Shawn McGlynn

Revisiting electrons, protons, and energy conservation at hydrothermal vents during the emergence of life

1
00:00:00,160 --> 00:00:14,750
[Music]

2
00:00:21,380 --> 00:00:19,820
hi everybody I want to thank arena and

3
00:00:23,330 --> 00:00:21,390
the conference organizers for putting on

4
00:00:24,500 --> 00:00:23,340
it's already at the first day a really

5
00:00:28,550 --> 00:00:24,510
awesome conference I've really been

6
00:00:30,770 --> 00:00:28,560
enjoying all the talks today sorry about

7
00:00:34,220 --> 00:00:30,780
my complicated title I really want to

8
00:00:35,450 --> 00:00:34,230
talk to you today about kind of recent

9
00:00:36,770 --> 00:00:35,460
concepts that I've been considering

10
00:00:40,010 --> 00:00:36,780
about energy conservation and energy

11
00:00:41,720 --> 00:00:40,020
flow through the first cells and this is

12
00:00:44,030 --> 00:00:41,730
kind of preliminary data that I'll

13
00:00:46,040 --> 00:00:44,040

present a small amounts of that and some

14
00:00:48,500 --> 00:00:46,050
concepts that I hope can foster some

15
00:00:50,210 --> 00:00:48,510
discussions with everybody and so what

16
00:00:52,310 --> 00:00:50,220
I've seen today and I hope to see during

17
00:00:53,930 --> 00:00:52,320
the rest of the presentation or more and

18
00:00:55,340 --> 00:00:53,940
more puzzle pieces that we might

19
00:00:57,590 --> 00:00:55,350
eventually be able to put together and

20
00:01:02,119 --> 00:00:57,600
have a better idea of how how this got

21
00:01:03,439 --> 00:01:02,129
started so when I think about what the

22
00:01:05,930 --> 00:01:03,449
first cells were doing and what their

23
00:01:08,719 --> 00:01:05,940
first Physiology was I I often remember

24
00:01:11,719 --> 00:01:08,729
that all life is using energy in the

25
00:01:12,950 --> 00:01:11,729
form of chemical potentials and putting

26
00:01:15,020 --> 00:01:12,960
that through the cells and organizing

27
00:01:17,330 --> 00:01:15,030
the cells that way of course there's

28
00:01:19,160 --> 00:01:17,340
photosynthetic cells but light converts

29
00:01:22,160 --> 00:01:19,170
chemicals into high-energy molecules and

30
00:01:24,680 --> 00:01:22,170
those are subsequently used sometimes

31
00:01:26,540 --> 00:01:24,690
it's convenient to divide energy flow in

32
00:01:28,790 --> 00:01:26,550
biological systems to a maintenance

33
00:01:31,400 --> 00:01:28,800
process that is how much energy does it

34
00:01:32,750 --> 00:01:31,410
just keep me just does it take for me to

35
00:01:35,330 --> 00:01:32,760
stand on the stage or if you're a

36
00:01:36,980 --> 00:01:35,340
microbe just to sit there and do your

37
00:01:38,840 --> 00:01:36,990
thing and then there's the reproductive

38
00:01:41,480 --> 00:01:38,850

cost which is really really high I don't

39
00:01:43,580 --> 00:01:41,490
have kids yet but I hear having having

40
00:01:47,030 --> 00:01:43,590
offspring is hard it's also hard if

41
00:01:48,560 --> 00:01:47,040
you're a microbe I assume but these are

42
00:01:50,780 --> 00:01:48,570
the kind of the two different pies that

43
00:01:54,230 --> 00:01:50,790
we can divide energy flow through when

44
00:01:57,020 --> 00:01:54,240
we consider life and so a really

45
00:01:58,340 --> 00:01:57,030
fascinated question for me is is what

46
00:01:59,899 --> 00:01:58,350
are the first energy flows that

47
00:02:01,550 --> 00:01:59,909
organized material in a way that

48
00:02:03,500 --> 00:02:01,560
resulted in what we call biology today

49
00:02:06,350 --> 00:02:03,510
and that's kind of what I what I really

50
00:02:08,509 --> 00:02:06,360
want to talk to you about us biologists

51
00:02:11,210 --> 00:02:08,519
we use kind of funny calm very funny

52
00:02:13,009 --> 00:02:11,220
words to talk about energy flow and we

53
00:02:15,170 --> 00:02:13,019
we use this term called energy

54
00:02:17,420 --> 00:02:15,180
conservation and it took me a long time

55
00:02:19,970 --> 00:02:17,430
to really understand what that meant and

56
00:02:22,280 --> 00:02:19,980
so I want to talk about that in a very

57
00:02:23,509 --> 00:02:22,290
basic way with you today so that we can

58
00:02:28,730 --> 00:02:23,519
all get on the same page about what it

59
00:02:30,980 --> 00:02:28,740
means it really means saving energy and

60
00:02:33,320 --> 00:02:30,990
losing energy to the environment in the

61
00:02:35,360 --> 00:02:33,330
form of heat and just dissipating it

62
00:02:37,940 --> 00:02:35,370
using the energy from the environment

63
00:02:39,830 --> 00:02:37,950

from sets of chemical reactions temper

64
00:02:43,640 --> 00:02:39,840
to temporarily hold matter in an

65
00:02:45,650 --> 00:02:43,650
organized state so sometimes I think

66
00:02:47,840 --> 00:02:45,660
about it more in terms of how can a

67
00:02:49,730 --> 00:02:47,850
chemical reactions save energy during

68
00:02:51,350 --> 00:02:49,740
the reaction progress if you talk to any

69
00:02:53,420 --> 00:02:51,360
biologists about it they'll say oh the

70
00:02:55,220 --> 00:02:53,430
energy conservation works this say this

71
00:02:56,900 --> 00:02:55,230
way or it works that way and you might

72
00:02:58,760 --> 00:02:56,910
ask what does it mean to conserve things

73
00:03:00,920 --> 00:02:58,770
I would encourage you to think about

74
00:03:03,530 --> 00:03:00,930
like oh the organism is saving energy

75
00:03:07,040 --> 00:03:03,540
along that reaction and it's organizing

76
00:03:11,480 --> 00:03:07,050
itself temporarily with that flow and so

77
00:03:13,010 --> 00:03:11,490
I'm gonna talk about possible energy

78
00:03:14,300 --> 00:03:13,020
flows that might have been occurring at

79
00:03:17,330 --> 00:03:14,310
hydrothermal events that might have

80
00:03:20,060 --> 00:03:17,340
organized material in the very from the

81
00:03:21,320 --> 00:03:20,070
start it doesn't mean that I think that

82
00:03:22,310 --> 00:03:21,330
hydrothermal vents are the place that

83
00:03:23,960 --> 00:03:22,320
life happened but I think they're

84
00:03:27,230 --> 00:03:23,970
interesting to consider because there's

85
00:03:30,380 --> 00:03:27,240
a sustained source of energy that flux

86
00:03:32,360 --> 00:03:30,390
coming out of them and because I chose

87
00:03:35,650 --> 00:03:32,370
to talk to you today about hydrothermal

88
00:03:38,810 --> 00:03:35,660

vents and the origin of life I wanted to

89
00:03:41,680 --> 00:03:38,820
just quickly bring up and go through a

90
00:03:44,000 --> 00:03:41,690
recent paper that also just discusses

91
00:03:47,000 --> 00:03:44,010
energy flow and physiology that's

92
00:03:50,600 --> 00:03:47,010
happening at hydrothermal vents and I

93
00:03:51,860 --> 00:03:50,610
want to do this because since I think a

94
00:03:53,390 --> 00:03:51,870
lot about hydrothermal vents and the

95
00:03:56,090 --> 00:03:53,400
origin of life and also contemporary

96
00:03:57,820 --> 00:03:56,100
life people recently asked me about this

97
00:03:59,900 --> 00:03:57,830
paper and what do I think about it and

98
00:04:03,140 --> 00:03:59,910
I'll tell you what I think about it in a

99
00:04:04,970 --> 00:04:03,150
couple slides here the goal of this

100
00:04:07,370 --> 00:04:04,980
paper was to analyze all contemporary

101
00:04:10,130 --> 00:04:07,380
genomes and find out what is the common

102
00:04:12,620 --> 00:04:10,140
set of proteins or enzymes that are

103
00:04:16,430 --> 00:04:12,630
found in the last common ancestor of

104
00:04:18,020 --> 00:04:16,440
bacteria and archaea and say and to be

105
00:04:19,729 --> 00:04:18,030
able to use that information to comment

106
00:04:22,160 --> 00:04:19,739
on what the physiology of that organism

107
00:04:25,370 --> 00:04:22,170
was you can argue whether or not that's

108
00:04:27,440 --> 00:04:25,380
a valid approach at all as in does it

109
00:04:29,450 --> 00:04:27,450
make any sense or how much sense how

110
00:04:31,100 --> 00:04:29,460
sure can you be just from genome

111
00:04:32,330 --> 00:04:31,110
analysis when you're talking about

112
00:04:34,190 --> 00:04:32,340
something that happened around four

113
00:04:36,200 --> 00:04:34,200

billion years ago but it's one way to go

114
00:04:37,580 --> 00:04:36,210
about it presumably there is a record

115
00:04:40,490 --> 00:04:37,590
contained in our genome that we can

116
00:04:42,110 --> 00:04:40,500
derive information from and the way that

117
00:04:42,470 --> 00:04:42,120
these authors chose to do it is quite

118
00:04:44,210 --> 00:04:42,480
some

119
00:04:46,760 --> 00:04:44,220
and it's nice that they made it simple

120
00:04:50,060 --> 00:04:46,770
they used two criteria to judge the

121
00:04:51,640 --> 00:04:50,070
presence of a protein or a gene in the

122
00:04:54,980 --> 00:04:51,650
common ancestor of archaea and bacteria

123
00:04:56,570 --> 00:04:54,990
one the present should be the protein or

124
00:04:58,970 --> 00:04:56,580
the gene should be present in at least

125
00:05:00,980 --> 00:04:58,980
two higher taxonomic groups and I'll

126
00:05:03,440 --> 00:05:00,990
describe what that means in a second of

127
00:05:05,000 --> 00:05:03,450
each bacteria and archaea and the second

128
00:05:07,940 --> 00:05:05,010
is that if you draw a phylogenetic tree

129
00:05:10,100 --> 00:05:07,950
of this protein individually it should

130
00:05:12,680 --> 00:05:10,110
split the archaea in the bacteria just

131
00:05:15,200 --> 00:05:12,690
like a ribosomal or an elongation factor

132
00:05:17,660 --> 00:05:15,210
gene would so what what do they mean by

133
00:05:19,870 --> 00:05:17,670
that they mean something like this here

134
00:05:22,460 --> 00:05:19,880
on the left are a bacteria in blue and

135
00:05:24,500 --> 00:05:22,470
if you squint your eyes or if you've got

136
00:05:26,630 --> 00:05:24,510
good eyes you can see that there are two

137
00:05:28,820 --> 00:05:26,640
dark blue lines on the bacterial tree

138
00:05:31,340 --> 00:05:28,830

this would be representing that a

139
00:05:33,590 --> 00:05:31,350
protein or a gene is present in two

140
00:05:35,180 --> 00:05:33,600
higher taxes of bacteria and on the

141
00:05:36,890 --> 00:05:35,190
right we've got this other group of

142
00:05:38,870 --> 00:05:36,900
organisms that we call the archaea and

143
00:05:40,070 --> 00:05:38,880
if you look closely there's two dark red

144
00:05:43,160 --> 00:05:40,080
lines and this would be indicative of

145
00:05:45,440 --> 00:05:43,170
two of these genes being present in

146
