
AbSciCon
2017
MESA, ARIZONA

1
00:00:12,250 --> 00:00:06,150
you

2
00:00:17,290 --> 00:00:14,460
[Music]

3
00:00:20,679 --> 00:00:17,300
thanks Eric Eric for the invitation to

4
00:00:22,359 --> 00:00:20,689
talk today so yeah my lab studies these

5
00:00:28,240 --> 00:00:22,369
King the synthetic iron oxidizing

6
00:00:30,099 --> 00:00:28,250
bacteria and on the one up here standing

7
00:00:32,830 --> 00:00:30,109
and presenting today but this is really

8
00:00:35,500 --> 00:00:32,840
the work of Gerald Murray who just got

9
00:00:37,810 --> 00:00:35,510
his PhD in Kerstin kuso's lab at the

10
00:00:40,600 --> 00:00:37,820
university of llena and roman Barco

11
00:00:42,520 --> 00:00:40,610
who's a actually an NSF postdoc who

12
00:00:45,190 --> 00:00:42,530
splits his time between my lab and Ken

13
00:00:47,979 --> 00:00:45,200

Nealson slab at USC and I also like to

14
00:00:50,740 --> 00:00:47,989
thank NASA Astrobiology for funding and

15
00:00:55,780 --> 00:00:50,750
NSF and in case any of you were

16
00:00:59,830 --> 00:00:57,430
that little symbol there that's the

17
00:01:05,290 --> 00:00:59,840
alchemists sign for iron which is what

18
00:01:06,790 --> 00:01:05,300
we study so why iron first of all it's

19
00:01:10,570 --> 00:01:06,800
probably the most abundant

20
00:01:12,969 --> 00:01:10,580
chemosynthetic element on earth and

21
00:01:16,330 --> 00:01:12,979
probably on any other rocky planet that

22
00:01:18,640 --> 00:01:16,340
we know about well maybe I shouldn't say

23
00:01:20,140 --> 00:01:18,650
that being in an astrobiology meeting

24
00:01:22,030 --> 00:01:20,150
but anyway I'll say it anyway because

25
00:01:25,800 --> 00:01:22,040
I'm a microbiologist and I can say

26
00:01:29,590 --> 00:01:25,810
stupid things about geology and plants

27
00:01:31,450 --> 00:01:29,600
so so another thing is bio signature so

28
00:01:33,190 --> 00:01:31,460
I'm sure some of the member you've seen

29
00:01:34,630 --> 00:01:33,200
this paper that you recently came out in

30
00:01:40,359 --> 00:01:34,640
nature where they were claiming for

31
00:01:43,630 --> 00:01:40,369
these iron oxide bio signatures in 3.8

32
00:01:47,980 --> 00:01:43,640
or older Giga billion year old rocks or

33
00:01:51,789 --> 00:01:47,990
older from the Hudson Bay and you know

34
00:01:53,770 --> 00:01:51,799
very interesting I'm a I study modern

35
00:01:55,270 --> 00:01:53,780
systems I've never actually gone out in

36
00:01:58,859 --> 00:01:55,280
the field and collected a rock or looked

37
00:02:01,620 --> 00:01:58,869
at a rock slide under the microscope but

38
00:02:03,880 --> 00:02:01,630

when I look at these types of structures

39
00:02:05,800 --> 00:02:03,890
you know they are somewhat consistent

40
00:02:07,240 --> 00:02:05,810
they certainly are not totally

41
00:02:09,249 --> 00:02:07,250
consistent with anything we see in the

42
00:02:14,640 --> 00:02:09,259
modern world but you know after four

43
00:02:18,220 --> 00:02:14,650
billion years who knows so I guess I'm a

44
00:02:21,910 --> 00:02:18,230
hopeful hopeful agnostic and that this

45
00:02:24,850 --> 00:02:21,920
work will really be borne out but just

46
00:02:27,190 --> 00:02:24,860
to show that you can find micro fossils

47
00:02:30,610 --> 00:02:27,200
that are very well preserved

48
00:02:32,620 --> 00:02:30,620
in this slide here is 170 million year

49
00:02:34,270 --> 00:02:32,630
