
AbSciCon
2019

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

2
00:00:11,880 --> 00:00:09,110
[Applause]

3
00:00:14,850 --> 00:00:11,890
thank you very much I'm sorry I'm not

4
00:00:17,910 --> 00:00:14,860
Benton Clark he gives great talks he's a

5
00:00:20,670 --> 00:00:17,920
big thinker and has a lot to say he's

6
00:00:22,740 --> 00:00:20,680
been involved in the Mars exploration

7
00:00:26,190 --> 00:00:22,750
program since the Viking mission so it's

8
00:00:30,650 --> 00:00:26,200
a little sad that he's not here so what

9
00:00:34,590 --> 00:00:30,660
you're looking at is ATP synthase it's a

10
00:00:37,290 --> 00:00:34,600
huge molecule equivalent mass of 50,000

11
00:00:41,760 --> 00:00:37,300
carbon atoms it sits in the in the wall

12
00:00:43,979 --> 00:00:41,770
of cells and it takes protons which are

13
00:00:49,830 --> 00:00:43,989

concentrated at the bottom in this

14
00:00:52,380 --> 00:00:49,840
picture they they rotate the that stem

15
00:00:57,650 --> 00:00:52,390
and they changes the conformation of the

16
00:01:01,799 --> 00:00:57,660
top and it takes and the the ATP ADP and

17
00:01:04,650 --> 00:01:01,809
phosphate are in this more dilute

18
00:01:09,620 --> 00:01:04,660
solution they get captured by the

19
00:01:13,859 --> 00:01:09,630
rotating molecule and it produces an ATP

20
00:01:15,750 --> 00:01:13,869
adp to ATP this this molecule is or

21
00:01:18,359 --> 00:01:15,760
something very close to it is present in

22
00:01:21,960 --> 00:01:18,369
virtually every living thing that's how

23
00:01:25,740 --> 00:01:21,970
we how everything produces the energy

24
00:01:30,359 --> 00:01:25,750
molecule adenosine triphosphate that is

25
00:01:34,530 --> 00:01:30,369
used in many many reactions so it's a

26
00:01:39,060 --> 00:01:34,540
really fundamental molecule so the next

27
00:01:41,280 --> 00:01:39,070
picture is is flipped unfortunately so

28
00:01:43,980 --> 00:01:41,290
the rotating part is on the bottom now

29
00:01:46,530 --> 00:01:43,990
the concentration of protons is at the

30
00:01:50,880 --> 00:01:46,540
top and the reason I put this up here is

31
00:01:53,370 --> 00:01:50,890
that this ATP synthase is a huge

32
00:01:57,359 --> 00:01:53,380
molecule and it's required by everything

33
00:01:59,609 --> 00:01:57,369
and it uses the flow of protons this

34
00:02:03,569 --> 00:01:59,619
time from the top to the bottom to make

35
00:02:07,400 --> 00:02:03,579
the ATP what was missing in the first

36
00:02:13,170 --> 00:02:07,410
picture is how that proton concentration

37
00:02:17,970 --> 00:02:13,180
happens and all living things today have

38
00:02:22,400 --> 00:02:17,980

a set of molecules that in in the cell

39
00:02:27,290 --> 00:02:22,410
wall these that create that

40
00:02:30,830 --> 00:02:27,300
flux of protons and so you might ask

41
00:02:34,460 --> 00:02:30,840
well which came first these this this

42
00:02:37,820 --> 00:02:34,470
complex that produces the ATP or the the

43
00:02:40,310 --> 00:02:37,830
sequence of other molecules that produce

44
00:02:42,470 --> 00:02:40,320
the gradient and people who have thought

45
00:02:46,730 --> 00:02:42,480
about this long before me said well I

46
00:02:50,060 --> 00:02:46,740
think you've got to have this first to

47
00:02:52,850 --> 00:02:50,070
make the ATP and so something else and

48
00:02:55,370 --> 00:02:52,860
this had become second so something else

49
00:03:02,180 --> 00:02:55,380
had to produce this concentration of

50
00:03:05,140 --> 00:03:02,190
protons in the environment so I just

51
00:03:08,540 --> 00:03:05,150
want to say when this all when ATP

52
00:03:14,570 --> 00:03:08,550
appeared so it's shared by everything up

53
00:03:16,670 --> 00:03:14,580
here and so that it and things there are

54
00:03:18,730 --> 00:03:16,680
things that precede that are not shared

55
00:03:21,320 --> 00:03:18,740
up here like this the type of cell wall

56
00:03:24,980 --> 00:03:21,330