00:05:47,060 --> 00:05:45,450
archaea and if you found a protein that

147
00:05:49,220 --> 00:05:47,070
looked like this according to these

148
00:05:50,540 --> 00:05:49,230
criteria you would conclude okay this

149
00:05:52,400 --> 00:05:50,550
this is a good candidate for something

150
00:05:55,160 --> 00:05:52,410
that was present in the last Universal

151
00:05:57,380 --> 00:05:55,170
Universal common ancestor or as I like

152
00:06:00,650 --> 00:05:57,390
to call just the last common ancestor of

153
00:06:02,360 --> 00:06:00,660
bacteria and archaea and in the paper

154
00:06:04,790 --> 00:06:02,370
they're thinking about hydrothermal

155
00:06:08,180 --> 00:06:04,800
vents and they come up with this scheme

156
00:06:10,010 --> 00:06:08,190
and when I was reading this paper it

157
00:06:12,500 --> 00:06:10,020
really caught my eye because they

158
00:06:14,900 --> 00:06:12,510
included a nitrogenous and also radical

159
00:06:16,580 --> 00:06:14,910
Sam proteins inside of those and those

160
00:06:18,890 --> 00:06:16,590
are these proteins here and I just want

161
00:06:20,780 --> 00:06:18,900
to discuss briefly what the phylogeny of

162
00:06:23,330 --> 00:06:20,790
those proteins looks like and whether or

163
00:06:25,790 --> 00:06:23,340

not this is a valid conclusion to

164
00:06:27,560 --> 00:06:25,800
include in their data set what is a

165
00:06:30,740 --> 00:06:27,570
nitrogenous and what is a radical Sam

166
00:06:33,080 --> 00:06:30,750
protein a nitrogenous is the only known

167
00:06:34,730 --> 00:06:33,090
biological catalyst that can take n2

168
00:06:36,500 --> 00:06:34,740
from the atmosphere and turn it into

169
00:06:37,970 --> 00:06:36,510
ammonium and so this is this vertical

170
00:06:41,390 --> 00:06:37,980
reaction on the left here where you take

171
00:06:43,100 --> 00:06:41,400
nitrogen gas plus six electrons you you

172
00:06:45,350 --> 00:06:43,110
spill off a couple electrons on the

173
00:06:46,460 --> 00:06:45,360
hydrogen that the enzyme can't hold on

174
00:06:48,890 --> 00:06:46,470
to the electrons and so you always make

175
00:06:52,840 --> 00:06:48,900
a little bit of hydrogen you have to

176
00:06:56,600 --> 00:06:52,850
push the reaction forward with ATP and

177
00:06:58,820 --> 00:06:56,610
this is a this is a phylogenetic tree

178
00:07:00,890 --> 00:06:58,830
of the actual catalytic subunit of the

179
00:07:02,689 --> 00:07:00,900
protein that's drawn on the left and so

180
00:07:04,339 --> 00:07:02,699
what we would like to ask ourselves at

181
00:07:05,839 --> 00:07:04,349
this stage is where are the Archaea

182
00:07:07,399 --> 00:07:05,849
industry and where are the bacteria does

183
00:07:09,589 --> 00:07:07,409
it recover the archaea bacteria split

184
00:07:11,809 --> 00:07:09,599
and is it present in two higher taxes of

185
00:07:14,510 --> 00:07:11,819
each of these same question we can ask

186
00:07:17,029 --> 00:07:14,520
for this radical Sam protein family

187
00:07:18,559 --> 00:07:17,039
radical Sam protein family they all

188
00:07:21,040 --> 00:07:18,569

carry out the reaction shown on the

189
00:07:24,830 --> 00:07:21,050
right they take s-adenosylmethionine

190
00:07:27,409 --> 00:07:24,840
which is a cool sulfonium ion and they

191
00:07:29,300 --> 00:07:27,419
donate a single electron from an iron

192
00:07:30,800 --> 00:07:29,310
sulfur cluster on to that sulfonium ion

193
00:07:32,779 --> 00:07:30,810
and then they make this deoxyadenosine

194
00:07:34,909 --> 00:07:32,789
radical that you see on the right and

195
00:07:36,920 --> 00:07:34,919
that deoxyadenosine radical can go on

196
00:07:39,439 --> 00:07:36,930
and do almost any chemical reaction that

197
00:07:43,129 --> 00:07:39,449
you want to dream up it's wonderfully an

198
00:07:46,070 --> 00:07:43,139
amazing lead diverse chemical chemically

199
00:07:47,300 --> 00:07:46,080
reactive enzyme it's found all over the

200
00:07:49,369 --> 00:07:47,310
place in biology it's probably it

201
00:07:51,499 --> 00:07:49,379
probably is a good candidate to include

202
00:07:54,679 --> 00:07:51,509
in toluca but what does what does the

203
00:07:56,330 --> 00:07:54,689
phylogeny look like so I want to just

204
00:07:59,300 --> 00:07:56,340
talk about those two protein families

205
00:08:01,640 --> 00:07:59,310
today first the nitrogenase is it

206
00:08:02,809 --> 00:08:01,650
present in two acts to higher taxes of

207
00:08:05,480 --> 00:08:02,819
archaea and bacteria

208
00:08:08,059 --> 00:08:05,490
well actually the nitrogenase is only

209
00:08:10,550 --> 00:08:08,069
present it's restricted to a sub group

210
00:08:13,369 --> 00:08:10,560
in in a in one particular phyla of

211
00:08:15,079 --> 00:08:13,379
archaea so it's actually well restricted

212
00:08:17,480 --> 00:08:15,089
within the archaea it's only present in

213
00:08:18,890 --> 00:08:17,490

methanogenic archaea which is surprising

214
00:08:21,350 --> 00:08:18,900
it's actually surprising that it's not

215
00:08:23,240 --> 00:08:21,360
distributed more widely again it's the

216
00:08:24,740 --> 00:08:23,250
only known biological catalyst to take

217
00:08:26,929 --> 00:08:24,750
nitrogen from the atmosphere and put it

218
00:08:28,850 --> 00:08:26,939
into biomass should be awesome to have

219
00:08:31,730 --> 00:08:28,860
this in your genome it's only present in

220
00:08:33,800 --> 00:08:31,740
meth an agenda query archaea as far as

221
00:08:36,259 --> 00:08:33,810
we know what our sequence is today let's

222
00:08:38,509 --> 00:08:36,269
take a look at the nitrogenous and ask

223
00:08:40,880 --> 00:08:38,519
ourselves where the archaea and the

224
00:08:43,100 --> 00:08:40,890
bacteria branch within one of these

225
00:08:45,769 --> 00:08:43,110
trees here I've colored all of the

226
00:08:47,660 --> 00:08:45,779
archaeal sequences in red and since it's

227
00:08:50,750 --> 00:08:47,670
kind of hard to see I just put a little

228
00:08:52,460 --> 00:08:50,760
orange arrow on those sequences and see

229
00:08:54,170 --> 00:08:52,470
you can see that the archaea branch

230
00:08:55,790 --> 00:08:54,180
super super polyfill ethically within

231
00:08:57,920 --> 00:08:55,800
this and this doesn't look a lot like

232
00:09:01,850 --> 00:08:57,930
this tree on the left where the bacteria

233
00:09:03,170 --> 00:09:01,860
and the Archaea are split and they that

234
00:09:04,699 --> 00:09:03,180
leads us to call them archaea and

235
00:09:06,620 --> 00:09:04,709
bacteria and give them the the

236
00:09:07,819 --> 00:09:06,630
designation of different domains the

237
00:09:09,920 --> 00:09:07,829
nitrogenous tree doesn't look like that

238
00:09:10,370 --> 00:09:09,930

so what I want to suggest to you is that

239
00:09:12,350 --> 00:09:10,380
based on

240
00:09:15,080 --> 00:09:12,360
the author's criteria that this is not a

241
00:09:17,090 --> 00:09:15,090
candidate to put into the last common

242
00:09:20,330 --> 00:09:17,100
ancestor of archaea and bacteria so I'll

243
00:09:22,160 --> 00:09:20,340
put an X through that and briefly I want

244
00:09:24,650 --> 00:09:22,170
to run through this radical Sam protein

245
00:09:26,750 --> 00:09:24,660
family is it present in all sorts of

246
00:09:29,120 --> 00:09:26,760
archaea and all sorts of bacteria it is

247
00:09:31,760 --> 00:09:29,130
it's a super super widely used enzyme

248
00:09:33,650 --> 00:09:31,770
family it's it's a pretty simple protein

249
00:09:35,900 --> 00:09:33,660
fold it binds an iron sulfur cluster it

250
00:09:37,430 --> 00:09:35,910
uses this common substrate it generates

251
00:09:38,990 --> 00:09:37,440
a radical mechanism and then that

252
00:09:41,720 --> 00:09:39,000
radical can go off and do all sorts of

253
00:09:43,520 --> 00:09:41,730
nice things for the cell but if you look

254
00:09:45,770 --> 00:09:43,530
at a phylogeny of it again you see that

255
00:09:48,620 --> 00:09:45,780
the archaea split up the bacterial

256
00:09:50,570 --> 00:09:48,630
distribution a lot there's a lot more

257
00:09:52,730 --> 00:09:50,580
black lines on this plot and also on the

258
00:09:54,200 --> 00:09:52,740
previous plot but this is because this

259
00:09:55,700 --> 00:09:54,210
is a sequence artifact because we don't

260
00:09:58,730 --> 00:09:55,710
have enough archaeal genomes right now

261
00:10:00,200 --> 00:09:58,740
however regardless of that you can see

262
00:10:05,630 --> 00:10:00,210
that it does not recover the archaea

263
00:10:08,120 --> 00:10:05,640

bacteria split and therefore I'd like to

264
00:10:13,220 --> 00:10:08,130
suggest that we cross this off of the

265
00:10:15,050 --> 00:10:13,230
list and so I want to use this kind of

266
00:10:18,230 --> 00:10:15,060
as fodder to get you to come to the very

267
00:10:21,050 --> 00:10:18,240
last session of the symposium the after

268
00:10:23,990 --> 00:10:21,060
shop that I'll be chairing on Tuesday

269
00:10:25,820 --> 00:10:24,000
where we're going to be discussing what

270
00:10:30,440 --> 00:10:25,830
are the ways that we can safely and

271
00:10:32,600 --> 00:10:30,450
justifiably discuss ancestral States of

272
00:10:34,550 --> 00:10:32,610
organisms this doesn't have to be all

273
00:10:36,260 --> 00:10:34,560
the way back at the very origination of

274
00:10:39,410 --> 00:10:36,270
life or the origination origination of

275
00:10:40,580 --> 00:10:39,420
cells but I'd like us to be able to get

276
00:10:41,990 --> 00:10:40,590
together and talk about what are the

277
00:10:43,400 --> 00:10:42,000
criteria that we can safely use to

278
00:10:47,350 --> 00:10:43,410
evaluate whether or not something was

279
00:10:50,090 --> 00:10:47,360
present in an ancestor of a group and

280
00:10:54,860 --> 00:10:50,100
when we might not be justified to do

281
00:10:56,870 --> 00:10:54,870
that I'm not a vulgar guy but I'll put

282
00:10:59,060 --> 00:10:56,880
this up because it was funny I'm not

283
00:11:01,400 --> 00:10:59,070
trying to trash any any work right here

284
00:11:04,730 --> 00:11:01,410
I'm actually just trying to be

285
00:11:06,650 --> 00:11:04,740
constructive this this editorial is

286
00:11:09,920 --> 00:11:06,660
actually really really nice and and the

287
00:11:11,690 --> 00:11:09,930
editor talks about what it's like to be

288
00:11:13,100 --> 00:11:11,700

an editor and get all these nice reviews

289
00:11:14,840 --> 00:11:13,110
or sometimes mean reviews and what you

290
00:11:15,800 --> 00:11:14,850
should do as an author about that but I

291
