1
00:00:06,760 --> 00:00:03,560
well good morning or afternoon depending

2
00:00:10,129 --> 00:00:06,770
on your time zone as Carl Pilcher and

3
00:00:13,669 --> 00:00:10,139
I'd like to welcome you to the new

4
00:00:16,550 --> 00:00:13,679
season of Nai director seminars and it

5
00:00:19,279 --> 00:00:16,560
is really a pleasure to kick off this

6
00:00:22,460 --> 00:00:19,289
season of seminars with a seminar from

7
00:00:25,279 --> 00:00:22,470
Norm pace Norma's I'm sure many of you

8
00:00:29,240 --> 00:00:25,289
know most of you know is an extremely

9
00:00:30,859 --> 00:00:29,250
distinguished microbiologist he is a

10
00:00:34,520 --> 00:00:30,869
member of the National Academy of

11
00:00:37,030 --> 00:00:34,530
Sciences and in 2001 he received the

12
00:00:39,590 --> 00:00:37,040
Selman a Waxman Award in microbiology

13
00:00:41,030 --> 00:00:39,600

which is given by the Academy and is

14
00:00:44,479 --> 00:00:41,040
generally considered the nation's

15
00:00:46,100 --> 00:00:44,489
highest award in microbiology that same

16
00:00:50,000 --> 00:00:46,110
year he also got a MacArthur Fellowship

17
00:00:51,770 --> 00:00:50,010
just for good measure and just this year

18
00:00:55,939 --> 00:00:51,780
he received the American Society for

19
00:00:57,470 --> 00:00:55,949
Microbiology x' adam abbott ASM lifetime

20
00:00:59,360 --> 00:00:57,480
achievement award for outstanding

21
00:01:02,299 --> 00:00:59,370
contributions to the field of microbial

22
00:01:05,210 --> 00:01:02,309
ecology I have to express personal

23
00:01:08,320 --> 00:01:05,220
appreciation to norm because over the

24
00:01:10,760 --> 00:01:08,330
years that he has been involved in

25
00:01:13,310 --> 00:01:10,770
exobiology and astrobiology which is

26
00:01:15,969 --> 00:01:13,320
quite a few years he has helped me a

27
00:01:18,289 --> 00:01:15,979
great deal just in understanding

28
00:01:21,200 --> 00:01:18,299
microbiology since I wasn't educated in

29
00:01:23,719 --> 00:01:21,210
it and so it's with really great

30
00:01:25,429 --> 00:01:23,729
pleasure that I introduce norm pace

31
00:01:27,620 --> 00:01:25,439
who's going to talk with us about life

32
00:01:36,039 --> 00:01:27,630
in the university expanding world of

33
00:01:43,999 --> 00:01:41,990
I'm norm ki mute your microphone let's

34
00:01:46,100 --> 00:01:44,009
try that again

35
00:01:49,399 --> 00:01:46,110
the title has slightly changed from that

36
00:01:51,740 --> 00:01:49,409
that Carl gave you I changed to life in

37
00:01:54,050 --> 00:01:51,750
the universe the terrestrial example

38
00:01:56,030 --> 00:01:54,060

because I believe that we are one

39
00:01:59,719 --> 00:01:56,040
example of a lot of life out there in

40
00:02:02,149 --> 00:01:59,729
the universe life in this planet has has

41
00:02:04,459 --> 00:02:02,159
penetrated every possible thermodynamic

42
00:02:06,410 --> 00:02:04,469
and physical niche and the requirements

43
00:02:08,300 --> 00:02:06,420
for life anywhere in the universe are

44
00:02:10,520 --> 00:02:08,310
going to be the same as they are here so

45
00:02:13,580 --> 00:02:10,530
I think we're seeing a way the life

46
00:02:15,900 --> 00:02:13,590
accommodates to life in the universe

47
00:02:18,809 --> 00:02:15,910
now the history of life on Earth of

48
00:02:22,260 --> 00:02:18,819
course began about 5 billion years ago

49
00:02:24,120 --> 00:02:22,270
in a star out on the edge of a galaxy

50
00:02:26,790 --> 00:02:24,130
not too different from the one shown

51
00:02:29,880 --> 00:02:26,800
here except that our own 5 billion years

52
00:02:31,800 --> 00:02:29,890
ago exploded in a supernova scattering

53
00:02:34,440 --> 00:02:31,810
star guts over perhaps a cubic

54
00:02:36,330 --> 00:02:34,450
light-years of space we know that we're

55
00:02:38,940 --> 00:02:36,340
a second or third generation star

56
00:02:43,170 --> 00:02:38,950
because of all of the heavy atoms that

57
00:02:45,630 --> 00:02:43,180
are in our solar system including carbon

58
00:02:48,780 --> 00:02:45,640
the heavy atom carbon only formed in the

59
00:02:50,460 --> 00:02:48,790
hearts of exploding stars so we expect

60
00:02:53,250 --> 00:02:50,470
life anywhere in the universe to be

61
00:02:55,440 --> 00:02:53,260
based on carbon and those who might like

62
00:02:57,270 --> 00:02:55,450
further discussion of that I refer you

63
00:03:00,120 --> 00:02:57,280

to the National Research Council report

64
00:03:02,309 --> 00:03:00,130
recently issued on the limits of organic

65
00:03:04,140 --> 00:03:02,319
life and planetary systems and I think

66
00:03:08,090 --> 00:03:04,150
there's general agreement that like

67
00:03:11,220 --> 00:03:08,100
chemistry will be organic chemistry so

68
00:03:13,170 --> 00:03:11,230
in talking about life's diversity then I

69
00:03:15,540 --> 00:03:13,180
first have to give you a metric of how

70
00:03:17,850 --> 00:03:15,550
to think about diversity and molecular

71
00:03:20,729 --> 00:03:17,860
math of life's diversity and evolution

72
00:03:23,310 --> 00:03:20,739
and will then take that perspective and

73
00:03:24,810 --> 00:03:23,320
use it to go into the natural microbial

74
00:03:26,940 --> 00:03:24,820
world to find out what kinds of

75
00:03:28,620 --> 00:03:26,950
organisms are on this planet it turns

76
00:03:31,020 --> 00:03:28,630
out we haven't known very much about

77
00:03:33,000 --> 00:03:31,030
that because microbiologists have always

78
00:03:35,310 --> 00:03:33,010
had to call sure organisms petri dishes

79
00:03:37,289 --> 00:03:35,320
and all that and it turns out we can't

80
00:03:39,810 --> 00:03:37,299
culture much of what's out there in the

81
00:03:41,670 --> 00:03:39,820
real world for many reasons but by using

82
00:03:43,229 --> 00:03:41,680
this new perspective of molecular

83
00:03:45,930 --> 00:03:43,239
spective we can go into this natural

84
00:03:47,729 --> 00:03:45,940
microbial world and explore that way

85
00:03:50,280 --> 00:03:47,739
which we haven't known very much about

86
00:03:53,910 --> 00:03:50,290
which I tongue-in-cheek call dark life

87
00:03:55,740 --> 00:03:53,920
of terrestrial biology using this

88
00:03:57,660 --> 00:03:55,750

technology and perspective I'll talk

89
00:04:00,420 --> 00:03:57,670
about expanding this tree and give you a

90
00:04:01,920 --> 00:04:00,430
general perspective of life's diversity

91
00:04:04,410 --> 00:04:01,930
that certainly hasn't hit the textbooks

92
00:04:05,940 --> 00:04:04,420
then finally I need to give you a public

93
00:04:08,610 --> 00:04:05,950
service message which will become clear

94
00:04:10,199 --> 00:04:08,620
later our textbooks aren't doing it very

95
00:04:11,870 --> 00:04:10,209
well these days in terms of biological

96
00:04:16,830 --> 00:04:11,880
diversity

97
00:04:18,990 --> 00:04:16,840
did you find it we've heard a lot of

98
00:04:20,370 --> 00:04:19,000
talk about biological diversity over the

99
00:04:23,040 --> 00:04:20,380
years but did you ever hear anybody

100
00:04:25,290 --> 00:04:23,050
define it I haven't in a satisfactory

101
00:04:26,460 --> 00:04:25,300
way however recently it's become

102
00:04:28,530 --> 00:04:26,470
possible by the

103
00:04:30,950 --> 00:04:28,540
lissa use of gene sequences to use

104
00:04:33,740 --> 00:04:30,960
sequence comparisons to study

105
00:04:36,780 --> 00:04:33,750
phylogenetic trees Philo relatedness

106
00:04:39,420 --> 00:04:36,790
genetically related ministries as

107
00:04:41,880 --> 00:04:39,430
metaphors for evolutionary

108
00:04:45,810 --> 00:04:41,890
diversification to make maps of

109
00:04:47,790 --> 00:04:45,820
evolution people have been thinking

110
00:04:50,270 --> 00:04:47,800
about relationships between organisms

111
00:04:53,070 --> 00:04:50,280
for a very long time of course this is a

112
00:04:56,670 --> 00:04:53,080
phylogenetic tree if you will from Ernst

113
00:04:58,770 --> 00:04:56,680

Haeckel in 1866 only a few years after

114
00:05:00,540 --> 00:04:58,780
Darwin and you'll see it's pretty much

115
00:05:02,690 --> 00:05:00,550
what you see in textbooks today down

116
00:05:05,520 --> 00:05:02,700
here to the bottom we had Monera

117
00:05:09,020 --> 00:05:05,530
animals and plants and in protists

118
00:05:11,910 --> 00:05:09,030
unicellular eukaryotes in the 1960s the

119
00:05:14,400 --> 00:05:11,920
1960s Bunji were plugged onto this to

120
00:05:16,550 --> 00:05:14,410
give the familiar five kingdoms tree and

121
00:05:19,620 --> 00:05:16,560
the name Monera was changed to

122
00:05:22,260 --> 00:05:19,630
prokaryote nothing else happened I'll

123
00:05:24,150 --> 00:05:22,270
return to that this is a subjective view

124
00:05:26,190 --> 00:05:24,160
of life based on the kinds of organisms

125
00:05:28,590 --> 00:05:26,200
that Haeckel could understand at that

126
00:05:30,930 --> 00:05:28,600
time a subjective view of life and it

127
00:05:33,570 --> 00:05:30,940
really wasn't until we had a molecular

128
00:05:35,100 --> 00:05:33,580
view learning about the past 30 years or

129
00:05:37,920 --> 00:05:35,110
so has it been possible to have an

130
00:05:39,150 --> 00:05:37,930
objective view of life diversity and

131
00:05:41,430 --> 00:05:39,160
this is through the techniques of

132
00:05:44,130 --> 00:05:41,440
molecular phylogeny it's about relating

133
00:05:46,140 --> 00:05:44,140
organisms by gene sequences this is a

134
00:05:48,030 --> 00:05:46,150
simple process in principle you get the

135
00:05:49,650 --> 00:05:48,040
organism sequences that you can compare

136
00:05:51,780 --> 00:05:49,660
from different organisms that you want

137
00:05:53,850 --> 00:05:51,790
to compare you very carefully line up

138
00:05:55,830 --> 00:05:53,860

those gene sequences and count the

139
00:05:57,330 --> 00:05:55,840
number of differences and that number of

140
00:05:59,790 --> 00:05:57,340
differences will be some measure of

141
00:06:02,460 --> 00:05:59,800
evolutionary distance there's been an

142
00:06:04,800 --> 00:06:02,470
issue based on those pairwise distances

143
00:06:07,320 --> 00:06:04,810
to calculate some sort of a mat a

144
00:06:10,430 --> 00:06:07,330
phylogenetic tree that most accurately

145
00:06:13,230 --> 00:06:10,440
represents all of the pairwise sequences

146
00:06:15,330 --> 00:06:13,240
now you can do this process with any

147
00:06:17,610 --> 00:06:15,340
gene that you would like but if you want

148
00:06:18,780 --> 00:06:17,620
to compare all of life's diversity there

149
00:06:20,640 --> 00:06:18,790
are only a few genes that are

150
00:06:23,700 --> 00:06:20,650
appropriate and the genes that have

151
00:06:26,040 --> 00:06:23,710
emerged as the gold standard if you will

152
00:06:29,030 --> 00:06:26,050
for deep phylogeny are the genes for the

153
00:06:32,520 --> 00:06:29,040
ribosomal RNAs highly conserved and

154
00:06:35,520 --> 00:06:32,530
present in all organisms well the first

155
00:06:37,560 --> 00:06:35,530
person to use ribosomal RNA genes to

156
00:06:38,730 --> 00:06:37,570
cast phylogenetic trees of all of life

157
00:06:41,010 --> 00:06:38,740
is Carl Wu

158
00:06:43,680 --> 00:06:41,020
then endow at the University of Illinois

159
00:06:46,499 --> 00:06:43,690
and I'll offer pians to NASA this time

160
00:06:48,659 --> 00:06:46,509
because NASA kept Karl Rove's live when

161
00:06:51,450 --> 00:06:48,669
all the other scientists in NSF and NIH

162
00:06:54,390 --> 00:06:51,460
and so forth said Karl this is just

163
00:06:56,070 --> 00:06:54,400

taxonomy NASA knew better and out of

164
00:06:59,100 --> 00:06:56,080
that came an absolutely spectacular

165
00:07:01,320 --> 00:06:59,110
picture a map of all of life this being

166
00:07:04,439 --> 00:07:01,330
one examples this is a phylogenetic tree

167
00:07:05,730 --> 00:07:04,449
which shows examples of all of life let

168
00:07:08,520 --> 00:07:05,740
me show you how to read it here's the

169
00:07:11,070 --> 00:07:08,530
scale 0.1 changes per site and

170
00:07:14,010 --> 00:07:11,080
evolutionary distance is read along line

171
00:07:16,320 --> 00:07:14,020
segments here we humans are out here all

172
00:07:19,350 --> 00:07:16,330
of animals could fit into this radiation

173
00:07:22,740 --> 00:07:19,360
all the fun G into this radiation all of

174
00:07:24,950 --> 00:07:22,750
plants and the line indicated by Xia and

175
00:07:26,909 --> 00:07:24,960
then of course there's the rest of

176
00:07:29,670 --> 00:07:26,919
biological diversity which is

177
00:07:31,890 --> 00:07:29,680
fundamentally microbial in nature now

178
00:07:34,020 --> 00:07:31,900
you can't find out where the origin of

179
00:07:35,999 --> 00:07:34,030
this big tree he is from ribosomal RNA

180
00:07:38,790 --> 00:07:36,009
sequences but there are other violent

181
00:07:40,950 --> 00:07:38,800
genetic methods that one can employ also

182
00:07:42,839 --> 00:07:40,960
with biochemical correlates show the

183
00:07:45,659 --> 00:07:42,849
route is out here deep on the bacterial

184
00:07:47,939 --> 00:07:45,669
line and that means as cartoon over here

185
00:07:50,909 --> 00:07:47,949
the origin was out here the bacteria

186
00:07:53,070 --> 00:07:50,919
line Eukarya and archaea are related to

187
00:07:55,439 --> 00:07:53,080
the exclusion of bacteria and I'll

188
00:07:57,029 --> 00:07:55,449

return to that one as well later and

189
00:07:59,909 --> 00:07:57,039
just to get a few points on that I want

190
00:08:02,550 --> 00:07:59,919
to make sure that I cover so just a few

191
00:08:04,800 --> 00:08:02,560
lessons from the big tree this map if

