,110
error correction meaning the biosphere

776
00:29:46,570 --> 00:29:44,570
has been with a planet the entire time

777
00:29:48,700 --> 00:29:46,580
even though all of its subunits of

778
00:29:50,110 --> 00:29:48,710
organization turnover that's the

779
00:29:52,269 --> 00:29:50,120
elephant in the room not only of all

780
00:29:54,100 --> 00:29:52,279
biology but of all reductionist science

781
00:29:57,220 --> 00:29:54,110
we don't have a theory of where that

782
00:29:58,869 --> 00:29:57,230
comes from the fact that it has a sub

783
00:30:00,700 --> 00:29:58,879
structure allows us to interpret

784
00:30:03,100 --> 00:30:00,710
biological phenomena in terms of

785
00:30:06,100 --> 00:30:03,110
directionality an important three-way

786
00:30:09,190 --> 00:30:06,110
trade off between redundancy complexity

787
00:30:11,350 --> 00:30:09,200
and reliability is what gives us the

788
00:30:13,180 --> 00:30:11,360

hierarchy where local things are rigid

789
00:30:16,629 --> 00:30:13,190
and the prior sources of constraint and

790
00:30:19,269 --> 00:30:16,639
the asymptotic unreliability of anything

791
00:30:21,669 --> 00:30:19,279
finite if it has any nonzero complexity

792
00:30:24,610 --> 00:30:21,679
is what gives us the need for unn codes

793
00:30:26,560 --> 00:30:24,620
that are the reference for everything

794
00:30:28,269 --> 00:30:26,570
else to come back to and I want to argue

795
00:30:30,610 --> 00:30:28,279
that universal core metabolism is the

796
00:30:32,769 --> 00:30:30,620
unco dand it's the classical state

797
00:30:35,710 --> 00:30:32,779
variable for the biosphere that defines

798
00:30:37,299 --> 00:30:35,720
the nature of life so all of the rest of

799
00:30:39,100 --> 00:30:37,309
the complexity is still there and it's

800
00:30:40,299 --> 00:30:39,110
as hard as it ever was this is only

801
00:30:41,649 --> 00:30:40,309
meant to be a way to try to

802
00:30:43,940 --> 00:30:41,659
systematically look at how we choose

803
00:30:49,640 --> 00:30:43,950
projects in it thank you Thanks

804
00:30:52,440 --> 00:30:49,650
[Applause]