00:11:17,420 --> 00:11:15,810
just want to make the point that I'm not

292
00:11:19,670 --> 00:11:17,430
trying to trash anything because I know

293
00:11:21,350 --> 00:11:19,680
that's easy to do I'm trying with

294
00:11:23,060 --> 00:11:21,360
everybody here to put together these

295
00:11:23,990 --> 00:11:23,070
different puzzle pieces and try to find

296
00:11:27,260 --> 00:11:24,000
some robust

297
00:11:30,020 --> 00:11:27,270
conclusions so back to my main topic

298
00:11:31,130 --> 00:11:30,030
here kind of asking this question what

299
00:11:33,800 --> 00:11:31,140
are the ways that the first cells

300
00:11:36,620 --> 00:11:33,810
conserve energy how did they take

301
00:11:38,240 --> 00:11:36,630
chemical act chemical reactions use

302
00:11:40,430 --> 00:11:38,250
chemical potentials that exist in the

303
00:11:42,740 --> 00:11:40,440
environment and save it temporarily so

304
00:11:44,780 --> 00:11:42,750
that they can order their cells how can

305
00:11:48,500 --> 00:11:44,790
they maintain themselves and then also

306
00:11:49,910 --> 00:11:48,510
reproduce and so I said to get everybody

307
00:11:51,860 --> 00:11:49,920
on the same page of this concept of

308
00:11:54,800 --> 00:11:51,870
energy conservation I would go to a very

309
00:11:56,570 --> 00:11:54,810
basic level and I will I'll take you

310
00:11:58,640 --> 00:11:56,580
guys to my freshmen in biology class

311
00:11:59,930 --> 00:11:58,650
where I start to talk about energy

312
00:12:02,390 --> 00:11:59,940
conservation and this isn't a perfect

313
00:12:03,830 --> 00:12:02,400

analogy but it's it's reasonable let's

314
00:12:06,590 --> 00:12:03,840
take a look at the left and if you drop

315
00:12:08,000 --> 00:12:06,600
a rock off of a cliff you can take

316
00:12:10,220 --> 00:12:08,010
potential energy and convert it into

317
00:12:11,680 --> 00:12:10,230
kinetic energy and then when it hits the

318
00:12:14,270 --> 00:12:11,690
ground it turns into heat and noise

319
00:12:16,100 --> 00:12:14,280
energy now you can save some of that

320
00:12:18,710 --> 00:12:16,110
energy when the rock drops you can put

321
00:12:20,630 --> 00:12:18,720
like a little rock windmill in there and

322
00:12:22,760 --> 00:12:20,640
then you can use that rock with no later

323
00:12:26,930 --> 00:12:22,770
on to do some work and this is kind of

324
00:12:29,480 --> 00:12:26,940
what biology does so let's get ready for

325
00:12:31,340 --> 00:12:29,490
a few molecules here this is kind of

326
00:12:33,980 --> 00:12:31,350
what biology does here here's the

327
00:12:35,570 --> 00:12:33,990
pathway of glycolysis in the middle up

328
00:12:37,760 --> 00:12:35,580
here there's a blurry molecule of

329
00:12:40,300 --> 00:12:37,770
glucose that's kind of the rock that's

330
00:12:42,530 --> 00:12:40,310
on top of the cliff it doesn't have any

331
00:12:44,840 --> 00:12:42,540
potential energy due to gravity at all

332
00:12:46,280 --> 00:12:44,850
but it does have potential energy in the

333
00:12:48,860 --> 00:12:46,290
form of chemical energy as you go to

334
00:12:51,290 --> 00:12:48,870
pyruvate and lactate and as it drops

335
00:12:53,720 --> 00:12:51,300
energetically what life is able to do is

336
00:12:56,600 --> 00:12:53,730
save some of that energy off on the left

337
00:12:58,340 --> 00:12:56,610
and that's by turning a little crank

338
00:13:01,400 --> 00:12:58,350

it's not really a gear it's an enzyme

339
00:13:03,890 --> 00:13:01,410
that smashes together phosphate and ATP

340
00:13:06,680 --> 00:13:03,900
and it makes ATP and so this is the way

341
00:13:08,960 --> 00:13:06,690
that life saves or conserves energy by

342
00:13:10,760 --> 00:13:08,970
substrate level phosphorylation now

343
00:13:13,130 --> 00:13:10,770
there are three ways that biology is

344
00:13:15,680 --> 00:13:13,140
known to save energy one is by using

345
00:13:18,650 --> 00:13:15,690
this process here either in glycolysis

346
00:13:19,880 --> 00:13:18,660
or some other set of reactions but they

347
00:13:21,740 --> 00:13:19,890
all have in common that they take a

348
00:13:23,840 --> 00:13:21,750
phosphate group in the and they put it

349
00:13:25,670 --> 00:13:23,850
onto another phosphate group and that

350
00:13:28,040 --> 00:13:25,680
gives them kind of a little molecular

351
00:13:29,750 --> 00:13:28,050
spring to drive reactions with and also

352
00:13:32,300 --> 00:13:29,760
sometimes people people discuss it as

353
00:13:33,800 --> 00:13:32,310
some dehydration powder because you're

354
00:13:35,930 --> 00:13:33,810
actually losing a water molecule when

355
00:13:37,879 --> 00:13:35,940
you put two phosphates together and so

356
00:13:40,460 --> 00:13:37,889
life saves this ATP and that's what

357
00:13:42,169 --> 00:13:40,470
we often call like the energy currency

358
00:13:43,609 --> 00:13:42,179
of life it doesn't necessarily have to

359
00:13:45,679 --> 00:13:43,619
be like that but it seems like that's

360
00:13:47,509 --> 00:13:45,689
what it uses today and again this is

361
00:13:48,499 --> 00:13:47,519
this concept of fuss substrate level

362
00:13:50,509 --> 00:13:48,509
phosphorylation

363
00:13:51,919 --> 00:13:50,519

let's compare dropping a rock off the

364
00:13:54,009 --> 00:13:51,929
cliff and having it go through a rock

365
00:13:56,929 --> 00:13:54,019
windmill and lifting it lifting a bucket

366
00:13:59,179 --> 00:13:56,939
to this you're taking a different form

367
00:14:01,009 --> 00:13:59,189
of energy but you're saving it in one

368
00:14:02,449 --> 00:14:01,019
case you're saving it with a bucket that

369
00:14:04,639 --> 00:14:02,459
you lift up and in this case you're

370
00:14:06,590 --> 00:14:04,649
saving it in a form another form of

371
00:14:09,139 --> 00:14:06,600
chemical energy and so what life is

372
00:14:11,629 --> 00:14:09,149
doing across all the diversity of life

373
00:14:14,119 --> 00:14:11,639
is taking different types of rocks ie

374
00:14:15,859 --> 00:14:14,129
metabolites and changing them all into a

375
00:14:17,239 --> 00:14:15,869
common currency ATP and that's very

376
00:14:18,650 --> 00:14:17,249
useful for the cell because then it can

377
00:14:21,049 --> 00:14:18,660
go and drive multiple different

378
00:14:23,090 --> 00:14:21,059
reactions with various chemical

379
00:14:26,150 --> 00:14:23,100
potentials so this is the concept of

380
00:14:29,299 --> 00:14:26,160
substrate level phosphorylation the

381
00:14:30,769 --> 00:14:29,309
other mechanism of energy conservation

382
00:14:33,619 --> 00:14:30,779
that I want to talk to you about today

383
00:14:36,369 --> 00:14:33,629
is the concept that was introduced to us

384
00:14:40,369 --> 00:14:36,379
by Mitchell energy conservation by

385
00:14:42,919 --> 00:14:40,379
chemiosmosis and so in this case the

386
00:14:46,609 --> 00:14:42,929
rock the chemical potential that's there

387
00:14:49,429 --> 00:14:46,619
is shown as electrons over here on the

388
00:14:51,650 --> 00:14:49,439

left in blue that are at a reduced

389
00:14:54,019 --> 00:14:51,660
potential and as they moved to a more

390
00:14:57,429 --> 00:14:54,029
oxidized potential onto something like

391
00:14:59,749 --> 00:14:57,439
oxygen or nitrate or manganese that

392
00:15:02,299 --> 00:14:59,759
energy release can be used to do some

393
00:15:04,549 --> 00:15:02,309
work this time it's not done in the way

394
00:15:07,519 --> 00:15:04,559
of putting two phosphates together it's

395
00:15:09,819 --> 00:15:07,529
done by extruding protons across the

396
00:15:12,949 --> 00:15:09,829
membrane and so this is an actual pump

397
00:15:15,319 --> 00:15:12,959
and so we can get by using analogies

398
00:15:17,150 --> 00:15:15,329
about machines in this stage because the

399
00:15:19,669 --> 00:15:17,160
what the protein is actually doing here

400
00:15:21,650 --> 00:15:19,679
is as an electron moves through it to

401
00:15:27,759 --> 00:15:21,660
one of these acceptors the protein is

402
00:15:29,929 --> 00:15:27,769
saving it's conserving energy by having

403
00:15:31,369 --> 00:15:29,939
conformational changes occur through the

404
00:15:33,229 --> 00:15:31,379
protein and it's actually squeezing out

405
00:15:35,150 --> 00:15:33,239
a proton from the inside to the outside

406
00:15:36,710 --> 00:15:35,160
and if the cell does that a bunch of

407
00:15:38,449 --> 00:15:36,720
times you can get a bunch of these

408
00:15:39,919 --> 00:15:38,459
yellow protons on the outside of the

409
00:15:44,299 --> 00:15:39,929
cell and then later on you can use

410
00:15:46,220 --> 00:15:44,309
another machine to allow that chemical

411
00:15:48,139 --> 00:15:46,230
potential when it gets dissipated to put

412
00:15:49,369 --> 00:15:48,149
two phosphates together its substrate

413
00:15:51,650 --> 00:15:49,379

level phosphorylation but it's

414
00:15:53,720 --> 00:15:51,660
accomplished by utilizing

415
00:15:55,400 --> 00:15:53,730
chemical chemical energy in the form of

416
00:15:57,560 --> 00:15:55,410
a membrane-spanning ion potential and

417
00:15:59,750 --> 00:15:57,570
that's what we call chemiosmosis this is

418
00:16:01,370 --> 00:15:59,760
the second out of three ways that we

419
00:16:02,990 --> 00:16:01,380
know biology works today

420
00:16:03,980 --> 00:16:03,000
it's remarkable there's only three ways

421
00:16:05,510 --> 00:16:03,990
one is substrate level phosphorylation

422
00:16:08,210 --> 00:16:05,520
and one is substrate level

423
00:16:09,380 --> 00:16:08,220
phosphorylation coupled chemiosmosis the

424
00:16:11,030 --> 00:16:09,390
other one has to do with electron

425
00:16:15,320 --> 00:16:11,040
transfer and I don't have time to talk

426
00:16:19,280 --> 00:16:15,330
about it today but I want us to ask what

427
00:16:21,800 --> 00:16:19,290
what is the way that the first cell or

428
00:16:24,380 --> 00:16:21,810
if we go liberally the first non

429
00:16:26,210 --> 00:16:24,390
compartmentalized form of life used to

430
00:16:30,530 --> 00:16:26,220
take chemical potentials and turn them

431
00:16:34,520 --> 00:16:30,540
in them into a common set of molecules

432
00:16:36,320 --> 00:16:34,530
that it can drive a metabolism with was

433
00:16:37,790 --> 00:16:36,330
it substrate level phosphorylation or

434
00:16:39,400 --> 00:16:37,800
was it chemiosmosis or was it something

435
00:16:41,990 --> 00:16:39,410
else it might be something else

436
00:16:44,960 --> 00:16:42,000
let's delve a little bit deeper into

437
00:16:48,380 --> 00:16:44,970