old earth crust where you see all these

50
00:02:36,460 --> 00:02:34,280
little filamentous structures that are

51
00:02:38,950 --> 00:02:36,470
about one or two microns in diameter

52
00:02:41,410 --> 00:02:38,960
this is about a three week old culture

53
00:02:43,600 --> 00:02:41,420
of an iron oxidizing bacteria that was

54
00:02:45,340 --> 00:02:43,610
grown in the lab and you can see there's

55
00:02:47,110 --> 00:02:45,350
a lot of similarity in those structures

56
00:02:49,150 --> 00:02:47,120
and when you look at the fine detail it

57
00:02:50,980 --> 00:02:49,160
becomes pretty clear that some of these

58
00:02:53,620 --> 00:02:50,990
types of structures clearly must have

59
00:02:55,450 --> 00:02:53,630
been formed by by microbes how closely

60
00:03:01,000 --> 00:02:55,460
related they are to the microbes we have

61
00:03:03,160 --> 00:03:01,010
today that's another question so we

62
00:03:06,310 --> 00:03:03,170
definitely see biogenic structures in

63
00:03:08,200 --> 00:03:06,320

nature that these organisms form and

64
00:03:13,840 --> 00:03:08,210
they can be small and large so on the

65
00:03:16,120 --> 00:03:13,850
left here is a intact microbial mat that

66
00:03:17,950 --> 00:03:16,130
we did a three dimensional imaging of

67
00:03:21,160 --> 00:03:17,960
with the confocal microscope and it was

68
00:03:23,440 --> 00:03:21,170
formed by this sheath forming bacterium

69
00:03:27,040 --> 00:03:23,450
here what's really cool about this is

70
00:03:29,170 --> 00:03:27,050
that that 50 micrometer or so layer at

71
00:03:31,720 --> 00:03:29,180
the leading edge of that mat is where

72
00:03:33,550 --> 00:03:31,730
all these sheaf forming bacteria are and

73
00:03:35,710 --> 00:03:33,560
all its red materials just the empty

74
00:03:37,810 --> 00:03:35,720
sheets that they leave behind so they

75
00:03:39,610 --> 00:03:37,820
really are geo engineers or ecological

76
00:03:42,729 --> 00:03:39,620
engineers they structure their

77
00:03:45,430 --> 00:03:42,739
environments and produce massive amounts

78
00:03:47,920 --> 00:03:45,440
of this amorphous very hydrate which is

79
00:03:52,000 --> 00:03:47,930
quite a reactive mineral to go to the

80
00:03:53,740 --> 00:03:52,010
other scale this is a the golden tower

81
00:03:55,810 --> 00:03:53,750
which we discovered a couple of years

82
00:03:59,320 --> 00:03:55,820
ago while doing submersible dives at the

83
00:04:01,330 --> 00:03:59,330
aschen event site and mariana that

84
00:04:03,370 --> 00:04:01,340
little bar down there is 10 centimeters

85
00:04:05,470 --> 00:04:03,380
so this structure is nearly 10 meters

86
00:04:07,150 --> 00:04:05,480
tall and it seemed as far as we could

87
00:04:09,220 --> 00:04:07,160
tell it was composed primarily a

88
00:04:12,250 --> 00:04:09,230

bacteria that looked like this form

89
00:04:14,620 --> 00:04:12,260
these long stalks so this is formed over

90
00:04:17,530 --> 00:04:14,630
a diffuse event flow where there was

91
00:04:19,479 --> 00:04:17,540
iron coming out and it just slowly built

92
00:04:21,789 --> 00:04:19,489
up over time as far as we could tell and

93
00:04:23,680 --> 00:04:21,799
form this massive structure in fact very

94
00:04:25,450 --> 00:04:23,690
interesting too that they undergo very

95
00:04:29,980 --> 00:04:25,460
little grazing and things like that by

96
00:04:31,810 --> 00:04:29,990
protozoa or shrimp so they don't undergo

97
00:04:34,390 --> 00:04:31,820