805
00:30:58,470 --> 00:30:52,450
so now we have time for questions

806
00:31:05,400 --> 00:30:58,480
I saw marks hand go up first we have so

807
00:31:08,820 --> 00:31:05,410
you have some marked right here it's a

808
00:31:09,960 --> 00:31:08,830
one question about the directionality do

809
00:31:12,990 --> 00:31:09,970
you think that the direct channel is

810
00:31:13,320 --> 00:31:13,000
affected by hysteresis and it's in any

811
00:31:16,020 --> 00:31:13,330
way

812
00:31:18,750 --> 00:31:16,030
so is there memory of how life you is

813
00:31:20,690 --> 00:31:18,760

the process of going from one phase

814
00:31:23,760 --> 00:31:20,700
transition to the next if you will

815
00:31:25,470 --> 00:31:23,770
affecting the evolution so if you change

816
00:31:31,050 --> 00:31:25,480
is somehow is there a memory of that

817
00:31:33,660 --> 00:31:31,060
changing for some things almost surely

818
00:31:36,480 --> 00:31:33,670
for other things I think it's less

819
00:31:39,120 --> 00:31:36,490
likely so Kurt Vonnegut wrote a book

820
00:31:40,980 --> 00:31:39,130
called cat's cradle about somebody who

821
00:31:42,330 --> 00:31:40,990
discovers a new form of ice that in all

822
00:31:44,100 --> 00:31:42,340
the oceans and all the history of the

823
00:31:45,990 --> 00:31:44,110
world was never discovered even though

824
00:31:47,550 --> 00:31:46,000
it happens at room temperature and it

825
00:31:49,980 --> 00:31:47,560
brings an end to the world because it

826
00:31:51,870 --> 00:31:49,990
propagates and freezes everything that

827
00:31:54,210 --> 00:31:51,880
kind of thing I think we can say never

828
00:31:56,700 --> 00:31:54,220
happens because the problem of finding

829
00:31:58,320 --> 00:31:56,710
an orientation of ice requires only

830
00:32:00,690 --> 00:31:58,330
getting a couple molecules into the

831
00:32:03,000 --> 00:32:00,700
right orientation so nothing like that

832
00:32:04,890 --> 00:32:03,010
has an opportunity for hysteresis those

833
00:32:07,230 --> 00:32:04,900
are the sorts of things where unique

834
00:32:10,290 --> 00:32:07,240
solutions get found incredibly robustly

835
00:32:12,270 --> 00:32:10,300
and usually very fast it is not clear

836
00:32:14,430 --> 00:32:12,280
yet whether core metabolism has that

837
00:32:15,900 --> 00:32:14,440
status and on a slide I didn't show you

838
00:32:17,700 --> 00:32:15,910

about where the forefront of current

839
00:32:18,750 --> 00:32:17,710
work is the reason it's not clear is

840
00:32:20,100 --> 00:32:18,760
that we don't know enough about the

841
00:32:22,290 --> 00:32:20,110
chemical state space in the chemical

842
00:32:23,970 --> 00:32:22,300
process space that question is

843
00:32:26,070 --> 00:32:23,980
answerable with work within the

844
00:32:28,410 --> 00:32:26,080
reasonable time frame of decades if we

845
00:32:30,930 --> 00:32:28,420
can just get organized and do it if you

846
00:32:32,820 --> 00:32:30,940
look at other things as far out as the

847
00:32:35,310 --> 00:32:32,830
distinction between simple amino acids

848
00:32:36,990 --> 00:32:35,320
and more complex amino acids or some of

849
00:32:39,300 --> 00:32:37,000
the later stages and biosynthesis of the

850
00:32:42,270 --> 00:32:39,310
cofactors I think there you may have a

851
00:32:44,280 --> 00:32:42,280
strong argument that ex-post selection

852
00:32:46,320 --> 00:32:44,290
can lock in features that are partly

853
00:32:48,750 --> 00:32:46,330
arbitrary and that have very long

854
00:32:50,910 --> 00:32:48,760
downstream consequences so for instance

855
00:32:53,820 --> 00:32:50,920
look at arginine as an amino acid has a

856
00:32:55,620 --> 00:32:53,830
very very specific role as positively

857
00:32:57,810 --> 00:32:55,630
charged coordination groups in all

858
00:32:59,610 --> 00:32:57,820
protein structure but the biosynthesis

859
00:33:00,270 --> 00:32:59,620
of that does not look like something

860
00:33:01,890 --> 00:33:00,280
that's

861
00:33:03,780 --> 00:33:01,900
absolutely inevitable given core

862
00:33:05,400 --> 00:33:03,790
metabolism looks like a sort of thing

863
00:33:08,490 --> 00:33:05,410

that can be locked in at a later stage

864
00:33:10,980 --> 00:33:08,500
so I think we see a progression from

865
00:33:12,810 --> 00:33:10,990
less to more hysteresis and to quantify

866
00:33:17,760 --> 00:33:12,820
that is one of the important areas of