this chemiosmosis topic because many

438
00:16:49,910 --> 00:16:48,390

people have said or at least some people

439
00:16:53,000 --> 00:16:49,920
that I apparently listen to and call

440
00:16:55,130 --> 00:16:53,010
many have said that chemiosmosis is the

441
00:16:57,680 --> 00:16:55,140
primordial feature of cells also let's

442
00:17:00,260 --> 00:16:57,690
do this so therefore the first cell does

443
00:17:02,240 --> 00:17:00,270
that I showed you one possible way of

444
00:17:04,670 --> 00:17:02,250
generating at chemiosmotic potential but

445
00:17:06,290 --> 00:17:04,680
I'd like to remind everybody or

446
00:17:08,090 --> 00:17:06,300
introduce you to the topic that there

447
00:17:10,310 --> 00:17:08,100
are a number of different ways of

448
00:17:13,130 --> 00:17:10,320
generating chem up chemical chemiosmotic

449
00:17:15,020 --> 00:17:13,140
potentials in a cell and basically we

450
00:17:17,900 --> 00:17:15,030
can break it down into two two things

451
00:17:19,700 --> 00:17:17,910
one is you remove positive charge from

452
00:17:21,320 --> 00:17:19,710
the cell that's what that proton pump

453
00:17:22,850 --> 00:17:21,330
was doing it was taking a positive ion

454
00:17:25,070 --> 00:17:22,860
and it was shoving it outside of the

455
00:17:26,480 --> 00:17:25,080
cell and that results in the outside

456
00:17:28,970 --> 00:17:26,490
being more positive in the inside being

457
00:17:30,620 --> 00:17:28,980
more negative or the other way to do

458
00:17:32,900 --> 00:17:30,630
this is to put negative charge inside of

459
00:17:35,110 --> 00:17:32,910
this cell so the same thing happens the

460
00:17:37,760 --> 00:17:35,120
inside of the cell becomes more negative

461
00:17:40,100 --> 00:17:37,770
than the outside and life is known to

462
00:17:42,890 --> 00:17:40,110
operate in both of these different ways

463
00:17:45,560 --> 00:17:42,900

at these general classes and so what are

464
00:17:47,630 --> 00:17:45,570
what would be a way that the first form

465
00:17:50,780 --> 00:17:47,640
of life could could accomplish something

466
00:17:55,760 --> 00:17:50,790
like this if that's indeed what what it

467
00:17:57,590 --> 00:17:55,770
was doing oftentimes methanogens and

468
00:18:00,740 --> 00:17:57,600
heceta genes which I mentioned in my

469
00:18:02,720 --> 00:18:00,750
abstract are introduced as possible

470
00:18:04,430 --> 00:18:02,730
organisms that would have accomplished

471
00:18:05,480 --> 00:18:04,440
this in a way that was similar to the

472
00:18:07,700 --> 00:18:05,490
first cells

473
00:18:09,830 --> 00:18:07,710
and people suggest this because they

474
00:18:12,110 --> 00:18:09,840
look a little bit simple it looks like

475
00:18:13,970 --> 00:18:12,120
you can just take co2 on the top and

476
00:18:16,250 --> 00:18:13,980
deliver electrons in the form of

477
00:18:19,970 --> 00:18:16,260
hydrogen hydrogen gas and make methane

478
00:18:21,890 --> 00:18:19,980
and you can run two pumps and make a

479
00:18:26,450 --> 00:18:21,900
chemiosmotic potential and everything's

480
00:18:28,370 --> 00:18:26,460
great these pumps though are are quite

481
00:18:30,530 --> 00:18:28,380
complicated I like to suggest to you and

482
00:18:32,510 --> 00:18:30,540
that's why I listed the the number of

483
00:18:35,270 --> 00:18:32,520
protein subunits that comprises each

484
00:18:37,010 --> 00:18:35,280
pump remember what these these pumps are

485
00:18:39,980 --> 00:18:37,020
doing is taking one form of chemical

486
00:18:42,260 --> 00:18:39,990
energy and and actually using that

487
00:18:43,910 --> 00:18:42,270
chemical energy to perform

488
00:18:45,919 --> 00:18:43,920

conformational changes in the protein

489
00:18:48,860 --> 00:18:45,929
and actually squeeze ions out of the

490
00:18:51,860 --> 00:18:48,870
membrane and it takes biology at least

491
00:18:53,750 --> 00:18:51,870
eight or nine individual peptide

492
00:18:55,460 --> 00:18:53,760
subunits to come together and exactly

493
00:18:58,190 --> 00:18:55,470
the right way to do this so I I think

494
00:19:00,950 --> 00:18:58,200
this is quite a complicated mechanism

495
00:19:05,360 --> 00:19:00,960
that we have here let's look at se

496
00:19:08,330 --> 00:19:05,370
doujins which are often times thought to

497
00:19:10,250 --> 00:19:08,340
also be simple they do a metabolism that

498
00:19:11,780 --> 00:19:10,260
looks a lot like methanogenesis except

499
00:19:14,690 --> 00:19:11,790
for its branched instead of making

500
00:19:16,850 --> 00:19:14,700
methane they make acetate and again they

501
00:19:17,960 --> 00:19:16,860
can exist with only two pumps inside of

502
00:19:20,600 --> 00:19:17,970
them two they use a different variety

503
00:19:22,490 --> 00:19:20,610
it's called R and F it happens to be

504
00:19:24,440 --> 00:19:22,500
able to run with six protein subunits so

505
00:19:25,160 --> 00:19:24,450
it looks a little bit simpler again a

506
00:19:28,220 --> 00:19:25,170
TPAs

507
00:19:32,169 --> 00:19:28,230
actually has to use nine different

508
00:19:34,549 --> 00:19:32,179
subunits it's pretty complicated so i I

509
00:19:36,049 --> 00:19:34,559
when I learned this I thought oh this is

510
00:19:38,299 --> 00:19:36,059
really really too hard for the first

511
00:19:40,730 --> 00:19:38,309
types of cells to learn and I started

512
00:19:44,330 --> 00:19:40,740
looking for other ways that life might

513
00:19:46,310 --> 00:19:44,340

be able to conserve energy and I'll

514
00:19:50,600 --> 00:19:46,320
introduce that topic to you but before I

515
00:19:52,280 --> 00:19:50,610
do I just want to go a little bit deeper

516
00:19:53,840 --> 00:19:52,290
into these diagrams these diagrams are

517
00:19:57,740 --> 00:19:53,850
kind of complicated there's a lot of

518
00:20:00,860 --> 00:19:57,750
arrows but this chemiosmotic nature of

519
00:20:02,930 --> 00:20:00,870
these cells here results in a really

520
00:20:04,549 --> 00:20:02,940
really remarkable similarity and that

521
00:20:06,770 --> 00:20:04,559
remarkable similarity goes right to the

522
00:20:08,860 --> 00:20:06,780
heart of chemiosmotic potential that

523
00:20:12,049 --> 00:20:08,870
similarity comes can be viewed in this

524
00:20:14,659 --> 00:20:12,059
slanted graph here that Steve's inter

525
00:20:17,000 --> 00:20:14,669
plotted in 1993 whereas he's plotting

526
00:20:19,100 --> 00:20:17,010
the chemical potential of the energy of

527
00:20:20,870 --> 00:20:19,110
the metabolism making methane or making

528
00:20:23,539 --> 00:20:20,880
acetate as a function of the hydrogen

529
00:20:26,780 --> 00:20:23,549
partial pressure how many what's the

530
00:20:28,250 --> 00:20:26,790
electron availability and how reducing

531
00:20:32,060 --> 00:20:28,260
is the solution to drive the reaction

532
00:20:34,610 --> 00:20:32,070
and where does the metabolism stop it

533
00:20:36,620 --> 00:20:34,620
turns out that both of these see where

534
00:20:41,110 --> 00:20:36,630
my cursor here is both of these things

535
00:20:44,870 --> 00:20:41,120
stop right around 30 kilojoules per mole

536
00:20:47,570 --> 00:20:44,880
of chemical reaction energy that is you

537
00:20:49,310 --> 00:20:47,580
can take a methanogens or a Necedah Jen

538
00:20:50,810 --> 00:20:49,320

which looks similar but they actually

539
00:20:52,820 --> 00:20:50,820
have different chemiosmotic pumping

540
00:20:54,740 --> 00:20:52,830
units you can stick them in a roomful of

541
00:20:57,289 --> 00:20:54,750
hydrogen and they will consume the

542
00:21:00,110 --> 00:20:57,299
hydrogen all the way until there's only

543
00:21:02,450 --> 00:21:00,120
enough to result in a Gibbs free energy

544
00:21:09,110 --> 00:21:02,460
of the reaction to be around 30

545
00:21:10,909 --> 00:21:09,120
kilojoules per mole so this I think is a

546
00:21:12,710 --> 00:21:10,919
product of the chemiosmotic potential

547
00:21:14,810 --> 00:21:12,720
and how how much energy it actually

548
00:21:15,289 --> 00:21:14,820
takes to pump a single ion across the

549
00:21:18,289 --> 00:21:15,299
membrane

550
00:21:20,690 --> 00:21:18,299
so this metabolism is driven by hydrogen

551
00:21:22,820 --> 00:21:20,700
gas combining on to co2 and eventually

552
00:21:24,799 --> 00:21:22,830
making methane how much energy does it

553
00:21:26,600 --> 00:21:24,809
take to do that or what's the

554
00:21:28,250 --> 00:21:26,610
concentration of hydrogen that it takes

555
00:21:29,750 --> 00:21:28,260
to do that the concentration to do that

556
00:21:33,169 --> 00:21:29,760
and make it throw my dynamically

557
00:21:35,659 --> 00:21:33,179
favorable is extremely low however to

558
00:21:37,310 --> 00:21:35,669
conserve energy or to save energy during

559
00:21:39,460 --> 00:21:37,320
the process you actually have to have

560
00:21:42,470 --> 00:21:39,470
enough to pump at least a single ion and

561
00:21:44,360 --> 00:21:42,480
that's probably why both methanogens and

562
00:21:47,210 --> 00:21:44,370
a/c didn't stop at the same chemical

563
00:21:49,090 --> 00:21:47,220

potential but because they have one

564
00:21:51,470 --> 00:21:49,100
makes methane and one makes acetate

565
00:21:55,630 --> 00:21:51,480
methanogens can always out-compete

566
00:21:57,650 --> 00:21:55,640
heceta jones for hydrogen so because of

567
00:21:59,600 --> 00:21:57,660
not because of the chemiosmotic

568
00:22:01,549 --> 00:21:59,610
potential but because simply because one

569
00:22:02,720 --> 00:22:01,559
makes methane and one makes acetate what

570
00:22:04,039 --> 00:22:02,730
we're seeing here is a profound

571
00:22:05,630 --> 00:22:04,049
ecological difference between

572
00:22:07,460 --> 00:22:05,640
methanogens and asita jhin's and it's

573
00:22:10,669 --> 00:22:07,470
all coming down to how much how much

574
00:22:16,610 --> 00:22:10,679
energy it takes to to push and on across

575
00:22:18,260 --> 00:22:16,620
them the membrane back to this question

576
00:22:20,330 --> 00:22:18,270
of complexity and whether or not any of

577
00:22:22,850 --> 00:22:20,340
this is relevant our consideration of

578
00:22:24,710 --> 00:22:22,860
the first cells I said that the ATP aise

579
00:22:27,590 --> 00:22:24,720
takes at least nine different protein

580
00:22:31,159 --> 00:22:27,600
subunits to function it does and here's

581
00:22:32,750 --> 00:22:31,169
a picture of it which now that I look at

582
00:22:33,860 --> 00:22:32,760
it I realize I haven't counted

583
00:22:36,200 --> 00:22:33,870
so it looks like it's actually really

