EARTH-LIFE
SCIENCE
INSTITUTE

Shawn McGlynn

The origin of microbial & communal life; the journey of the progenote to the Last Universal Common Ancestor

1
00:00:14,480 --> 00:00:12,170
[Music]

2
00:00:18,029 --> 00:00:14,490
thanks everybody for coming it's my

3
00:00:21,690 --> 00:00:18,039
great pleasure to talk to you today

4
00:00:23,580 --> 00:00:21,700
about some questions so I want to tell

5
00:00:26,370 --> 00:00:23,590
you briefly three things about my talk

6
00:00:29,130 --> 00:00:26,380
one is that it's the top with the

7
00:00:31,589 --> 00:00:29,140
longest title so it's going to be a

8
00:00:33,299 --> 00:00:31,599
little bit complicated the second is I

9
00:00:35,070 --> 00:00:33,309
think my talk is the first one that

10
00:00:38,610 --> 00:00:35,080
doesn't have any movies in it so sorry

11
00:00:41,070 --> 00:00:38,620
about that but please hold on and the

12
00:00:45,780 --> 00:00:41,080
third is that my talk really is a talk

13
00:00:47,400 --> 00:00:45,790

about questions that we're yet to define

14
00:00:49,139 --> 00:00:47,410
exactly what the answers to these

15
00:00:52,740 --> 00:00:49,149
questions are but I would like to

16
00:00:54,389 --> 00:00:52,750
introduce to you today a set of ways of

17
00:00:56,880 --> 00:00:54,399
thinking about life that might help us

18
00:00:59,400 --> 00:00:56,890
address questions concerning how it

19
00:01:02,549 --> 00:00:59,410
started and what the early evolution of

20
00:01:04,020 --> 00:01:02,559
this biological system was like so Jim

21
00:01:06,900 --> 00:01:04,030
already showed us a picture of a cell

22
00:01:09,630 --> 00:01:06,910
here is another picture of a cell in

23
00:01:12,570 --> 00:01:09,640
this case it's not a real cell

24
00:01:14,699 --> 00:01:12,580
it's a beautiful watercolor painting

25
00:01:16,199 --> 00:01:14,709
that was made by David Goodsell who is

26
00:01:19,440 --> 00:01:16,209
at the Scripps Institute in California

27
00:01:21,690 --> 00:01:19,450
and as Jim mentioned the cell is

28
00:01:23,460 --> 00:01:21,700
incredibly complicated it's beautifully

29
00:01:26,219 --> 00:01:23,470
complicated I would say since I'm a

30
00:01:28,710 --> 00:01:26,229
biologist this particular cell has one

31
00:01:30,900 --> 00:01:28,720
single membrane here and it has all of

32
00:01:32,880 --> 00:01:30,910
these green bits inside of it these are

33
00:01:34,859 --> 00:01:32,890
proteins that are inside of the membrane

34
00:01:36,990 --> 00:01:34,869
and it's covered with this hairy stuff

35
00:01:38,730 --> 00:01:37,000
on the outside and that hairy stuff is a

36
00:01:41,160 --> 00:01:38,740
way for the cell to communicate with

37
00:01:43,050 --> 00:01:41,170
other cells in the environment and then

38
00:01:46,559 --> 00:01:43,060

in the inside are these protein machines

39
00:01:49,290 --> 00:01:46,569
and information units that Jim already

40
00:01:51,330 --> 00:01:49,300
introduced and so in addition to asking

41
00:01:53,969 --> 00:01:51,340
the question of how these types of

42
00:01:55,949 --> 00:01:53,979
molecules originally came together and

43
00:01:58,320 --> 00:01:55,959
resulted eventually into the formation

44
00:02:01,020 --> 00:01:58,330
of a cell we have very fundamental

45
00:02:04,320 --> 00:02:01,030
questions left to address concerning the

46
00:02:05,520 --> 00:02:04,330
early evolution of life and how are we

47
00:02:07,619 --> 00:02:05,530
going to think about that early

48
00:02:09,930 --> 00:02:07,629
evolution life comes in many shapes and

49
00:02:13,830 --> 00:02:09,940
sizes it does many many things on the

50
00:02:16,050 --> 00:02:13,840
planet if we went outside today and

51
00:02:18,300 --> 00:02:16,060
started collecting cells or not even

52
00:02:19,710 --> 00:02:18,310
outside from this from this room we

53
00:02:21,510 --> 00:02:19,720
would be able to find cells of many

54
00:02:23,790 --> 00:02:21,520
different shapes and many different

55
00:02:25,500 --> 00:02:23,800
sizes some

56
00:02:27,720 --> 00:02:25,510
time's rarely they become in these

57
00:02:29,460 --> 00:02:27,730
fantastic star shapes sometimes they

58
00:02:31,050 --> 00:02:29,470
look like little salt crystals and they

59
00:02:32,760 --> 00:02:31,060
were originally mistaken to be salt

60
00:02:35,040 --> 00:02:32,770
crystals because they're so square in

61
00:02:37,860 --> 00:02:35,050