867
00:33:19,140 --> 00:33:17,770
work yes sir um

868
00:33:20,640 --> 00:33:19,150
you use the word Universal core

869
00:33:23,190 --> 00:33:20,650
metabolism and I and I assume you mean

870
00:33:24,390 --> 00:33:23,200
global core metabolism or do you really

871
00:33:26,340 --> 00:33:24,400
mean universal in the sense that we

872
00:33:28,290 --> 00:33:26,350
should look for it on Mars and other

873
00:33:30,000 --> 00:33:28,300
earth-like planets elsewhere in the

874
00:33:31,920 --> 00:33:30,010
universe but the question then becomes

875
00:33:33,980 --> 00:33:31,930
if we're gonna look for this core

876
00:33:37,020 --> 00:33:33,990
metabolism what is the biggest

877
00:33:39,030 --> 00:33:37,030
observational signature of it that we

878
00:33:41,160 --> 00:33:39,040
would look for on a place like Mars or

879
00:33:43,470 --> 00:33:41,170
eventually other planets the atmospheres

880
00:33:45,300 --> 00:33:43,480
of chemical disequilibrium and other

881
00:33:47,580 --> 00:33:45,310
planets yeah great

882
00:33:49,470 --> 00:33:47,590
when I say Universal I mean empirically

883
00:33:52,440 --> 00:33:49,480
Universal with respect to the way all

884
00:33:54,570 --> 00:33:52,450
the life forms we know use it I do I

885
00:33:56,490 --> 00:33:54,580
cannot yet make the claim that it is

886
00:33:58,680 --> 00:33:56,500
predicted from first principles of

887
00:34:00,600 --> 00:33:58,690
physics and a knowledge of the planetary

888
00:34:01,800 --> 00:34:00,610

boundary conditions for exactly the

889
00:34:03,030 --> 00:34:01,810
point we just discussed we don't know

890
00:34:05,400 --> 00:34:03,040
enough about the state space the

891
00:34:08,070 --> 00:34:05,410
question about how you map that into

892
00:34:10,980 --> 00:34:08,080
exoplanet signatures is actually really

893
00:34:13,350 --> 00:34:10,990
hard because the difference between a

894
00:34:17,250 --> 00:34:13,360
nonliving earth and alert and earth with

895
00:34:20,130 --> 00:34:17,260
only anaerobic life unless rosing and

896
00:34:22,950 --> 00:34:20,140
sleep and Alberta Day are right and this

897
00:34:24,990 --> 00:34:22,960
has an effect on continent formation

898
00:34:26,940 --> 00:34:25,000
that you can separate from a null model

899
00:34:28,770 --> 00:34:26,950
that you can control I don't even know

900
00:34:31,560 --> 00:34:28,780
what you look for in planetary surface

901
00:34:32,730 --> 00:34:31,570
conditions the sledgehammer on earth was

902
00:34:34,649 --> 00:34:32,740
the emergence of oxygen 'ok

903
00:34:37,320 --> 00:34:34,659
photosynthesis and the burial of the

904
00:34:39,690 --> 00:34:37,330
resulting organic carbon and even that

905
00:34:40,919 --> 00:34:39,700
the exoplanet people are still willing

906
00:34:43,440 --> 00:34:40,929
to argue about whether they could

907
00:34:45,720 --> 00:34:43,450
reliably distinguish and that's between

908
00:34:46,950 --> 00:34:45,730
you know the Archaean and the

909
00:34:49,409 --> 00:34:46,960
Proterozoic that's not part of the

910
00:34:50,970 --> 00:34:49,419
universal core but how that I don't

911
00:34:55,010 --> 00:34:50,980
think we can argue as part of the

912
00:35:03,120 --> 00:34:55,020
universal core from the things I can see

913
00:35:08,999 --> 00:35:05,809

I was going to ask a similar question

914
00:35:10,620 --> 00:35:09,009
basically the universal core would be

915
00:35:13,829 --> 00:35:10,630
the equivalent of a thermodynamic

916
00:35:15,089 --> 00:35:13,839
minimum is that correct exactly it would

917
00:35:17,069 --> 00:35:15,099
be a state variable that there's only

918
00:35:19,829 --> 00:35:17,079
one solution right so is there any way

919
00:35:21,599 --> 00:35:19,839
to actually do a delta on that and test

920
00:35:26,460 --> 00:35:21,609
to see whether or not it falls back into

921
00:35:28,950 --> 00:35:26,470
that minimum I don't know how you do

922
00:35:31,440 --> 00:35:28,960
that experimentally on the time scales

923
00:35:34,920 --> 00:35:31,450
we have but I do think that you can use

924
00:35:37,950 --> 00:35:34,930
comparative evolutionary analysis to

925
00:35:41,279 --> 00:35:37,960
make arguments that are not completely

926
00:35:44,700 --> 00:35:41,289
empty so evolution is full of dogs that

927
00:35:46,740 --> 00:35:44,710
didn't bark in the sense that once you

928
00:35:48,359 --> 00:35:46,750