584
00:22:37,820 --> 00:22:36,210
complicated but that's that there's a

585
00:22:40,760 --> 00:22:37,830
lot of those L copies in there but we

586
00:22:42,620 --> 00:22:40,770
could count those as one here it is this

587
00:22:44,540 --> 00:22:42,630
is a cartoon diagram but it's it's very

588
00:22:46,460 --> 00:22:44,550

complicated the way it works is that

589
00:22:48,860 --> 00:22:46,470
it's actually spinning around in there

590
00:22:51,020 --> 00:22:48,870
and as it's spinning around it can bind

591
00:22:54,020 --> 00:22:51,030
ADP and phosphate and move them together

592
00:22:57,110 --> 00:22:54,030
it operates kind of like a von Kalenjin

593
00:22:59,780 --> 00:22:57,120
if any of you are Mazda aficionados and

594
00:23:02,620 --> 00:22:59,790
you know about the rx-7 it operates kind

595
00:23:08,870 --> 00:23:07,430
we can talk cars later so you've got

596
00:23:10,790 --> 00:23:08,880
something that operates and you can

597
00:23:12,950 --> 00:23:10,800
compare it to a funcle' engine and

598
00:23:14,450 --> 00:23:12,960
people have because it works in these

599
00:23:18,080 --> 00:23:14,460
three different cycles with these lobes

600
00:23:20,030 --> 00:23:18,090
and we can ask ourselves how can we ever

601
00:23:21,410 --> 00:23:20,040
think about the first cells existing

602
00:23:24,080 --> 00:23:21,420
with a membrane and having a protein

603
00:23:25,460 --> 00:23:24,090
complex like this embedded in it and I

604
00:23:28,250 --> 00:23:25,470
don't know how to do that I think this

605
00:23:31,160 --> 00:23:28,260
is a really big problem for us and what

606
00:23:32,750 --> 00:23:31,170
I what I want to consider with you and

607
00:23:35,060 --> 00:23:32,760
I'm gonna welcome your comments here in

608
00:23:37,010 --> 00:23:35,070
a few moments is what what are the ways

609
00:23:38,990 --> 00:23:37,020
that earlier energy conservation could

610
00:23:40,400 --> 00:23:39,000
have been operative here what I've done

611
00:23:43,730 --> 00:23:40,410
on the right here in this little table

612
00:23:47,360 --> 00:23:43,740
is just taken kind of a little bucket

613
00:23:49,190 --> 00:23:47,370

list of early or simple protein

614
00:23:51,230 --> 00:23:49,200
complexes that are able to conserve

615
00:23:54,860 --> 00:23:51,240
energy with a chemiosmotic potential and

616
00:23:56,570 --> 00:23:54,870
just for simplicity for us to quickly

617
00:23:59,030 --> 00:23:56,580
judge the level of complexity that we're

618
00:24:01,310 --> 00:23:59,040
talking about here I've listed the

619
00:24:03,140 --> 00:24:01,320
number of protein subunits associated

620
00:24:03,590 --> 00:24:03,150
with those six six thirteen eight eight

621
00:24:05,150 --> 00:24:03,600
nine

622
00:24:07,160 --> 00:24:05,160
so we're I think that we're talking

623
00:24:09,380 --> 00:24:07,170
about a really quite late an advanced

624
00:24:10,820 --> 00:24:09,390
stage in biological evolution by the

625
00:24:15,770 --> 00:24:10,830
time we're talking about using some of

626
00:24:17,740 --> 00:24:15,780
these protein pumps and so that got me

627
00:24:21,020 --> 00:24:17,750
thinking how could this ever happen and

628
00:24:22,220 --> 00:24:21,030
as I said before there's two ways that

629
00:24:24,050 --> 00:24:22,230
cells can actually generate a

630
00:24:26,510 --> 00:24:24,060
chemiosmotic potential one is to use a

631
00:24:30,250 --> 00:24:26,520
pump and one is to just have an input of

632
00:24:32,930 --> 00:24:30,260
electrical charge inside of it last year

633
00:24:34,940 --> 00:24:32,940
two years ago now two years ago we

634
00:24:37,220 --> 00:24:34,950
discovered a brand of archaea that

635
00:24:39,650 --> 00:24:37,230
covers itself with a conductive protein

636
00:24:41,780 --> 00:24:39,660
blanket and it's able to export

637
00:24:43,670 --> 00:24:41,790
electrons from it itself and so what I

638
00:24:45,290 --> 00:24:43,680

started considering was the reverse of

639
00:24:46,190 --> 00:24:45,300
the process that we discovered two years

640
00:24:48,500 --> 00:24:46,200
ago it

641
00:24:51,530 --> 00:24:48,510
would it be possible to run a managed

642
00:24:54,710 --> 00:24:51,540
and Excel in the way of having direct

643
00:24:56,360 --> 00:24:54,720
electrons enter into the cell and in

644
00:24:59,000 --> 00:24:56,370
that way generate a chemiosmotic

645
00:25:02,030 --> 00:24:59,010
potential by virtue simply of proton

646
00:25:04,970 --> 00:25:02,040
consumption so anytime you reduce co2 it

647
00:25:06,770 --> 00:25:04,980
it requires hydrogen to do that in the

648
00:25:09,260 --> 00:25:06,780
form of protons and that might be a way

649
00:25:10,760 --> 00:25:09,270
of inputting a negative charge into the

650
00:25:12,350 --> 00:25:10,770
cell and generating a cammeo somatic

651
00:25:16,280 --> 00:25:12,360
potential and what I'm trying to get at

652
00:25:17,600 --> 00:25:16,290
here is to imagine a selection pressure

653
00:25:19,040 --> 00:25:17,610
that might have resulted in the

654
00:25:22,100 --> 00:25:19,050
emergence of these pumps at some point

655
00:25:24,800 --> 00:25:22,110
in in biological history you could do

656
00:25:26,330 --> 00:25:24,810
this with any any autotrophic metabolism

657
00:25:28,130 --> 00:25:26,340
you could take the RS CA cycle you could

658
00:25:30,800 --> 00:25:28,140
take in a CD gen anytime you put

659
00:25:32,390 --> 00:25:30,810
electrons on to co2 it requires protons

660
00:25:34,760 --> 00:25:32,400
and so you can consume protons this way

661
00:25:36,200 --> 00:25:34,770
and make a chemiosmotic potential but

662
00:25:38,780 --> 00:25:36,210
where would the electrons come from

663
00:25:40,280 --> 00:25:38,790

where would the organic carbon come from

664
00:25:43,520 --> 00:25:40,290
for this whole process to be happening

665
00:25:44,990 --> 00:25:43,530
and what about the catalysts I blew my

666
00:25:46,340 --> 00:25:45,000
cover earlier and I told you I was going

667
00:25:49,130 --> 00:25:46,350
to talk a little bit about hydrothermal

668
00:25:52,010 --> 00:25:49,140
events today and I started considering

669
00:25:54,830 --> 00:25:52,020
what about this possibility kind of

670
00:25:59,540 --> 00:25:54,840
riffing on Mike Russell's concepts where

671
00:26:01,300 --> 00:25:59,550
if there was a high pH full loaded with

672
00:26:05,540 --> 00:26:01,310
hydrogen hydrogen or Mille event

673
00:26:07,250 --> 00:26:05,550
surrounded by our kind of a slightly

674
00:26:08,690 --> 00:26:07,260
acidic ocean it seems like I got my

675
00:26:11,560 --> 00:26:08,700
number wrong compared to the last talk

676
00:26:14,600 --> 00:26:11,570
should be around 6.5 I think compared to

677
00:26:15,920 --> 00:26:14,610
Vernors calculation but you have a

678
00:26:18,170 --> 00:26:15,930
slightly acidic ocean and what this does

679
00:26:19,850 --> 00:26:18,180
between acid and bases it gives you a

680
00:26:22,730 --> 00:26:19,860
nerd steam potential it makes the

681
00:26:25,220 --> 00:26:22,740
hydrogen more reducing or a more more

682
00:26:27,950 --> 00:26:25,230
electronegative and we could make a

683
00:26:30,560 --> 00:26:27,960
cartoon diagram like this where you

684
00:26:32,390 --> 00:26:30,570
could have hydrogen oxidation coupled to

685
00:26:35,630 --> 00:26:32,400
co2 reduction but that would happen over

686
00:26:37,570 --> 00:26:35,640
a conductive mineral layer here and so

687
00:26:39,410 --> 00:26:37,580
maybe that would be a way of

688
00:26:42,410 --> 00:26:39,420

accumulating organic carbon on the

689
00:26:44,840 --> 00:26:42,420
surface of one of these vents and this

690
00:26:47,660 --> 00:26:44,850
is kind of totally inspired by my

691
00:26:49,460 --> 00:26:47,670
colleagues nakamura-san and yamamoto

692
00:26:51,080 --> 00:26:49,470
saad who actually discovered that a lot

693
00:26:55,010 --> 00:26:51,090
of hydrothermal vents are electronically

694
00:26:57,980 --> 00:26:55,020
conductive and then this is where I'm

695
00:26:59,930 --> 00:26:57,990
really dreaming here but maybe this

696
00:27:01,730 --> 00:26:59,940
would be a way for cells to actually be

697
00:27:06,169 --> 00:27:01,740
there and generating and chemiosmotic

698
00:27:08,840 --> 00:27:06,179
potentials simply by influx of negative

699
00:27:10,850 --> 00:27:08,850
charge and not having any pumps so

700
00:27:13,100 --> 00:27:10,860
possibly before the origination of

701
00:27:14,659 --> 00:27:13,110
chemiosmotic pumping there was the

702
00:27:16,249 --> 00:27:14,669
introduction of negative charge in a way

703
00:27:19,639 --> 00:27:16,259
that led to a selection pressure that

704
00:27:21,080 --> 00:27:19,649
would allow pumps to exist okay this is

705
00:27:23,560 --> 00:27:21,090
all just dreams how are we going to do

706
00:27:26,680 --> 00:27:23,570
it in the lab we're starting to make

707
00:27:29,060 --> 00:27:26,690
Hydra kind of very simple a simple

708
00:27:31,279 --> 00:27:29,070
simulated hydrothermal vents where we

709
00:27:32,749 --> 00:27:31,289
pump a solution of iron and carbonate

710
00:27:34,909 --> 00:27:32,759
and other carbon compounds and on the

711
00:27:36,950 --> 00:27:34,919
Left we put that into a sulphate

712
00:27:38,899 --> 00:27:36,960
solution on the right we can make a iron

713
00:27:41,119 --> 00:27:38,909

sulfur layer and we can ask this

714
00:27:43,220 --> 00:27:41,129
question can you actually oxidize

715
00:27:45,259 --> 00:27:43,230
hydrogen and couple that to co2 reaction

716
00:27:47,690 --> 00:27:45,269
or other carbon molecule reduction in

717
00:27:49,369 --> 00:27:47,700
this flat diagram the thing on the left

718
00:27:50,990 --> 00:27:49,379
would be the ocean that side of the

719
00:27:52,279 --> 00:27:51,000
layer would be the ocean and the and the

720
00:27:56,840 --> 00:27:52,289
solution on the right would be the

721
00:27:59,450 --> 00:27:56,850
actual hydrothermal vent solution so

722
00:28:01,700 --> 00:27:59,460
woojae Chang who's been a visitor

723
00:28:04,190 --> 00:28:01,710
supported by the Eon program twice now

724
00:28:07,639 --> 00:28:04,200
he's he's now working on this and also

725
00:28:10,070 --> 00:28:07,649
Victor Sojo who is with with us today he

726
00:28:13,850 --> 00:28:10,080
came up with the same idea independently

727
00:28:17,629 --> 00:28:13,860
and he's now a visitor at Rican and he's

728
00:28:19,399 --> 00:28:17,639
supported by an MPO fellowship and we're

729
00:28:21,919 --> 00:28:19,409
collaborating together Victor's using a