shape most of the cells that we know

62
00:02:39,510 --> 00:02:37,870
from our biology books and most that we

63
00:02:41,610 --> 00:02:39,520

would see if we started looking under a

64
00:02:44,880 --> 00:02:41,620
microscope today would be these rod

65
00:02:50,160 --> 00:02:44,890
shaped cells or these kind of sphere

66
00:02:51,360 --> 00:02:50,170
achill shaped cells and we're left with

67
00:02:53,580 --> 00:02:51,370
this question how did all of this

68
00:02:55,980 --> 00:02:53,590
diversity arise and what was early

69
00:02:57,600 --> 00:02:55,990
diversity like on the planet what were

70
00:03:00,270 --> 00:02:57,610
the early mechanisms for diversity

71
00:03:02,760 --> 00:03:00,280
generation and I want to make a point

72
00:03:04,260 --> 00:03:02,770
that the growth of the cell as we

73
00:03:06,930 --> 00:03:04,270
understand it today is intrinsically

74
00:03:09,120 --> 00:03:06,940
linked to the replication of DNA DNA

75
00:03:12,390 --> 00:03:09,130
being the informational polymer of the

76
00:03:14,220 --> 00:03:12,400
cell it's the way that cell cells are

77
00:03:17,550 --> 00:03:14,230
able to pass information from generation

78
00:03:19,890 --> 00:03:17,560
to generation and if we thought about a

79
00:03:22,140 --> 00:03:19,900
cell we can draw an outline around this

80
00:03:24,180 --> 00:03:22,150
DNA molecule we could think about that

81
00:03:26,460 --> 00:03:24,190
DNA replicating and then we would have

82
00:03:29,100 --> 00:03:26,470
two cells here and four cells and so on

83
00:03:31,280 --> 00:03:29,110
from a contemporary perspective of today

84
00:03:34,530 --> 00:03:31,290
one of the most fundamental notions of

85
00:03:36,660 --> 00:03:34,540
biology cells are the fundamental unit

86
00:03:37,800 --> 00:03:36,670
of biology on the planet today and all

87
00:03:41,310 --> 00:03:37,810
cells replicate and they replicate

88
00:03:43,020 --> 00:03:41,320

through this DNA process what I want to

89
00:03:45,210 --> 00:03:43,030
try to do today is try to ask the

90
00:03:48,180 --> 00:03:45,220
question what was it like before this

91
00:03:51,000 --> 00:03:48,190
nice clean DNA replication process and

92
00:03:52,790 --> 00:03:51,010
how do we think about that so again

93
00:03:55,370 --> 00:03:52,800
going back to diversity generation

94
00:03:58,080 --> 00:03:55,380
there's many types of cells many shapes

95
00:04:00,810 --> 00:03:58,090
of cells many types of metabolisms on

96
00:04:03,210 --> 00:04:00,820
the planet and all of this is going to

97
00:04:05,070 --> 00:04:03,220
be linked the generation of this type of

98
00:04:07,920 --> 00:04:05,080
diversity is linked to this fundamental

99
00:04:10,650 --> 00:04:07,930
process of DNA separation and

100
00:04:15,030 --> 00:04:10,660
replication followed by the packaging

101
00:04:16,830 --> 00:04:15,040
into new cells and sometimes when DNA is

102
00:04:18,390 --> 00:04:16,840
replicated there's a mistake that

103
00:04:21,110 --> 00:04:18,400
happens and this is what we usually

104
00:04:23,190 --> 00:04:21,120
refer to as a mutation but this is a

105
00:04:26,190 --> 00:04:23,200
really really fundamental part of

106
00:04:28,830 --> 00:04:26,200
biology in addition to self replication

107
00:04:30,390 --> 00:04:28,840
of DNA molecules we have to always

108
00:04:32,250 --> 00:04:30,400
understand that it's not perfect

109
00:04:34,320 --> 00:04:32,260
there's always mistakes that are made in

110
00:04:35,399 --> 00:04:34,330
this replication process but these

111
00:04:36,929 --> 00:04:35,409
mistakes

112
00:04:39,329 --> 00:04:36,939
English the word mistake has a kind of

113
00:04:41,369 --> 00:04:39,339

negative connotation mistakes are not a

114
00:04:44,429 --> 00:04:41,379
negative process in biological systems

115
00:04:46,979 --> 00:04:44,439
per se in fact when we look at the total

116
00:04:50,009 --> 00:04:46,989
biodiversity on the planet these

117
00:04:54,989 --> 00:04:50,019
mistakes which are accruing through

118
00:04:56,939 --> 00:04:54,999
history here are leading to diversity

119
00:04:59,669 --> 00:04:56,949
generation so all of the life that we

120
00:05:02,489 --> 00:04:59,679
see on the planet is in part a product

121
00:05:05,909 --> 00:05:02,499
of mistakes and so mistakes using that

122
00:05:08,909 --> 00:05:05,919
word is a little bit of a no-no maybe a

123
00:05:11,579 --> 00:05:08,919