the same kinds of pressures that for

98
00:04:35,860 --> 00:04:34,400
example sulfur oxidizing mats too so

99
00:04:37,400 --> 00:04:35,870
they so they have the potential to

100
00:04:39,860 --> 00:04:37,410
really accumulate

101
00:04:42,140 --> 00:04:39,870
so what's going on how do these bacteria

102
00:04:44,900 --> 00:04:42,150
actually oxidizing iron and that's the

103
00:04:46,900 --> 00:04:44,910
primary topic I want to discuss today so

104
00:04:50,270 --> 00:04:46,910
this is a model that we came up with

105
00:04:52,790 --> 00:04:50,280
published last year which is based on

106
00:04:55,070 --> 00:04:52,800
both comparative genomics and some

107
00:04:56,870 --> 00:04:55,080
wholesale proteomics we did with an

108
00:04:58,670 --> 00:04:56,880
organism we've been studying in lab for

109
00:05:01,340 --> 00:04:58,680
a while Mary profundus roxton's

110
00:05:04,490 --> 00:05:01,350
so this is an example of extracellular

111
00:05:06,560 --> 00:05:04,500
electrons transfer because it cells they

112
00:05:08,000 --> 00:05:06,570
so they oxidize iron on the outer

113
00:05:09,980 --> 00:05:08,010

membrane because again they have the

114
00:05:11,420 --> 00:05:09,990
problem as soon a neutral pH as soon as

115
00:05:13,640 --> 00:05:11,430
you oxidize iron you immediately

116
00:05:15,050 --> 00:05:13,650
precipitate a faery hydride mineral if

117
00:05:17,870 --> 00:05:15,060
you do inside the cell you're going to

118
00:05:20,960 --> 00:05:17,880
fill yourself with insoluble iron oxides

119
00:05:22,640 --> 00:05:20,970
so we believe this process should occur

120
00:05:24,410 --> 00:05:22,650
at the outer membrane so there you have

121
00:05:26,990 --> 00:05:24,420
floor you have to get electrons from the

122
00:05:28,580 --> 00:05:27,000
outer membrane across the periplasm to

123
00:05:31,850 --> 00:05:28,590
the inner membrane to the electron

124
00:05:33,860 --> 00:05:31,860
transport chain and so we found in all

125
00:05:35,630 --> 00:05:33,870
the iron oxidizers both from freshwater

126
00:05:41,360 --> 00:05:35,640
and marine systems that we've looked at

127
00:05:44,840 --> 00:05:41,370
is this cyc to homolog should call cyc

128
00:05:48,190 --> 00:05:44,850
to pv-1 and we believe this could be the

129
00:05:52,120 --> 00:05:48,200
did the initial iron oxidase this is a

130
00:05:56,780 --> 00:05:52,130
it's a poor in cytochrome C complex and

131
00:05:58,910 --> 00:05:56,790
and then electrons would so that would

132
00:06:00,320 --> 00:05:58,920
be the initial electron acceptor and

133
00:06:01,610 --> 00:06:00,330
that electrons get transferred across

134
00:06:04,400 --> 00:06:01,620
the periplasm

135
00:06:06,020 --> 00:06:04,410
through we found some other cytochromes

136
00:06:08,060 --> 00:06:06,030
it could be potential shuttles whether

137
00:06:09,710 --> 00:06:08,070
your shuttles or could form a wire we

138
00:06:12,170 --> 00:06:09,720

don't really know and then there's an

139
00:06:17,270 --> 00:06:12,180
electron transport chain which has the

140
00:06:20,300 --> 00:06:17,280
different components interesting aspects

141
00:06:22,040 --> 00:06:20,310
of this are this alternative complex 3

142
00:06:25,340 --> 00:06:22,050
which we quite commonly find the

143
00:06:27,110 --> 00:06:25,350
military oxido reductase system and then

144
00:06:29,960 --> 00:06:27,120
most of these organisms use the

145
00:06:32,390 --> 00:06:29,970