730
00:28:22,369 --> 00:28:21,929
more organized solution than what we're

731
00:28:24,919 --> 00:28:22,379
using

732
00:28:27,470 --> 00:28:24,929
but they both accomplish the same goal

733
00:28:29,690 --> 00:28:27,480
and the overall experiments that we can

734
00:28:33,680 --> 00:28:29,700
start to do is pump this thing up full

735
00:28:35,990 --> 00:28:33,690
of iron pump it up full of iron and a

736
00:28:37,999 --> 00:28:36,000
carbon solution hydrogen on the other

737
00:28:39,649 --> 00:28:38,009
side and ask this question again I think

738
00:28:41,090 --> 00:28:39,659

we're looking at do you get electron

739
00:28:42,649 --> 00:28:41,100
transfer from one side to the other

740
00:28:45,320 --> 00:28:42,659
hydrogen oxidation couple two co2

741
00:28:47,720 --> 00:28:45,330
reduction that's pretty hard we're not

742
00:28:48,919 --> 00:28:47,730
sure about it Chris butch had the good

743
00:28:51,320 --> 00:28:48,929
idea thanks Chris

744
00:28:52,639 --> 00:28:51,330
to put an already reduced carbon

745
00:28:54,590 --> 00:28:52,649
molecule in there and use that to test

746
00:28:57,409 --> 00:28:54,600
we've got these really weak and sketchy

747
00:29:00,529 --> 00:28:57,419
NMR peaks that seem like oxalic acid was

748
00:29:02,060 --> 00:29:00,539
turned into an alcohol and we're

749
00:29:03,799 --> 00:29:02,070
currently working on developing that

750
00:29:04,789 --> 00:29:03,809
more we've also got even more weak data

751
00:29:06,980 --> 00:29:04,799
that where it looks like we're seeing

752
00:29:08,600 --> 00:29:06,990
acetate but hold on because I don't want

753
00:29:10,999 --> 00:29:08,610
to present that to you until I'm more

754
00:29:12,799 --> 00:29:11,009
sure about it these are just very very

755
00:29:15,470 --> 00:29:12,809
preliminary results that

756
00:29:17,119 --> 00:29:15,480
are aimed at testing the hypothesis that

757
00:29:18,739 --> 00:29:17,129
organic material could accumulate on the

758
00:29:20,239 --> 00:29:18,749
exterior of a hydrothermal vent and that

759
00:29:22,190 --> 00:29:20,249
might have been an area where chemical

760
00:29:23,659 --> 00:29:22,200
evolution might be happening previous

761
00:29:25,039 --> 00:29:23,669
hypotheses in the origin of life have

762
00:29:26,539 --> 00:29:25,049
all said it was happening on the inside

763
00:29:28,610 --> 00:29:26,549

all I want to suggest to you that

764
00:29:32,330 --> 00:29:28,620
outside is a more positive it's a more

765
00:29:36,019 --> 00:29:32,340
reasonable location and I'm so far out

766
00:29:38,690 --> 00:29:36,029
of time this is I want us to remember

767
00:29:40,399 --> 00:29:38,700
that when people talk about hydrothermal

768
00:29:41,869 --> 00:29:40,409
vents in the origin of life everybody's

769
00:29:43,369 --> 00:29:41,879
talking about a different thing and they

770
00:29:45,440 --> 00:29:43,379
don't often it acknowledged that and

771
00:29:46,460 --> 00:29:45,450
this is just a slide ask me for it later

772
00:29:47,779 --> 00:29:46,470
and I'll discuss for it later I don't

773
00:29:49,580 --> 00:29:47,789
have time to talk about it but ever

774
00:29:50,930 --> 00:29:49,590
since 1993 when Mike Russell and

775
00:29:52,249 --> 00:29:50,940
colleagues started talking about

776
00:29:54,019 --> 00:29:52,259
hydrothermal vents in the original life

777
00:29:55,129 --> 00:29:54,029
these concepts have been presented in

778
00:29:56,989 --> 00:29:55,139
slightly different ways and I think

779
00:29:58,850 --> 00:29:56,999
that's a little bit confusing it's okay

780
00:29:59,899 --> 00:29:58,860
it's a complicated world but be careful

781
00:30:02,239 --> 00:29:59,909
when you hear somebody talking about the

782
00:30:04,340 --> 00:30:02,249
origin of life finally I have wonderful

783
00:30:06,320 --> 00:30:04,350
colleagues Reva Nakamura widget hang and

784
00:30:07,639 --> 00:30:06,330
I'm really happy that Victor Soto has

785
00:30:09,470 --> 00:30:07,649
come to Japan and is working and

786
00:30:11,090 --> 00:30:09,480
collaboration now and these are my

787
00:30:21,379 --> 00:30:11,100
summary or marks thank you very much for

788
00:30:24,590 --> 00:30:21,389

your time do we have questions on the

789
00:30:27,139 --> 00:30:24,600
far side there first right here uh I

790
00:30:28,789 --> 00:30:27,149
think that what you said about the

791
00:30:30,799 --> 00:30:28,799
Martin paper I don't I think he should

792
00:30:32,659 --> 00:30:30,809
write that up and that's kind of

793
00:30:34,759 --> 00:30:32,669
important that that be understood by

794
00:30:37,009 --> 00:30:34,769
everybody so I would like to encourage

795
00:30:37,369 --> 00:30:37,019
you to do that but that's not my

796
00:30:45,739 --> 00:30:37,379
question

797
00:30:47,149 --> 00:30:45,749
about gradients and chemiosmosis and you

798
00:30:48,799 --> 00:30:47,159
know you said that that's universal to

799
00:30:50,119 --> 00:30:48,809
all cells but you know that you could

800
00:30:52,820 --> 00:30:50,129
say that there's a huge list of things

801
00:30:55,039 --> 00:30:52,830
right phosphorylation condensation

802
00:30:58,009 --> 00:30:55,049
dehydration and so I don't quite

803
00:31:00,379 --> 00:30:58,019
understand why you have chosen that as I

804
00:31:02,090 --> 00:31:00,389
mean you can store energy all kinds of

805
00:31:04,340 --> 00:31:02,100
different ways chemically and some of

806
00:31:06,470 --> 00:31:04,350
them are very easy and it seems like you

807
00:31:08,889 --> 00:31:06,480
like like you said if you look at these

808
00:31:12,440 --> 00:31:08,899
synthetases they're so complicated so

809
00:31:15,680 --> 00:31:12,450
I'm just not understanding why you're

810
00:31:20,570 --> 00:31:15,690
focused on the chemiosmosis as something

811
00:31:21,769 --> 00:31:20,580
early in the origin of life thanks for

812
00:31:23,650 --> 00:31:21,779
that question and thanks very encouraged

813
00:31:26,050 --> 00:31:23,660

me too

814
00:31:27,430 --> 00:31:26,060
I would like to be more focused on

815
00:31:30,280 --> 00:31:27,440
something like substrate level

816
00:31:32,080 --> 00:31:30,290
phosphorylation the trouble with

817
00:31:33,640 --> 00:31:32,090
substrate level phosphorylation it just

818
00:31:37,540 --> 00:31:33,650
takes more chemical potential to drive

819
00:31:39,640 --> 00:31:37,550
it if you use ATP and ATP as cells use

820
00:31:42,210 --> 00:31:39,650
it today however this is all just a

821
00:31:44,890 --> 00:31:42,220
function of concentrations right and so

822
00:31:48,670 --> 00:31:44,900
what I would like to learn more about

823
00:31:50,740 --> 00:31:48,680
and consider together is what how far

824
00:31:52,210 --> 00:31:50,750
from equilibrium were the first cells

825
00:31:54,250 --> 00:31:52,220
that's what this is going to come down

826
00:31:56,350 --> 00:31:54,260
to in many ways it seems like these

827
00:31:58,360 --> 00:31:56,360
chemiosmotic cells these methanogens and

828
00:32:00,580 --> 00:31:58,370
asita jhin's they've just become super

829
00:32:02,770 --> 00:32:00,590
super adept at living with really really

830
00:32:04,870 --> 00:32:02,780
low chemical potentials they both

831
00:32:06,910 --> 00:32:04,880
stopped at my minus 30 kilojoules per

832
00:32:09,700 --> 00:32:06,920
mole because they both pump one to two

833
00:32:11,470 --> 00:32:09,710
ions at one chemiosmotic step that's

834
00:32:13,630 --> 00:32:11,480
about as low as we know anything can go

835
00:32:15,100 --> 00:32:13,640
and so in one way it seems like they're

836
00:32:19,480 --> 00:32:15,110
super super adapted to low chemical

837
00:32:22,210 --> 00:32:19,490
potentials yeah so I'm not necessarily

838
00:32:23,980 --> 00:32:22,220

tied to it yeah and I think it would be

839
00:32:26,470 --> 00:32:23,990
better if we could it would be very

840
00:32:28,300 --> 00:32:26,480
helpful if we could consider other sets

841
00:32:31,000 --> 00:32:28,310
of molecules that chemical energy could

842
00:32:33,070 --> 00:32:31,010
be channeled into and then used broadly

843
00:32:34,570 --> 00:32:33,080
distributed in a metabolic Network I'm

844
00:32:38,110 --> 00:32:34,580
not sure exactly what that is but let's

845
00:32:39,640 --> 00:32:38,120
talk more later yeah comment did a

846
00:32:41,260 --> 00:32:39,650
question you notice that in his question

847
00:32:43,960 --> 00:32:41,270
he used energy storage rather than

848
00:32:45,550 --> 00:32:43,970
energy conservation I can I can support

849
00:32:47,200 --> 00:32:45,560
that wholeheartedly as a physicist cuz

850
00:32:49,360 --> 00:32:47,210
energy conservation is the first law of

851
00:32:51,400 --> 00:32:49,370
thermodynamics and everything does it

852
00:32:53,770 --> 00:32:51,410
not just life-forms that are trying to

853
00:32:55,810 --> 00:32:53,780
say I would say storage of free energy

854
00:32:59,260 --> 00:32:55,820
might be even more appropriate comment

855
00:33:00,700 --> 00:32:59,270
question in these nine unit things and

856
00:33:02,310 --> 00:33:00,710
the six unit things I think you called

857
00:33:05,560 --> 00:33:02,320
them R and F these are transmembrane

858
00:33:08,470 --> 00:33:05,570
proteins or in any case have you looked

859
00:33:10,120 --> 00:33:08,480
at the phylogenetic trees of the various

860
00:33:12,730 --> 00:33:10,130
versions of them to see if they have a

861
00:33:14,740 --> 00:33:12,740
common ancestor in which you might say

862
00:33:16,870 --> 00:33:14,750
oh there were three subunits and they

863
00:33:18,280 --> 00:33:16,880

were that they overlap between them are

864
00:33:21,340 --> 00:33:18,290
you saying when you were they nine

865
00:33:22,900 --> 00:33:21,350
separate sub units that did not overlap

866
00:33:26,860 --> 00:33:22,910
with the six or and there's no

867
00:33:29,410 --> 00:33:26,870
connection identifiable between them I

868
00:33:30,880 --> 00:33:29,420
haven't I haven't done that and maybe

869
00:33:32,920 --> 00:33:30,890
other people have and if anybody else

870
00:33:34,780 --> 00:33:32,930
and there has already done that please

871
00:33:36,760 --> 00:33:34,790
pipe up I know there's ATP synthase

872
00:33:37,570 --> 00:33:36,770
trees but I didn't anyone try to connect

873
00:33:40,690 --> 00:33:37,580
that to what you call

874
00:33:44,979 --> 00:33:40,700
or an F tree yeah yeah you can yeah and

875
00:33:46,899 --> 00:33:44,989
you can make the rnf tree it comes down

876
00:33:48,639 --> 00:33:46,909