mutation is a better word on the left

124
00:05:14,040 --> 00:05:11,589
I'm showing a plot that was generated

125
00:05:16,589 --> 00:05:14,050
just last year from a group in the US

126
00:05:18,350 --> 00:05:16,599
and what this group was able to do was

127
00:05:20,609 --> 00:05:18,360
take the same type of organism and

128
00:05:23,519 --> 00:05:20,619
follow the number of mistakes or

129
00:05:25,019 --> 00:05:23,529
mutations over time and there's a couple

130
00:05:26,609 --> 00:05:25,029
there's a many many interesting things

131
00:05:28,739 --> 00:05:26,619
about this plot and we could spend a lot

132
00:05:30,809 --> 00:05:28,749
of time looking at it today even though

133
00:05:33,619 --> 00:05:30,819
the initial population or cell types

134
00:05:36,059 --> 00:05:33,629
were identical basically identical

135
00:05:38,699 --> 00:05:36,069
different bottles or different tubes

136
00:05:40,169 --> 00:05:38,709
started behaving differently and so even

137
00:05:42,509 --> 00:05:40,179
if we start with the same type of a

138
00:05:43,469 --> 00:05:42,519

system we get different results remember

139
00:05:46,079 --> 00:05:43,479
earlier this morning

140
00:05:48,839 --> 00:05:46,089
what Ramon taught us about the formation

141
00:05:50,519 --> 00:05:48,849
of planets and the universe if he starts

142
00:05:53,269 --> 00:05:50,529
a simulation again he gets a different

143
00:05:55,319 --> 00:05:53,279
set of planets out of here and this

144
00:05:56,790 --> 00:05:55,329
different behavior happening in

145
00:05:59,699 --> 00:05:56,800
different bottles tells us something

146
00:06:01,109 --> 00:05:59,709
about the way evolution works it works

147
00:06:03,149 --> 00:06:01,119
in a way that's not completely

148
00:06:05,399 --> 00:06:03,159
predictable these yellow ones started

149
00:06:07,409 --> 00:06:05,409
changing really really rapidly and then

150
00:06:10,319 --> 00:06:07,419
there was a group of cells here hiding

151
00:06:12,209 --> 00:06:10,329
behind this brown color are a number of

152
00:06:14,699 --> 00:06:12,219
different dots which represent different

153
00:06:17,369 --> 00:06:14,709
bottles and they were all behaving more

154
00:06:19,379 --> 00:06:17,379
similar to one another but so that the

155
00:06:21,419 --> 00:06:19,389
kind of result of this slide is that we

156
00:06:23,189 --> 00:06:21,429
can understand that there is diversity

157
00:06:27,569 --> 00:06:23,199
even when things appear to be the same

158
00:06:31,139 --> 00:06:27,579
and so over time the accumulation of

159
00:06:32,429 --> 00:06:31,149
these isotopes it does happen it doesn't

160
00:06:34,649 --> 00:06:32,439
happen to everybody but it does happen

161
00:06:39,119 --> 00:06:34,659
and it's fundamentally linked to this

162
00:06:41,189 --> 00:06:39,129
process of DNA replication so we're left

163
00:06:42,529 --> 00:06:41,199

with this question to try to think about

164
00:06:44,909 --> 00:06:42,539
how this happened on the early Earth

165
00:06:47,790 --> 00:06:44,919
today we have what's known as the

166
00:06:49,170 --> 00:06:47,800
central dogma of biology where DNA

167
00:06:51,090 --> 00:06:49,180
molecules make RNA

168
00:06:53,219 --> 00:06:51,100
molecules and then those go on to make

169
00:06:55,050 --> 00:06:53,229
these protein molecules these beautiful

170
00:06:57,600 --> 00:06:55,060
machines that Jim showed us these

171
00:06:59,279 --> 00:06:57,610
wonderful videos about this is kind of

172
00:07:01,499 --> 00:06:59,289
how we understand biology operating

173
00:07:04,680 --> 00:07:01,509
today we have an informational component

174
00:07:06,600 --> 00:07:04,690
we have a kind of intermediary between

175
00:07:08,520 --> 00:07:06,610
the information and the function and

176
00:07:11,490 --> 00:07:08,530
then we have this functional component

177
00:07:15,420 --> 00:07:11,500
which is most largely represented by

178
00:07:18,240 --> 00:07:15,430
proteins on the early Earth what could

179
00:07:21,600 --> 00:07:18,250
it have been could it have been proteins

180
00:07:24,390 --> 00:07:21,610
only could it have been RNA only could

181
00:07:25,439 --> 00:07:24,400
it have been DNA only could have been

182
00:07:28,439 --> 00:07:25,449
everything together

183
00:07:32,730 --> 00:07:28,449
I don't know and nobody nobody really

184
00:07:34,379 --> 00:07:32,740
