
AbSciCon
2019

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

2
00:00:12,970 --> 00:00:09,210
[Applause]

3
00:00:15,150 --> 00:00:12,980
yeah thank you so I think one of the

4
00:00:17,440 --> 00:00:15,160
overarching challenges facing

5
00:00:20,230 --> 00:00:17,450
astrobiology and origins of life

6
00:00:22,470 --> 00:00:20,240
research is this need to find a set of

7
00:00:26,050 --> 00:00:22,480
principles that we know can apply to

8
00:00:28,450 --> 00:00:26,060
both detailed and general problems of

9
00:00:30,759 --> 00:00:28,460
living systems in a variety of contexts

10
00:00:32,230 --> 00:00:30,769
and this is generally been challenging

11
00:00:34,470 --> 00:00:32,240
thus far and the hope is that we can

12
00:00:37,210 --> 00:00:34,480
someday find this set of principles

13
00:00:40,720 --> 00:00:37,220

today I'll talk mostly about how we can

14
00:00:43,060 --> 00:00:40,730
go from extant life to thinking about

15
00:00:45,670 --> 00:00:43,070
the types of general principles that

16
00:00:47,560 --> 00:00:45,680
that life points us towards so I think

17
00:00:49,270 --> 00:00:47,570
typically there are two ends of a

18
00:00:51,460 --> 00:00:49,280
spectrum for thinking about the

19
00:00:54,160 --> 00:00:51,470
principles of life at one end we have a

20
00:00:56,560 --> 00:00:54,170
set of abstract theoretical principles

21
00:01:00,730 --> 00:00:56,570
typically mathematical or computational

22
00:01:02,890 --> 00:01:00,740
and these are often very general and we

23
00:01:05,590 --> 00:01:02,900
should expect to apply to any living

24
00:01:08,260 --> 00:01:05,600
system for which we can shape them into

25
00:01:09,940 --> 00:01:08,270
one of these constructs and at the other

26
00:01:11,770 --> 00:01:09,950
end we have all of the life we've seen

27
00:01:13,810 --> 00:01:11,780
and the question is can we take all the

28
00:01:16,090 --> 00:01:13,820
life that we've seen and extract another

29
00:01:18,250 --> 00:01:16,100
set of principles from that as well and

30
00:01:20,770 --> 00:01:18,260
the hope is that from both ends of the

31
00:01:22,990 --> 00:01:20,780
spectrum we can find some set of general

32
00:01:24,850 --> 00:01:23,000
principles once you have those you can

33
00:01:26,410 --> 00:01:24,860
build some universal theory of life

34
00:01:27,700 --> 00:01:26,420
similar to the universal theories of

35
00:01:30,250 --> 00:01:27,710
chemistry and physics that we already

36
00:01:32,940 --> 00:01:30,260
have and then once you have this theory

37
00:01:35,350 --> 00:01:32,950
you can expand back out into specific

38
00:01:38,410 --> 00:01:35,360

applications such as thinking of a

39
00:01:39,460 --> 00:01:38,420
variety of origins of life or thinking

40
00:01:42,670 --> 00:01:39,470
about searching for life in

41
00:01:43,719 --> 00:01:42,680
astrobiological context so at this end

42
00:01:45,730 --> 00:01:43,729
of the spectrum where we have these

43
00:01:46,960 --> 00:01:45,740
abstract theoretical principles we

44
00:01:49,960 --> 00:01:46,970
already have some of these that's worth

45
00:01:52,719 --> 00:01:49,970
noting examples include the error

46
00:01:55,420 --> 00:01:52,729
threshold or pattern formation so for

47
00:01:58,780 --> 00:01:55,430
the error threshold we know if you can

48
00:02:00,250 --> 00:01:58,790
formalize how a system replicates and

49
00:02:02,789 --> 00:02:00,260
you can formalize what the inheritance

50
00:02:05,230 --> 00:02:02,799
mechanism is then you can set a maximum

51
00:02:07,330 --> 00:02:05,240
mutation rate in order for that system

52
00:02:10,300 --> 00:02:07,340
to be able to evolve now the trick here

53
00:02:12,280 --> 00:02:10,310
becomes abstracting a variety of systems

54
00:02:14,530 --> 00:02:12,290
into this framework but if you can do

55
00:02:16,589 --> 00:02:14,540
that we have a lot to say so this is one

56
00:02:18,970 --> 00:02:16,599
nice principle that we already have

57
00:02:20,229 --> 00:02:18,980