have the sophistication of genomes and

929
00:35:51,319 --> 00:35:48,369
proteins you would think you could

930
00:35:53,700 --> 00:35:51,329
innovate an awful lot of stuff and yet

931
00:35:55,680 --> 00:35:53,710
innovation in things like carbon

932
00:35:57,839 --> 00:35:55,690
fixation pathways has been extremely

933
00:36:01,039 --> 00:35:57,849
limited and it has apparently existed

934
00:36:03,839 --> 00:36:01,049
within a restricted frame in time so of

935
00:36:05,789 --> 00:36:03,849
course the things that are not strong

936
00:36:08,099 --> 00:36:05,799
enough to be constraints in the sense

937
00:36:09,990 --> 00:36:08,109
that there's no possible variation can

938
00:36:12,329 --> 00:36:10,000

still show up as strong forces to

939
00:36:14,220 --> 00:36:12,339
evolutionary convergence or the

940
00:36:19,680 --> 00:36:14,230
inability for things to gain a fitness

941
00:36:22,109 --> 00:36:19,690
advantage from by deviating from so it's

942
00:36:25,079 --> 00:36:22,119
not as good as a controlled experiment

943
00:36:26,519 --> 00:36:25,089
but we can try to argue that the absence

944
00:36:28,980 --> 00:36:26,529
of innovations where you would think

945
00:36:31,349 --> 00:36:28,990
genomically we had the technology to do

946
00:36:33,870 --> 00:36:31,359
it points to paths of least resistance

947
00:36:37,099 --> 00:36:33,880
in the small molecule chemistry that

948
00:36:46,609 --> 00:36:37,109
there was no advantage to departing from

949
00:36:52,740 --> 00:36:49,560
so the universal core is a product of an

950
00:36:55,260 --> 00:36:52,750
information processing as well it has

951
00:36:57,090 --> 00:36:55,270
enzymes and and it was our product of

952
00:37:00,480 --> 00:36:57,100
the information so where would that

953
00:37:03,570 --> 00:37:00,490
leave them the universal core core being

954
00:37:05,430 --> 00:37:03,580
on a product of encode yeah uncoated

955
00:37:07,650 --> 00:37:05,440
I don't think I would say it's a product

956
00:37:09,750 --> 00:37:07,660
of them I would say that the only place

957
00:37:12,720 --> 00:37:09,760
we see it today is where it's supported

958
00:37:15,570 --> 00:37:12,730
by them it may be because it's a product

959
00:37:17,130 --> 00:37:15,580
of them but it could be that we have a

960
00:37:20,400 --> 00:37:17,140
new thing in science that we have to

961
00:37:22,560 --> 00:37:20,410
understand which is how can there be

962
00:37:24,690 --> 00:37:22,570
only one solution to something but the

963
00:37:26,940 --> 00:37:24,700

only context in which we see that one

964
00:37:28,620 --> 00:37:26,950
solution is when it's supported by

965
00:37:44,030 --> 00:37:28,630
feedback from things that have many

966
00:37:44,040 --> 00:37:51,300
Charlie that's one

967
00:37:54,750 --> 00:37:53,520
erican the beginning of you talk you you

968
00:37:56,400 --> 00:37:54,760
mentioned you had a nice diagram where

969
00:37:58,530 --> 00:37:56,410
you've talked about otto and hetero and

970
00:38:01,050 --> 00:37:58,540
then you've compared that to anaerobe

971
00:38:03,150 --> 00:38:01,060
purses arrow and you said that one of

972
00:38:04,770 --> 00:38:03,160
those dichotomies was more fundamental

973
00:38:06,690 --> 00:38:04,780
than the other one yeah for an argument

974
00:38:08,580 --> 00:38:06,700
I did I couldn't follow that could you

975
00:38:10,110 --> 00:38:08,590
okay clean a little bit sure in order

976
00:38:12,420 --> 00:38:10,120
for something to be an autotroph or a

977
00:38:14,010 --> 00:38:12,430
heterotroph it has to actually exist as

978
00:38:15,930 --> 00:38:14,020
an organism that's distinct from the

979
00:38:18,660 --> 00:38:15,940
ecosystem that it inhabits or that is

980
00:38:20,160 --> 00:38:18,670
coextensive with the ecosystem right so

981
00:38:22,230 --> 00:38:20,170
an autotroph is biochemically

982
00:38:24,030 --> 00:38:22,240
self-sufficient which means that you can

983
00:38:26,220 --> 00:38:24,040
put it in a mineral medium and it will

984
00:38:28,170 --> 00:38:26,230
survive a heterotroph is not

985
00:38:30,090 --> 00:38:28,180
biochemically self-sufficient which

986
00:38:32,460 --> 00:38:30,100
means without the detailed dependence on

987
00:38:33,720 --> 00:38:32,470
its ecosystem it doesn't persist but

988
00:38:36,090 --> 00:38:33,730

that's actually a question of the

989
00:38:38,570 --> 00:38:36,100
relation between biochemistry and the