knows for sure but one idea that I think

185
00:07:36,300 --> 00:07:34,389
makes a lot of sense and a lot of people

186
00:07:38,969 --> 00:07:36,310
agree it makes a lot of sense is that

187
00:07:42,150 --> 00:07:38,979
this RNA molecule might be a candidate

188
00:07:44,760 --> 00:07:42,160

to participate in the process of cell

189
00:07:47,550 --> 00:07:44,770
prett self replication and have some

190
00:07:50,400 --> 00:07:47,560
function attributed to it and this is

191
00:07:51,810 --> 00:07:50,410
this idea is really a result of a series

192
00:07:54,240 --> 00:07:51,820
of amazing discoveries that have

193
00:07:57,089 --> 00:07:54,250
happened over the last twenty years or

194
00:07:59,610 --> 00:07:57,099
so where people have found that indeed

195
00:08:02,790 --> 00:07:59,620
RNA molecules are possible of making

196
00:08:05,300 --> 00:08:02,800
themselves again and so they have an

197
00:08:07,770 --> 00:08:05,310
informational component inside of them

198
00:08:10,170 --> 00:08:07,780
because they're able to do things are

199
00:08:13,500 --> 00:08:10,180
able to catalyze chemical reactions or

200
00:08:16,439 --> 00:08:13,510
change the behavior of molecules we can

201
00:08:16,860 --> 00:08:16,449
assign a functional attribute to them as

202
00:08:19,350 --> 00:08:16,870
well

203
00:08:21,779 --> 00:08:19,360
and so RNA takes a special place in

204
00:08:23,640 --> 00:08:21,789
biology it's one of the only polymers

205
00:08:26,010 --> 00:08:23,650
that we know that has a both

206
00:08:28,980 --> 00:08:26,020
informational capacity as well as a

207
00:08:30,899 --> 00:08:28,990
functional capacity proteins we can't

208
00:08:32,399 --> 00:08:30,909
you can try to imagine how that would

209
00:08:33,659 --> 00:08:32,409
store information but it's a little bit

210
00:08:36,810 --> 00:08:33,669
more difficult and not straightforward

211
00:08:39,360 --> 00:08:36,820
and functionally DNA seems to be

212
00:08:42,089 --> 00:08:39,370
chemically almost inert it doesn't have

213
00:08:46,530 --> 00:08:42,099

this ability to hold on to molecules and

214
00:08:48,860 --> 00:08:46,540
change molecules in solution so this is

215
00:08:51,360 --> 00:08:48,870
kind of an idea for how early

216
00:08:53,880 --> 00:08:51,370
replication might happen on the earth

217
00:08:55,889 --> 00:08:53,890
this is a long polymer looks like a

218
00:08:57,300 --> 00:08:55,899
spaghetti noodle on here but we could

219
00:09:00,170 --> 00:08:57,310
imagine that it's actually made out of

220
00:09:03,030 --> 00:09:00,180
oligonucleotides all linked together in

221
00:09:06,420 --> 00:09:03,040
today's biology like I mentioned pre

222
00:09:08,449 --> 00:09:06,430
ously cell growth and proliferation is

223
00:09:11,370 --> 00:09:08,459
fundamentally linked to this process of

224
00:09:13,590 --> 00:09:11,380
duplicating the chromosome and that

225
00:09:16,980 --> 00:09:13,600
changes over time and that gives us this

226
00:09:19,650 --> 00:09:16,990
picture Jim showed earlier a picture

227
00:09:23,420 --> 00:09:19,660
drawn by Darwin who was one of the first

228
00:09:26,280 --> 00:09:23,430
people or two famously draw a

229
00:09:28,499 --> 00:09:26,290
phylogenetic tree which is a graphical

230
00:09:30,930 --> 00:09:28,509
way of depicting relationships in

231
00:09:34,559 --> 00:09:30,940
biology and here's a cartoon diagram

232
00:09:37,980 --> 00:09:34,569
another drawing that was drawn by a Ford

233
00:09:40,740 --> 00:09:37,990
Doolittle in 1999 and it shows this idea

234
00:09:42,780 --> 00:09:40,750
that sometime in the past here on the

235
00:09:45,269 --> 00:09:42,790
bottom would be in the past and the top

236
00:09:47,670 --> 00:09:45,279
would be going forward in time

237
00:09:50,490 --> 00:09:47,680
it shows the idea of diversification

238
00:09:52,199 --> 00:09:50,500

happening and that diversification again

239
00:09:54,930 --> 00:09:52,209
is linked to these mistakes these

240
00:09:57,660 --> 00:09:54,940
mutations that happen and as those

241
00:09:59,400 --> 00:09:57,670
mistakes or mutations happen we can kind

242
00:10:01,499 --> 00:09:59,410
of think about adding more colors or

243
00:10:04,170 --> 00:10:01,509
more diversity to life here so this is

244
00:10:06,509 --> 00:10:04,180
how life is evolving today and continues

245
00:10:10,530 --> 00:10:06,519
to evolve on the planet so how did that