cytochrome C VD 3 type terminal oxidase

146
00:06:34,340 --> 00:06:32,400
which is a high affinity iron oxidation

147
00:06:42,670 --> 00:06:34,350
that makes sense because we think these

148
00:06:44,900 --> 00:06:42,680
organs are generally micro silica so

149
00:06:47,300 --> 00:06:44,910
that's what we've known and most of the

150
00:06:48,790 --> 00:06:47,310
organs we've isolated have been obligate

151
00:06:52,510 --> 00:06:48,800
iron oxidizes I should

152
00:06:54,700 --> 00:06:52,520
say but recently relaxed not that recent

153
00:06:56,529 --> 00:06:54,710
now but a few years ago I isolated this

154
00:06:59,469 --> 00:06:56,539
new organism which were just in the

155
00:07:02,320 --> 00:06:59,479
process of publishing on and of calling

156
00:07:03,659 --> 00:07:02,330
it your CEO by Laura it represents a new

157
00:07:06,189 --> 00:07:03,669
genus in this group of Zeta

158
00:07:08,260 --> 00:07:06,199
proteobacteria Zeta proteobacteria are

159
00:07:11,020 --> 00:07:08,270
almost exclusively iron oxidizers that

160
00:07:13,659 --> 00:07:11,030
live in marine environments so isolated

161
00:07:15,249 --> 00:07:13,669
one strain from the tagged vent site in

162
00:07:17,110 --> 00:07:15,259
the mid-atlantic ridge and another one

163
00:07:19,149 --> 00:07:17,120

from the snail vents in the Marianas on

164
00:07:22,119 --> 00:07:19,159
the opposite sides of the world at least

165
00:07:23,680 --> 00:07:22,129
and it's kind of a nondescript organism

166
00:07:25,390 --> 00:07:23,690
in terms of them if you have a lot of

167
00:07:28,059 --> 00:07:25,400
the other iron oxidizers it's a little

168
00:07:30,070 --> 00:07:28,069
rod and it forms these very amorphous

169
00:07:31,480 --> 00:07:30,080
particulate iron oxides it doesn't make

170
00:07:34,089 --> 00:07:31,490
any of those structures that I was

171
00:07:37,839 --> 00:07:34,099
showing earlier but what's really cool

172
00:07:40,589 --> 00:07:37,849
about it is it grow not only on iron but

173
00:07:43,149 --> 00:07:40,599
also on hydrogen and so those

174
00:07:45,730 --> 00:07:43,159
organization on or enriched and isolated

175
00:07:48,219 --> 00:07:45,740
on zero valent iron which is both a

176
00:07:49,480 --> 00:07:48,229
source of iron and we use it as that but

177
00:07:51,189 --> 00:07:49,490
you also have to be careful because it

178
00:07:54,670 --> 00:07:51,199
can be a source of hydrogen as well and

179
00:07:56,050 --> 00:07:54,680
it turned out this organism grew really

180
00:07:57,969 --> 00:07:56,060
well in the enrichment and part of the

181
00:07:59,709 --> 00:07:57,979
reason was that because it was growing

182
00:08:01,779 --> 00:07:59,719
both on the iron and the hydrogen and

183
00:08:04,659 --> 00:08:01,789
when we separate those out and grow it

184
00:08:07,300 --> 00:08:04,669
on ferrous chloride or hydrogen you can

185
00:08:09,909 --> 00:08:07,310
see in the squares here is the hydrogen

186
00:08:11,830 --> 00:08:09,919
it grows a little bit better and in the

187
00:08:15,070 --> 00:08:11,840
circles here is growing on ferrous

188
00:08:17,230 --> 00:08:15,080

chloride and a pretty pretty decent cell

189
00:08:19,809 --> 00:08:17,240
yields and doubling times on the order

190
00:08:21,850 --> 00:08:19,819
of 15 to 20 hours if you don't add

191
00:08:25,930 --> 00:08:21,860
either hydrogen or iron there's no

192
00:08:28,180 --> 00:08:25,940