192
00:08:06,930 --> 00:08:04,810
you will this cartoon map of all of

193
00:08:09,270 --> 00:08:06,940
life's diversity the three main

194
00:08:11,370 --> 00:08:09,280
relatedness groups three kinds of

195
00:08:14,790 --> 00:08:11,380
organisms at the deep level bacteria

196
00:08:16,290 --> 00:08:14,800
Eukarya and archaea the origins i

197
00:08:18,540 --> 00:08:16,300
already mentioned is out here on the

198
00:08:21,930 --> 00:08:18,550
bacterial line or the line leading to

199
00:08:24,270 --> 00:08:21,940
bacteria which means that are related to

200
00:08:25,980 --> 00:08:24,280
the exclusion of bacteria and indeed

201
00:08:28,409 --> 00:08:25,990
much biochemistry would say that the

202
00:08:30,540 --> 00:08:28,419
fundamental many fundamental aspects of

203
00:08:32,899 --> 00:08:30,550
the biochemistry of these organisms far

204
00:08:36,300 --> 00:08:32,909
more similar than either as to bacteria

205
00:08:37,980 --> 00:08:36,310
now the analyses such as these show very

206
00:08:40,250 --> 00:08:37,990
clearly that the chloroplast in the

207
00:08:42,719 --> 00:08:40,260
mitochondria are of bacterial origin

208
00:08:44,280 --> 00:08:42,729
endosymbiotic origins for chloroplasts

209
00:08:45,269 --> 00:08:44,290
and mitochondria is now very

210
00:08:47,950 --> 00:08:45,279
well-established

211
00:08:50,590 --> 00:08:47,960
however the eukaryotic new

212
00:08:53,410 --> 00:08:50,600
your line of descent is as old as the

213
00:08:55,330 --> 00:08:53,420

archaeal line of descent and drive from

214
00:08:59,200 --> 00:08:55,340
something more rudimentary than either

215
00:09:01,090 --> 00:08:59,210
bacteria or archaea that means that the

216
00:09:03,640 --> 00:09:01,100
prokaryote eukaryote model for

217
00:09:06,430 --> 00:09:03,650
biological organizations shot throughout

218
00:09:08,680 --> 00:09:06,440
our books our textbooks our literature

219
00:09:11,590 --> 00:09:08,690
in our language it means that that model

220
00:09:14,680 --> 00:09:11,600
for Biological organization was wrong

221
00:09:16,780 --> 00:09:14,690
I'll return to that most important for

222
00:09:19,270 --> 00:09:16,790
the current presentation is sequences

223
00:09:22,060 --> 00:09:19,280
ribosomal RNA gene or other sequences

224
00:09:24,250 --> 00:09:22,070
are identifiers of organisms barcodes if

225
00:09:26,380 --> 00:09:24,260
you like with a specific organism you

226
00:09:29,400 --> 00:09:26,390
don't need to culture in order to

227
00:09:31,810 --> 00:09:29,410
identify that's important because

228
00:09:34,150 --> 00:09:31,820
microbiology has always been paralyzed

229
00:09:35,980 --> 00:09:34,160
as already mentioned microbiologist

230
00:09:37,900 --> 00:09:35,990
always had the culture organisms to

231
00:09:40,120 --> 00:09:37,910
detect and identify them and you don't

232
00:09:42,010 --> 00:09:40,130
culture very much of what's out there if

233
00:09:43,510 --> 00:09:42,020
I go down behind our building to Boulder

234
00:09:45,370 --> 00:09:43,520
Creek and pick up a little bit of water

235
00:09:47,470 --> 00:09:45,380
and count directly the number of

236
00:09:49,240 --> 00:09:47,480
organisms in that water and then do what

237
00:09:51,550 --> 00:09:49,250
I can do to culture them I'm going to

238
00:09:55,060 --> 00:09:51,560

culture perhaps one in 10,000 of what I

239
00:09:59,050 --> 00:09:55,070
see in the microscope more importantly

240
00:10:01,030 --> 00:09:59,060
you don't culture 99.999% of what's out

241
00:10:02,830 --> 00:10:01,040
there and that's what our understanding

242
00:10:04,810 --> 00:10:02,840
of biological diversity has been based

243
00:10:07,630 --> 00:10:04,820
on until quite recently

244
00:10:09,130 --> 00:10:07,640
but using sequences identifiers x' we

245
00:10:11,620 --> 00:10:09,140
can open up the whole panoply of

246
00:10:14,110 --> 00:10:11,630
molecular biology to explore the natural

247
00:10:16,390 --> 00:10:14,120
microbial world so you go out get

248
00:10:19,210 --> 00:10:16,400
yourself a natural sample you prepare

249
00:10:22,180 --> 00:10:19,220
DNA from that and then use for example

250
00:10:23,920 --> 00:10:22,190
PCR to grow up ribosomal RNA genes of

251
00:10:26,110 --> 00:10:23,930
all representatives in the community

252
00:10:28,810 --> 00:10:26,120
it's always a complex nature so you have

253
00:10:30,400 --> 00:10:28,820
to clone these ribosomal RNA genes in

254
00:10:32,230 --> 00:10:30,410
order to separate them into their

255
00:10:35,110 --> 00:10:32,240
individual components which are then

256
00:10:36,670 --> 00:10:35,120
sequence phylogenetic analysis if you

257
00:10:38,650 --> 00:10:36,680
like but this is more than a game in

258
00:10:40,660 --> 00:10:38,660
sequence collection because you can do

259
00:10:43,030 --> 00:10:40,670
something with the sequences for example

260
00:10:45,640 --> 00:10:43,040
use the sequences that you determined to

261
00:10:47,740 --> 00:10:45,650
make hybridization probes or PCR primers

262
00:10:49,720 --> 00:10:47,750
to explore various of aspects of the

263
00:10:51,670 --> 00:10:49,730

natural samples or chase the critter

264
00:10:52,620 --> 00:10:51,680
into culture if that's an essential

265
00:10:55,180 --> 00:10:52,630
thing to do

266
00:10:57,160 --> 00:10:55,190
so in this opens up a very easy

267
00:10:59,620 --> 00:10:57,170
experiment to begin to explore the

268
00:11:00,960 --> 00:10:59,630
natural microbial world you get yourself

269
00:11:03,329 --> 00:11:00,970
a sample you makers

270
00:11:05,699 --> 00:11:03,339
DNA through some PCR you cloned the

271
00:11:08,100 --> 00:11:05,709
products and determines sequence very

272
00:11:09,990 --> 00:11:08,110
simple experiment and absolutely

273
00:11:11,639 --> 00:11:10,000
wonderful experiment because it's easy

274
00:11:13,679 --> 00:11:11,649
to do when you do the same thing again

275
00:11:15,150 --> 00:11:13,689
and again and again and you always get

276
00:11:17,189 --> 00:11:15,160
an interesting is that an interesting

277
00:11:19,439 --> 00:11:17,199
answer and so I'm going to give you some

278
00:11:21,710 --> 00:11:19,449
examples of some of these interesting of

279
00:11:24,929 --> 00:11:21,720
some of these some of these interesting

280
00:11:26,340 --> 00:11:24,939
examples first I want to tell you a

281
00:11:28,800 --> 00:11:26,350
little story about Yellowstone because

282
00:11:30,030 --> 00:11:28,810
this illustrates a real problem we're up

283
00:11:31,889 --> 00:11:30,040
against in studying the natural

284
00:11:34,290 --> 00:11:31,899
microbial world using molecular

285
00:11:36,059 --> 00:11:34,300
technology so it's easy to go out and

286
00:11:37,350 --> 00:11:36,069
get sequences and do pilot genetic

287
00:11:39,509 --> 00:11:37,360
analysis and say oh how look at all

288
00:11:41,429 --> 00:11:39,519

these interesting organisms but the real

289
00:11:43,710 --> 00:11:41,439
challenge now is what are they doing out

290
00:11:45,269 --> 00:11:43,720
there we can tell you who's out there we

291
00:11:47,400 --> 00:11:45,279
can identify organisms in the

292
00:11:48,809 --> 00:11:47,410
environment but how to find out what

293
00:11:51,360 --> 00:11:48,819
they're doing so this is just to

294
00:11:53,550 --> 00:11:51,370
indicate that the lump we're up against

295
00:11:55,439 --> 00:11:53,560
at this stage from Philo type to

296
00:11:57,360 --> 00:11:55,449
phenotype for what an organism is

297
00:11:59,790 --> 00:11:57,370
phylogenetically to what that organism

298
00:12:02,189 --> 00:11:59,800
is doing how to do that there's only one

299
00:12:04,170 --> 00:12:02,199
principle that you have in studying all

300
00:12:05,999 --> 00:12:04,180
of these otherwise unknown organisms

301
00:12:07,889 --> 00:12:06,009
this is the representatives of a

302
00:12:09,509 --> 00:12:07,899
particular phylogenetic group are

303
00:12:11,639 --> 00:12:09,519
expected to have the properties that are

304
00:12:13,470 --> 00:12:11,649
common to that group sopra can relate

305
00:12:16,350 --> 00:12:13,480
organisms in the environment to those

306
00:12:17,879 --> 00:12:16,360
that are known with spec with particular

307
00:12:20,009 --> 00:12:17,889
properties we can lay those same

308
00:12:21,540 --> 00:12:20,019
properties on that organism we don't

309
00:12:25,199 --> 00:12:21,550
know anything about at least in

310
00:12:27,360 --> 00:12:25,209
principle this is a an aerial view of

311
00:12:29,309 --> 00:12:27,370
Grand Prismatic spring is large hot

312
00:12:31,079 --> 00:12:29,319
spring it's about 88 degrees centigrade

313
00:12:32,639 --> 00:12:31,089

here's the board walk over there with

314
00:12:35,069 --> 00:12:32,649
people walking along

315
00:12:37,949 --> 00:12:35,079
it's the largest hot spring of its type

316
00:12:39,960 --> 00:12:37,959
anywhere you can see it's kind of

317
00:12:41,879 --> 00:12:39,970
discolored around the edges of the pool

318
00:12:43,939 --> 00:12:41,889
and the reason it's discolored it's

319
00:12:46,829 --> 00:12:43,949
because of microbial biofabrication

320
00:12:48,869 --> 00:12:46,839
center around them around the sides of

321
00:12:50,730 --> 00:12:48,879
the pool we've done a lot of work in

322
00:12:52,259 --> 00:12:50,740
Yellowstone over the years we don't work

323
00:12:54,329 --> 00:12:52,269
in Grand Prismatic because they're going

324
00:12:56,189 --> 00:12:54,339
to be tourists walking by and the Park

325
00:12:58,019 --> 00:12:56,199
Service doesn't like us to do that so we

326
00:12:59,850 --> 00:12:58,029
work in backcountry pools such as

327
00:13:03,150 --> 00:12:59,860
octopus spring here absolutely

328
00:13:06,540 --> 00:13:03,160
remarkable place 88 to 90 degrees water

329
00:13:08,009 --> 00:13:06,550
wells up and flows out can't see it in

330
00:13:10,799 --> 00:13:08,019
this photograph but again it's kind of

331
00:13:13,260 --> 00:13:10,809
pinkish around the edges of the pool if

332
00:13:15,540 --> 00:13:13,270
you hang a string across the outflow

333
00:13:17,730 --> 00:13:15,550
channel over there just over the course

334
00:13:21,030 --> 00:13:17,740
of a couple of days this gelatinous

335
00:13:22,860 --> 00:13:21,040
filamentous material accumulates is it

336
00:13:24,750 --> 00:13:22,870
alive well if you take a picture of that

337
00:13:27,930 --> 00:13:24,760
stuff and make a microscope slide which

338
00:13:30,180 --> 00:13:27,940

is stained DNA with Diana Dino and Linda

339
00:13:33,000 --> 00:13:30,190
and look at it and for us a microscope

340
00:13:35,580 --> 00:13:33,010
you see aha these filaments buying Gaby

341
00:13:37,530 --> 00:13:35,590
they must contain DNA they must be alive

342
00:13:39,570 --> 00:13:37,540
and if you look at them in the scanning

343
00:13:43,050 --> 00:13:39,580
electron microscope also you see that

344
00:13:45,090 --> 00:13:43,060
this is characteristic of life at ninety

345
00:13:49,170 --> 00:13:45,100
degrees centigrade that is really hot

346
00:13:51,180 --> 00:13:49,180
you do not stick your toe in that or

347
00:13:53,130 --> 00:13:51,190
nearby obsidian pool where we've done a

348
00:13:55,710 --> 00:13:53,140
lot of work absolute marketplace looks

349
00:13:57,120 --> 00:13:55,720
like a real origin life place it's a hot

350
00:13:59,580 --> 00:13:57,130
pool depending on where you stick the

351
00:14:02,430 --> 00:13:59,590
temperature probe 75 to 95 degrees

352
00:14:05,010 --> 00:14:02,440
centigrade sparged from below by gases

353
00:14:07,470 --> 00:14:05,020
that make a real boiling pot kicking up

354
00:14:09,630 --> 00:14:07,480
obsidian sand around the side real

355
00:14:11,940 --> 00:14:09,640
hellhole looking place but they take a

356
00:14:14,010 --> 00:14:11,950
clean microscope slide and stick it in

357
00:14:16,230 --> 00:14:14,020
that sludge just over the course of a

358
00:14:19,050 --> 00:14:16,240
few days the microscope lights light

359
00:14:22,230 --> 00:14:19,060
loads up with biofilm so here after two

360
00:14:24,600 --> 00:14:22,240
days four days six days that is very

361
00:14:26,640 --> 00:14:24,610
rapid growth on that microscope slide

362
00:14:28,230 --> 00:14:26,650
four organisms in the natural microbial

363
00:14:30,930 --> 00:14:28,240

world what are you doing for a living

364
00:14:32,400 --> 00:14:30,940
out there anyway well they eating takes

365
00:14:34,230 --> 00:14:32,410
energy to do that biology is in the

366
00:14:36,540 --> 00:14:34,240
business of capturing energy and using

367
00:14:37,950 --> 00:14:36,550
that energy to make more of itself where

368
00:14:39,570 --> 00:14:37,960
are they getting energy they're

369
00:14:41,940 --> 00:14:39,580
certainly not doing photosynthesis this

370
00:14:45,900 --> 00:14:41,950
doesn't happen above about 70 degrees

371
00:14:47,970 --> 00:14:45,910
centigrade or so well as you walk around

372
00:14:49,920 --> 00:14:47,980
in Yellowstone or if you pick up books

373
00:14:52,020 --> 00:14:49,930
that talk about Yellowstone for example

374
00:14:53,700 --> 00:14:52,030
you're usually led to believe that

375
00:14:55,890 --> 00:14:53,710
there's a lot of hydrogen sulfide around

376
00:14:59,520 --> 00:14:55,900
as there is walk around Yellowstone lots

377
00:15:02,550 --> 00:14:59,530
of steam lots of sulphate expelling odor

378
00:15:03,720 --> 00:15:02,560
and oftentimes the textbooks will tell

379
00:15:05,430 --> 00:15:03,730
you if they tell you anything at all

380
00:15:06,990 --> 00:15:05,440
about the nutrition of organisms at high

381
00:15:08,930 --> 00:15:07,000