990
00:38:43,110 --> 00:38:38,580
way genome control is partitioned among

991
00:38:45,030 --> 00:38:43,120
autonomous units and that's distinct

992
00:38:46,620 --> 00:38:45,040
from the question of whether or not your

993
00:38:48,090 --> 00:38:46,630
electron flow is downhill in the

994
00:38:51,540 --> 00:38:48,100
reducing direction or downhill in the

995
00:38:54,270 --> 00:38:51,550
oxidizing direction yes but you said one

996
00:38:56,910 --> 00:38:54,280
of those dichotomies was more Universal

997
00:38:58,920 --> 00:38:56,920
I can't I can't express Auto hetero

998
00:39:00,900 --> 00:38:58,930
dichotomy for an ecosystem because all

999
00:39:04,530 --> 00:39:00,910
ecosystems are self-sufficient there is

1000
00:39:07,320 --> 00:39:04,540
no distinction available so anaerobe and

1001
00:39:10,890 --> 00:39:07,330
air robe is the more fundamental thing

1002
00:39:12,600 --> 00:39:10,900
that came first and then came the yeah

1003
00:39:14,430 --> 00:39:12,610
it's more than I gave you reason to

1004
00:39:16,500 --> 00:39:14,440
believe in this talk but I would argue

1005
00:39:19,490 --> 00:39:16,510
that that is a prior constraint at the

1006
00:39:22,590 --> 00:39:19,500
ecosystem level and that then organism

1007
00:39:24,930 --> 00:39:22,600
organization distills out of that once

1008
00:39:26,760 --> 00:39:24,940
you solve a lot of other problems of how

1009
00:39:30,180 --> 00:39:26,770
you want to partition the control of

1010
00:39:33,030 --> 00:39:30,190
that biochemistry under the mechanism of

1011
00:39:33,930 --> 00:39:33,040
Darwinian selection acting on genomes so

1012
00:39:38,910 --> 00:39:33,940
another way to say that is that

1013
00:39:40,410 --> 00:39:38,920

ecosystems are Auto know that that's a

1014
00:39:42,330 --> 00:39:40,420
very popular way to say it but I think

1015
00:39:44,220 --> 00:39:42,340
that is one of these popular things in

1016
00:39:46,830 --> 00:39:44,230
science that makes it harder to think

1017
00:39:49,560 --> 00:39:46,840
clearly Auto trophy and hetero trophy

1018
00:39:52,230 --> 00:39:49,570
are ecological concepts and so to talk

1019
00:39:54,600 --> 00:39:52,240
about an ecosystem as being autotrophic

1020
00:39:56,400 --> 00:39:54,610
is to take the term out of the place

1021
00:39:57,960 --> 00:39:56,410
where it makes a helpful distinction and

1022
00:40:03,549 --> 00:39:57,970
put it into a place where it makes it

1023
00:40:11,870 --> 00:40:05,809
just to continue on this question how do

1024
00:40:13,819 --> 00:40:11,880
you define an ecosystem them an eco said

1025
00:40:18,229 --> 00:40:13,829
okay good there are two ways you can

1026
00:40:20,479 --> 00:40:18,239
look at it the way that is less than

1027
00:40:22,699 --> 00:40:20,489
complete is to define an ecosystem as an

1028
00:40:24,680 --> 00:40:22,709
assembled community of member species

1029
00:40:26,959 --> 00:40:24,690
that have some necessary relations to

1030
00:40:28,819 --> 00:40:26,969
each other biochemical or behavioral or

1031
00:40:31,130 --> 00:40:28,829
niche constructing or whatever

1032
00:40:33,650 --> 00:40:31,140
I think that's inadequate because it

1033
00:40:35,719 --> 00:40:33,660
denies the ecosystem the status of being

1034
00:40:37,699 --> 00:40:35,729
an elementary entity in its own right

1035
00:40:39,410 --> 00:40:37,709
and I think that's what gave us the

1036
00:40:41,779 --> 00:40:39,420
unfortunate departure into the Gaia

1037
00:40:43,999 --> 00:40:41,789
hypothesis because they were left with

1038
00:40:46,249 --> 00:40:44,009

no way to refer to the ecosystem as an

1039
00:40:48,529 --> 00:40:46,259
elementary entity they had to try to

1040
00:40:50,420 --> 00:40:48,539
call it a super organism but it's not

1041
00:40:53,509 --> 00:40:50,430
organized and it doesn't change the way

1042
00:40:55,999 --> 00:40:53,519
an organism does ecosystems may be more

1043
00:40:58,039 --> 00:40:56,009
or less self-sufficient so to do this

1044
00:41:00,349 --> 00:40:58,049
carefully what you want to say is with

1045
00:41:09,999 --> 00:41:00,359
respect to a certain criterion of

1046
00:41:14,989 --> 00:41:13,489
or coral reef is for other purposes a

1047
00:41:16,309 --> 00:41:14,999
lake or a coral reef are not

1048
00:41:24,549 --> 00:41:16,319
self-sufficient enough and you have to

1049
00:41:24,559 --> 00:41:32,060
okay so thank you Eric