to there's going to be subunits that

877
00:33:51,940 --> 00:33:48,649
look like it and are similar to it but

878
00:33:53,320 --> 00:33:51,950
don't bind to it and so he Ben it's you

879
00:33:54,729 --> 00:33:53,330
have to only consider that ones that are

880
00:33:56,320 --> 00:33:54,739
the full package it's kind of like

881
00:33:57,940 --> 00:33:56,330
looking at the evolution of the eye you

882
00:34:00,039 --> 00:33:57,950
know like it happened with all these

883
00:34:01,299 --> 00:34:00,049
different things happening unrelated and

884
00:34:05,049 --> 00:34:01,309
then eventually it was started forming

885
00:34:06,580 --> 00:34:05,059
this complex so there's still proteins

886
00:34:07,989 --> 00:34:06,590
that are out there that look like these

887
00:34:10,960 --> 00:34:07,999
different subunits but they're different

888
00:34:12,849 --> 00:34:10,970

doing different jobs so I think it makes

889
00:34:14,169 --> 00:34:12,859
that analysis a little bit hard but

890
00:34:16,329 --> 00:34:14,179
again I haven't actually done that

891
00:34:19,409 --> 00:34:16,339
analysis if anybody has would be cool to

892
00:34:22,059 --> 00:34:19,419
talk about that's a good question Eric

893
00:34:24,789 --> 00:34:22,069
Sean hi there were two points in your

894
00:34:26,500 --> 00:34:24,799
talk where there were sort of equally

895
00:34:28,030 --> 00:34:26,510
urgent things where I wanted to hear

896
00:34:30,280 --> 00:34:28,040
your opinion because you've thought well

897
00:34:32,680 --> 00:34:30,290
about some of this I agree with your

898
00:34:35,530 --> 00:34:32,690
point about not wanting to trash

899
00:34:38,859 --> 00:34:35,540
articles there's no use in that but at

900
00:34:40,960 --> 00:34:38,869
the same time within proper

901
00:34:43,389 --> 00:34:40,970
phylogenetics people have put a lot of

902
00:34:45,280 --> 00:34:43,399
effort into defining things like maximum

903
00:34:47,740 --> 00:34:45,290
likelihood methods and Bayesian methods

904
00:34:50,889 --> 00:34:47,750
for which they understand the properties

905
00:34:53,500 --> 00:34:50,899
of these statistical approaches as

906
00:34:55,510 --> 00:34:53,510
probability models now they're often

907
00:34:57,129 --> 00:34:55,520
under specified and so they leave out a

908
00:34:59,740 --> 00:34:57,139
lot of what we would like to consider in

909
00:35:02,589 --> 00:34:59,750
data but one of the reasons people don't

910
00:35:05,109 --> 00:35:02,599
just dream up criteria and then write

911
00:35:07,030 --> 00:35:05,119
papers about them is that criteria with

912
00:35:08,710 --> 00:35:07,040
no known properties give you answers

913
00:35:10,900 --> 00:35:08,720

that you don't know how to interpret and

914
00:35:12,789 --> 00:35:10,910
so for a lot of these deep protein

915
00:35:17,410 --> 00:35:12,799
phylogeny Xand questions about what is

916
00:35:19,870 --> 00:35:17,420
in old organisms I have wondered how

917
00:35:22,539 --> 00:35:19,880
much of this can we referee by putting

918
00:35:24,190 --> 00:35:22,549
it against models with known properties

919
00:35:26,319 --> 00:35:24,200
and figuring out whether we believe it

920
00:35:28,480 --> 00:35:26,329
at all but before I ask you to answer

921
00:35:31,809 --> 00:35:28,490
that there's a question barely related

922
00:35:34,329 --> 00:35:31,819
to it because this is in the domain of

923
00:35:35,829 --> 00:35:34,339
semantics material semantics information

924
00:35:37,930 --> 00:35:35,839
that's hard to put into maximum

925
00:35:40,660 --> 00:35:37,940
likelihood models but seems relevant

926
00:35:44,109 --> 00:35:40,670
it's the next point about where we place

927
00:35:46,660 --> 00:35:44,119
old ATP synthesis and the complexity of

928
00:35:50,109 --> 00:35:46,670
them in addition to the protein itself

929
00:35:51,370 --> 00:35:50,119
if I look at methanogens the role of the

930
00:35:53,890 --> 00:35:51,380
ATP synthase is

931
00:35:55,930 --> 00:35:53,900
outside both the energy branch on the

932
00:35:58,569 --> 00:35:55,940
carbon fixation branch of the one-carbon

933
00:36:00,460 --> 00:35:58,579
system you use it to capture energy to

934
00:36:03,880 --> 00:36:00,470
do the rest of what the cell needs to do

935
00:36:06,849 --> 00:36:03,890
if I look at a cedar jens the ATP

936
00:36:08,349 --> 00:36:06,859
synthase stands actually between the

937
00:36:11,079 --> 00:36:08,359
energy branch and the carbon fixation

938
00:36:13,089 --> 00:36:11,089

branch so if it were not there the

939
00:36:14,799 --> 00:36:13,099
fundamental function of using the c1

940
00:36:17,410 --> 00:36:14,809
metabolism to couple and exergonic

941
00:36:18,130 --> 00:36:17,420
process to a carbon fixation would be

942
00:36:20,380 --> 00:36:18,140
impaired

943
00:36:22,839 --> 00:36:20,390
so architectural II they have extremely

944
00:36:24,579 --> 00:36:22,849
different roles so when we look at that

945
00:36:27,900 --> 00:36:24,589
and we try to figure out even if they

946
00:36:31,450 --> 00:36:27,910
are deep or basal claves respectively in

947
00:36:33,640 --> 00:36:31,460
archaea and bacteria we look at the very

948
00:36:35,589 --> 00:36:33,650
different roles of the ATP synthase

949
00:36:37,390 --> 00:36:35,599
architectural e in the two systems and

950
00:36:38,920 --> 00:36:37,400
then we know that phylogenetic

951
00:36:41,499 --> 00:36:38,930
reconstruction for these things that

952
00:36:43,930 --> 00:36:41,509
have more than one homologous group are

953
00:36:45,670 --> 00:36:43,940
difficult what is the right way to think

954
00:36:50,160 --> 00:36:45,680
in a disciplined way about what ancient

955
00:36:59,319 --> 00:36:54,400
thank you that's yeah I have a lot to

956
00:37:00,579 --> 00:36:59,329
think about now for the for the first

957
00:37:06,069 --> 00:37:00,589
question

958
00:37:10,299 --> 00:37:06,079
I don't yeah I don't know of the

959
00:37:13,779 --> 00:37:10,309
literature where people have taken

960
00:37:15,700 --> 00:37:13,789
sequences if this isn't done let's do it

961
00:37:17,470 --> 00:37:15,710
let's take sequences and put them in

962
00:37:21,579 --> 00:37:17,480
little artificial cells and then have

963
00:37:23,890 --> 00:37:21,589

them evolve with a certain evolutionary

964
00:37:26,499 --> 00:37:23,900
model and then build trees and then

965
00:37:28,749 --> 00:37:26,509
build trees and then let it go and keep

966
00:37:30,910 --> 00:37:28,759
building trees I do know of examples

967
00:37:34,269 --> 00:37:30,920
where it seems pretty obvious just based

968
00:37:36,430 --> 00:37:34,279
on actual domains and so when we when we

969
00:37:39,160 --> 00:37:36,440
have sequence information and we and we

970
00:37:41,380 --> 00:37:39,170
also have domain information sometimes

971
00:37:43,269 --> 00:37:41,390
these domains can swap around and you

972
00:37:45,160 --> 00:37:43,279
and you and this is a glaring example

973
00:37:47,710 --> 00:37:45,170
where you know your secret your sequence

974
00:37:51,789 --> 00:37:47,720
alignment is wrong but it works you can

975
00:37:54,339 --> 00:37:51,799
align anything and in these in in these

976
00:37:56,230 --> 00:37:54,349
cases I do know of cases where the

977
00:37:57,970 --> 00:37:56,240
branching order does swap around and so

978
00:38:00,700 --> 00:37:57,980
something that should be very very far

979
00:38:02,470 --> 00:38:00,710
out and ends up being basal because

980
00:38:03,630 --> 00:38:02,480
based on the model that becomes the most

981
00:38:08,310 --> 00:38:03,640
probable thing

982
00:38:11,880 --> 00:38:08,320
but it you you have to supervise the

983
00:38:13,500 --> 00:38:11,890
computer when you do this it might be

984
00:38:15,840 --> 00:38:13,510
worthwhile considering some simulations

985
00:38:16,980 --> 00:38:15,850
if people haven't done to do that the

986
00:38:19,080 --> 00:38:16,990
other way to do that is to go to the

987
00:38:20,880 --> 00:38:19,090
Levin and let the let the microbes crank

988
00:38:27,420 --> 00:38:20,890

but that takes more time than the

989
00:38:31,230 --> 00:38:27,430
simulation the second question about met

990
00:38:32,790 --> 00:38:31,240
antigens and heceta genes and this

991
00:38:38,190 --> 00:38:32,800
different structure that accomplishes

992
00:38:40,530 --> 00:38:38,200
roughly the same thing I don't they

993
00:38:44,880 --> 00:38:40,540
would I don't know why there's not a

994
00:38:46,620 --> 00:38:44,890
third way this is a way to back out of

995
00:38:47,760 --> 00:38:46,630
answering that complicated question but

996
00:38:49,200 --> 00:38:47,770
there is kind of a third way the

997
00:38:52,380 --> 00:38:49,210
methanogens and the exceeded ends both

998
00:38:55,140 --> 00:38:52,390
come in at in at least you know three

999
00:38:56,910 --> 00:38:55,150
different flavors apiece and they all

1000
00:38:57,900 --> 00:38:56,920
have different protein subunits and

1001
00:38:59,220 --> 00:38:57,910
they're all accomplishing the same

1002
00:39:02,040 --> 00:38:59,230
reaction but they do it with different

1003
00:39:04,710 --> 00:39:02,050
enzyme arrangements or architectures

1004
00:39:07,080 --> 00:39:04,720
inside of the cell and so in my head I

1005
00:39:10,140 --> 00:39:07,090
think oh this is part of the this is

1006
00:39:12,150 --> 00:39:10,150
part of how material responds to an

1007
00:39:14,070 --> 00:39:12,160
energy flow this is how it can get

1008
00:39:16,620 --> 00:39:14,080
organized and in methanogens and the

1009
00:39:18,150 --> 00:39:16,630
citizens it's somewhat degenerate in the

1010
00:39:19,650 --> 00:39:18,160
sense that they both pull the hydrogen

1011
00:39:21,660 --> 00:39:19,660
concentration to the pretty much the

1012
00:39:24,930 --> 00:39:21,670
exact same chemical potential but

1013
00:39:27,060 --> 00:39:24,940

they're doing it in different ways yeah

1014
00:39:30,420 --> 00:39:27,070
I think the only way for me to safely

1015
00:39:32,360 --> 00:39:30,430
back out is to say like what would be

1016
00:39:35,940 --> 00:39:32,370
the other ways that that could work and

1017
00:39:37,170 --> 00:39:35,950
that might be good to look for there

1018
00:39:39,990 --> 00:39:37,180
should be different I see de gens out

1019
00:39:42,510 --> 00:39:40,000
there too that don't link the processes

1020
00:39:44,160 --> 00:39:42,520
in the same way maybe or if there's not

1021
00:39:46,620 --> 00:39:44,170
maybe it's something really special I'm

1022
00:39:51,240 --> 00:39:46,630
not quite sure about that very cool