another would be pattern formation we

58
00:02:20,890 --> 00:02:20,239
understand how certain sorts of

59
00:02:23,380 --> 00:02:20,900
dynamical

60
00:02:25,899 --> 00:02:23,390
systems give rise to patterns naturally

61
00:02:28,119 --> 00:02:25,909
even give rise to sort of naturally

62
00:02:30,640 --> 00:02:28,129
replicating systems and so in this end

63
00:02:32,170 --> 00:02:30,650

of the spectrum we have two of a very

64
00:02:35,080 --> 00:02:32,180
long list of principles we've already

65
00:02:36,520 --> 00:02:35,090
built up and then for extant life we

66
00:02:40,420 --> 00:02:36,530
have a lot of very detailed knowledge

67
00:02:42,399 --> 00:02:40,430
about particular physiology or what our

68
00:02:43,690 --> 00:02:42,409
actual genetic inheritance mechanism

69
00:02:46,390 --> 00:02:43,700
looks like what the central dogma of

70
00:02:47,740 --> 00:02:46,400
molecular biology looks like and so the

71
00:02:50,920 --> 00:02:47,750
question is how do we take those

72
00:02:52,930 --> 00:02:50,930
specific details and generalize them

73
00:02:55,180 --> 00:02:52,940
into this set of general principles

74
00:02:56,800 --> 00:02:55,190
where they start to meet these abstract

75
00:02:59,080 --> 00:02:56,810
theoretical concepts that we already

76
00:03:02,710 --> 00:02:59,090
have and so this is what I'll talk about

77
00:03:04,330 --> 00:03:02,720
today is how we can look at life in a

78
00:03:07,750 --> 00:03:04,340
slightly different way than we typically

79
00:03:11,710 --> 00:03:07,760
have and start to find some generalities

80
00:03:14,379 --> 00:03:11,720
there one nice example is the

81
00:03:17,679 --> 00:03:14,389
observation of allometric scaling or

82
00:03:19,629 --> 00:03:17,689
power laws in biology so these show up

83
00:03:21,460 --> 00:03:19,639
for a variety of classes of organisms

84
00:03:23,770 --> 00:03:21,470
and what they typically show is that if

85
00:03:26,259 --> 00:03:23,780
you have many orders of magnitude and

86
00:03:27,520 --> 00:03:26,269
organism size plotted against some

87
00:03:30,009 --> 00:03:27,530
feature of an organism in this case

88
00:03:32,619 --> 00:03:30,019

metabolic rate you see that all

89
00:03:35,319 --> 00:03:32,629
organisms within a class fall along a

90
00:03:37,720 --> 00:03:35,329
single power law relationship with some

91
00:03:40,360 --> 00:03:37,730
amount of scatter so this is sort of

92
00:03:41,680 --> 00:03:40,370
amazing because it says that despite all

93
00:03:44,500 --> 00:03:41,690
of the detailed evolution that's

94
00:03:47,619 --> 00:03:44,510
occurring adaptation to particular

95
00:03:49,869 --> 00:03:47,629
niches particular evolutionary histories

96
00:03:52,629 --> 00:03:49,879
path dependency despite that there's

97
00:03:57,039 --> 00:03:52,639
some set of constraints common enough to

98
00:03:59,219 --> 00:03:57,049
a body plan to give rise to these single

99
00:04:01,240 --> 00:03:59,229
regularities for diverse organisms

100
00:04:03,159 --> 00:04:01,250
what's also interesting about these

101
00:04:05,680 --> 00:04:03,169
relationships is that they shift as you

102
00:04:08,229 --> 00:04:05,690
go across organism architecture so these

103
00:04:10,990 --> 00:04:08,239
are all single-cell bacteria then you

104
00:04:12,610 --> 00:04:11,000
shift to the single-cell eukaryotes and

105
00:04:15,129 --> 00:04:12,620
then you go to small multicellular

106
00:04:16,810 --> 00:04:15,139
eukaryotes and each time you do that the

107
00:04:18,729 --> 00:04:16,820
exponent of this power loss shifts

108
00:04:21,520 --> 00:04:18,739
telling you that there's some shift in

109
00:04:24,520 --> 00:04:21,530
constraints associated with architecture

110
00:04:25,839 --> 00:04:24,530
and metabolism so this is great and we

111
00:04:27,399 --> 00:04:25,849
can just understand what principles are

112
00:04:29,110 --> 00:04:27,409
causing this we might be able to say

113
00:04:30,940 --> 00:04:29,120