it's different between these so

57
00:03:27,370 --> 00:03:24,990
something happened here ATP synthase the

58
00:03:31,520 --> 00:03:27,380
genetic code other things happened over

59
00:03:34,310 --> 00:03:31,530
3 billion years ago and our last common

60
00:03:36,800 --> 00:03:34,320
ancestor is in this region too so our

61
00:03:40,730 --> 00:03:36,810
last common answer universal common

62
00:03:41,780 --> 00:03:40,740
answers also had ATP synthase so the

63
00:03:46,130 --> 00:03:41,790

people have been thinking about what

64
00:03:49,400 --> 00:03:46,140
came first the ATP synthase or the the

65
00:03:51,530 --> 00:03:49,410
gener are the are the system that

66
00:03:55,490 --> 00:03:51,540
produces the proton gradient started

67
00:03:57,710 --> 00:03:55,500
thinking about this and recently some

68
00:03:59,840 --> 00:03:57,720
colleagues of mine and I started

69
00:04:02,060 --> 00:03:59,850
thinking about it as well that the

70
00:04:03,850 --> 00:04:02,070
common thinking is that here on the

71
00:04:07,850 --> 00:04:03,860
mid-atlantic ridge you get a natural

72
00:04:13,970 --> 00:04:07,860
gradient of protons by the mixing of

73
00:04:17,479 --> 00:04:13,980
hydrothermal waters and it's a widely

74
00:04:18,710 --> 00:04:17,489
cited widely talked about mechanism so

75
00:04:20,539 --> 00:04:18,720
my colleagues and I have been talking

76
00:04:24,080 --> 00:04:20,549
about another mechanism which I want to

77
00:04:29,690 --> 00:04:24,090
spend a little more time on here in am a

78
00:04:34,130 --> 00:04:29,700
different Ridge system so this is the

79
00:04:35,510 --> 00:04:34,140
model of Russell Martin Nick Lane in

80
00:04:38,240 --> 00:04:35,520
which the here

81
00:04:42,140 --> 00:04:38,250
is a the lost city chimneys these are

82
00:04:44,540 --> 00:04:42,150
massive ten tens of meters high they're

83
00:04:48,050 --> 00:04:44,550
made out of carbonate and they funnel

84
00:04:50,270 --> 00:04:48,060
high pH water from the sea floor some of

85
00:04:53,390 --> 00:04:50,280
the bottle in the crust up through these

86
00:04:55,490 --> 00:04:53,400
chimneys out into seawater and so the

87
00:04:58,640 --> 00:04:55,500
seawater pH there is about seven and a

88
00:05:01,219 --> 00:04:58,650

half this is this is 10 so you right

89
00:05:03,710 --> 00:05:01,229
where this mixing occurs here this is

90
00:05:06,200 --> 00:05:03,720
this this is a little section of the

91
00:05:09,710 --> 00:05:06,210
carbonate chimney and this is only about

92
00:05:12,800 --> 00:05:09,720
three centimeters across the the high pH

93
00:05:16,879 --> 00:05:12,810
fluid is coming through here and mixing

94
00:05:19,879 --> 00:05:16,889
in this region right at the edge of the

95
00:05:22,760 --> 00:05:19,889
chimney so you got two two and a half

96
00:05:25,219 --> 00:05:22,770
units of pH difference right here so

97
00:05:27,620 --> 00:05:25,229
lots of protons here not many protons

98
00:05:32,899 --> 00:05:27,630
here if you had a little chamber in this

99
00:05:35,450 --> 00:05:32,909
region you could write for Bruce proton

100
00:05:37,490 --> 00:05:35,460
flux a natural proton flux which is what

101
00:05:39,830 --> 00:05:37,500
people are looking for so this is their

102
00:05:46,779 --> 00:05:39,840
model so here's that here's the chimney

103
00:05:51,290 --> 00:05:46,789
here's a protocell a self-assembling

104
00:05:53,870 --> 00:05:51,300
membrane and here's the high the low pH

105
00:05:57,080 --> 00:05:53,880
high proton concentration on the outside

106
00:06:00,800 --> 00:05:57,090
here's the vent water down here pH 10

107
00:06:03,409 --> 00:06:00,810
and this protocell sits between and if

108
00:06:06,320 --> 00:06:03,419
you were to put some sort of proto

109
00:06:10,399 --> 00:06:06,330
mechanism for converting the photon flux

110
00:06:12,770 --> 00:06:10,409
into an energy molecule it would sit in

111
00:06:16,490 --> 00:06:12,780
the in this cell sit in this cell wall