temperature is it well they're probably

382
00:15:11,310 --> 00:15:08,940
doing some aspect of hydrogen sulfide

383
00:15:13,170 --> 00:15:11,320
metabolism well I know that's not the

384
00:15:14,220 --> 00:15:13,180
case in octopus Spring for example

385
00:15:16,950 --> 00:15:14,230
because I know there's no hydrogen

386
00:15:19,140 --> 00:15:16,960
sulfide and octopus spring water so what

387
00:15:20,330 --> 00:15:19,150
are these organisms and the hot springs

388
00:15:22,230 --> 00:15:20,340

doing for a living

389
00:15:24,300 --> 00:15:22,240
we've been messing around with that

390
00:15:25,950 --> 00:15:24,310
question for about the last 20 years and

391
00:15:27,720 --> 00:15:25,960
we've looked a ribosome RNA

392
00:15:29,430 --> 00:15:27,730
other gene sequences in a lot of

393
00:15:32,270 --> 00:15:29,440
Yellowstone Hot Springs over the years

394
00:15:34,530 --> 00:15:32,280
and when we first started accumulating

395
00:15:35,970 --> 00:15:34,540
sequences all we could say is that jeez

396
00:15:37,620 --> 00:15:35,980
these organisms are really different

397
00:15:39,570 --> 00:15:37,630
from anything that we know about but

398
00:15:42,180 --> 00:15:39,580
then also over the over the years

399
00:15:44,010 --> 00:15:42,190
cultivars claw cultured organisms came

400
00:15:46,410 --> 00:15:44,020
out that will now allow us to reflect

401
00:15:48,570 --> 00:15:46,420
the kinds of organisms that we see in

402
00:15:51,180 --> 00:15:48,580
the Yellowstone Hot Springs to those

403
00:15:53,610 --> 00:15:51,190
which have been examined in culture and

404
00:15:56,040 --> 00:15:53,620
the bottom line is that roughly 80% of

405
00:15:58,020 --> 00:15:56,050
the kinds of organisms we've seen over

406
00:16:00,420 --> 00:15:58,030
the years in Yellowstone Hot Springs are

407
00:16:02,810 --> 00:16:00,430
the kinds of organisms that only are

408
00:16:05,070 --> 00:16:02,820
known to eat hydrogen for a live

409
00:16:06,540 --> 00:16:05,080
hydrogen who would have thought of

410
00:16:08,730 --> 00:16:06,550
hydrogen in Yellowstone Hot Springs

411
00:16:10,920 --> 00:16:08,740
would now going back to measured a lot

412
00:16:13,080 --> 00:16:10,930
of hydrogen and a lot of lot of

413
00:16:16,350 --> 00:16:13,090

Yellowstone Hot Springs hate all of them

414
00:16:19,380 --> 00:16:16,360
have hydrogen from 15 an animal or two

415
00:16:21,870 --> 00:16:19,390
up to 300 an animal in the waters of

416
00:16:24,390 --> 00:16:21,880
these Hot Springs and even 15 Manta

417
00:16:27,510 --> 00:16:24,400
molars fat city if you can eat hydrogen

418
00:16:28,920 --> 00:16:27,520
for a living so that's one arena have

419
00:16:31,110 --> 00:16:28,930
studied another arena it's been a

420
00:16:33,690 --> 00:16:31,120
particular interest to them to the NAI

421
00:16:37,170 --> 00:16:33,700
his studies at the Guerrero negra hyper

422
00:16:39,630 --> 00:16:37,180
saline microbial mat folks at nai Ames

423
00:16:42,510 --> 00:16:39,640
have for many years been studying this

424
00:16:44,670 --> 00:16:42,520
site isn't as an example of a of an

425
00:16:46,500 --> 00:16:44,680
ecosystem microbial ecosystem you could

426
00:16:49,140 --> 00:16:46,510
hope to get a take on what what's

427
00:16:50,850 --> 00:16:49,150
supporting the Gulf grown a grow is a

428
00:16:53,280 --> 00:16:50,860
small town about halfway down the

429
00:16:55,230 --> 00:16:53,290
western coast of Baja California here

430
00:16:56,580 --> 00:16:55,240
seen here in an aerial view and the

431
00:16:59,300 --> 00:16:56,590
interesting thing about it is that

432
00:17:02,670 --> 00:16:59,310
there's a Salt Works they're producing

433
00:17:05,100 --> 00:17:02,680
industrial grade salt there's a cartoon

434
00:17:06,780 --> 00:17:05,110
in this Lagoon water is taken out and

435
00:17:09,480 --> 00:17:06,790
then in backwards do they moves up

436
00:17:11,970 --> 00:17:09,490
through a series of pools to ultimately

437
00:17:14,340 --> 00:17:11,980
crystallize and there's a lot of life in

438
00:17:17,910 --> 00:17:14,350

these in these in these pools there's a

439
00:17:19,560 --> 00:17:17,920
quite dense microbial mat from 5 to 8 or

440
00:17:22,140 --> 00:17:19,570
so centimeters thick about the

441
00:17:24,240 --> 00:17:22,150
consistency of tofu a photosynthetic

442
00:17:26,240 --> 00:17:24,250
driven community which we've been

443
00:17:30,330 --> 00:17:26,250
studying so here's an example this tofu

444
00:17:32,730 --> 00:17:30,340
no one's had nerve yet to have a

445
00:17:35,590 --> 00:17:32,740
barbecue with this stuff

446
00:17:38,139 --> 00:17:35,600
in any case we take core samples and

447
00:17:40,450 --> 00:17:38,149
chop these down into into layers to

448
00:17:42,850 --> 00:17:40,460
studies of microbial makeup by virtue of

449
00:17:44,799 --> 00:17:42,860
the ribosomal RNA distribution we've

450
00:17:48,220 --> 00:17:44,809
studied quite a few of these now we have

451
00:17:50,259 --> 00:17:48,230
about 140,000 ribosomal RNA gene

452
00:17:52,120 --> 00:17:50,269
sequences from this environment and it's

453
00:17:54,389 --> 00:17:52,130
by far the most complex environment

454
00:17:56,649 --> 00:17:54,399
that's ever been studied in this way

455
00:17:58,570 --> 00:17:56,659
who's an interest in community as you

456
00:18:01,120 --> 00:17:58,580
get up toward the high salinity levels

457
00:18:03,430 --> 00:18:01,130
you begin to see salt crystals dropping

458
00:18:05,769 --> 00:18:03,440
out along with gypsum giving a gypsum

459
00:18:08,139 --> 00:18:05,779
halite structures like these it looks

460
00:18:10,480 --> 00:18:08,149
like a pretty lifeless place but if you

461
00:18:12,789 --> 00:18:10,490
take one of these chunks and cut it over

462
00:18:14,950 --> 00:18:12,799
then you see the in reality that's shot

463
00:18:17,830 --> 00:18:14,960

through with microbial biomass this is a

464
00:18:20,019 --> 00:18:17,840
chunk of this gypsum halite so you see

465
00:18:22,779 --> 00:18:20,029
the colors the photosynthetic colors at

466
00:18:24,759 --> 00:18:22,789
the microbes stratifying in the in the

467
00:18:26,139 --> 00:18:24,769
salt crystals and including some sort of

468
00:18:28,180 --> 00:18:26,149
larvae and here munching on the

469
00:18:30,070 --> 00:18:28,190
microbial biomass there are lots of

470
00:18:33,129 --> 00:18:30,080
eukaryotes in this environment as well

471
00:18:34,810 --> 00:18:33,139
most any motives as it turns out so we

472
00:18:37,090 --> 00:18:34,820
can get a take on the diversity by

473
00:18:38,889 --> 00:18:37,100
looking at the ribosomal RNA gene

474
00:18:41,799 --> 00:18:38,899
sequence population just as an example

475
00:18:43,960 --> 00:18:41,809
of that this is the detail of this isn't

476
00:18:45,580 --> 00:18:43,970
important to say versus the relationship

477
00:18:48,310 --> 00:18:45,590
of the ribosomal RNA sequence is a

478
00:18:51,340 --> 00:18:48,320
number of operational taxonomic units so

479
00:18:53,590 --> 00:18:51,350
if you if you summed over this line you

480
00:18:56,680 --> 00:18:53,600
have a representation of the diversity

481
00:18:59,499 --> 00:18:56,690
of the guerrero negra microbial mat and

482
00:19:02,289 --> 00:18:59,509
if you summed under this line you would

483
00:19:02,740 --> 00:19:02,299
get the complexity of the human gut the

484
00:19:04,119 --> 00:19:02,750
mouse

485
00:19:05,799 --> 00:19:04,129
distal got both of which would be

486
00:19:09,129 --> 00:19:05,809
considered complex systems but

487
00:19:12,100 --> 00:19:09,139
overwhelmed by the situation in guerrero

488
00:19:14,799 --> 00:19:12,110

negra we probably understand why that

489
00:19:16,629 --> 00:19:14,809
extensive diversity because in these out

490
00:19:18,399 --> 00:19:16,639
in the anoxic environments it's

491
00:19:20,259 --> 00:19:18,409
represented by these microbial mats

492
00:19:22,330 --> 00:19:20,269
there's no oxygen when you get below a

493
00:19:23,889 --> 00:19:22,340
millimeter or two when these are in

494
00:19:25,450 --> 00:19:23,899
these Antarctic environment you can

495
00:19:27,580 --> 00:19:25,460
accumulate a lot of biochemical

496
00:19:29,259 --> 00:19:27,590
gradients that would be rapidly sorted

497
00:19:32,080 --> 00:19:29,269
out if you will chemically by exposure

498
00:19:34,210 --> 00:19:32,090
to oxygen so that high level of

499
00:19:36,210 --> 00:19:34,220
complexity of organic chemistry makes

500
00:19:40,810 --> 00:19:36,220
for high levels of complexity of

501
00:19:43,419 --> 00:19:40,820
microbial species as well we've done the

502
00:19:44,760 --> 00:19:43,429
same business of ribosomal RNA and other

503
00:19:47,010 --> 00:19:44,770
gene sequence analysis

504
00:19:48,870 --> 00:19:47,020
a lot of areas over the world we've

505
00:19:52,130 --> 00:19:48,880
studied hydrothermal vents ranging from

506
00:19:54,990 --> 00:19:52,140
black smokers to tubeworms for example

507
00:19:57,060 --> 00:19:55,000
you studied acid mine drainage this

508
00:19:59,520 --> 00:19:57,070
photograph was taken inside Iron

509
00:20:03,140 --> 00:19:59,530
Mountain in California's water running

510
00:20:06,330 --> 00:20:03,150
out of there's very acidic pH 0.1 and

511
00:20:08,610 --> 00:20:06,340
loaded the really nasty metals and yet

512
00:20:10,500 --> 00:20:08,620
look at all that luxurious microbial

513
00:20:15,270 --> 00:20:10,510

growth being sapped at here by Brett

514
00:20:17,040 --> 00:20:15,280
Goble the open ocean you think of life

515
00:20:19,350 --> 00:20:17,050
in the open ocean you tend to think of

516
00:20:21,900 --> 00:20:19,360
fish and seals and whales and stuff like

517
00:20:24,030 --> 00:20:21,910
that man forget it in terms of overall

518
00:20:26,420 --> 00:20:24,040
contribution of biomass and the open

519
00:20:28,890 --> 00:20:26,430
oceans the game is the microbial world

520
00:20:31,350 --> 00:20:28,900
it's a wonderful picture which I got

521
00:20:34,530 --> 00:20:31,360
from Jed Fuhrman this is a fluorescence

522
00:20:36,600 --> 00:20:34,540
pic a little bit of seawater it was

523
00:20:39,720 --> 00:20:36,610
stained with the with the duck die cyber

524
00:20:41,910 --> 00:20:39,730
green which again binds to DNA so this

525
00:20:44,340 --> 00:20:41,920
is life in the ocean this is most of way

526
00:20:46,080 --> 00:20:44,350
more than 995 personal life in the ocean

527
00:20:48,990 --> 00:20:46,090
if you see a little bit of chlorophyll

528
00:20:51,330 --> 00:20:49,000
fluorescence hearing these large actual

529
00:20:53,220 --> 00:20:51,340
eukaryotic organisms probably eukaryotic

530
00:20:55,110 --> 00:20:53,230
organisms they see these little blobs

531
00:20:57,510 --> 00:20:55,120
here in this photograph

532
00:21:00,090 --> 00:20:57,520
those are bacteria so-called marine eco

533
00:21:01,770 --> 00:21:00,100
plankton each about only half a micron

534
00:21:03,810 --> 00:21:01,780
in diameter and the thing that

535
00:21:06,150 --> 00:21:03,820
fascinates me about this photograph is

536
00:21:08,940 --> 00:21:06,160
beyond the little blobs of the bacteria

537
00:21:12,810 --> 00:21:08,950
all these little dots all these little

538
00:21:16,680 --> 00:21:12,820

dots viruses wherever you look the virus

539
00:21:18,330 --> 00:21:16,690
to cell count is ten to one you look and

540
00:21:20,850 --> 00:21:18,340
that virus community of course is

541
00:21:23,940 --> 00:21:20,860
carrying around meta-genome if you will

542
00:21:26,190 --> 00:21:23,950
of the largest biome on the planet the

543
00:21:28,110 --> 00:21:26,200
ocean is the largest biome on the planet

544
00:21:30,390 --> 00:21:28,120
70% of the earth's surface on average

545
00:21:35,690 --> 00:21:30,400
four kilometres deep that compares with

546
00:21:38,310 --> 00:21:35,700
our 30% of our aerobic tour our air

547
00:21:40,920 --> 00:21:38,320
terrestrial if you will 30 percent of

548
00:21:43,170 --> 00:21:40,930
the world's surface only called it 20

549
00:21:45,210 --> 00:21:43,180
meters deep largest biome on the planet

550
00:21:49,950 --> 00:21:45,220
a very little understood very little

551
00:21:53,070 --> 00:21:49,960
known about it it's nice to go out

552
00:21:54,630 --> 00:21:53,080
nature and look at the life most people

553
00:21:55,670 --> 00:21:54,640
when they go to Yosemite would look at

554
00:21:57,560 --> 00:21:55,680
the trees and the

555
00:22:00,170 --> 00:21:57,570
or whatever else is that Yosemite that's

556
00:22:02,450 --> 00:22:00,180
big and walks around I like to look at

557
00:22:04,910 --> 00:22:02,460
things like the stains up on the rocks

558
00:22:06,560 --> 00:22:04,920
stains pigments the microorganisms

559
00:22:08,360 --> 00:22:06,570
living on the surface of the rock and

560
00:22:11,840 --> 00:22:08,370
you'll know to gets black I'm here my

561
00:22:14,570 --> 00:22:11,850
bridal veil falls that's water drives

562
00:22:16,580 --> 00:22:14,580
life pigments photosynthetic pigments

563
00:22:18,680 --> 00:22:16,590

the life is out there not only on the

564
00:22:21,080 --> 00:22:18,690
surface of the rock if you took a chunk

565
00:22:22,400 --> 00:22:21,090
of this rock and broke it off if you

566
00:22:24,080 --> 00:22:22,410
don't do it there we'll do it somewhere

567
00:22:26,450 --> 00:22:24,090
else will go out behind my house and the

568
00:22:28,010 --> 00:22:26,460
Flatirons study a graduate student Jeff

569
00:22:30,650 --> 00:22:28,020
Walker Jeff Walker when he was a

570
00:22:33,530 --> 00:22:30,660
graduate student study of these endo

571
00:22:36,590 --> 00:22:33,540