something very general about the

114
00:04:34,360 --> 00:04:30,950
connection between organism architecture

115
00:04:35,140 --> 00:04:34,370
and various physiological features we

116
00:04:36,660 --> 00:04:35,150
can also take some

117
00:04:39,850 --> 00:04:36,670
like this and make it much more detailed

118
00:04:42,130 --> 00:04:39,860
for example by setting up a very simple

119
00:04:43,930 --> 00:04:42,140
partitioning of metabolism so we say in

120
00:04:45,670 --> 00:04:43,940
general metabolism needs to be

121
00:04:47,590 --> 00:04:45,680
partitioned between some ability to

122
00:04:49,750 --> 00:04:47,600
produce new biomass and towards

123
00:04:51,130 --> 00:04:49,760
replication and some amount of energy to

124
00:04:53,470 --> 00:04:51,140
maintain the biomass that you already

125
00:04:55,810 --> 00:04:53,480
have because there are certainly decay

126
00:04:58,210 --> 00:04:55,820
processes and then we can say metabolism

127
00:05:00,160 --> 00:04:58,220
equals growth plus maintenance we can

128
00:05:02,920 --> 00:05:00,170
rewrite that in a more detailed bio

129
00:05:04,870 --> 00:05:02,930
energetic form where you have metabolism

130
00:05:06,760 --> 00:05:04,880
on the left-hand side here is equal to

131
00:05:08,470 --> 00:05:06,770
some power law and that equals some

132
00:05:10,270 --> 00:05:08,480
energy to produce a new unit of biomass

133
00:05:12,670 --> 00:05:10,280
times the rate of biomass production

134
00:05:14,740 --> 00:05:12,680
plus some energy to maintain an existing

135
00:05:17,920 --> 00:05:14,750
unit of biomass times how much mass you

136
00:05:20,230 --> 00:05:17,930
actually have and then you can solve all

137
00:05:21,910 --> 00:05:20,240
of this to predict a variety of things

138
00:05:23,200 --> 00:05:21,920

such as the growth trajectory of a

139
00:05:25,390 --> 00:05:23,210
single organism through its life cycle

140
00:05:27,880 --> 00:05:25,400
or the population growth rate of

141
00:05:29,920 --> 00:05:27,890
organisms where if we know the sort of

142
00:05:32,620 --> 00:05:29,930
average bioenergetic parameters of life

143
00:05:35,440 --> 00:05:32,630
which we do we can then make these broad

144
00:05:37,240 --> 00:05:35,450
predictions for say all bacteria all

145
00:05:39,910 --> 00:05:37,250
units are eukaryotes and all small

146
00:05:42,550 --> 00:05:39,920
multicellular organisms in terms of the

147
00:05:44,860 --> 00:05:42,560
the specific population growth rate as a

148
00:05:47,080 --> 00:05:44,870
function of body size and so again we

149
00:05:49,570 --> 00:05:47,090
see these architectural shifts showing

150
00:05:52,870 --> 00:05:49,580
up here whereas bacteria become larger

151
00:05:54,640 --> 00:05:52,880
they are grow faster and faster whereas

152
00:05:56,980 --> 00:05:54,650
the units are eukaryotes as body size

153
00:05:58,450 --> 00:05:56,990
evolved to be larger grow more slowly

154
00:06:00,930 --> 00:05:58,460
and this is due to the difference in

155
00:06:03,880 --> 00:06:00,940
these energetics as connected with

156
00:06:06,280 --> 00:06:03,890
architecture and we see that we can

157
00:06:08,440 --> 00:06:06,290
predict distinct scales where these

158
00:06:11,590 --> 00:06:08,450
architectures break down so we can set a

159
00:06:12,790 --> 00:06:11,600
minimum size on bacteria where

160
00:06:15,490 --> 00:06:12,800
maintenance becomes the entire

161
00:06:17,110 --> 00:06:15,500
metabolism we can set a maximum size on

162
00:06:18,180 --> 00:06:17,120
unis or eukaryotes again where

163
00:06:20,620 --> 00:06:18,190

maintenance becomes the entire

164
00:06:22,630 --> 00:06:20,630
metabolism and here we see that this

165
00:06:24,880 --> 00:06:22,640
does a good job of predicting where you

166
00:06:26,650 --> 00:06:24,890
stop seeing unicel eukaryotic life and

167
00:06:28,630 --> 00:06:26,660
you start seeing small multicellular

168
00:06:30,430 --> 00:06:28,640
eukaryotic life so this predicts the

169