growth so we sequence the genomes of

193
00:08:30,159 --> 00:08:28,190
these two organisms and found that they

194
00:08:33,250 --> 00:08:30,169
did indeed have hydrogenase the

195
00:08:37,719 --> 00:08:33,260
hydrogenation subunits for uptake of

196
00:08:39,370 --> 00:08:37,729
hydrogen and then we compared so we have

197
00:08:41,260 --> 00:08:39,380
a bunch of single-cell genomes from

198
00:08:43,839 --> 00:08:41,270
others ada proteobacteria that we've

199
00:08:46,150 --> 00:08:43,849
isolated or sorry we haven't ISIL we've

200
00:08:50,620 --> 00:08:46,160
isolated the single cells and sequence

201
00:08:52,540 --> 00:08:50,630
the genomes and we found that they all

202
00:08:56,530 --> 00:08:52,550
belong to this single clade here which

203
00:08:58,420 --> 00:08:56,540
recalls 800 tu9 and they were different

204
00:09:01,390 --> 00:08:58,430
from these other isolates that we have

205
00:09:04,150 --> 00:09:01,400
which represent different clades within

206
00:09:06,070 --> 00:09:04,160
group and so that was interesting so it

207
00:09:07,990 --> 00:09:06,080
seemed like it was this one clade that

208
00:09:11,560 --> 00:09:08,000
we have that it seems to have the

209
00:09:14,350 --> 00:09:11,570
ability to it has these hydrogenases

210
00:09:18,250 --> 00:09:14,360
that are capable of promoting growth on

211
00:09:20,230 --> 00:09:18,260
hydrogen and so then we were asked the

212
00:09:24,100 --> 00:09:20,240
question of well how where are they

213
00:09:27,700 --> 00:09:24,110

found and so we scraped the short read

214
00:09:29,830 --> 00:09:27,710
archive to look specifically for this

215
00:09:33,280 --> 00:09:29,840
particular group and so we found about

216
00:09:35,140 --> 00:09:33,290
50,000 projects that have been done that

217
00:09:37,300 --> 00:09:35,150
are non-human associated there's about

218
00:09:39,670 --> 00:09:37,310
30,000 human associated projects in

219
00:09:42,190 --> 00:09:39,680
there and we found only about four or

220
00:09:44,260 --> 00:09:42,200
five projects where the this particular

221
00:09:46,360 --> 00:09:44,270
OTU is found and they were all at higher

222
00:09:48,340 --> 00:09:46,370
environments that makes us think these

223
00:09:50,860 --> 00:09:48,350
organisms although they can grow on

224
00:09:57,400 --> 00:09:50,870
hydrogen they may be more adapted for

225
00:10:01,480 --> 00:09:57,410
growing on iron so what can we learn so

226
00:10:03,160 --> 00:10:01,490
I meant to say that the beauty of having

227
00:10:04,720 --> 00:10:03,170
this organism is everything we've done

228
00:10:06,490 --> 00:10:04,730
before was done an obligate iron

229
00:10:08,710 --> 00:10:06,500
oxidizer so now we have an organism that

230
00:10:11,380 --> 00:10:08,720
can grow on both hydrogen iron we can at

231
00:10:13,360 --> 00:10:11,390
least do some comparative proteomics in

232
00:10:16,480 --> 00:10:13,370
this case and so this was work that

233
00:10:22,660 --> 00:10:16,490
Romans been doing and so I'm showing

234
00:10:24,520 --> 00:10:22,670
here is the proteome map so so we as I

235
00:10:26,530 --> 00:10:24,530
said we sequence the genome it's about

236
00:10:29,140 --> 00:10:26,540
99 plus percent complete but there are

237
00:10:31,270 --> 00:10:29,150
gaps in it so these shows the 13

238
00:10:33,430 --> 00:10:31,280

different contexts on the outside here

239
00:10:35,440 --> 00:10:33,440
which is the genome and then all the