246
00:10:13,110 --> 00:10:10,540
begin originally it's possible that this

247
00:10:15,809 --> 00:10:13,120
cartoon diagram on the top would have

248
00:10:18,540 --> 00:10:15,819
been quite a bit more messy in a world

249
00:10:19,439 --> 00:10:18,550
that was made of RNA molecules that were

250
00:10:21,990 --> 00:10:19,449
self-replicating

251
00:10:25,829 --> 00:10:22,000
and part of this mess would be derived

252
00:10:28,920 --> 00:10:25,839
from the the non specificity of this

253
00:10:31,769 --> 00:10:28,930
replication apparatus and so we could

254
00:10:33,660 --> 00:10:31,779
think about what these messy early

255
00:10:37,590 --> 00:10:33,670
moments in time would be like in biology

256
00:10:40,290 --> 00:10:37,600
before life gained the capacity to to

257
00:10:43,590 --> 00:10:40,300
almost perfectly replicate we would have

258
00:10:46,110 --> 00:10:43,600
a situation where we wouldn't be able to

259
00:10:48,379 --> 00:10:46,120
draw nice clean relationships between

260
00:10:50,759 --> 00:10:48,389
different organisms shown on the top

261
00:10:54,059 --> 00:10:50,769
instead we would have more of this net

262
00:10:57,809 --> 00:10:54,069
or this web on the bottom let me point

263
00:11:00,269 --> 00:10:57,819

out here these arrows these arrows

264
00:11:02,100 --> 00:11:00,279
corresponds to gene sharing or the

265
00:11:04,740 --> 00:11:02,110
sharing of DNA between different

266
00:11:07,439 --> 00:11:04,750
organisms we can call this horizontal

267
00:11:09,210 --> 00:11:07,449
gene transfer and it happens a lot and

268
00:11:11,280 --> 00:11:09,220
it's a it's a mechanism of generating

269
00:11:12,660 --> 00:11:11,290
diversity but most of these lines are

270
00:11:14,970 --> 00:11:12,670
vertical and they don't have many

271
00:11:16,740 --> 00:11:14,980
horizontal lines going on between them

272
00:11:18,810 --> 00:11:16,750
in the past

273
00:11:21,180 --> 00:11:18,820
it's possible that things were quite a

274
00:11:24,420 --> 00:11:21,190
bit more messy in the sense that this

275
00:11:27,930 --> 00:11:24,430
was not replicating with as high as a

276
00:11:29,580 --> 00:11:27,940
fidelity and there was more mixing going

277
00:11:32,460 --> 00:11:29,590
on so this is gonna create an

278
00:11:34,260 --> 00:11:32,470
informational e very messy world so we

279
00:11:35,970 --> 00:11:34,270
have to face up to that this idea that

280
00:11:38,430 --> 00:11:35,980
maybe early life was doing information

281
00:11:41,310 --> 00:11:38,440
transfer in different different ways and

282
00:11:42,990 --> 00:11:41,320
so sometime in the past how can we

283
00:11:47,670 --> 00:11:43,000
imagine what this web would be like or

284
00:11:49,470 --> 00:11:47,680
this kind of messy area today we're kind

285
00:11:51,390 --> 00:11:49,480
of taught in our biology books that we

286
00:11:54,180 --> 00:11:51,400
can separate life and the types of life

287
00:11:56,160 --> 00:11:54,190
quite cleanly and indeed we can for

288
00:11:58,290 --> 00:11:56,170

today's biology today's biology is quite

289
00:12:00,030 --> 00:11:58,300
old it's probably been here for three

290
00:12:02,760 --> 00:12:00,040
and a half or four billion years and

291
00:12:05,520 --> 00:12:02,770
we've these vertical lines we can trace

292
00:12:07,470 --> 00:12:05,530
and we can draw a nice network like this

293
00:12:10,170 --> 00:12:07,480
but in the past how can we imagine that

294
00:12:12,060 --> 00:12:10,180
I want to introduce this concept of the

295
00:12:14,190 --> 00:12:12,070
progeny oak just kind of one of the key

296
00:12:16,410 --> 00:12:14,200
words of the talk that I'm getting here

297
00:12:18,960 --> 00:12:16,420
and it refers to a period of life of

298
00:12:23,070 --> 00:12:18,970
biological history where information

299
00:12:25,310 --> 00:12:23,080
transfer was not happening as cleanly or

300
00:12:28,320 --> 00:12:25,320
with the fidelity that it happens today

301
00:12:30,420 --> 00:12:28,330
instead there was massive gene sharing

302
00:12:31,200 --> 00:12:30,430
and the capacity for life to

303
00:12:34,640 --> 00:12:31,210
self-replicate

304
00:12:38,130 --> 00:12:34,650
was not as good as it was today and so

305
00:12:39,690 --> 00:12:38,140
here's contemporary biology somewhere in

306
00:12:41,730 --> 00:12:39,700
the past there would be a common

307
00:12:43,829 --> 00:12:41,740