00:06:32,410 --> 00:06:30,440
need for an evolutionary transition and

170
00:06:34,630 --> 00:06:32,420
this sets a lower bound and sort of the

171
00:06:36,210 --> 00:06:34,640
smallest bacteria we see which agrees

172
00:06:38,820 --> 00:06:36,220
very well with the the recent

173
00:06:40,990 --> 00:06:38,830
measurements out of gel Banfield's lab

174
00:06:44,380 --> 00:06:41,000
which has the new right world record

175
00:06:45,790 --> 00:06:44,390
holder for smallest life so this is

176
00:06:47,740 --> 00:06:45,800
really nice we now have these broad

177
00:06:48,500 --> 00:06:47,750
taxonomic predictions we can understand

178
00:06:50,990 --> 00:06:48,510
where architects

179
00:06:53,930 --> 00:06:51,000
fail and we can also continue to drill

180
00:06:55,400 --> 00:06:53,940
down on one class of organisms to try

181
00:06:58,640 --> 00:06:55,410
and understand something more specific

182
00:07:01,100 --> 00:06:58,650
about the physiology again from a very

183
00:07:03,350 --> 00:07:01,110
average or general perspective so for

184
00:07:06,080 --> 00:07:03,360
example one thing we can do is knowing

185
00:07:07,760 --> 00:07:06,090
what we know about the energetics of

186
00:07:10,010 --> 00:07:07,770
these organisms we can start to predict

187
00:07:13,670 --> 00:07:10,020
the need for ribosomes at various scales

188
00:07:15,620 --> 00:07:13,680

so we could take the average physiology

189
00:07:17,930 --> 00:07:15,630
of the central dogma and break out each

190
00:07:20,870 --> 00:07:17,940
component and understand what's driving

191
00:07:22,520 --> 00:07:20,880
that and so in this case I'm showing our

192
00:07:25,340 --> 00:07:22,530
theory for the predicted number of

193
00:07:27,230 --> 00:07:25,350
ribosomes converted to volume units as a

194
00:07:30,680 --> 00:07:27,240
function of cell size just in bacteria

195
00:07:32,060 --> 00:07:30,690
this is the total cell size this is sort

196
00:07:34,340 --> 00:07:32,070
of a best power-law fit to those data

197
00:07:36,980 --> 00:07:34,350
and here are the very messy data from a

198
00:07:39,560 --> 00:07:36,990
variety of bacteria where this is messy

199
00:07:41,300 --> 00:07:39,570
mostly because ribosomes are sort of one

200
00:07:45,290 --> 00:07:41,310
of the main dimensions where organisms

201
00:07:47,170 --> 00:07:45,300
tune physiology so we see here is we do

202
00:07:51,170 --> 00:07:47,180
a good job of predicting this broad

203
00:07:53,480 --> 00:07:51,180
consistency of organisms we also predict

204
00:07:55,640 --> 00:07:53,490
an upper bound on bacterial size right

205
00:07:58,670 --> 00:07:55,650
so we predict now that there becomes a

206
00:08:00,410 --> 00:07:58,680
distinct scale at which you would need

207
00:08:02,390 --> 00:08:00,420
more ribosomes than can fit in the cell

208
00:08:04,940 --> 00:08:02,400
so this now predicts an upper bound on

209
00:08:07,070 --> 00:08:04,950
bacteria which we didn't have in this

210
00:08:09,110 --> 00:08:07,080
relationship but because this growth

211
00:08:10,550 --> 00:08:09,120
rate is increasing quickly you need more

212
00:08:12,740 --> 00:08:10,560
you need ribosomes to keep up with that

213
00:08:14,900 --> 00:08:12,750

and so eventually that becomes

214
00:08:18,320 --> 00:08:14,910
impossible so we have another reason for

215
00:08:20,930 --> 00:08:18,330
this architecture breaking down now I

216
00:08:22,340 --> 00:08:20,940
won't show it but we've expanded this to

217
00:08:25,610 --> 00:08:22,350
sort of capture all of the main

218
00:08:27,200 --> 00:08:25,620
components of bacterial physiology here

219
00:08:28,610 --> 00:08:27,210
is total cell volume for reference and

220
00:08:31,220 --> 00:08:28,620
then everything else has converted to

221
00:08:34,460 --> 00:08:31,230
volume units for cross comparison and

222
00:08:36,520 --> 00:08:34,470
you can see that bacteria across their

223
00:08:39,230 --> 00:08:36,530
range have sort of this dramatic change