112
00:06:21,370 --> 00:06:16,500
for this proto cell wall that's the the

113
00:06:26,120 --> 00:06:21,380

model for hide the thermal chimneys so

114
00:06:29,330 --> 00:06:26,130
the one that we came up with was uses a

115
00:06:32,830 --> 00:06:29,340
system which is which is vast on the in

116
00:06:36,469 --> 00:06:32,840
the oceans this ocean crust aquifer

117
00:06:40,520 --> 00:06:36,479
covers about 60% of the Earth's surface

118
00:06:42,920 --> 00:06:40,530
in the sea here are some details this

119
00:06:45,409 --> 00:06:42,930
one on the Juan de Fuca Ridge is 64

120
00:06:46,640 --> 00:06:45,419
degrees there's no oxygen pH seven and a

121
00:06:49,190 --> 00:06:46,650
half which is not too different from

122
00:06:51,950 --> 00:06:49,200
seawater it also has some traces of

123
00:06:55,880 --> 00:06:51,960
compounds that are important for life

124
00:07:00,080 --> 00:06:55,890
and in there we think the the natural

125
00:07:01,670 --> 00:07:00,090
proton gradient is formed so I didn't

126
00:07:05,030 --> 00:07:01,680
bring up this big chunk of basalt which

127
00:07:08,300 --> 00:07:05,040
I brought with me is on the seafloor

128
00:07:12,050 --> 00:07:08,310
there are these really heavy dark black

129
00:07:14,420 --> 00:07:12,060
rocks which for now almost twenty years

130
00:07:18,410 --> 00:07:14,430
now we've been talking about these

131
00:07:21,530 --> 00:07:18,420
little tunnels that form inside the rock

132
00:07:23,960 --> 00:07:21,540
so this big chunk of rock has cracks

133
00:07:26,360 --> 00:07:23,970
through it and starting at the cracks

134
00:07:29,300 --> 00:07:26,370
there are tunnels that extend out into

135
00:07:30,800 --> 00:07:29,310
the glass so this is solid material this

136
00:07:32,900 --> 00:07:30,810
is an open fracture which would have

137
00:07:36,980 --> 00:07:32,910
water in it and these tunnels have

138
00:07:38,840 --> 00:07:36,990

formed somehow the consider I wouldn't

139
00:07:41,450 --> 00:07:38,850
say the consensus a lot of people think

140
00:07:46,700 --> 00:07:41,460
they're biological they may not be but I

141
00:07:48,830 --> 00:07:46,710
think they are so the question that we

142
00:07:53,240 --> 00:07:48,840
were approaching was how do these things

143
00:07:55,130 --> 00:07:53,250
form and what is what is going on in

144
00:08:02,900 --> 00:07:55,140
this dark region that we can't really

145
00:08:06,110 --> 00:08:02,910
see very well so oh yeah back up just a

146
00:08:08,780 --> 00:08:06,120
second so if you were able to if you cut

147
00:08:12,530 --> 00:08:08,790
one of these tunnels in half or across

148
00:08:15,200 --> 00:08:12,540
there and look at it in detail it looks

149
00:08:19,370 --> 00:08:15,210
like this so this is the solid rock

150
00:08:22,180 --> 00:08:19,380
solid volcanic rock glass this is the

151
00:08:26,230 --> 00:08:22,190
interior of the tunnel and this is all a

152
00:08:30,890 --> 00:08:26,240
fibrous porous phyllosilicate clay and

153
00:08:38,330 --> 00:08:30,900
this barrier here somehow forms along

154
00:08:41,620 --> 00:08:38,340
that tunnel and it's woops I see but I

155
00:08:45,200 --> 00:08:41,630
didn't do something wrong here

156
00:08:48,110 --> 00:08:45,210
so the alteration of volcanic glass to

157
00:08:51,470 --> 00:08:48,120
clay happens by the replacement of all

158
00:08:54,230 --> 00:08:51,480
the cations in the glass by protons so

159
00:08:56,600 --> 00:08:54,240
all of this used to be have a lot of

160
00:08:59,600 --> 00:08:56,610
elements in it that are now gone a lot

161
00:09:01,890 --> 00:08:59,610
of calcium magnesium iron maybe sodium

162
00:09:04,530 --> 00:09:01,900
and potassium they're all gone and

163
00:09:11,040 --> 00:09:04,540

you end up with this silicon aluminum

164
00:09:12,960 --> 00:09:11,050
silicate sodium oxide silicate and they

165
00:09:15,240 --> 00:09:12,970
grow you can see by their length they

166
00:09:18,360 --> 00:09:15,250