lytic microbial communities and lit the

572
00:22:38,840 --> 00:22:36,600
inside rock so if you look at a piece of

573
00:22:40,520 --> 00:22:38,850
flat iron sandstone for example that's

574
00:22:42,020 --> 00:22:40,530
what it looks like on the surface and it

575
00:22:44,570 --> 00:22:42,030
cut off a chunk that's what it looks

576
00:22:46,460 --> 00:22:44,580
like here's the service and greening

577
00:22:49,340 --> 00:22:46,470
stuff and other colors into the penet

578
00:22:50,770 --> 00:22:49,350
penetrating the rock there's a scale one

579
00:22:52,490 --> 00:22:50,780
millimeter and you can see that this

580
00:22:55,010 --> 00:22:52,500
coloration that you can see with your

581
00:22:57,200 --> 00:22:55,020
eye extends about a centimeter into the

582
00:22:59,030 --> 00:22:57,210
rock rock it's actually remarkably

583
00:23:01,700 --> 00:22:59,040
transparent at least a lot of it is in

584
00:23:03,890 --> 00:23:01,710
this photograph Jeff put a flash on up

585
00:23:06,500 --> 00:23:03,900
here and then shot it off and took a

586
00:23:08,180 --> 00:23:06,510
photograph at right angles to him you

587
00:23:10,070 --> 00:23:08,190
could see the light penetrates the rock

588
00:23:12,500 --> 00:23:10,080

pretty well in effectively if the rock

589
00:23:14,660 --> 00:23:12,510
were if the rock were wet so the one

590
00:23:17,210 --> 00:23:14,670
could get reflectance around the silica

591
00:23:18,740 --> 00:23:17,220
grains would go very much deeper four

592
00:23:21,080 --> 00:23:18,750
point yes there's plenty of energy out

593
00:23:22,700 --> 00:23:21,090
there in fact living in the rock is a

594
00:23:24,500 --> 00:23:22,710
good place to live some places on the

595
00:23:26,720 --> 00:23:24,510
planet for example and the Dry Valleys

596
00:23:29,420 --> 00:23:26,730
of Antarctica that's the only kind of

597
00:23:32,510 --> 00:23:29,430
light that you find now these are all

598
00:23:33,710 --> 00:23:32,520
rather exotic places compared to us and

599
00:23:35,060 --> 00:23:33,720
so I thought I would show you another

600
00:23:37,430 --> 00:23:35,070
project that we're currently involved

601
00:23:39,500 --> 00:23:37,440
with is studying the microbiology of the

602
00:23:41,720 --> 00:23:39,510
indoor environment it's all around us

603
00:23:43,520 --> 00:23:41,730
there's postdoc Laura Baumgartner

604
00:23:45,890 --> 00:23:43,530
collecting air in the New York City

605
00:23:49,070 --> 00:23:45,900
Subway which turns out to be a pretty

606
00:23:51,740 --> 00:23:49,080
interesting place microbiologically or

607
00:23:54,680 --> 00:23:51,750
even this room if I take a deep breath I

608
00:23:56,660 --> 00:23:54,690
probably suck in something like a couple

609
00:23:58,820 --> 00:23:56,670
thousand bacteria something like that

610
00:24:01,460 --> 00:23:58,830
what are they mostly don't know what

611
00:24:03,320 --> 00:24:01,470
kinds of organisms are all around us or

612
00:24:10,279 --> 00:24:03,330
if you happen to take a shower in the

613
00:24:25,510 --> 00:24:17,549

well sorry guys it's what you get for

614
00:24:29,030 --> 00:24:27,530
so if you take a shower in the morning

615
00:24:31,490 --> 00:24:29,040
and if you look at your shower curtain

616
00:24:33,080 --> 00:24:31,500
let's age is white speckles down at the

617
00:24:36,650 --> 00:24:33,090
bottom of this shower curtain we call it

618
00:24:38,210 --> 00:24:36,660
so scum some young early well if you

619
00:24:40,460 --> 00:24:38,220
scrape off a little bit of that soap

620
00:24:43,130 --> 00:24:40,470
scum and put it onto a microscope slide

621
00:24:44,060 --> 00:24:43,140
and staining with a dna-binding die

622
00:24:46,940 --> 00:24:44,070
Daffy

623
00:24:49,670 --> 00:24:46,950
there's your soap scum and when you turn

624
00:24:52,330 --> 00:24:49,680
your shower on and it blasts up a little

625
00:24:55,520 --> 00:24:52,340
bit of that soap scum into an aerosol

626
00:24:57,020 --> 00:24:55,530
you breathe kinds of organisms are those

627
00:24:58,400 --> 00:24:57,030
well we mostly don't know we can

628
00:25:00,020 --> 00:24:58,410
actually tell you we've studied shower

629
00:25:00,650 --> 00:25:00,030
curtain soaps comes I can tell you a lot

630
00:25:02,540 --> 00:25:00,660
about it

631
00:25:04,310 --> 00:25:02,550
they also there's a lot of variation

632
00:25:08,360 --> 00:25:04,320
nothing dangerous unless you are moon

633
00:25:11,090 --> 00:25:08,370
compromised or having open wound we

634
00:25:13,220 --> 00:25:11,100
indeed are embedded in a microbial world

635
00:25:15,200 --> 00:25:13,230
ladies and gentlemen well these studies

636
00:25:17,360 --> 00:25:15,210
over the over the years now really

637
00:25:19,610 --> 00:25:17,370
expanded pretty dramatically our view of

638
00:25:21,919 --> 00:25:19,620

microbial diversity so this is just a

639
00:25:25,669 --> 00:25:21,929
plot which Dan Frank did it stopped

640
00:25:28,640 --> 00:25:25,679
around in my mid 2005 here's the

641
00:25:30,440 --> 00:25:28,650
accumulation of sequences of cultured

642
00:25:32,360 --> 00:25:30,450
organisms actually mostly the same

643
00:25:34,880 --> 00:25:32,370
organism lots of eco lies lots of

644
00:25:36,560 --> 00:25:34,890
Salmonella here the environmental seed

645
00:25:39,910 --> 00:25:36,570
was not being picked at picking up as

646
00:25:42,169 --> 00:25:39,920
the technology has improved and so in

647
00:25:45,080 --> 00:25:42,179
mid-2005 the number of environmental

648
00:25:46,940 --> 00:25:45,090
sequences in the database past the

649
00:25:48,919 --> 00:25:46,950
number of cultured those number of those

650
00:25:51,080 --> 00:25:48,929
sequences from cultured organisms and

651
00:25:53,299 --> 00:25:51,090
it's really screamed up now either now

652
00:25:55,580 --> 00:25:53,309
there's probably in the order of 400,000

653
00:25:58,970 --> 00:25:55,590
ribosomal RNA gene sequences in the

654
00:26:01,430 --> 00:25:58,980
databases this has really expanded our

655
00:26:03,740 --> 00:26:01,440
view of diversity as well what I mean by

656
00:26:05,990 --> 00:26:03,750
that this is what's happened to

657
00:26:09,260 --> 00:26:06,000
bacterial diversity over the past 20

658
00:26:09,950 --> 00:26:09,270
years this is a cartoon of a bacterial

659
00:26:12,140 --> 00:26:09,960
diversity

660
00:26:14,210 --> 00:26:12,150
each of these lines itself is a

661
00:26:17,330 --> 00:26:14,220
radiation of different kinds of bacteria

662
00:26:19,580 --> 00:26:17,340
these would represent the main file of

663
00:26:22,340 --> 00:26:19,590

bacteria the divisions of bacteria

664
00:26:25,430 --> 00:26:22,350
different kinds of bacteria is a cartoon

665
00:26:29,630 --> 00:26:25,440
of diversity if you will when Carlos

666
00:26:31,100 --> 00:26:29,640
could first do this summary in 1987 at

667
00:26:33,340 --> 00:26:31,110
that time there were 12 of these

668
00:26:35,380 --> 00:26:33,350
divisions all of which had called

669
00:26:36,460 --> 00:26:35,390
representation none with uncultured

670
00:26:38,620 --> 00:26:36,470
representation

671
00:26:40,900 --> 00:26:38,630
after a decade things really begin to

672
00:26:43,299 --> 00:26:40,910
expand we were up to about 36 divinity

673
00:26:44,799 --> 00:26:43,309
of these divisions about 20 of which

674
00:26:46,960 --> 00:26:44,809
were culture they're indicated by the

675
00:26:48,820 --> 00:26:46,970
bold lines the lighter lines or

676
00:26:53,289 --> 00:26:48,830
environmental sequences that have no

677
00:26:54,520 --> 00:26:53,299
culture of representation by today 2007

678
00:26:57,070 --> 00:26:54,530
were up to about a hundred of these

679
00:26:58,779 --> 00:26:57,080
bacterial divisions only about 30

680
00:27:01,779 --> 00:26:58,789
returning as generous have cultured

681
00:27:04,210 --> 00:27:01,789
representation and a 70 or so have no

682
00:27:06,340 --> 00:27:04,220
cultured representation at this time and

683
00:27:08,740 --> 00:27:06,350
all of these hundred or so bacterial

684
00:27:10,750 --> 00:27:08,750
Mane phyla only seven have any

685
00:27:12,789 --> 00:27:10,760
significant cultural representation

686
00:27:14,169 --> 00:27:12,799
those are the plates those are the

687
00:27:17,080 --> 00:27:14,179
relatedness groups that contain a

688
00:27:20,200 --> 00:27:17,090

pathogen microbiology study of diversity

689
00:27:23,919 --> 00:27:20,210
has heavily been directed by medical

690
00:27:25,990 --> 00:27:23,929
relevance so this is a cartoon then of

691
00:27:30,010 --> 00:27:26,000
what I think the big tree looks like at

692
00:27:32,230 --> 00:27:30,020
this time so the bacteria more than 70

693
00:27:33,909 --> 00:27:32,240
about a hundred at this stage just put

694
00:27:36,460 --> 00:27:33,919
some names on these I will pick through

695
00:27:38,200 --> 00:27:36,470
it archaea two main groups seemingly at

696
00:27:41,110 --> 00:27:38,210
this time crenarchaeota and Yuri are

697
00:27:43,510 --> 00:27:41,120
Kyoto and rather more complex picture of

698
00:27:45,730 --> 00:27:43,520
eukaryotes and more controversial tree I

699
00:27:47,830 --> 00:27:45,740
put some fuzz around the base of these

700
00:27:49,870 --> 00:27:47,840
radiations just to indicate the

701
00:27:51,669 --> 00:27:49,880
uncertainty of the radiations I don't

702
00:27:55,870 --> 00:27:51,679
want to get tied up with that at this

703
00:27:58,230 --> 00:27:55,880
stage of the game here so our view of

704
00:28:00,279 --> 00:27:58,240
Biological Diversity at this stage is

705
00:28:02,799 --> 00:28:00,289
approximately this with respect to

706
00:28:05,289 --> 00:28:02,809
overall genome evolution if you will and

707
00:28:07,690 --> 00:28:05,299
let's do remember that genomes are more

708
00:28:11,080 --> 00:28:07,700
complex than ribosomal RNA genes alone

709
00:28:13,659 --> 00:28:11,090
but this does represent a rough map of

710
00:28:15,490 --> 00:28:13,669
the course of terrestrial evolution

711
00:28:17,380 --> 00:28:15,500
absolutely wonderful and it's a

712
00:28:19,720 --> 00:28:17,390
measurement it's not a guess it's

713
00:28:23,470 --> 00:28:19,730

imagining rough to be sure but it's a

714
00:28:28,840 --> 00:28:23,480
measurement that brings me to my final

715
00:28:32,020 --> 00:28:28,850
topic we need to change the way that we

716
00:28:33,850 --> 00:28:32,030
think about terrestrial biological

717
00:28:39,490 --> 00:28:33,860
diversity and it's not being done well

718
00:28:42,460 --> 00:28:39,500
at this time we need to do away with

719
00:28:45,620 --> 00:28:42,470
this notion of prokaryote there isn't

720
00:28:51,630 --> 00:28:49,260
and it's more than terminology this is

721
00:28:54,300 --> 00:28:51,640
much more than terminology it speaks to

722
00:28:58,580 --> 00:28:54,310
the very foundations on which biological

723
00:29:00,480 --> 00:28:58,590
thought rests and I'll defend that I

724
00:29:02,340 --> 00:29:00,490
don't care what the scientific

725
00:29:05,520 --> 00:29:02,350
discipline discipline is there are

726
00:29:07,260 --> 00:29:05,530
basically two things two issues that the

727
00:29:09,960 --> 00:29:07,270
discipline worries about the discipline

728
00:29:12,030 --> 00:29:09,970
has to worry about order this would be

729
00:29:13,830 --> 00:29:12,040
the organization and relationships of

730
00:29:15,270 --> 00:29:13,840
the things that you would study so for

731
00:29:17,670 --> 00:29:15,280
example the chemist would study the

732
00:29:21,180 --> 00:29:17,680
periodic table the biologists would

733
00:29:23,250 --> 00:29:21,190
study phylogenetic relationships the

734
00:29:25,410 --> 00:29:23,260
other fundamental thing that any science

735
00:29:29,550 --> 00:29:25,420
worries about is how what one studies

736
00:29:31,140 --> 00:29:29,560
changes how things evolved so for

737
00:29:33,510 --> 00:29:31,150
example the astronomers were studying

738
00:29:35,550 --> 00:29:33,520

the hertzsprung-russell star series to

739
00:29:38,040 --> 00:29:35,560
understand the evolution of stars the

740
00:29:39,960 --> 00:29:38,050
function of stars the biochemist was

741
00:29:42,320 --> 00:29:39,970
studying biochemical mechanisms the

742
00:29:45,690 --> 00:29:42,330
chemistry study radioactive decay and

743
00:29:48,480 --> 00:29:45,700
biologists now have a metric with which

744
00:29:53,580 --> 00:29:48,490
to understand biological change the tree

745
00:29:56,460 --> 00:29:53,590
of life there's the tree of life I don't

746
00:30:00,240 --> 00:29:56,470
see a prokaryote on their ceiling about

747
00:30:03,210 --> 00:30:00,250
prokaryotes in there that's a

748
00:30:07,500 --> 00:30:03,220
measurement a map a lot of hypotheses a

749
00:30:11,060 --> 00:30:07,510
rough map an important issue of that map

750
00:30:13,890 --> 00:30:11,070
is that the prokaryote eukaryote concept

751
00:30:16,200 --> 00:30:13,900
two kinds of organisms prokaryotes

752
00:30:22,860 --> 00:30:16,210
giving rise to eukaryotes it's wrong

753
00:30:25,580 --> 00:30:22,870
flat-out wrong flat-out wrong idea for

754
00:30:32,070 --> 00:30:25,590
the essence of biological thought

755
00:30:33,600 --> 00:30:32,080
organization and evolution well here's

756
00:30:35,280 --> 00:30:33,610
where I came from I already mentioned

757
00:30:37,410 --> 00:30:35,290
that to you this is where prokaryote

758
00:30:40,380 --> 00:30:37,420
eukaryote came from right out of the

759
00:30:43,470 --> 00:30:40,390
19th century so heckle had his monera

760
00:30:47,370 --> 00:30:43,480
down here plants and protists and

761
00:30:50,880 --> 00:30:47,380