224
00:08:42,980 --> 00:08:39,240
in both physiology where they go from

225
00:08:46,700 --> 00:08:42,990
being mostly composed of proteins and

226
00:08:49,850 --> 00:08:46,710
DNA encapsulated in a membrane to being

227
00:08:52,040 --> 00:08:49,860
mostly RNA components as the cell

228
00:08:54,710 --> 00:08:52,050
becomes larger and eventually this

229
00:08:56,660 --> 00:08:54,720
limits their total size so this has a

230
00:08:58,220 --> 00:08:56,670
variety of implications for what you

231
00:08:59,350 --> 00:08:58,230
might measure stoichiometrically in an

232
00:09:02,680 --> 00:08:59,360
environment

233
00:09:04,840 --> 00:09:02,690
it says that on average bacterial

234
00:09:06,490 --> 00:09:04,850
physiology is not comparable and you

235
00:09:08,470 --> 00:09:06,500
should expect specific environments to

236
00:09:10,360 --> 00:09:08,480
select four distinct sizes of bacteria

237
00:09:12,760 --> 00:09:10,370
these are all really nice things to know

238
00:09:14,650 --> 00:09:12,770

ahead of time it also tells us something

239
00:09:16,389 --> 00:09:14,660
about physiological flexibility because

240
00:09:18,790 --> 00:09:16,399
you can see that at both the small and

241
00:09:20,410 --> 00:09:18,800
large end of bacteria they're running

242
00:09:22,389 --> 00:09:20,420
out of space for the essential

243
00:09:24,220 --> 00:09:22,399
physiology so we have the space

244
00:09:26,590 --> 00:09:24,230
constraint that limits now both ends of

245
00:09:28,480 --> 00:09:26,600
the spectrum this happens at the same

246
00:09:31,240 --> 00:09:28,490
size that we saw this energetic

247
00:09:33,010 --> 00:09:31,250
restriction and in between these two you

248
00:09:34,660 --> 00:09:33,020
have sort of this extra space seems to

249
00:09:36,310 --> 00:09:34,670
be mostly filled with water but what

250
00:09:38,710 --> 00:09:36,320
comes with that is an added flexibility

251
00:09:40,810 --> 00:09:38,720
to say increase the number of a

252
00:09:42,910 --> 00:09:40,820
particular protein in response to

253
00:09:45,250 --> 00:09:42,920
environmental fluctuation so we also now

254
00:09:47,710 --> 00:09:45,260
predict that there's differences and the

255
00:09:49,540 --> 00:09:47,720
responsiveness of bacterial physiology

256
00:09:50,500 --> 00:09:49,550
at different size scales again telling

257
00:09:51,760 --> 00:09:50,510
us something about what sorts of

258
00:09:54,730 --> 00:09:51,770
environment should to select for what

259
00:09:56,790 --> 00:09:54,740
sorts of species now everything I've

260
00:09:59,290 --> 00:09:56,800
said has been very much from an

261
00:10:02,440 --> 00:09:59,300
optimization perspective so we've looked

262
00:10:03,760 --> 00:10:02,450
at for example the central dogma in

263
00:10:06,280 --> 00:10:03,770

terms of what would be optimal for

264
00:10:10,120 --> 00:10:06,290
cellular physiology as a function of

265
00:10:12,940 --> 00:10:10,130
these size shifts but one could ask what

266
00:10:14,769 --> 00:10:12,950
are the boundaries of this physiology so

267
00:10:18,610 --> 00:10:14,779
it's hard to map what you would do in

268
00:10:20,079 --> 00:10:18,620
every particular niche but you might get

269
00:10:21,910 --> 00:10:20,089
around that by just saying what are sort

270
00:10:24,160 --> 00:10:21,920
of how far could you push to push this

271
00:10:26,530 --> 00:10:24,170
physiology to understand its its

272
00:10:28,269 --> 00:10:26,540
ultimate bound and so that's sort of the

273
00:10:30,730 --> 00:10:28,279
hope is how do we now start to abstract

274
00:10:32,290 --> 00:10:30,740
this even further to just say even for

275
00:10:34,180 --> 00:10:32,300
life as we know it what is what is the

276
00:10:35,680 --> 00:10:34,190
hard boundary around that look like for

277
00:10:38,230 --> 00:10:35,690
upper and lower bounds of various

278
00:10:40,360 --> 00:10:38,240
processes it's one way we can do that is

279
00:10:41,590 --> 00:10:40,370