1023
00:39:52,560 --> 00:39:51,250
thank you next question here I just to

1024
00:39:54,240 --> 00:39:52,570
follow up on that a little bit I think

1025
00:39:56,400 --> 00:39:54,250
it is interesting that you focus on

1026
00:40:00,600 --> 00:39:56,410
heceta genesis methanogenesis because

1027
00:40:02,790 --> 00:40:00,610
there are arguments against looking at

1028
00:40:05,250 --> 00:40:02,800
those as ancient forms of metabolism

1029
00:40:08,430 --> 00:40:05,260
well they may be more derived Nitschke

1030
00:40:10,470 --> 00:40:08,440
and Russell's work where they're looking

1031
00:40:11,880 --> 00:40:10,480
at those processes and saying that they

1032
00:40:14,190 --> 00:40:11,890
must be more derived because you only

1033
00:40:16,590 --> 00:40:14,200
see a Seeta Genesis in bacteria you only

1034
00:40:17,520 --> 00:40:16,600
see methane in Genesis in archaea and so

1035
00:40:20,760 --> 00:40:17,530
they may have been derived

1036
00:40:23,070 --> 00:40:20,770
later on far after the leuco that's more

1037
00:40:24,270 --> 00:40:23,080
of a comment than a question though but

1038
00:40:26,280 --> 00:40:24,280

I was wondering if you could touch a

1039
00:40:28,200 --> 00:40:26,290
little bit on a statement you made

1040
00:40:30,270 --> 00:40:28,210
earlier about how it's more likely that

1041
00:40:31,680 --> 00:40:30,280
you would find this early metabolism on

1042
00:40:33,210 --> 00:40:31,690
the outside of the vents then on the

1043
00:40:39,060 --> 00:40:33,220
inside of the vents can you explain why

1044
00:40:40,410 --> 00:40:39,070
you feel that way so the for the for the

1045
00:40:42,690 --> 00:40:40,420
first concept I think you're completely

1046
00:40:44,610 --> 00:40:42,700
right and I think that all the stuff

1047
00:40:46,230 --> 00:40:44,620
that I've talked about here today which

1048
00:40:47,790 --> 00:40:46,240
references modern biology might be

1049
00:40:50,610 --> 00:40:47,800
totally misguided to talk about biology

1050
00:40:53,160 --> 00:40:50,620
in any way four billion years ago I'm so

1051
00:40:54,720 --> 00:40:53,170
comfortable with saying that I'm a

1052
00:40:56,250 --> 00:40:54,730
little bit radical that I would be

1053
00:40:58,590 --> 00:40:56,260
totally fine if there's a completely

1054
00:41:00,630 --> 00:40:58,600
alternative genetic code or no genetic

1055
00:41:01,560 --> 00:41:00,640
code or something four billion years ago

1056
00:41:04,500 --> 00:41:01,570
and a totally different type of

1057
00:41:06,000 --> 00:41:04,510
metabolism so this is part of what I

1058
00:41:09,260 --> 00:41:06,010
also want to talk about at our after

1059
00:41:12,210 --> 00:41:09,270
shop is how far can we go we've got

1060
00:41:14,070 --> 00:41:12,220
we've got some decent rock data that

1061
00:41:16,620 --> 00:41:14,080
there was life based on light isotopes

1062
00:41:17,760 --> 00:41:16,630
so like 3.8 billion years ago but so

1063
00:41:19,200 --> 00:41:17,770

what maybe it was a different form of

1064
00:41:21,360 --> 00:41:19,210
life that didn't didn't do anything like

1065
00:41:22,830 --> 00:41:21,370
that and what are our safeguards so I

1066
00:41:24,330 --> 00:41:22,840
think this is a totally valid concern

1067
00:41:26,550 --> 00:41:24,340
and it would be awesome to figure out

1068
00:41:30,780 --> 00:41:26,560
ways to guard ourselves against that the

1069
00:41:32,340 --> 00:41:30,790
second question is only because of this

1070
00:41:35,670 --> 00:41:32,350
concept of the nernst and potential

1071
00:41:37,380 --> 00:41:35,680
difference so if you take hydrogen at pH

1072
00:41:39,330 --> 00:41:37,390
0 the way we define it is that the redox

1073
00:41:40,860 --> 00:41:39,340
potential is zero that is it's not it

1074
00:41:42,810 --> 00:41:40,870
doesn't want to give electrons out it's

1075
00:41:44,540 --> 00:41:42,820
at equilibrium with taking them and as

1076
00:41:48,240 --> 00:41:44,550
you crank the pH up higher and higher

1077
00:41:50,490 --> 00:41:48,250
hydrogen h2 becomes more less and less

1078
00:41:52,140 --> 00:41:50,500
stable and it wants to shoot out its

1079
00:41:54,600 --> 00:41:52,150
electrons more and more or when the

1080
00:41:56,460 --> 00:41:54,610
electrons get shot out is that a more

1081
00:41:58,740 --> 00:41:56,470
reducing potential so if you can do that

1082
00:42:00,990 --> 00:41:58,750
at pH 10 the electrons really come

1083
00:42:02,760 --> 00:42:01,000
screaming out of the hydrogen and if

1084
00:42:06,090 --> 00:42:02,770
those if those electrons go over a

1085
00:42:08,210 --> 00:42:06,100
conductive mineral wall they can hit the

1086
00:42:11,070 --> 00:42:08,220
carbon and reduce it so

1087
00:42:13,200 --> 00:42:11,080
thermodynamically you can't it's really

1088
00:42:14,880 --> 00:42:13,210

hard to have carbon reduction in the

1089
00:42:16,200 --> 00:42:14,890
inside because the redox potential if

1090
00:42:19,260 --> 00:42:16,210
the carbon also gets more and more

1091
00:42:21,930 --> 00:42:19,270
negative so the two things shift but if

1092
00:42:24,780 --> 00:42:21,940
you can separate the protons from the

1093
00:42:26,220 --> 00:42:24,790
carbon but not the electrons that's when

1094
00:42:30,210 --> 00:42:26,230
you can have the energy flow happen

1095
00:42:31,330 --> 00:42:30,220
really thermodynamically favorable thank

1096
00:42:33,270 --> 00:42:31,340
you very great talk

1097
00:42:39,580 --> 00:42:33,280
oh thank you hey last question over here

1098
00:42:42,340 --> 00:42:39,590
okay exciting now quickly so this means

1099
00:42:44,830 --> 00:42:42,350
they appear is a gradient in pH is a

1100
00:42:49,240 --> 00:42:44,840
reason why I think this is a good

1101
00:42:53,170 --> 00:42:49,250
location and there are any other

1102
00:42:55,570 --> 00:42:53,180
locations earlier cited these kind of pH

1103
00:43:01,780 --> 00:42:55,580
gradient might have existed

1104
00:43:03,160 --> 00:43:01,790
other than hydrothermal systems yes

1105
00:43:04,210 --> 00:43:03,170
although had like other people that

1106
00:43:08,950 --> 00:43:04,220
helped me out because I think they know

1107
00:43:12,010 --> 00:43:08,960
more about the earth with that so but to

1108
00:43:14,620 --> 00:43:12,020
step back as a kind of physiologist and

1109
00:43:16,120 --> 00:43:14,630
and go back to this hydrogen thing when

1110
00:43:17,530 --> 00:43:16,130
we look at methanogens aniseed engines

1111
00:43:20,020 --> 00:43:17,540
today whether or not that's a good guide

1112
00:43:21,700 --> 00:43:20,030
for us is another question they're able

1113
00:43:24,070 --> 00:43:21,710

to live on these low hydrogen partial

1114
00:43:26,710 --> 00:43:24,080
pressures because they can take that

1115
00:43:28,810 --> 00:43:26,720
energy that's happening later on in in

1116
00:43:31,300 --> 00:43:28,820
the formation of methane and kind of

1117
00:43:34,350 --> 00:43:31,310
pipe that energy back up to the initial

1118
00:43:37,690 --> 00:43:34,360
step and so and they have to do that

1119
00:43:38,710 --> 00:43:37,700
they have to pipe the energy up because

1120
00:43:40,120 --> 00:43:38,720
there's not enough hydrogen

1121
00:43:41,890 --> 00:43:40,130
concentration which means that the redox

1122
00:43:43,840 --> 00:43:41,900
potential is not negative enough to

1123
00:43:45,580 --> 00:43:43,850
drive Carbon Reduction in this case it

1124
00:43:47,680 --> 00:43:45,590
should just be spontaneous and the whole

1125
00:43:48,610 --> 00:43:47,690
thing like if if there's catalysts you

1126
00:43:49,870 --> 00:43:48,620
know this is the thing the

1127
00:43:51,730 --> 00:43:49,880
thermodynamics are there but who knows

1128
00:43:53,290 --> 00:43:51,740
if the catalysts are there but it

1129
00:43:55,660 --> 00:43:53,300
becomes a kinetic problem and not a I'm

1130
00:43:57,130 --> 00:43:55,670
not a thermodynamic with the ambient

1131
00:43:58,840 --> 00:43:57,140
concentrations that you might be able to

1132
00:44:02,350 --> 00:43:58,850
get out of one of these vents your

1133
00:44:05,110 --> 00:44:02,360
question is where else would this have

1134
00:44:08,110 --> 00:44:05,120
to be it depends on what we think the

1135
00:44:11,170 --> 00:44:08,120
original electron donor for life was and

1136
00:44:12,340 --> 00:44:11,180
so before the oxygenation of the planet

1137
00:44:14,320 --> 00:44:12,350
there probably wasn't a lot of high

1138
00:44:15,850 --> 00:44:14,330

potential acceptors around so this gets

1139
00:44:18,580 --> 00:44:15,860
us back to our morning talk with Eric

1140
00:44:20,620 --> 00:44:18,590
when you have high electron high

1141
00:44:22,150 --> 00:44:20,630
potential very positive electron

1142
00:44:24,400 --> 00:44:22,160
acceptors around it's kind of a whole

1143
00:44:26,680 --> 00:44:24,410
different metabolic world then when you

1144
00:44:29,650 --> 00:44:26,690
only have low potential electron donors

1145
00:44:31,510 --> 00:44:29,660
around these cells are using co2 as an

1146
00:44:34,180 --> 00:44:31,520
electron acceptor which kind of sucks

1147
00:44:35,740 --> 00:44:34,190
but they're able to do that and they can

1148
00:44:38,530 --> 00:44:35,750
only do that because they can pipe the

1149
00:44:40,810 --> 00:44:38,540
energy back up us we can go eat our

1150
00:44:42,670 --> 00:44:40,820
onigiri and we burn it with oxygen and

1151
00:44:44,110 --> 00:44:42,680
we can we can you know we can do all

1152
00:44:44,650 --> 00:44:44,120
sorts of stuff because there's so much

1153
00:44:49,359 --> 00:44:44,660
energy

1154
00:44:51,400 --> 00:44:49,369
couple so we do need to consider very

1155
00:44:53,650 --> 00:44:51,410
very seriously if hydrogen is the only

1156
00:44:55,900 --> 00:44:53,660
real at electron acceptor for the origin

1157
00:44:57,370 --> 00:44:55,910
of of cells or for powering them there

1158
00:44:59,079 --> 00:44:57,380
might be other ones what else we have

1159
00:45:03,309 --> 00:44:59,089
we've got ferrous iron midpoint

1160
00:45:04,960 --> 00:45:03,319
potentials not good so if if we're

1161
00:45:06,819 --> 00:45:04,970
limited to hydrogen we do have to think

1162
00:45:10,120 --> 00:45:06,829
about how we can charge those electrons

1163
00:45:12,370 --> 00:45:10,130

up biology does it today by rerouting

1164
00:45:15,789 --> 00:45:12,380
the electrons back up this is a way that

1165
00:45:21,099 --> 00:45:15,799
would circumvent that but it yeah I'll

1166
00:45:25,680 --> 00:45:21,109
try to think okay let's thank the