animals as I already mentioned in 1960s

762
00:30:53,610 --> 00:30:50,890
in 1960s mycologist by the name of

763
00:30:55,050 --> 00:30:53,620

Whitaker club gone funky because he

764
00:30:57,370 --> 00:30:55,060
thought they were born and indeed they

765
00:31:00,210 --> 00:30:57,380
are and

766
00:31:05,980 --> 00:31:00,220
named monera was changed to prokaryote

767
00:31:10,660 --> 00:31:05,990
nothing else happened prokaryote means

768
00:31:13,840 --> 00:31:10,670
non eukaryote nothing more not being

769
00:31:17,080 --> 00:31:13,850
something is not a scientifically valid

770
00:31:20,200 --> 00:31:17,090
concept or name rain Rousseff's name is

771
00:31:24,520 --> 00:31:20,210
a prokaryote no one can tell me what is

772
00:31:26,410 --> 00:31:24,530
prokaryote only what it is not well

773
00:31:28,600 --> 00:31:26,420
we're scientists let's test that

774
00:31:30,580 --> 00:31:28,610
prokaryote eukaryote Marlon here's what

775
00:31:32,350 --> 00:31:30,590
I mean by the prokaryote eukaryote model

776
00:31:34,390 --> 00:31:32,360
I think the most students coming out of

777
00:31:38,800 --> 00:31:34,400
university education looking this is

778
00:31:40,750 --> 00:31:38,810
what they believe here's a cartoon the

779
00:31:42,900 --> 00:31:40,760
cartoon is the prokaryotes are a group

780
00:31:46,240 --> 00:31:42,910
they gave rise to eukaryotes eukaryotes

781
00:31:49,300 --> 00:31:46,250
are of a kind ie all eukaryotes that

782
00:31:52,500 --> 00:31:49,310
triangle while prokaryotes are of a kind

783
00:31:55,570 --> 00:31:52,510
related to each other to exclusion

784
00:31:58,470 --> 00:31:55,580
variants there are two forms of cellular

785
00:32:02,170 --> 00:31:58,480
organization function prokaryotic type

786
00:32:04,720 --> 00:32:02,180
eukaryotic type prokaryotes is kind of a

787
00:32:08,320 --> 00:32:04,730
sub line here prokaryotes are simpler

788
00:32:11,440 --> 00:32:08,330

than eukaryotes and finally that

789
00:32:13,270 --> 00:32:11,450
prokaryotes gave rise to more advanced

790
00:32:15,580 --> 00:32:13,280
eukaryotes and there's any number of

791
00:32:18,280 --> 00:32:15,590
models where archaea fused with bacteria

792
00:32:21,940 --> 00:32:18,290
and who knows what but prokaryotes gave

793
00:32:24,340 --> 00:32:21,950
rise to eukaryotes would be the model we

794
00:32:27,310 --> 00:32:24,350
now have a database with which to test

795
00:32:28,920 --> 00:32:27,320
that model just put under the table

796
00:32:41,110 --> 00:32:28,930
again essentially in the 19th century

797
00:32:44,200 --> 00:32:41,120
modified so we can now test this notion

798
00:32:46,720 --> 00:32:44,210
of prokaryote eukaryote and here's the

799
00:32:48,910 --> 00:32:46,730
here's the model that we can test it

800
00:32:51,820 --> 00:32:48,920
against or rather the data the map that

801
00:32:53,800 --> 00:32:51,830
we can test it against so all eukaryotes

802
00:32:55,900 --> 00:32:53,810
are off a kind specifically related to

803
00:33:01,120 --> 00:32:55,910
one another that's true all you get into

804
00:33:03,550 --> 00:33:01,130
that triangle all prokaryotes are of a

805
00:33:05,680 --> 00:33:03,560
kind related to these because it's false

806
00:33:07,509 --> 00:33:05,690
there are two kinds of them there

807
00:33:08,950 --> 00:33:07,519
would be prokaryotes out there one of

808
00:33:11,139 --> 00:33:08,960
which is more closely related to

809
00:33:15,960 --> 00:33:11,149
eukaryotes than it is than either of

810
00:33:19,810 --> 00:33:18,070
there are two forms of cellular

811
00:33:21,369 --> 00:33:19,820
organization named you having nuclear

812
00:33:24,399 --> 00:33:21,379
membranes and not having nuclear

813
00:33:26,619 --> 00:33:24,409

membranes well there may be two forms or

814
00:33:29,049 --> 00:33:26,629
maybe three forms or maybe sixteen forms

815
00:33:31,480 --> 00:33:29,059
for all I know I do know that cellular

816
00:33:33,820 --> 00:33:31,490
organization is more complex far more

817
00:33:36,669 --> 00:33:33,830
complex than simply presence or absence

818
00:33:38,919 --> 00:33:36,679
of a nuclear membrane I think you

819
00:33:40,869 --> 00:33:38,929
shouldn't poison the question by edict

820
00:33:44,230 --> 00:33:40,879
that there are two forms of cellular

821
00:33:47,740 --> 00:33:44,240
organization and function these

822
00:33:49,629 --> 00:33:47,750
scientists shouldn't prokaryotes are

823
00:33:51,340 --> 00:33:49,639
simpler than eukaryotes well I argue

824
00:33:52,899 --> 00:33:51,350
that's not really an evolutionary issue

825
00:33:55,570 --> 00:33:52,909
at all it has to do with NIC niche

826
00:33:58,659 --> 00:33:55,580
occupancy yes it has evolutionary flavor

827
00:34:01,810 --> 00:33:58,669
to it but if I take a 2000 gene

828
00:34:04,180 --> 00:34:01,820
prochlorococcus and a 30,000 gene dog

829
00:34:06,700 --> 00:34:04,190
and drop them both out into the largest

830
00:34:08,680 --> 00:34:06,710
biome on the planet the open ocean which

831
00:34:14,409 --> 00:34:08,690
one do you think is going to make it's

832
00:34:16,559 --> 00:34:14,419
not going to be the dog and finally not

833
00:34:19,329 --> 00:34:16,569
concept that prokaryotes gave rise to

834
00:34:22,089 --> 00:34:19,339
eukaryotes that's false the eukaryotic

835
00:34:23,980 --> 00:34:22,099
nuclear line of descent this is old and

836
00:34:30,250 --> 00:34:23,990
derived from something more rudimentary

837
00:34:32,379 --> 00:34:30,260
than what became archaea so the

838
00:34:35,050 --> 00:34:32,389

eukaryotic nuclear line of descent is

839
00:34:37,540 --> 00:34:35,060
not derived from either archaea or

840
00:34:40,329 --> 00:34:37,550
bacteria rather from something far more

841
00:34:46,510 --> 00:34:40,339
rudimentary and certainly from neither

842
00:34:47,980 --> 00:34:46,520
archaea bacteria why am i incensed at

843
00:34:49,809 --> 00:34:47,990
this some of you out there will have

844
00:34:52,000 --> 00:34:49,819
heard me give you something like this

845
00:34:55,359 --> 00:34:52,010
story before why am i incensed about

846
00:34:57,160 --> 00:34:55,369
this well it's because truth is

847
00:34:58,930 --> 00:34:57,170
important and prokaryote is

848
00:35:01,510 --> 00:34:58,940
scientifically unjustified it was

849
00:35:03,130 --> 00:35:01,520
invented to fill a gap in knowledge we

850
00:35:05,890 --> 00:35:03,140
didn't know what that little stuff was

851
00:35:08,740 --> 00:35:05,900
and it was all dumped into monera

852
00:35:11,020 --> 00:35:08,750
aka Pro carrier the name has false

853
00:35:13,030 --> 00:35:11,030
implication in deep evolutionary matters

854
00:35:14,440 --> 00:35:13,040
the textbooks flat-out that will tell

855
00:35:16,180 --> 00:35:14,450
you that prokaryotes gave rise to

856
00:35:17,570 --> 00:35:16,190
eukaryotes on baby

857
00:35:19,420 --> 00:35:17,580
prokaryotes of

858
00:35:21,740 --> 00:35:19,430
will the bacteria gave rise to

859
00:35:24,050 --> 00:35:21,750
mitochondria no question and gave rise

860
00:35:28,550 --> 00:35:24,060
to the chloroplast no question but not

861
00:35:30,770 --> 00:35:28,560
the nuclear line of descent this false

862
00:35:32,960 --> 00:35:30,780
understanding quenches legitimate

863
00:35:35,210 --> 00:35:32,970

inquiry it is interesting to know what

864
00:35:36,890 --> 00:35:35,220
means cellular organization in archaea

865
00:35:41,180 --> 00:35:36,900
because it probably speaks through our

866
00:35:43,550 --> 00:35:41,190
own rather than bacteria and here's the

867
00:35:45,860 --> 00:35:43,560
one that really bums me prokaryote

868
00:35:48,530 --> 00:35:45,870
eukaryote teaches our students false

869
00:35:50,770 --> 00:35:48,540
concepts at the most fundamental levels

870
00:35:53,420 --> 00:35:50,780
of biological order and evolution

871
00:35:55,700 --> 00:35:53,430
biological order and evolution should be

872
00:35:57,650 --> 00:35:55,710
the foundation for biological thought

873
00:36:00,710 --> 00:35:57,660
and for progress and biological thought

874
00:36:04,580 --> 00:36:00,720
and prokaryote eukaryote models the

875
00:36:05,840 --> 00:36:04,590
issue but what else to call them well

876
00:36:07,910 --> 00:36:05,850
that of course depends on what you mean

877
00:36:10,040 --> 00:36:07,920
by them if you mean the little stuff out

878
00:36:12,110 --> 00:36:10,050
there dry microbes microbial life stop

879
00:36:13,910 --> 00:36:12,120
using the word it's harder to stop using

880
00:36:17,780 --> 00:36:13,920
that word prokaryote because it's so

881
00:36:20,300 --> 00:36:17,790
ingrained but try microbial microbes and

882
00:36:22,610 --> 00:36:20,310
this there's a lot of little weird

883
00:36:24,500 --> 00:36:22,620
mostly ignored eukaryotes out there too

884
00:36:26,840 --> 00:36:24,510
since I'm dissing them when dealing with

885
00:36:28,820 --> 00:36:26,850
the microbial world if you're talking

886
00:36:30,770 --> 00:36:28,830
function or evolutionary issues you need

887
00:36:32,960 --> 00:36:30,780
to be more precise than prokaryotes so

888
00:36:35,390 --> 00:36:32,970

for example how many textbook chapters

889
00:36:38,000 --> 00:36:35,400
are there on prokaryotic RNA synthesis a

890
00:36:39,890 --> 00:36:38,010
lot of them and they're not not very

891
00:36:42,860 --> 00:36:39,900
meaningful because they speak only to

892
00:36:45,620 --> 00:36:42,870
bacterial RNA synthesis or a bacterial

893
00:36:48,320 --> 00:36:45,630
protein synthesis for example whereas

894
00:36:50,030 --> 00:36:48,330
bacteria use Sigma factors to where

895
00:36:52,550 --> 00:36:50,040
transcription initiation for promoter

896
00:36:54,770 --> 00:36:52,560
selection so bacteria use Sigma factors

897
00:36:56,660 --> 00:36:54,780
and we eukaryotes we don't do that we

898
00:36:58,640 --> 00:36:56,670
use so-called tata binding proteins at

899
00:37:01,070 --> 00:36:58,650
different mechanism so dual archaea use

900
00:37:02,990 --> 00:37:01,080
tata binding proteins and crystal

901
00:37:05,390 --> 00:37:03,000
structures of the archaea tata binding

902
00:37:10,310 --> 00:37:05,400
protein inform our structures of the

903
00:37:12,440 --> 00:37:10,320
eukaryotic version so prokaryotic RNA

904
00:37:15,340 --> 00:37:12,450
synthesis prokaryotic protein synthesis

905
00:37:18,110 --> 00:37:15,350
that's an oxymoron doesn't mean anything

906
00:37:20,240 --> 00:37:18,120
humans conceptualize in language our

907
00:37:24,710 --> 00:37:20,250
students conceptualize in language we

908
00:37:26,740 --> 00:37:24,720
order our thought in language less than

909
00:37:29,960 --> 00:37:26,750
the language is the understanding

910
00:37:34,380 --> 00:37:29,970
prokaryote has to go

911
00:37:36,540 --> 00:37:34,390
it it's intellectually not defensible at

912
00:37:39,690 --> 00:37:36,550
this time those who would defend

913
00:37:45,360 --> 00:37:39,700

prokaryote simply don't understand deep

914
00:37:46,950 --> 00:37:45,370
issues in biological evolution thank you

915
00:37:48,630 --> 00:37:46,960
ladies and gentlemen a lot of people

916
00:37:51,660 --> 00:37:48,640
have been involved in this project over

917
00:37:53,760 --> 00:37:51,670
the years and I list them here not only

918
00:37:54,660 --> 00:37:53,770
the studies that I told you but a lot of

919
00:37:56,430 --> 00:37:54,670
others as well

920
00:38:02,360 --> 00:37:56,440
so thanks to you all and I'll be very

921
00:38:05,580 --> 00:38:02,370
happy to answer questions floor to Carl

922
00:38:07,710 --> 00:38:05,590
norm thank you very much I would just

923
00:38:10,470 --> 00:38:07,720
like to ask everybody who just heard

924
00:38:12,780 --> 00:38:10,480
this great talk to remind colleagues who

925
00:38:14,970 --> 00:38:12,790
weren't able to hear it that it will be

926
00:38:17,850 --> 00:38:14,980
archived on the NAI website and that

927
00:38:21,540 --> 00:38:17,860
should be up within a day or two and I'd

928
00:38:23,670 --> 00:38:21,550
like to take advantage of having the

929
00:38:25,950 --> 00:38:23,680
open mic to ask the first question and

930
00:38:28,350 --> 00:38:25,960
that is norm what conclusions do you

931
00:38:34,410 --> 00:38:28,360
draw from everything you've told us

932
00:38:36,180 --> 00:38:34,420
about about life off the earth well Carl

933
00:38:38,130 --> 00:38:36,190
I don't think we can say anything about

934
00:38:40,740 --> 00:38:38,140
life off the earth except by the

935
00:38:43,020 --> 00:38:40,750
extrapolation that we expect life

936
00:38:45,870 --> 00:38:43,030
anywhere in the universe to be organic

937
00:38:47,940 --> 00:38:45,880
chemistry it's likely that there will be

938
00:38:50,010 --> 00:38:47,950

minor differences from the kinds of life

939
00:38:53,130 --> 00:38:50,020
that we see on earth but I bet not a lot

940
00:38:54,990 --> 00:38:53,140
I would love to see by the way this

941
00:38:56,970 --> 00:38:55,000
again the life anywhere has the same

942
00:39:00,060 --> 00:38:56,980
constraints as life or nerves name it to

943
00:39:02,940 --> 00:39:00,070
grab energy and to convert something co2

944
00:39:04,890 --> 00:39:02,950
ultimately into organic material life

945
00:39:06,780 --> 00:39:04,900
does life on this planet does this in a

946
00:39:08,460 --> 00:39:06,790
number of ways and so I think if we see

947
00:39:10,830 --> 00:39:08,470
not the detail then at least the

948
00:39:17,070 --> 00:39:10,840
generality of how life would accomplish

949
00:39:22,110 --> 00:39:17,080
this any place in the universe beyond

950
00:39:23,310 --> 00:39:22,120
that it would be bad way thanks norm and