to say well what happened if life had a

280
00:10:44,160 --> 00:10:41,600
differently different evolutionary

281
00:10:47,199 --> 00:10:44,170
history what if we discovered a ribosome

282
00:10:48,460 --> 00:10:47,209
that was better or worse than was

283
00:10:51,790 --> 00:10:48,470
discovered by the evolutionary

284
00:10:53,319 --> 00:10:51,800
trajectory that we had and so you can

285
00:10:55,540 --> 00:10:53,329
think about the ribosome basically as

286
00:10:59,019 --> 00:10:55,550
the number of base pairs that can

287
00:11:00,280 --> 00:10:59,029
produce per second given its size and so

288
00:11:01,720 --> 00:11:00,290

you get sort of this base pairs per

289
00:11:03,819 --> 00:11:01,730
second for volume is the critical

290
00:11:06,280 --> 00:11:03,829
parameter and all these models for

291
00:11:08,230 --> 00:11:06,290
ribosomes and if you took the ribosomes

292
00:11:10,150 --> 00:11:08,240
to be exactly the size as the one that

293
00:11:11,880 --> 00:11:10,160
we know but you said imagine it was able

294
00:11:14,550 --> 00:11:11,890
to process base pairs

295
00:11:16,590 --> 00:11:14,560
ten times faster or 40 times slower well

296
00:11:18,180 --> 00:11:16,600
if it could process 10 times faster you

297
00:11:19,860 --> 00:11:18,190
actually get an extra order of magnitude

298
00:11:22,530 --> 00:11:19,870
on the upper bound for bacteria so you

299
00:11:23,880 --> 00:11:22,540
should expect all bacteria to be larger

300
00:11:26,040 --> 00:11:23,890
you expect to see where that transition

301
00:11:27,540 --> 00:11:26,050
between bacterial architecture and

302
00:11:29,579 --> 00:11:27,550
unicellular unicel you carry I got

303
00:11:31,470 --> 00:11:29,589
architecture to be pushed to a larger

304
00:11:33,300 --> 00:11:31,480
size regime now it's up to the

305
00:11:35,460 --> 00:11:33,310
biochemists to decide if this is if this

306
00:11:37,920 --> 00:11:35,470
is actually possible or not but we can

307
00:11:40,290 --> 00:11:37,930
sort of in an abstract sense say once we

308
00:11:42,870 --> 00:11:40,300
know the biochemical limit we can back

309
00:11:45,240 --> 00:11:42,880
out on the physiological limit and now

310
00:11:47,730 --> 00:11:45,250
if the ribosome was 40 times slower you

311
00:11:52,139 --> 00:11:47,740
can't get encapsulated life at all so

312
00:11:53,970 --> 00:11:52,149
you if for all sizes it's impossible to

313
00:11:55,949 --> 00:11:53,980

have enough ribosomes to actually run

314
00:11:57,000 --> 00:11:55,959
cellular replication I'm holding some

315
00:11:59,519 --> 00:11:57,010
other features of cell physiology

316
00:12:00,780 --> 00:11:59,529
constant here that should be noted so

317
00:12:02,850 --> 00:12:00,790
you might be able to tune those a little

318
00:12:04,860 --> 00:12:02,860
bit but given that conditional statement

319
00:12:07,650 --> 00:12:04,870
we can sort of understand the effect of

320
00:12:12,329 --> 00:12:07,660
a better or worse ribosome discovered in

321
00:12:14,400 --> 00:12:12,339
evolutionary history so I think taking

322
00:12:17,310 --> 00:12:14,410
all of that together what this shows is

323
00:12:18,750 --> 00:12:17,320
that by looking at this macro physiology

324
00:12:22,110 --> 00:12:18,760
and thinking about these scaling laws

325
00:12:23,610 --> 00:12:22,120
there are ways to start to go from the

326
00:12:26,100 --> 00:12:23,620
broad diversity of life that we've seen

327
00:12:28,350 --> 00:12:26,110
to some set of general principles about

328
00:12:30,480 --> 00:12:28,360
that life I haven't talked much about it

329
00:12:32,880 --> 00:12:30,490
but in lots of the cases where we've

330
00:12:36,269 --> 00:12:32,890
looked and predicted this these cross

331
00:12:38,040 --> 00:12:36,279
species relationships we understand sort

332
00:12:39,810 --> 00:12:38,050
of the dominant physical constraint or

333
00:12:42,900 --> 00:12:39,820
the main physical process limiting that

334
00:12:44,880 --> 00:12:42,910