ancestor but there's the possibility

308
00:12:46,650 --> 00:12:43,839
that deep in time there would be this

309
00:12:48,630 --> 00:12:46,660
location or this phase of biological

310
00:12:52,200 --> 00:12:48,640
evolution that we could call the pro

311
00:12:53,490 --> 00:12:52,210
Jeannot - and that would be where this

312
00:12:56,160 --> 00:12:53,500
massive gene sharing going on

313
00:12:59,100 --> 00:12:56,170

information transfer is not happening

314
00:13:00,780 --> 00:12:59,110
as cleanly as it does today so let's

315
00:13:04,050 --> 00:13:00,790
work through this idea a little bit if

316
00:13:06,480 --> 00:13:04,060
we represent the diversity of life in

317
00:13:08,130 --> 00:13:06,490
this clean network here we could divide

318
00:13:11,010 --> 00:13:08,140
life that we see on the planet today

319
00:13:13,590 --> 00:13:11,020
between what karl was initially

320
00:13:16,560 --> 00:13:13,600
described as our key bacteria today we

321
00:13:18,420 --> 00:13:16,570
call them archaea we could also make a

322
00:13:21,000 --> 00:13:18,430
group that includes us and this bean

323
00:13:25,290 --> 00:13:21,010
sprout' here which we call eukaryotes

324
00:13:27,270 --> 00:13:25,300
and karl was is other group that he he

325
00:13:29,070 --> 00:13:27,280
and others discovered was what he called

326
00:13:30,329 --> 00:13:29,080
the you bacteria but we can call

327
00:13:34,619 --> 00:13:30,339
bacteria today

328
00:13:37,920 --> 00:13:34,629
our question is from where did this bean

329
00:13:40,230 --> 00:13:37,930
sprout really branch out and lead to the

330
00:13:42,749 --> 00:13:40,240
diversification of life that we see

331
00:13:44,790 --> 00:13:42,759
today could have been here and then

332
00:13:46,470 --> 00:13:44,800
diversity went in this direction could

333
00:13:49,199 --> 00:13:46,480
it have been here and diversity went

334
00:13:50,670 --> 00:13:49,209
that direction and this direction or

335
00:13:53,720 --> 00:13:50,680
could it have been somewhere in the

336
00:13:57,299 --> 00:13:53,730
middle where would that diversity

337
00:14:00,119 --> 00:13:57,309
generation take place from and what time

338
00:14:05,790 --> 00:14:00,129

on the earth would that be those are of

339
00:14:08,549 --> 00:14:05,800
questions so here's a diagram I made on

340
00:14:11,400 --> 00:14:08,559
my kitchen table trying to show you this

341
00:14:16,499 --> 00:14:11,410
idea in the past there would be some

342
00:14:18,749 --> 00:14:16,509
start of information transfer this might

343
00:14:23,189 --> 00:14:18,759
be something you might classify as the

344
00:14:24,869 --> 00:14:23,199
origin of life and diversity generation

345
00:14:26,369 --> 00:14:24,879
would start to happening as that

346
00:14:28,290 --> 00:14:26,379
information was passed along and

347
00:14:30,749 --> 00:14:28,300
propagated remember I said that a

348
00:14:33,329 --> 00:14:30,759
fundamental part of DNA replication is

349
00:14:36,660 --> 00:14:33,339
mistakes and those mistakes then go on

350
00:14:38,569 --> 00:14:36,670
to lead to diversity generation so this

351
00:14:41,249 --> 00:14:38,579
is always going to be happening and

352
00:14:43,319 --> 00:14:41,259
there's also always going to be lots of

353
00:14:44,549 --> 00:14:43,329
extinctions happening on the earth we

354
00:14:46,499 --> 00:14:44,559
don't really know how many different

355
00:14:48,480 --> 00:14:46,509
types of life have lived on the earth

356
00:14:50,069 --> 00:14:48,490
because we don't know how to accurately

357
00:14:51,329 --> 00:14:50,079
quantify the number of extinctions that

358
00:14:54,030 --> 00:14:51,339
have happened through the history of

359
00:14:55,829 --> 00:14:54,040
Earth but we could represent them on

360
00:14:58,919 --> 00:14:55,839
paper by having these terminal lines

361
00:15:00,449 --> 00:14:58,929
here there's another extinction here's

362
00:15:04,439 --> 00:15:00,459
some other extinction here's another

363
00:15:08,699 --> 00:15:04,449

extinction what we see today is kind of

364
00:15:11,610 --> 00:15:08,709
this highly evolved area which doesn't

365
00:15:14,549 --> 00:15:11,620
necessarily go that far back deep into

366
00:15:16,769 --> 00:15:14,559
the past so it's a huge challenge to try

367
00:15:21,569 --> 00:15:16,779
to gain insight into an area that we

368
00:15:24,179 --> 00:15:21,579