951
00:39:25,080 --> 00:39:23,320
I think I'm going to turn it over to

952
00:39:27,060 --> 00:39:25,090
Marko if you have a question would you

953
00:39:29,940 --> 00:39:27,070
please raise your hand on WebEx and

954
00:39:34,950 --> 00:39:29,950
Marco will call on people with raised

955
00:39:39,010 --> 00:39:37,270
well since we don't have any raised

956
00:39:47,530 --> 00:39:39,020
hands on WebEx would anybody like to

957
00:39:50,740 --> 00:39:47,540
jump in with the question okay yes Mike

958
00:39:54,250 --> 00:39:50,750
Mike Newman countered Boyd Norman that

959
00:39:56,559 --> 00:39:54,260
was a fantastic talk first of all but

960
00:40:00,970 --> 00:39:56,569
beyond that I really liked your analogy

961
00:40:04,510 --> 00:40:00,980
of the dog in the ocean and what it

962
00:40:08,799 --> 00:40:04,520
really made me suddenly jump back in my

963
00:40:11,559 --> 00:40:08,809

chair and think about was okay maybe in

964
00:40:14,880 --> 00:40:11,569
fact the highest life-forms have evolved

965
00:40:17,770 --> 00:40:14,890
to fill some niches that are so specific

966
00:40:20,049 --> 00:40:17,780
if you take them out of those niches or

967
00:40:23,410 --> 00:40:20,059
modify the niche in some way you then

968
00:40:26,020 --> 00:40:23,420
threaten the very survival of the life

969
00:40:27,790 --> 00:40:26,030
form itself and of course we're not

970
00:40:30,760 --> 00:40:27,800
going to throw six billion humans into

971
00:40:33,160 --> 00:40:30,770
the ocean but what if we I mean to what

972
00:40:36,970 --> 00:40:33,170
degree do you see that we we might

973
00:40:39,430 --> 00:40:36,980
actually be modifying those other Echo's

974
00:40:44,440 --> 00:40:39,440
forms that permit us to occupy this

975
00:40:46,480 --> 00:40:44,450
unique niche that we have I think that

976
00:40:47,380 --> 00:40:46,490
that's really an excellent from two

977
00:40:49,960 --> 00:40:47,390
standpoints

978
00:40:53,020 --> 00:40:49,970
number one is we humans are wrecking the

979
00:40:56,170 --> 00:40:53,030
planet and I sometimes to my students

980
00:40:58,539 --> 00:40:56,180
like to refer to the lash of Gaia which

981
00:41:01,329 --> 00:40:58,549
we will one day feel and really already

982
00:41:04,180 --> 00:41:01,339
are the other thing that microbial world

983
00:41:05,650 --> 00:41:04,190
offers is in analogy in the sense that

984
00:41:07,240 --> 00:41:05,660
there are basically two kinds of

985
00:41:09,970 --> 00:41:07,250
organisms there are organisms that

986
00:41:11,859 --> 00:41:09,980
conduct primary productivity that is

987
00:41:15,430 --> 00:41:11,869
captured some sort of energy and convert

988
00:41:17,289 --> 00:41:15,440

co2 into biomass the second kinds of

989
00:41:19,900 --> 00:41:17,299
organisms are so called heterotrophs

990
00:41:24,010 --> 00:41:19,910
these are the organisms that use the

991
00:41:26,680 --> 00:41:24,020
reduced carbon to drive themselves we

992
00:41:29,620 --> 00:41:26,690
humans need to take note of that as we

993
00:41:31,930 --> 00:41:29,630
continue to dig up and modify the planet

994
00:41:33,730 --> 00:41:31,940
in order to get it reduced carbon that

995
00:41:36,910 --> 00:41:33,740
we can burn in our automobiles and in

996
00:41:40,359 --> 00:41:36,920
our power plants we humans need to begin

997
00:41:42,640 --> 00:41:40,369
to note that as with biological settings

998
00:41:45,579 --> 00:41:42,650
anywhere we have to be able to harvest

999
00:41:46,250 --> 00:41:45,589
exogenous energy and for us humans that

1000
00:41:49,400 --> 00:41:46,260
means

1001
00:41:51,470 --> 00:41:49,410
or nuclear energy and we have to move to

1002
00:41:53,750 --> 00:41:51,480
that as soon as we very possibly can

1003
00:41:55,819 --> 00:41:53,760
because the return to the first point

1004
00:41:59,270 --> 00:41:55,829
there were rapidly poisoning the planet

1005
00:42:03,530 --> 00:41:59,280
either by co2 by other organic output

1006
00:42:05,569 --> 00:42:03,540
from human activities again the humans

1007
00:42:12,400 --> 00:42:05,579
need to pay attention or we won't live

1008
00:42:15,620 --> 00:42:12,410
very long in the comment on that yeah

1009
00:42:18,140 --> 00:42:15,630
points another one that I think is

1010
00:42:20,930 --> 00:42:18,150
really extremely relevant is the issue

1011
00:42:23,810 --> 00:42:20,940
of what unforeseen consequences might

1012
00:42:28,579 --> 00:42:23,820
you as a microbiologist think of in

1013
00:42:32,240 --> 00:42:28,589

terms of genetically modified plants

1014
00:42:34,609 --> 00:42:32,250
whose products will eat and one wonders

1015
00:42:36,890 --> 00:42:34,619
whether in fact over time this couldn't

1016
00:42:40,339 --> 00:42:36,900
cause internal genetic modifications

1017
00:42:41,390 --> 00:42:40,349
that could in fact in a relatively blink

1018
00:42:43,730 --> 00:42:41,400
of an eye

1019
00:42:49,040 --> 00:42:43,740
change the ability of humans to actually

1020
00:42:50,870 --> 00:42:49,050
survive well I think we humans are

1021
00:42:55,460 --> 00:42:50,880
pretty tough creatures unless we do it

1022
00:42:57,079 --> 00:42:55,470
ourselves I think yes things like

1023
00:42:59,210 --> 00:42:57,089
genetically modified plants could

1024
00:43:00,950 --> 00:42:59,220
introduce genes in the environment at

1025
00:43:02,900 --> 00:43:00,960
this stage of the game at least in terms

1026
00:43:04,579 --> 00:43:02,910
of US federal ready US federal

1027
00:43:06,859 --> 00:43:04,589
regulations you're not supposed to

1028
00:43:08,540 --> 00:43:06,869
introduce modified genomes into the

1029
00:43:09,140 --> 00:43:08,550
environment but of course it happens all

1030
00:43:11,030 --> 00:43:09,150
the time

1031
00:43:12,410 --> 00:43:11,040
and of course modification of genomes

1032
00:43:14,870 --> 00:43:12,420
and the environment happens all the time

1033
00:43:18,170 --> 00:43:14,880
need one mentioned only the spread of

1034
00:43:21,859 --> 00:43:18,180
antibiotic resistance on Earth's surface

1035
00:43:24,230 --> 00:43:21,869
our last lines of last hopes for

1036
00:43:27,040 --> 00:43:24,240
antibiotics are rapidly going away and

1037
00:43:29,390 --> 00:43:27,050
we certainly need to explore new ones so

1038
00:43:32,270 --> 00:43:29,400

just in summary I think we humans have

1039
00:43:32,750 --> 00:43:32,280
indeed already had a major impact on the

1040
00:43:37,160 --> 00:43:32,760
planet

1041
00:43:38,660 --> 00:43:37,170
we forced extinctions and you know I

1042
00:43:40,940 --> 00:43:38,670
used to be more optimistic about

1043
00:43:43,609 --> 00:43:40,950
humankind getting getting their act

1044
00:43:46,250 --> 00:43:43,619
together but now I'm less less

1045
00:43:47,690 --> 00:43:46,260
optimistic I rather fear that over the

1046
00:43:49,550 --> 00:43:47,700
next couple of hundred years we're going

1047
00:43:53,569 --> 00:43:49,560
to turn the planet into what is

1048
00:43:55,700 --> 00:43:53,579
modern-day Haiti and need one only

1049
00:43:56,300 --> 00:43:55,710
mention the ongoing population problem

1050
00:43:58,430 --> 00:43:56,310
which is not

1051
00:44:01,370 --> 00:43:58,440
even part of the political discourse it

1052
00:44:03,980 --> 00:44:01,380
seems to me so to repeat one could go on

1053
00:44:05,870 --> 00:44:03,990
about this but I think that yes we have

1054
00:44:25,310 --> 00:44:05,880
a lot of evidence for human impact yes

1055
00:44:27,860 --> 00:44:25,320
we can see a lot of organism presumably

1056
00:44:31,100 --> 00:44:27,870
you're starting to expand those three

1057
00:44:34,010 --> 00:44:31,110
triangles that you have would you expect

1058
00:44:41,440 --> 00:44:34,020
to be a sign that you have done the

1059
00:44:46,400 --> 00:44:44,450
well archaea and eukaryotes meet all the

1060
00:44:49,460 --> 00:44:46,410
time your guts are loaded with them for

1061
00:44:54,290 --> 00:44:49,470
example hmm we have a lot of methanogens

1062
00:44:55,640 --> 00:44:54,300
in us was a rakia so it just if you're

1063
00:44:58,940 --> 00:44:55,650

looking to see what the distribution

1064
00:45:00,890 --> 00:44:58,950
around the planet might be from the many

1065
00:45:02,810 --> 00:45:00,900
environments that we've looked at now if

1066
00:45:06,110 --> 00:45:02,820
I go out and grab a handful and do a

1067
00:45:08,720 --> 00:45:06,120
ribosomal RNA sequence analysis 90 to 99

1068
00:45:11,180 --> 00:45:08,730
percent of the ribosomal RNA genes I see

1069
00:45:14,000 --> 00:45:11,190
will be bacterial one to ten percent

1070
00:45:16,550 --> 00:45:14,010
will be party'll and one percent or less

1071
00:45:18,110 --> 00:45:16,560
will be eukaryotic unless you grab a

1072
00:45:21,950 --> 00:45:18,120
nematode wish you get a whole lot of

1073
00:45:23,480 --> 00:45:21,960
eukaryotic ribosomal RNA genes so and

1074
00:45:26,120 --> 00:45:23,490
we're all living together all of the

1075
00:45:28,220 --> 00:45:26,130
time I don't see that there's any place

1076
00:45:30,230 --> 00:45:28,230
to look you need really to look to see

1077
00:45:31,730 --> 00:45:30,240
where they meet the most extreme

1078
00:45:33,020 --> 00:45:31,740
environments some of the most extreme

1079
00:45:35,960 --> 00:45:33,030
environments we've looked at for example

1080
00:45:38,660 --> 00:45:35,970
the Guerrero neg row the Guerrero neg

1081
00:45:39,950 --> 00:45:38,670
row microbiome at hyper saline mat or

1082
00:45:42,260 --> 00:45:39,960
even the salt crystals there are

1083
00:45:44,690 --> 00:45:42,270
eukaryotic ribosomal RNA genes in there

1084
00:45:49,460 --> 00:45:44,700
not a lot of them but that's typical of

1085
00:45:51,170 --> 00:45:49,470
what we see around the planet not sure

1086
00:45:53,390 --> 00:45:51,180
whether I'm answering this question I'm

1087
00:45:55,670 --> 00:45:53,400
not sure that you are either so let me

1088
00:46:00,140 --> 00:45:55,680

let me go back you had for example

1089
00:46:02,930 --> 00:46:00,150
Giardia sitting at the nearly the tip of

1090
00:46:05,450 --> 00:46:02,940
the eukaryote sequence and presumably

1091
00:46:09,850 --> 00:46:05,460
there could be other things with even

1092
00:46:12,970 --> 00:46:09,860
fewer fewer inserts

1093
00:46:16,000 --> 00:46:12,980
into them from from bacterial lines and

1094
00:46:18,580 --> 00:46:16,010
I'm just wondering what what you would

1095
00:46:21,520 --> 00:46:18,590
be expecting to find as you as you found

1096
00:46:26,560 --> 00:46:21,530
things that were nearer and nearer to

1097
00:46:28,510 --> 00:46:26,570
the origin of the eukaryotes well we've

1098
00:46:31,390 --> 00:46:28,520
certainly been looking we haven't we've

1099
00:46:34,240 --> 00:46:31,400
seen gene sequences that of other

1100
00:46:36,340 --> 00:46:34,250
branches deep in the tree and they're

1101
00:46:38,470 --> 00:46:36,350
useful in the sense that it allows us to

1102
00:46:39,970 --> 00:46:38,480
deal phylogenetically with the

1103
00:46:43,000 --> 00:46:39,980
eukaryotic tree better

1104
00:46:45,040 --> 00:46:43,010
that's project Rhea the eukaryotes is

1105
00:46:46,480 --> 00:46:45,050
more controversial because if you use

1106
00:46:48,040 --> 00:46:46,490
other genes you get different sorts of

1107
00:46:50,800 --> 00:46:48,050
things the best information at this

1108
00:46:52,270 --> 00:46:50,810
stage of the game is that such lineages

1109
00:46:54,190 --> 00:46:52,280
the diplom own ads which would be

1110
00:46:56,710 --> 00:46:54,200
Giardia or the trichomonas which would

1111
00:46:58,780 --> 00:46:56,720
include trichomonas and some of these

1112
00:47:01,060 --> 00:46:58,790
deeply divergent lines that in

1113
00:47:04,300 --> 00:47:01,070

phylogenetic calculations are not long

1114
00:47:06,070 --> 00:47:04,310
lines and so from the ribosomal

1115
00:47:08,530 --> 00:47:06,080
perspective there is this basal

1116
00:47:10,690 --> 00:47:08,540
radiation of eukaryotes just like you

1117
00:47:12,910 --> 00:47:10,700
see a basal radiation in the bacteria

1118
00:47:15,730 --> 00:47:12,920
and a basal radiation in the archaea

1119
00:47:18,220 --> 00:47:15,740
Rose has written about this it all boils

1120
00:47:21,040 --> 00:47:18,230
down to these long blank lines at the

1121
00:47:23,470 --> 00:47:21,050
base of the individual domains those

1122
00:47:25,990 --> 00:47:23,480
long blank lines were probably a period

1123
00:47:28,630 --> 00:47:26,000
of evolution before the invention of

1124
00:47:30,940 --> 00:47:28,640
sufficient biochemical complexity that

1125
00:47:33,790 --> 00:47:30,950
the particular lineage could carry an

1126
00:47:35,470 --> 00:47:33,800
independent line of descent so Carlos's

1127
00:47:37,600 --> 00:47:35,480
pet Paine has painted those early days

1128
00:47:39,910 --> 00:47:37,610
of biochemical evolutions being very

1129
00:47:42,940 --> 00:47:39,920
communal when genes could move around

1130
00:47:44,770 --> 00:47:42,950
between replicating fossa however as the

1131
00:47:46,690 --> 00:47:44,780
biochemistry grew more sophisticated

1132
00:47:48,610 --> 00:47:46,700
this means that macromolecules would be

1133
00:47:51,820 --> 00:47:48,620
working with other macromolecules in

1134
00:47:53,770 --> 00:47:51,830
very specific ways and so as evolution

1135
00:47:56,020 --> 00:47:53,780
went on any particular macro molecule

1136
00:47:59,950 --> 00:47:56,030
could less easily be transferred out of

1137
00:48:02,260 --> 00:47:59,960
its own expression and replication focus

1138
00:48:02,980 --> 00:48:02,270

and so only when the sophistication was

1139