so that makes those predictions very

335
00:12:46,199 --> 00:12:44,890
general and then you can play the sorts

336
00:12:48,269 --> 00:12:46,209
of games I just described about the

337
00:12:51,150 --> 00:12:48,279
layering the detailed physiology on top

338
00:12:52,920 --> 00:12:51,160

of that to understand say the bounds of

339
00:12:55,460 --> 00:12:52,930
our life I mean so this gives us

340
00:12:58,560 --> 00:12:55,470
hopefully the possibility of going from

341
00:13:00,449 --> 00:12:58,570
physics to then a variety of

342
00:13:04,079 --> 00:13:00,459
physiological possibilities to

343
00:13:06,030 --> 00:13:04,089
understand the bounds of life or the you

344
00:13:08,400 --> 00:13:06,040
know how far we might expect something

345
00:13:10,889 --> 00:13:08,410
to exist away from the types of

346
00:13:12,900 --> 00:13:10,899
organisms that we already see so with

347
00:13:14,220 --> 00:13:12,910
that I'd like to thank a long set of

348
00:13:16,530 --> 00:13:14,230
collaborators many of whom are here

349
00:13:19,230 --> 00:13:16,540
today I'd like to acknowledge NASA and

350
00:13:22,170 --> 00:13:19,240
NSF for generous funding throughout

351
00:13:23,280 --> 00:13:22,180
various portions of these papers

352
00:13:25,710 --> 00:13:23,290
and with that I'd be happy to take any

353
00:13:34,950 --> 00:13:25,720
questions if we have time and thank you

354
00:13:36,150 --> 00:13:34,960
for your attention so that yeah there's

355
00:13:45,000 --> 00:13:36,160
a microphone up front please use it for

356
00:13:46,590 --> 00:13:45,010
questions hello okay hi Micah Wong

357
00:13:47,970 --> 00:13:46,600
University of Washington I I'm not

358
00:13:51,300 --> 00:13:47,980
really in this field but it was a really

359
00:13:53,280 --> 00:13:51,310
interesting talk and I've read in the

360
00:13:55,950 --> 00:13:53,290
work of like Nick Lane and others that

361
00:13:58,440 --> 00:13:55,960
the sort of cell size maximum can be

362
00:14:00,060 --> 00:13:58,450
attributed to a sort of surface area to

363
00:14:02,070 --> 00:14:00,070

volume ratio kind of thing where

364
00:14:03,780 --> 00:14:02,080
chemiosmosis happens along the surface

365
00:14:06,120 --> 00:14:03,790
area of cells and so it's wondering if

366
00:14:08,340 --> 00:14:06,130
this ribosomal limit is complementary or

367
00:14:10,230 --> 00:14:08,350
contradictory to that argument and if

368
00:14:10,590 --> 00:14:10,240
you have thoughts on that yeah I mean so

369
00:14:13,680 --> 00:14:10,600
I won't

370
00:14:15,810 --> 00:14:13,690
detail because we have a lot to say

371
00:14:18,390 --> 00:14:15,820
about that but the the broad point I

372
00:14:21,090 --> 00:14:18,400
will make is that many of these sort of

373
00:14:22,890 --> 00:14:21,100
limits occur at you know at the same

374
00:14:25,590 --> 00:14:22,900
place for different perspectives so this

375
00:14:27,180 --> 00:14:25,600
this size based you know just this

376
00:14:28,980 --> 00:14:27,190
packing problem for the smallest cells

377
00:14:31,290 --> 00:14:28,990
that limit is almost identical to the

378
00:14:32,490 --> 00:14:31,300
energetic problem and that really tells

379
00:14:34,140 --> 00:14:32,500
you that two things should be being

380
00:14:35,970 --> 00:14:34,150
co-opted amaizing

381
00:14:38,160 --> 00:14:35,980
right so it says that you have a set of

382
00:14:39,750 --> 00:14:38,170
constraints and evolution pushes on the

383
00:14:41,580 --> 00:14:39,760
constraints at most matters until

384
00:14:43,080 --> 00:14:41,590
they've sort of all read some boundary

385
00:14:44,700 --> 00:14:43,090
that they can't go beyond and so there's

386
00:14:46,220 --> 00:14:44,710
there's some very complicated Co

387
00:14:48,720 --> 00:14:46,230
optimization we haven't worked out yet

388
00:14:50,160 --> 00:14:48,730

related to why some of many of these

389
00:14:51,660 --> 00:14:50,170
constraints occur at the same scales and

390
00:14:54,960 --> 00:14:51,670