240
00:10:37,960 --> 00:10:35,450
proteins that we identified are in this

241
00:10:40,480 --> 00:10:37,970
inner blue ring here and then proteins

242
00:10:45,010 --> 00:10:40,490
that are upregulated on hydrogen are

243
00:10:49,120 --> 00:10:45,020
shown in the green and on iron on in the

244
00:10:51,010 --> 00:10:49,130
red so basically we found about 42

245
00:10:53,290 --> 00:10:51,020
percent of the proteins and the

246
00:10:55,180 --> 00:10:53,300
proteomics experiment and about a

247
00:10:59,320 --> 00:10:55,190
hundred of them are upregulated on iron

248
00:11:03,430 --> 00:10:59,330
and about 1.5 or I'm sorry about 150

249
00:11:04,930 --> 00:11:03,440
were upregulated on hydrogen and it's

250
00:11:06,430 --> 00:11:04,940
easy for me to put this slide up here

251
00:11:07,900 --> 00:11:06,440
and talk about it but took Rome on

252
00:11:10,660 --> 00:11:07,910
several months to do this you had to

253
00:11:13,690 --> 00:11:10,670
grow all these cells in triplicate

254
00:11:16,270 --> 00:11:13,700
batches to get really robust statistics

255
00:11:18,550 --> 00:11:16,280
and the challenge with these we can't do

256
00:11:19,900 --> 00:11:18,560
genetics with them and the challenge

257
00:11:21,310 --> 00:11:19,910
with biochemistry is getting enough

258
00:11:23,080 --> 00:11:21,320
biomass and then you've got all these

259
00:11:24,430 --> 00:11:23,090
iron oxides around that you have to deal

260
00:11:25,780 --> 00:11:24,440
with the hydrogen actually was a lot

261
00:11:28,000 --> 00:11:25,790
easier of course because we didn't have

262
00:11:30,580 --> 00:11:28,010
the iron around but still it was it was

263
00:11:35,470 --> 00:11:30,590

a technical challenge to do this and so

264
00:11:38,290 --> 00:11:35,480
what did we find in terms of the

265
00:11:40,780 --> 00:11:38,300
comparative proteomics in terms of what

266
00:11:43,960 --> 00:11:40,790
was expressed and what wasn't so we

267
00:11:47,400 --> 00:11:43,970
found the hydrogenase operon on hydrogen

268
00:11:50,350 --> 00:11:47,410
was more highly expressed that was good

269
00:11:52,120 --> 00:11:50,360
we found that the phosphate that there's

270
00:11:53,740 --> 00:11:52,130
a transport system for phosphate which

271
00:11:55,540 --> 00:11:53,750
is highly expressed on iron this is

272
00:11:57,880 --> 00:11:55,550
actually nice internal control because

273
00:11:59,710 --> 00:11:57,890
as e self expire knock sides those iron

274
00:12:02,170 --> 00:11:59,720
oxides very strongly buying phosphorus

275
00:12:03,970 --> 00:12:02,180
and so the fact that they overexpressed

276
00:12:06,400 --> 00:12:03,980
these systems for taking up phosphorus

277
00:12:09,310 --> 00:12:06,410
is sort of makes sense there was also

278
00:12:11,200 --> 00:12:09,320
this thyroid auxin reductase which is

279
00:12:14,440 --> 00:12:11,210
involved and one of the things that's

280
00:12:16,270 --> 00:12:14,450
involved in is probably defense against

281
00:12:17,920 --> 00:12:16,280
reactive oxygen species again when you

282
00:12:20,020 --> 00:12:17,930
have iron around an oxygen you're going

283
00:12:22,140 --> 00:12:20,030
to get the potential for reactive oxygen

284
00:12:24,970 --> 00:12:22,150
species these lawyers had to deal with

285
00:12:27,490 --> 00:12:24,980
what was not differentially regulated

286
00:12:29,500 --> 00:12:27,500
with Rubisco there their ability to

287