00:48:06,540 --> 00:48:02,990
complete

1140
00:48:10,690 --> 00:48:08,800
sufficiently sophisticated that

1141
00:48:12,820 --> 00:48:10,700
organisms could have an independent line

1142
00:48:15,130 --> 00:48:12,830
of descent only then could the

1143
00:48:17,020 --> 00:48:15,140
diversification be seen and that would

1144
00:48:18,160 --> 00:48:17,030
be seen as the radiations at the base of

1145
00:48:21,150 --> 00:48:18,170
the domains

1146
00:48:24,029 --> 00:48:21,160
Carlos is called that the

1147
00:48:26,700 --> 00:48:24,039
Darwinian boundary or Darwinian border

1148
00:48:30,930 --> 00:48:26,710
when Darwinian evolution could then be

1149
00:48:33,720 --> 00:48:30,940
it then way I don't the question also

1150
00:48:35,099 --> 00:48:33,730
often times come comes up is well jeez

1151
00:48:37,410 --> 00:48:35,109
are you going to see a fourth or a fifth

1152
00:48:39,390 --> 00:48:37,420
domain and when we first started this

1153
00:48:41,220 --> 00:48:39,400
work a long time ago alas I was after

1154
00:48:42,599 --> 00:48:41,230
fourth domains and fifth domains and so

1155
00:48:44,700 --> 00:48:42,609
forth we've accumulated a lot of

1156
00:48:46,920 --> 00:48:44,710
ribosomal RNA gene sequences from a lot

1157
00:48:48,390 --> 00:48:46,930
of places and we've seen lots of archaea

1158
00:48:50,099 --> 00:48:48,400
and lots of bacteria and lots of

1159
00:48:52,589 --> 00:48:50,109
eukaryotes and we've never seen anything

1160
00:48:54,900 --> 00:48:52,599
that even smells like a fourth line of

1161
00:48:56,819 --> 00:48:54,910
descent I don't think it's out there at

1162
00:48:58,859 --> 00:48:56,829
the stage or if it is out there we can't

1163
00:49:01,650 --> 00:48:58,869

detect it with our tools but all quickly

1164
00:49:03,930 --> 00:49:01,660
remember be the first to admit that the

1165
00:49:06,029 --> 00:49:03,940
sorts of tools we use namely ribosomal

1166
00:49:08,700 --> 00:49:06,039
RNA or other molecular based tools are

1167
00:49:10,890 --> 00:49:08,710
all based on organisms of the kinds that

1168
00:49:12,750 --> 00:49:10,900
we have already seen so are there other

1169
00:49:14,490 --> 00:49:12,760
lions out there I think it's a

1170
00:49:19,109 --> 00:49:14,500
possibility but at this stage I don't

1171
00:49:22,849 --> 00:49:19,119
think it's likely thank you we have a

1172
00:49:27,589 --> 00:49:25,049
yeah I appreciate the talk I think

1173
00:49:30,269 --> 00:49:27,599
you've made it accessible very

1174
00:49:31,769 --> 00:49:30,279
presentation accessible to simple

1175
00:49:33,630 --> 00:49:31,779
country geologists and I really

1176
00:49:35,640 --> 00:49:33,640
appreciate that

1177
00:49:38,099 --> 00:49:35,650
a question that comes to me harder is

1178
00:49:40,650 --> 00:49:38,109
where on this planet would you go to

1179
00:49:45,680 --> 00:49:40,660
find the most primitive life-form

1180
00:49:48,269 --> 00:49:45,690
possible or what possible exploration

1181
00:49:51,210 --> 00:49:48,279
strategies would you put in in motion

1182
00:49:56,250 --> 00:49:51,220
now for we're getting there five 10 15

1183
00:49:58,650 --> 00:49:56,260
years ago I think that there is no such

1184
00:50:01,529 --> 00:49:58,660
thing as a primitive organism alive on

1185
00:50:03,539 --> 00:50:01,539
earth today all forms of life on alive

1186
00:50:06,059 --> 00:50:03,549
today are the products of four billion

1187
00:50:08,730 --> 00:50:06,069
years of evolution all exquisitely

1188
00:50:10,230 --> 00:50:08,740

fitted to the niche that they occupy and

1189
00:50:11,940 --> 00:50:10,240
if they didn't somebody would eat them

1190
00:50:13,760 --> 00:50:11,950
so I don't think that there's a

1191
00:50:18,329 --> 00:50:13,770
primitive organism to be found anyplace

1192
00:50:20,250 --> 00:50:18,339
simple organisms yes simple now it turns

1193
00:50:21,720 --> 00:50:20,260
out the simplest free living organisms

1194
00:50:24,390 --> 00:50:21,730
that we know off at this stage of the

1195
00:50:26,609 --> 00:50:24,400
game are found in the open ocean these

1196
00:50:28,440 --> 00:50:26,619
are organisms such as the cyanobacterium

1197
00:50:30,329 --> 00:50:28,450
prochlorococcus and other kinds of

1198
00:50:32,410 --> 00:50:30,339
organisms that live out there in the

1199
00:50:34,810 --> 00:50:32,420
open ocean and they're doing it on 50

1200
00:50:37,120 --> 00:50:34,820
hundred to two thousand genes or

1201
00:50:39,700 --> 00:50:37,130
methanogens for example a toxic

1202
00:50:41,500 --> 00:50:39,710
environments environments are making a

1203
00:50:43,810 --> 00:50:41,510
living off of eating hydrogen and

1204
00:50:46,000 --> 00:50:43,820
breathing co2 can't get much more

1205
00:50:48,310 --> 00:50:46,010
rear-entry than that and again math

1206
00:50:51,550 --> 00:50:48,320
anagen some methanogens genomes are in

1207
00:50:53,620 --> 00:50:51,560
the order of 1,500 to 2,000 genes so I

1208
00:50:55,450 --> 00:50:53,630
think that those are the simplest or the

1209
00:50:57,490 --> 00:50:55,460
kinds of organisms that one can find

1210
00:50:59,410 --> 00:50:57,500
anyplace and probably the fewest number

1211
00:51:01,780 --> 00:50:59,420
of genes that one can operate on

1212
00:51:13,690 --> 00:51:01,790
anywhere in the universe that primitive

1213
00:51:15,670 --> 00:51:13,700

they're not well no it hasn't it's

1214
00:51:18,550 --> 00:51:15,680
changed and the life has changed along

1215
00:51:22,030 --> 00:51:18,560
with it now I would have argued not too

1216
00:51:23,410 --> 00:51:22,040
long ago that yes it's probable that

1217
00:51:25,270 --> 00:51:23,420
life came to be in geothermal

1218
00:51:27,370 --> 00:51:25,280
environments and so if we went into

1219
00:51:28,690 --> 00:51:27,380
geothermal environments we would find

1220
00:51:30,850 --> 00:51:28,700
organisms that are particularly

1221
00:51:32,740 --> 00:51:30,860
primitive and the fact is that you don't

1222
00:51:34,990 --> 00:51:32,750
find primitive organisms by primitive

1223
00:51:37,120 --> 00:51:35,000
organisms I mean those that would either

1224
00:51:39,400 --> 00:51:37,130
branch very deeply or have very short

1225
00:51:41,890 --> 00:51:39,410
line segments and therefore be most

1226
00:51:45,610 --> 00:51:41,900
closely related statistically at least

1227
00:51:48,010 --> 00:51:45,620
to the common ancestor you do see short

1228
00:51:50,440 --> 00:51:48,020
line segments in some types of organisms

1229
00:51:53,380 --> 00:51:50,450
that would occupy extreme environments

1230
00:51:54,850 --> 00:51:53,390
for example the crenarchaeota that live

1231
00:51:56,440 --> 00:51:54,860
at high temperatures are not

1232
00:51:57,670 --> 00:51:56,450
particularly simple genomes they

1233
00:52:00,760 --> 00:51:57,680
typically will have four or five

1234
00:52:02,770 --> 00:52:00,770
thousand genes and they do however have

1235
00:52:05,410 --> 00:52:02,780
relatively short branch lengths in

1236
00:52:08,800 --> 00:52:05,420
forests and trees based on ribosomal RNA

1237
00:52:10,600 --> 00:52:08,810
I think however this short branches does

1238
00:52:13,810 --> 00:52:10,610

not reflect permittivity or less

1239
00:52:16,270 --> 00:52:13,820
evolution I think it represents more

1240
00:52:17,920 --> 00:52:16,280
limited sequence space available to

1241
00:52:19,740 --> 00:52:17,930
high-temperature organisms than to

1242
00:52:22,240 --> 00:52:19,750
low-temperature organisms namely

1243
00:52:30,510 --> 00:52:22,250
constraints on structure enforced by the

1244
00:52:36,720 --> 00:52:33,570
have a question that is there any

1245
00:52:39,030 --> 00:52:36,730
analysis done based on not the

1246
00:52:42,390 --> 00:52:39,040
phylogenetic

1247
00:52:43,510 --> 00:52:42,400
classification but system of

1248
00:52:45,350 --> 00:52:43,520
bioenergetics

1249
00:52:50,290 --> 00:52:45,360
like how minimum

1250
00:52:57,190 --> 00:52:50,300
that a life can utilize and survive and

1251
00:53:01,580 --> 00:52:57,200
for afraid something like that well

1252
00:53:05,380 --> 00:53:01,590
bioenergetics is is pretty common

1253
00:53:09,770 --> 00:53:05,390
throughout life's diversity on earth

1254
00:53:13,100 --> 00:53:09,780
organisms use ATP metabolisms organisms

1255
00:53:15,470 --> 00:53:13,110
use Kinison chemiosmotic energy

1256
00:53:19,130 --> 00:53:15,480
harvesting all kinds of organisms do

1257
00:53:21,730 --> 00:53:19,140
that the types of energy sources that

1258
00:53:24,800 --> 00:53:21,740
are being used of course hydrogen

1259
00:53:27,560 --> 00:53:24,810
hydrogen sulfide all kinds of reduced

1260
00:53:29,000 --> 00:53:27,570
compounds those are found in many many

1261
00:53:31,660 --> 00:53:29,010
kinds of organisms they're not

1262
00:53:34,010 --> 00:53:31,670
particularly phylogenetically limited

1263
00:53:36,290 --> 00:53:34,020

organisms harvest light in different

1264
00:53:38,450 --> 00:53:36,300
ways that the Calvin cycle of which

1265
00:53:40,700 --> 00:53:38,460
everybody is probably familiar ribulose

1266
00:53:43,130 --> 00:53:40,710
bisphosphate carboxylase and all that

1267
00:53:45,170 --> 00:53:43,140
that is indeed an important mode of

1268
00:53:47,180 --> 00:53:45,180
photosynthesis that you see distributed

1269
00:53:49,160 --> 00:53:47,190
in a lot of kinds of organisms it's not

1270
00:53:51,500 --> 00:53:49,170
the only way to do it the reverse TCA

1271
00:53:53,180 --> 00:53:51,510
cycle in fact may be more common

1272
00:53:55,820 --> 00:53:53,190
certainly as common in the microbial

1273
00:53:57,320 --> 00:53:55,830
world as is the calvin cycle we know

1274
00:53:59,450 --> 00:53:57,330
very little about the distribution of

1275
00:54:03,290 --> 00:53:59,460
that protein rhodopsin is another big

1276
00:54:06,680 --> 00:54:03,300
game it was thought that the rhodopsin

1277
00:54:08,090 --> 00:54:06,690
had its origins in archaea since it was

1278
00:54:09,860 --> 00:54:08,100
first recognized there but it

1279
00:54:11,540 --> 00:54:09,870
subsequently turned out that rhodopsins

1280
00:54:13,970 --> 00:54:11,550
are present in a lot of bacteria as well

1281
00:54:16,430 --> 00:54:13,980
first discovered by Ed DeLong in the

1282
00:54:18,260 --> 00:54:16,440
context of protea rhodopsin but now seen

1283
00:54:21,520 --> 00:54:18,270
as a lot of places is an alternative way

1284
00:54:24,560 --> 00:54:21,530
to harvest light not as trick as

1285
00:54:27,290 --> 00:54:24,570
chlorophyll base photosynthesis but it

1286
00:54:29,510 --> 00:54:27,300
works so I don't know what to say about

1287
00:54:32,090 --> 00:54:29,520
that I don't see particular file o

1288
00:54:34,880 --> 00:54:32,100

genetic risk constraints on the kinds of

1289
00:54:37,100 --> 00:54:34,890
energy energy harvesting and energy

1290
00:54:40,100 --> 00:54:37,110
utilizing mechanisms that are employed

1291
00:54:41,750 --> 00:54:40,110
by terrestrial terrestrial life and

1292
00:54:43,880 --> 00:54:41,760
again we're in the universe I would

1293
00:54:47,960 --> 00:54:43,890
expect to find not exactly the same

1294
00:54:54,430 --> 00:54:47,970
solutions but similar solutions can you

1295
00:54:56,120 --> 00:54:54,440
see any trend if you classified based on

1296
00:54:58,700 --> 00:54:56,130
bioenergetics how much

1297
00:55:01,670 --> 00:54:58,710
they use us something like that then

1298
00:55:04,370 --> 00:55:01,680
don't you see some trend

1299
00:55:11,030 --> 00:55:04,380
besides phylogenetic trend I mean like a

1300
00:55:14,300 --> 00:55:11,040
tree of life the yeah I don't see any

1301
00:55:16,310 --> 00:55:14,310
particular trend similar kinds of energy

1302
00:55:19,160 --> 00:55:16,320
metabolism are used by a lot of

1303
00:55:20,570 --> 00:55:19,170
different kinds of organisms if the if

1304
00:55:22,910 --> 00:55:20,580
you're trying to get at the question of

1305
00:55:25,700 --> 00:55:22,920
what's the best energy source the best

1306
00:55:27,860 --> 00:55:25,710
energy source is probably probably the

1307
00:55:30,020 --> 00:55:27,870
most rudimentary thermodynamically

1308
00:55:31,610 --> 00:55:30,030
speaking probably the best way to make a

1309
00:55:34,490 --> 00:55:31,620
living in terms of harvesting energy

1310
00:55:38,240 --> 00:55:34,500
from the simplest stuff is to consume

1311
00:55:40,280 --> 00:55:38,250
hydrogen and breathe oxygen those are at

1312
00:55:42,350 --> 00:55:40,290
the extremes of the thermodynamic ladder

1313
00:55:45,470 --> 00:55:42,360

and probably the most efficient way to

1314
00:55:55,840 --> 00:55:45,480
make a living and a lot of organisms do

1315
00:56:01,670 --> 00:55:58,160
we have another question here at nai

1316
00:56:04,100 --> 00:56:01,680
central hi norm this is David Morrison I

1317
00:56:06,680 --> 00:56:04,110
want you to help me with a class of

1318
00:56:09,410 --> 00:56:06,690
questions I get to ask an astrobiologist

1319
00:56:12,470 --> 00:56:09,420
from what I presume our high school

1320
00:56:15,080 --> 00:56:12,480
teachers who are bothered by whether the

1321
00:56:17,359 --> 00:56:15,090
kingdom concept still means anything in

1322
00:56:20,720 --> 00:56:17,369
terms of modern domains whether there

1323
00:56:23,600 --> 00:56:20,730
are kingdoms whether that applies to any

1324
00:56:28,700 --> 00:56:23,610
of the organisms outside the Eukarya can

1325
00:56:32,170 --> 00:56:28,710
you help me with that well it's an issue

1326
00:56:35,150 --> 00:56:32,180
of historical nomenclature David and

1327
00:56:37,490 --> 00:56:35,160
indeed when the original four kingdoms

1328
00:56:40,550 --> 00:56:37,500