I think that relates to some of Nick

391
00:14:55,650 --> 00:14:54,970
lanes arguments well thank you more time

392
00:15:01,470 --> 00:14:55,660
for one more question

393
00:15:04,470 --> 00:15:01,480
I am I'm really struggling to understand

394
00:15:07,320 --> 00:15:04,480
why you think cell volume is a relevant

395
00:15:08,790 --> 00:15:07,330
sort of independent variable to describe

396
00:15:10,380 --> 00:15:08,800
these two processes because I guess

397
00:15:12,780 --> 00:15:10,390
thinking from my point of view is that

398
00:15:15,180 --> 00:15:12,790
biochemist I mean most bacteria are

399
00:15:17,070 --> 00:15:15,190
about one femto leader and you know that

400
00:15:19,020 --> 00:15:17,080
basically comprises a huge spectrum of

401
00:15:21,660 --> 00:15:19,030
things like e.coli that basically can

402
00:15:23,910 --> 00:15:21,670
double every 20 minutes and have 50,000

403
00:15:26,370 --> 00:15:23,920
ribosomes to things like you know soil

404
00:15:28,350 --> 00:15:26,380
bacteria that are the same size and

405
00:15:30,540 --> 00:15:28,360
basically double once every month and

406
00:15:32,640 --> 00:15:30,550
have maybe a thousand ribosomes and are

407
00:15:35,580 --> 00:15:32,650
just as happy in terms of they can

408
00:15:37,140 --> 00:15:35,590
persist in their niche so I guess if you

409
00:15:39,230 --> 00:15:37,150
could have like things that have such a

410
00:15:41,220 --> 00:15:39,240
different metabolic sort of you know

411
00:15:43,230 --> 00:15:41,230
lifestyle very different number

412
00:15:43,620 --> 00:15:43,240
ribosomes and are the same volume I

413
00:15:45,570 --> 00:15:43,630

don't

414
00:15:47,730 --> 00:15:45,580
understand why is the volume so relevant

415
00:15:49,710 --> 00:15:47,740
for your study yeah it's a great

416
00:15:51,600 --> 00:15:49,720
question I mean it's saying at the top

417
00:15:53,340 --> 00:15:51,610
level volumes are relevant parameter

418
00:15:56,970 --> 00:15:53,350
mostly because it interacts with a

419
00:15:59,010 --> 00:15:56,980
variety of physical constraints so where

420
00:16:00,360 --> 00:15:59,020
your boundary is has dramatic

421
00:16:01,440 --> 00:16:00,370
implications at the you know for the

422
00:16:04,050 --> 00:16:01,450
simplest example for things like

423
00:16:05,460 --> 00:16:04,060
diffusion right and so size immediately

424
00:16:07,290 --> 00:16:05,470
tells you something about the physics

425
00:16:09,180 --> 00:16:07,300
and that's one of the reasons that we

426
00:16:11,070 --> 00:16:09,190
think about this boundary as it

427
00:16:13,770 --> 00:16:11,080
constrained now how much you want to

428
00:16:15,660 --> 00:16:13,780
change that concentration within that

429
00:16:17,070 --> 00:16:15,670
boundary is a more complicated question

430
00:16:19,440 --> 00:16:17,080
something I should mention here too is

431
00:16:21,690 --> 00:16:19,450
that this is all for a maximum growth

432
00:16:25,110 --> 00:16:21,700
rate perspective and under these maximum

433
00:16:27,510 --> 00:16:25,120
growth rate considerations you often see

434
00:16:29,700 --> 00:16:27,520
shifts and cell size when you move away

435
00:16:33,330 --> 00:16:29,710
from those conditions so I think I think

436
00:16:36,140 --> 00:16:33,340
there are in tremendous relationships

437
00:16:39,090 --> 00:16:36,150
across you could even do something like

438
00:16:40,410 --> 00:16:39,100

concentration of the ribosome is your as

439
00:16:41,640 --> 00:16:40,420
you're generating parameter and then you

440
00:16:43,530 --> 00:16:41,650
would see a strong correlation with cell

441
00:16:45,500 --> 00:16:43,540
volume but it would D correlate from

442
00:16:47,550 --> 00:16:45,510
lots of other things because it's not as

443
00:16:49,140 --> 00:16:47,560
directly related to certain physical

444
00:16:50,880 --> 00:16:49,150
constraints so that I think it's it's

445
00:16:55,410 --> 00:16:50,890
the connection with with obvious physics