grow lengthwise they do not grow wider

167
00:09:21,210 --> 00:09:18,370
as time goes on and I think it's because

168
00:09:27,960 --> 00:09:21,220
there's no alteration out here this this

169
00:09:31,890 --> 00:09:27,970
thing is a barrier three minutes okay so

170
00:09:34,380 --> 00:09:31,900
this is how the glass is altered

171
00:09:36,750 --> 00:09:34,390
you've got protons on the outside they

172
00:09:39,000 --> 00:09:36,760
are moving across the boundary they are

173
00:09:43,920 --> 00:09:39,010
replacing cations on the inside you have

174
00:09:47,130 --> 00:09:43,930
a proton flux into the rock and so what

175
00:09:50,610 --> 00:09:47,140
we've said is that okay here's that

176
00:09:52,890 --> 00:09:50,620
here's a drawing of that fracture the

177
00:09:55,890 --> 00:09:52,900
water in here here's the glass here's

178
00:09:57,930 --> 00:09:55,900
the rock and here's a cell we were just

179
00:10:02,220 --> 00:09:57,940
hypothetically put a cell on the surface

180
00:10:05,520 --> 00:10:02,230
of the fracture and it's the the protons

181
00:10:08,280 --> 00:10:05,530
they're moving into this tunnel now they

182
00:10:10,830 --> 00:10:08,290
moved to the end they go into the rock

183
00:10:13,680 --> 00:10:10,840
they replace sodium potassium magnesium

184
00:10:16,800 --> 00:10:13,690
calcium so that you have a flux of

185
00:10:20,280 --> 00:10:16,810
protons from this pH seven water out

186
00:10:22,440 --> 00:10:20,290
into the rock and if you look at the the

187
00:10:27,480 --> 00:10:22,450
normal rate at which a rock will

188
00:10:30,240 --> 00:10:27,490

dissolve in in seawater at pH seven and

189
00:10:32,450 --> 00:10:30,250
a half and 50 to 60 degrees which is

190
00:10:34,920 --> 00:10:32,460
what the temperature is of that aquifer

191
00:10:36,630 --> 00:10:34,930
you can then these measures have been

192
00:10:39,960 --> 00:10:36,640
made by other people

193
00:10:43,650 --> 00:10:39,970
workers and useless inin in Iceland you

194
00:10:47,640 --> 00:10:43,660
can determine that for the area of the

195
00:10:50,850 --> 00:10:47,650
end of this tunnel you're moving 10,000

196
00:10:53,460 --> 00:10:50,860
protons a second into that rock and

197
00:10:55,920 --> 00:10:53,470
you're getting equivalent charge out of

198
00:10:58,710 --> 00:10:55,930
that rock back through here this cell

199
00:11:02,610 --> 00:10:58,720
then is in the position to harvest the

200
00:11:04,830 --> 00:11:02,620
energy of 10,000 protons a second it's a

201
00:11:10,440 --> 00:11:04,840
it's it's a significant amount of energy

202
00:11:13,680 --> 00:11:10,450
so this the cell makes it this barrier

203
00:11:14,780 --> 00:11:13,690
here on the surface the protons enter

204
00:11:16,400 --> 00:11:14,790
the glass

205
00:11:18,320 --> 00:11:16,410
Tunnel is initiated and probably wasn't

206
00:11:22,520 --> 00:11:18,330
a tunnel to begin with it just a little

207
00:11:26,360 --> 00:11:22,530
indentation here pH in the tunnel rises

208
00:11:32,180 --> 00:11:26,370
to 9.8 they form the clay that you saw

209
00:11:37,040 --> 00:11:32,190
in that picture and the the potential

210
00:11:40,280 --> 00:11:37,050
across here due to the 7.5 29.8 pH

211
00:11:41,300 --> 00:11:40,290
difference is 100 - 120 milli hundred

212
00:11:44,540 --> 00:11:41,310
and twenty-eight millivolts

213
00:11:47,000 --> 00:11:44,550

that's a big charge and it's very

214
00:11:49,670 --> 00:11:47,010
similar to what is produced in cells

215
00:11:52,490 --> 00:11:49,680
when they make their own proton gradient

216
00:11:58,550 --> 00:11:52,500
with those three little molecules I was

217
00:12:02,120 --> 00:11:58,560
pointing out early on and the power the

218
00:12:05,740 --> 00:12:02,130
power to the cell is 3 times 10 to the

219
00:12:08,930 --> 00:12:05,750
minus 16 joules per second per cell

220
00:12:11,780 --> 00:12:08,940
because of this proton flux the the

221
00:12:13,910 --> 00:12:11,790