of life were defined or five kingdoms of

1329
00:56:42,830 --> 00:56:40,560
life that was what was known and since

1330
00:56:46,480 --> 00:56:42,840
then we've learned that that that the

1331
00:56:49,670 --> 00:56:46,490
tree of life is way bigger than that

1332
00:56:52,040 --> 00:56:49,680
subjective view of life's diversity so

1333
00:56:53,660 --> 00:56:52,050
kingdoms was originally a name which was

1334
00:56:56,570 --> 00:56:53,670
given to what were considered to be the

1335
00:56:57,800 --> 00:56:56,580
major provinces of life we now know that

1336
00:57:00,260 --> 00:56:57,810
there are a lot more of those provinces

1337
00:57:02,180 --> 00:57:00,270
but even the definition of a kingdom is

1338
00:57:05,330 --> 00:57:02,190

a little bit messy they're about the 30

1339
00:57:07,460 --> 00:57:05,340
of the they're about 30 phylogenetics

1340
00:57:10,280 --> 00:57:07,470
what we would call clades relatedness

1341
00:57:12,980 --> 00:57:10,290
groups about 30 big relatedness groups

1342
00:57:14,780 --> 00:57:12,990
in the in the eukaryotes for example or

1343
00:57:18,080 --> 00:57:14,790
others all kingdoms well I would say so

1344
00:57:19,460 --> 00:57:18,090
but most professional systematists most

1345
00:57:21,859 --> 00:57:19,470
professional taxonomy

1346
00:57:24,080 --> 00:57:21,869
are still in denial about what's

1347
00:57:25,730 --> 00:57:24,090
happened in terms of the explosion of

1348
00:57:28,160 --> 00:57:25,740
our view of life's diversity just

1349
00:57:33,950 --> 00:57:28,170
frankly in denial and hasn't been dealt

1350
00:57:36,190 --> 00:57:33,960
with and the bacterial what was when he

1351
00:57:38,780 --> 00:57:36,200
first wrote about bacterial diversity

1352
00:57:40,220 --> 00:57:38,790
described the bacterial divisions or

1353
00:57:42,920 --> 00:57:40,230
file or whatever you want to call them

1354
00:57:44,960 --> 00:57:42,930
he used also the metaphor of kingdoms to

1355
00:57:47,390 --> 00:57:44,970
describe those of the bacteria or the

1356
00:57:49,220 --> 00:57:47,400
metaphor of kingdoms to describe the two

1357
00:57:51,680 --> 00:57:49,230
major kinds of archaea that we currently

1358
00:57:53,540 --> 00:57:51,690
recognize so there isn't a

1359
00:57:55,930 --> 00:57:53,550
straightforward answer to your question

1360
00:57:58,940 --> 00:57:55,940
David because it's so muddied by history

1361
00:58:02,210 --> 00:57:58,950
for a professional system is to agree

1362
00:58:05,570 --> 00:58:02,220
that there is a kingdom of diplomats you

1363
00:58:07,620 --> 00:58:05,580

would probably find to be a professional

1364
00:58:08,880 --> 00:58:07,630
system assay well that's not really one

1365
00:58:11,580 --> 00:58:08,890
the kingdoms that we historically

1366
00:58:13,230 --> 00:58:11,590
recognized hey I agree with that but on

1367
00:58:16,020 --> 00:58:13,240
the other hand there's as much at least

1368
00:58:18,300 --> 00:58:16,030
ribosomal RNA diversity in the tricky

1369
00:58:20,280 --> 00:58:18,310
moments where the diplom monads as there

1370
00:58:23,340 --> 00:58:20,290
isn't among the animals all of the

1371
00:58:25,920 --> 00:58:23,350
animals now what means biological

1372
00:58:28,080 --> 00:58:25,930
diversity we use these ribosomal RNA

1373
00:58:30,150 --> 00:58:28,090
trees as a metaphor for diversity and

1374
00:58:32,370 --> 00:58:30,160
I'm quick to add a metaphor for

1375
00:58:35,640 --> 00:58:32,380
diversity because biological diversity

1376
00:58:39,270 --> 00:58:35,650
is far more the biological diversity of

1377
00:58:40,770 --> 00:58:39,280
the organisms is far more than the code

1378
00:58:43,080 --> 00:58:40,780
let's call those are the simple pictures

1379
00:58:45,630 --> 00:58:43,090
painted by the phylogenetic trees of

1380
00:58:47,910 --> 00:58:45,640
ribosomal RNA but I do believe that the

1381
00:58:50,730 --> 00:58:47,920
ribosomal RNA tree gives us a backbone

1382
00:58:59,900 --> 00:58:50,740
of large-scale evolution of terrestrial

1383
00:59:04,860 --> 00:59:02,580
okay does anybody else have any

1384
00:59:14,700 --> 00:59:04,870
questions that they'd like to pose to

1385
00:59:16,770 --> 00:59:14,710
norm looks like we have one Goddard and

1386
00:59:18,600 --> 00:59:16,780
you mentioned all this might be

1387
00:59:19,920 --> 00:59:18,610
prokaryote this might be eukaryote and

1388
00:59:22,640 --> 00:59:19,930

it was also these little tiny things

1389
00:59:25,380 --> 00:59:22,650
that you said that might be viruses

1390
00:59:28,710 --> 00:59:25,390
virus DNA and I was wondering at that

1391
00:59:31,410 --> 00:59:28,720
time I mean how much it is possible that

1392
00:59:34,650 --> 00:59:31,420
it could be just free-floating DNA some

1393
00:59:37,640 --> 00:59:34,660
DNA which just is remnants of some

1394
00:59:41,040 --> 00:59:37,650
organisms it decayed and do you have any

1395
00:59:48,450 --> 00:59:41,050
idea how much time would it take of this

1396
00:59:50,400 --> 00:59:48,460
DNA decay a couple of answers one those

1397
00:59:52,290 --> 00:59:50,410
little specks of light are indeed

1398
00:59:54,000 --> 00:59:52,300
viruses they've been concentrated and

1399
00:59:55,920 --> 00:59:54,010
looked at in the electron microscope and

1400
00:59:57,510 --> 00:59:55,930
a couple of labs around the world or

1401
00:59:59,910 --> 00:59:57,520
studying the meta-genome makes you if

1402
01:00:01,920 --> 00:59:59,920
you will of the marine virus community

1403
01:00:04,410 --> 01:00:01,930
that's right so you can see them there

1404
01:00:07,080 --> 01:00:04,420
virus is not specks of DNA the question

1405
01:00:09,150 --> 01:00:07,090
of how long free DNA would live in the

1406
01:00:11,220 --> 01:00:09,160
marine environment is an interesting one

1407
01:00:13,380 --> 01:00:11,230
and people have done measurements where

1408
01:00:15,630 --> 01:00:13,390
they'll take radioactive labeled DNA and

1409
01:00:18,480 --> 01:00:15,640
mix it with raw sewage or with other

1410
01:00:19,680 --> 01:00:18,490
kinds of stream water pond water ocean

1411
01:00:22,050 --> 01:00:19,690
water stuff like that

1412
01:00:24,210 --> 01:00:22,060
and the answer is that if you throw DNA

1413
01:00:26,370 --> 01:00:24,220

into raw sewage sludge that lasts for

1414
01:00:28,140 --> 01:00:26,380
about 30 minutes something like that if

1415
01:00:30,840 --> 01:00:28,150
you put it into marine water

1416
01:00:33,660 --> 01:00:30,850
it lasts for maybe a week half-life of

1417
01:00:36,990 --> 01:00:33,670
about a week so it goes away relatively

1418
01:00:39,060 --> 01:00:37,000
fast at the cosmic scale but but DNA

1419
01:00:40,620 --> 01:00:39,070
that's within viruses is probably pretty

1420
01:00:42,690 --> 01:00:40,630
well-protected since that's how those

1421
01:00:44,250 --> 01:00:42,700
viruses make their living and like I say

1422
01:00:46,890 --> 01:00:44,260
you can draw these dial into the right

1423
01:00:49,080 --> 01:00:46,900
kinds of filters and see viral normal

1424
01:00:50,850 --> 01:00:49,090
types without any problem it's pretty

1425
01:00:53,160 --> 01:00:50,860
well-documented those little specks of

1426
01:00:54,540 --> 01:00:53,170
light represent viruses I don't think

1427
01:00:57,060 --> 01:00:54,550
you would see little pieces of DNA

1428
01:01:00,150 --> 01:00:57,070
perhaps a little piece of DNA stuck on

1429
01:01:01,740 --> 01:01:00,160
piece of fish scars or something but not

1430
01:01:07,320 --> 01:01:01,750
not that very large number of little

1431
01:01:10,270 --> 01:01:07,330
spots of line we have a question from

1432
01:01:22,930 --> 01:01:16,150
yeah yeah very well get closer

1433
01:01:25,770 --> 01:01:22,940
hi yes I'm curious what's your your take

1434
01:01:28,390 --> 01:01:25,780
on the semiotic origin of materials and

1435
01:01:34,210 --> 01:01:28,400
specifically how that ties into

1436
01:01:35,650 --> 01:01:34,220
experience I procure you know would you

1437
01:01:37,080 --> 01:01:35,660
repeat that I couldn't hear that

1438
01:01:42,630 --> 01:01:37,090

question very well at all

1439
01:01:47,260 --> 01:01:42,640
yeah many people in the field early

1440
01:01:51,040 --> 01:01:47,270
period origins believe that eukaryote

1441
01:01:55,600 --> 01:01:51,050
arose at least both psychologically and

1442
01:01:58,090 --> 01:01:55,610
also genetically through symbiosis so

1443
01:02:01,270 --> 01:01:58,100
it's not really a vertical inherent in

1444
01:02:06,960 --> 01:02:01,280
that sense so they would argue that

1445
01:02:09,490 --> 01:02:06,970
perhaps there is a prokaryote eukaryote

1446
01:02:14,190 --> 01:02:09,500
distinction how do you argue against

1447
01:02:16,930 --> 01:02:14,200
that I don't see any evidence for it I

1448
01:02:20,080 --> 01:02:16,940
don't see any evidence for creating a

1449
01:02:22,540 --> 01:02:20,090
relatedness group of prokaryotes I do

1450
01:02:25,150 --> 01:02:22,550
see evidence that there are three lines

1451
01:02:27,450 --> 01:02:25,160
of descent there's hard evidence that

1452
01:02:31,420 --> 01:02:27,460
the eukaryotic nuclear line of descent

1453
01:02:34,660 --> 01:02:31,430
is as it came out of something even more

1454
01:02:37,150 --> 01:02:34,670
rudimentary than archaea and developed

1455
01:02:38,080 --> 01:02:37,160
as ultimately into what became the

1456
01:02:44,080 --> 01:02:38,090
eukaryotic cell

1457
01:02:47,050 --> 01:02:44,090
in bacterial symbionts chloroplasts

1458
01:02:51,310 --> 01:02:47,060
mitochondria that seems to be in the

1459
01:02:53,620 --> 01:02:51,320
general theme of eukaryotic complexity

1460
01:02:56,440 --> 01:02:53,630
basically you eukaryotic metabolism

1461
01:02:58,120 --> 01:02:56,450
energy Matassa metabolism for example is

1462
01:03:00,970 --> 01:02:58,130
really rudimentary is basically

1463
01:03:03,160 --> 01:03:00,980

fermentated the eukaryotes have achieved

1464
01:03:05,440 --> 01:03:03,170
nutritional diversification by again

1465
01:03:08,530 --> 01:03:05,450
taking in a partner symbiotic bacteria

1466
01:03:11,020 --> 01:03:08,540
more chloroplasts when did that happen

1467
01:03:12,760 --> 01:03:11,030
when did the earliest eukaryote arise I

1468
01:03:15,220 --> 01:03:12,770
don't know when did the earliest

1469
01:03:17,250 --> 01:03:15,230
archaeon arise well the eukaryotic

1470
01:03:19,980 --> 01:03:17,260
nuclear line of descent was in

1471
01:03:21,599 --> 01:03:19,990
at that time now that earliest

1472
01:03:24,150 --> 01:03:21,609
eukaryotic cell did not have

1473
01:03:26,070 --> 01:03:24,160
mitochondria and chloroplasts because it

1474
01:03:28,109 --> 01:03:26,080
could only bring those in when the

1475
01:03:31,040 --> 01:03:28,119
organisms that gave rise to chloroplast

1476
01:03:32,550 --> 01:03:31,050
cyanobacteria or alternatively my toca

1477
01:03:34,770 --> 01:03:32,560
proteobacteria which gave rise to

1478
01:03:37,530 --> 01:03:34,780
mitochondria we know that the

1479
01:03:39,950 --> 01:03:37,540
chloroplast ik line of descent came to

1480
01:03:42,750 --> 01:03:39,960
be as early as the cyanobacteria

1481
01:03:45,150 --> 01:03:42,760
radiation occurred that is to say if I

1482
01:03:47,580 --> 01:03:45,160
make a cyanobacteria phylogenetic tree

1483
01:03:50,550 --> 01:03:47,590
which includes chloroplasts ik c quences

1484
01:03:52,609 --> 01:03:50,560
I will see that the chloroplast roots

1485
01:03:55,890 --> 01:03:52,619
into the base of the cyanobacteria

1486
01:03:57,840 --> 01:03:55,900
radiation that is to say the chloroplast

1487
01:04:00,330 --> 01:03:57,850
is not derived from any modern kind of

1488
01:04:03,000 --> 01:04:00,340

cyanobacteria but rather originated at

1489
01:04:06,000 --> 01:04:03,010
the same time as the cyanobacteria

1490
01:04:09,450 --> 01:04:06,010
radiation as a whole and of course the

1491
01:04:18,650 --> 01:04:09,460
the chloroplasts less eukaryotic cells

1492
01:04:24,810 --> 01:04:21,650
let me go further and say don't confuse

1493
01:04:26,910 --> 01:04:24,820
the modern kind of eukaryotic cell that

1494
01:04:29,760 --> 01:04:26,920
most of us think about those that have

1495
01:04:31,260 --> 01:04:29,770
mitochondria and/or chloroplasts a lot

1496
01:04:33,450 --> 01:04:31,270
of eukaryotes don't have mitochondria

1497
01:04:35,640 --> 01:04:33,460
and chloroplasts these would include the

1498
01:04:38,220 --> 01:04:35,650
diplom own as the trichomonas these

1499
01:04:40,620 --> 01:04:38,230
basal divergences from the eukaryotic

1500
01:04:42,630 --> 01:04:40,630
tree some have argued that these things

1501
01:04:44,760 --> 01:04:42,640
used to have mitochondria and then lost

1502
01:04:47,280 --> 01:04:44,770
them but the data for that are not good

1503
01:04:49,920 --> 01:04:47,290
at all the main reason to believe in

1504
01:04:52,320 --> 01:04:49,930
prokaryote you carry out at this time is

1505
01:04:55,500 --> 01:04:52,330
because Aaron's heckle told us that

1506
01:04:59,310 --> 01:04:55,510
manera gave rise to eukaryotes I repeat

1507
01:05:01,530 --> 01:04:59,320
in the 1970s punji were added to give us

1508
01:05:04,200 --> 01:05:01,540
the five kingdoms and the name monera

1509
01:05:06,330 --> 01:05:04,210
was changed to prokaryote nothing else

1510
01:05:08,790 --> 01:05:06,340
happened and that's what our children

1511
01:05:12,060 --> 01:05:08,800
are being taught in high schools and

1512
01:05:14,349 --> 01:05:12,070
colleges I think it's a travesty enough

1513
01:05:16,910 --> 01:05:14,359

said

1514
01:05:19,160 --> 01:05:16,920
well I think we'll let norm have the