can't see so instead of this clean

369
00:15:26,759 --> 00:15:24,189
relationship of drawing one beansprout

370
00:15:28,499 --> 00:15:26,769
or one source leading to the diversity

371
00:15:30,059 --> 00:15:28,509
that we see today I want to suggest to

372
00:15:31,619 --> 00:15:30,069
you that the past might have been a lot

373
00:15:33,329 --> 00:15:31,629
more complicated and it might have

374
00:15:38,490 --> 00:15:33,339
looked like this whole pack of beans

375
00:15:40,350 --> 00:15:38,500
that I incorporated into soup but here

376
00:15:42,020 --> 00:15:40,360
I'm using to display this complicated

377
00:15:44,270 --> 00:15:42,030
Network in the

378
00:15:46,190 --> 00:15:44,280
that may have been on the earth so we

379
00:15:49,040 --> 00:15:46,200
don't know exactly when life started and

380
00:15:51,140 --> 00:15:49,050
we don't know exactly how fast diversity

381
00:15:54,670 --> 00:15:51,150
was generated on the planet to lead to

382
00:15:58,010 --> 00:15:54,680
what we see today we don't know that

383
00:16:00,710 --> 00:15:58,020
life could have started relatively later

384
00:16:03,950 --> 00:16:00,720
probably not this late but I'll use this

385
00:16:06,710 --> 00:16:03,960
as a point just to draw some questions

386
00:16:10,130 --> 00:16:06,720
from you like life may have started here

387
00:16:11,450 --> 00:16:10,140
or a life may have started here and here

388
00:16:14,540 --> 00:16:11,460

on the bottom what I'm showing you is

389
00:16:16,010 --> 00:16:14,550
this kind of from you where we have the

390
00:16:18,590 --> 00:16:16,020
formation of the earth somewhere around

391
00:16:21,440 --> 00:16:18,600
here this is what Ramon was talking

392
00:16:23,840 --> 00:16:21,450
about here we are today so we don't know

393
00:16:25,430 --> 00:16:23,850
exactly where this tree where this

394
00:16:27,470 --> 00:16:25,440
diversity generation would have started

395
00:16:29,480 --> 00:16:27,480
it could have happened on another planet

396
00:16:31,790 --> 00:16:29,490
and that life could have came to this

397
00:16:33,380 --> 00:16:31,800
planet and just continued becoming more

398
00:16:36,050 --> 00:16:33,390
and more diverse or it could have

399
00:16:37,250 --> 00:16:36,060
happened later on our planet how are we

400
00:16:39,980 --> 00:16:37,260
going to get ourselves out of this

401
00:16:41,870 --> 00:16:39,990
problem this is difficult problem we can

402
00:16:44,630 --> 00:16:41,880
constrain some things on this planet by

403
00:16:46,910 --> 00:16:44,640
knowing something about like Ramon told

404
00:16:49,100 --> 00:16:46,920
us this moon-forming impact probably

405
00:16:50,960 --> 00:16:49,110
would have sterilized the planet the

406
00:16:52,850 --> 00:16:50,970
planet became so hot that it wouldn't be

407
00:16:55,580 --> 00:16:52,860
possible to have life as we would really

408
00:16:59,060 --> 00:16:55,590
accept it to be on the planet and on

409
00:17:01,640 --> 00:16:59,070
these molten Lakes we know that sometime

410
00:17:05,060 --> 00:17:01,650
after that relatively soon there were

411
00:17:06,530 --> 00:17:05,070
there was water on the planet so as far

412
00:17:09,110 --> 00:17:06,540
as we understand life today all life

413
00:17:11,300 --> 00:17:09,120

requires water on this planet so after

414
00:17:12,860 --> 00:17:11,310
the formation of water would it planet

415
00:17:15,860 --> 00:17:12,870
cooled down enough to have liquid water

416
00:17:18,199 --> 00:17:15,870
on it we would be able to say maybe life

417
00:17:20,540 --> 00:17:18,209
could be starting around here and so but

418
00:17:22,880 --> 00:17:20,550
there's a huge range of when cells that

419
00:17:26,360 --> 00:17:22,890
we could recognize today actually began

420
00:17:29,210 --> 00:17:26,370
and this range is so big that I would

421
00:17:30,800 --> 00:17:29,220
suggest that it's not really until later

422
00:17:32,260 --> 00:17:30,810
in evolution that we can be really sure

423
00:17:35,720 --> 00:17:32,270
that we have something that is

424
00:17:38,120 --> 00:17:35,730
recognizable as a cell today here I used

425
00:17:40,490 --> 00:17:38,130
the idea of having cyanobacteria which

426
00:17:43,910 --> 00:17:40,500
can acquire electrons from water and

427
00:17:44,960 --> 00:17:43,920
make oxygen as the strongest sign of

428
00:17:47,030 --> 00:17:44,970
life

429