minimum energy needed for a cell is

222
00:12:16,430 --> 00:12:13,920
probably somewhere around 10 to the

223
00:12:18,590 --> 00:12:16,440
minus 20 joules per second so you've got

224
00:12:22,940 --> 00:12:18,600
several orders of magnitude more energy

225
00:12:29,810 --> 00:12:22,950
from this process than the minimum so

226
00:12:31,460 --> 00:12:29,820
the the main points the tunnels in the

227
00:12:33,620 --> 00:12:31,470
basalt they must grow longer and they

228
00:12:36,860 --> 00:12:33,630
don't get wider they're a channel for

229
00:12:39,050 --> 00:12:36,870
protons so they diffuse from water down

230
00:12:41,150 --> 00:12:39,060
the tunnel out into the glass and the

231
00:12:44,600 --> 00:12:41,160
cell at the entrance would generate

232
00:12:48,290 --> 00:12:44,610
would be able to generate ATP from that

233
00:12:51,590 --> 00:12:48,300
flux so what are the implications these

234
00:12:55,640 --> 00:12:51,600
water to basalt proton gradients had to

235
00:12:57,950 --> 00:12:55,650
be available on earth from the time the

236
00:13:01,670 --> 00:12:57,960
earth formed when there were solid rock

237
00:13:03,650 --> 00:13:01,680
on the surface and water this could have

238
00:13:06,680 --> 00:13:03,660

been going on since the beginning of the

239
00:13:08,030 --> 00:13:06,690
planet there have been tunnels very

240
00:13:09,530 --> 00:13:08,040
similar to the ones I showed you in

241
00:13:12,130 --> 00:13:09,540
three-and-a-half billion year old the

242
00:13:15,080 --> 00:13:12,140
salts on earth so if those are

243
00:13:16,580 --> 00:13:15,090
equivalent which is evidence for life at

244
00:13:18,800 --> 00:13:16,590
three-and-a-half billion based on the

245
00:13:20,930 --> 00:13:18,810
same mechanism there's also one martian

246
00:13:23,390 --> 00:13:20,940
type of martian meteor that has some

247
00:13:25,170 --> 00:13:23,400
tunnels very similar I don't know where

248
00:13:30,600 --> 00:13:25,180
to go with that

249
00:13:32,910 --> 00:13:30,610
and based on recent discoveries of

250
00:13:36,240 --> 00:13:32,920
exoplanets with rock and want that have

251
00:13:39,360 --> 00:13:36,250
rock and water maybe 25% of the planets

252
00:13:42,410 --> 00:13:39,370
near us could use this mechanism to

253
00:13:52,740 --> 00:13:42,420
generate energy to drive metabolism

254
00:14:08,210 --> 00:13:52,750
that's it we have time for one quick

255
00:14:13,290 --> 00:14:11,850
yeah so yeah the question was why is it

256
00:14:15,330 --> 00:14:13,300
just one cell and no it doesn't the

257
00:14:18,390 --> 00:14:15,340
whole surface I I didn't explain

258
00:14:21,570 --> 00:14:18,400
everything I think that's a really good

259
00:14:24,770 --> 00:14:21,580
point but I think the cell must control

260
00:14:28,380 --> 00:14:24,780
its local environment by laying down a

261
00:14:30,150 --> 00:14:28,390
proton impermeable layer around it so

262
00:14:33,090 --> 00:14:30,160
that the protons have to go through the

263
00:14:34,560 --> 00:14:33,100

cell because if you're if what you if

264
00:14:36,720 --> 00:14:34,570
they didn't do that they were just

265
00:14:39,300 --> 00:14:36,730
totally erode the surface and you would

266
00:14:41,400 --> 00:14:39,310
have no no tunnels so I think there must

267
00:14:43,260 --> 00:14:41,410
be another component which was actually

268
00:14:47,130 --> 00:14:43,270
drawn in the in the model but I didn't

269
00:14:49,590 --> 00:14:47,140
have time to talk about it there's a

270
00:14:54,620 --> 00:14:49,600
poster tonight 7 o'clock if you want to

271
00:14:54,630 --> 00:14:59,480
have time for one more question

272
00:14:59,490 --> 00:15:31,800
yes

273
00:15:38,309 --> 00:15:36,389
that could be and so the questions about

274
00:15:40,819 --> 00:15:38,319
thinking about energy in Broadway so I'm

275
00:16:16,160 --> 00:15:40,829
thinking about the potential across the

276
00:16:20,480 --> 00:16:19,080
yeah yeah please discuss later thank you