00:17:49,880 --> 00:17:47,040
in terms of something that we could file

430
00:17:51,800 --> 00:17:49,890
a genetically recognized today before

431
00:17:53,750 --> 00:17:51,810
this time we have little hints like

432
00:17:54,770 --> 00:17:53,760
these mounds of life these piles of

433
00:17:56,750 --> 00:17:54,780
cells but

434
00:17:59,660 --> 00:17:56,760
could we recognize those to be part of

435
00:18:03,050 --> 00:17:59,670
the Tree of Life maybe maybe not we have

436
00:18:04,520 --> 00:18:03,060
some signs of metabolism isn't the same

437
00:18:06,650 --> 00:18:04,530
type of metabolism that we see today

438
00:18:09,920 --> 00:18:06,660

maybe maybe not this is difficult

439
00:18:13,730 --> 00:18:09,930
question so we're left with a series of

440
00:18:15,290 --> 00:18:13,740
questions and our job is to try to dig

441
00:18:18,290 --> 00:18:15,300
through the evidence and try to come up

442
00:18:21,800 --> 00:18:18,300
with the best answer here and just

443
00:18:24,140 --> 00:18:21,810
briefly I want to talk about how we can

444
00:18:28,220 --> 00:18:24,150
start trying to constrain this one way

445
00:18:30,440 --> 00:18:28,230
is to use an energy perspective and like

446
00:18:32,510 --> 00:18:30,450
a chemist would like Jim would say that

447
00:18:34,280 --> 00:18:32,520
life's not too different from other

448
00:18:37,070 --> 00:18:34,290
chemical process here's a butane lighter

449
00:18:40,700 --> 00:18:37,080
it takes butane molecules and combines

450
00:18:42,080 --> 00:18:40,710
them with oxygen and it makes flames I'd

451
00:18:44,260 --> 00:18:42,090
like to introduce the concept to you

452
00:18:47,240 --> 00:18:44,270
that life is not so different from this

453
00:18:49,700 --> 00:18:47,250
in fact all life can be partly

454
00:18:52,280 --> 00:18:49,710
understood as an electronic process so

455
00:18:54,920 --> 00:18:52,290
for example our bodies today we're now

456
00:18:58,400 --> 00:18:54,930
taking electrons that were taking in my

457
00:19:00,710 --> 00:18:58,410
case from my tempura dawn that I had for

458
00:19:04,040 --> 00:19:00,720
lunch and I'm taking those electrons and

459
00:19:05,870 --> 00:19:04,050
my cells are allowing these electrons to

460
00:19:07,640 --> 00:19:05,880
flow through my cell and my cells are

461
00:19:10,100 --> 00:19:07,650
doing some work and that work I'm up

462
00:19:13,310 --> 00:19:10,110
here able to talk and so what we're

463
00:19:15,170 --> 00:19:13,320

going to try to do and our big challenge

464
00:19:18,350 --> 00:19:15,180
is to try to understand how to link

465
00:19:22,220 --> 00:19:18,360
energy and work processes in the cell

466
00:19:23,960 --> 00:19:22,230
with this informational history today we

467
00:19:25,700 --> 00:19:23,970
can understand energy processes on the

468
00:19:29,330 --> 00:19:25,710
earth but what were those energy

469
00:19:31,010 --> 00:19:29,340
processes like in the past combining

470
00:19:33,350 --> 00:19:31,020
these knowledge together the energy

471
00:19:34,520 --> 00:19:33,360
systems and the DNA systems gives us

472
00:19:36,530 --> 00:19:34,530
these different energetic and

473
00:19:38,030 --> 00:19:36,540
information fingerprints and it's these

474
00:19:39,500 --> 00:19:38,040
types of fingerprints that we're going

475
00:19:41,930 --> 00:19:39,510
to be able to use in the future to try

476
00:19:44,630 --> 00:19:41,940
try to define what early biological

477
00:19:47,420 --> 00:19:44,640
evolution was like we don't know what

478
00:19:48,530 --> 00:19:47,430
that would like look like exactly but

479
00:19:51,290 --> 00:19:48,540
it's probably going to be something

480
00:19:54,110 --> 00:19:51,300
complicated like this diagram which is

481
00:19:56,660 --> 00:19:54,120
shown in gray many possible paths of

482
00:19:59,090 --> 00:19:56,670
evolution and then in black just the

483
00:20:01,780 --> 00:19:59,100
types of life that we see today so our

484
00:20:05,450 --> 00:20:01,790
our grand challenge is to try to uncover

485
00:20:08,120 --> 00:20:05,460
this period of biological history for

486
00:20:09,800 --> 00:20:08,130
which we can't really see I hope

487
00:20:12,500 --> 00:20:09,810
to be able to tell you in five or ten

488
00:20:13,820 --> 00:20:12,510

years more about this area thank you

489
00:20:17,580 --> 00:20:13,830
very much

490
00:20:48,960 --> 00:20:34,270
[Music]