00:12:34,510 --> 00:12:29,510
succeed too that's not surprising or the

288
00:12:37,930 --> 00:12:34,520

CVD 3 the AC t system also was expressed

289
00:12:43,290 --> 00:12:37,940
in both cases and the cyc 2 was also

290
00:12:45,730 --> 00:12:43,300
expressed about equivalently this was a

291
00:12:47,380 --> 00:12:45,740
little disappointing I guess because of

292
00:12:49,270 --> 00:12:47,390
course we were hoping to see this stuff

293
00:12:52,540 --> 00:12:49,280
regulated when they were growing on hot

294
00:12:54,580 --> 00:12:52,550
on iron and downregulated a hydrogen so

295
00:12:58,900 --> 00:12:54,590
the case was true for how the hydrogen

296
00:13:00,880 --> 00:12:58,910
is but not for the cyc 2 so I'll just

297
00:13:03,970 --> 00:13:00,890
come back to the model here so I mean it

298
00:13:05,350 --> 00:13:03,980
was good that we saw cyc 2 highly

299
00:13:07,720 --> 00:13:05,360
expressed in these because we'd only

300
00:13:11,100 --> 00:13:07,730
done this in a different species before

301
00:13:14,140 --> 00:13:11,110
so that's consistent with it being there

302
00:13:15,610 --> 00:13:14,150
we didn't see the cyc one we think

303
00:13:19,720 --> 00:13:15,620
there's a different system that they may

304
00:13:21,250 --> 00:13:19,730
use for shuttling electrons so you know

305
00:13:23,980 --> 00:13:21,260
what's going on here in terms of this

306
00:13:26,140 --> 00:13:23,990
well I can wave my hands and say they're

307
00:13:27,340 --> 00:13:26,150
probably constitutively expressing the

308
00:13:29,560 --> 00:13:27,350
cyc 2 and

309
00:13:31,420 --> 00:13:29,570
and the primary argument I could make

310
00:13:33,190 --> 00:13:31,430
sure that an ecological right but these

311
00:13:35,500 --> 00:13:33,200
organs really want to grow on iron and

312
00:13:37,900 --> 00:13:35,510
so they always have they're always ready

313
00:13:40,330 --> 00:13:37,910

to grow on iron but if some hydrogen

314
00:13:42,790 --> 00:13:40,340
comes along and they can adapt and take

315
00:13:46,570 --> 00:13:42,800
over and use that instead so with that

316
00:13:48,490 --> 00:13:46,580
I'm going to conclude again these

317
00:13:51,130 --> 00:13:48,500
neutral philic iron oxidizers are

318
00:13:55,120 --> 00:13:51,140
obligate and this utilized

319
00:13:58,570 --> 00:13:55,130
extracellular electron transfer and as I

320
00:14:01,330 --> 00:13:58,580
said cyc too seems to be constitutively

321
00:14:04,540 --> 00:14:01,340
expressed and I just talked about the

322
00:14:05,920 --> 00:14:04,550
the ecological reason for that but

323
00:14:07,450 --> 00:14:05,930
another thing that we're thinking about

324
00:14:10,930 --> 00:14:07,460
it would be really interesting now is

325
00:14:13,030 --> 00:14:10,940
perhaps your sea of Ivor is essential as

326
00:14:15,580 --> 00:14:13,040
a sentinel for the presence of hydrogen

327
00:14:17,830 --> 00:14:15,590
a diffuse flow events because we only

328
00:14:19,000 --> 00:14:17,840
see it in some communities so it would

329
00:14:20,140 --> 00:14:19,010
be interesting go out and see if those

330
00:14:29,890 --> 00:14:20,150
are the communities where as more

331
00:14:32,470 --> 00:14:29,900
hydrogen present so thanks thank you

332
00:14:39,780 --> 00:14:32,480
Dave time for again probably one

333
00:14:43,800 --> 00:14:42,240
hi David my name is Sandra um I was only

334
00:14:45,810 --> 00:14:43,810
thinking expand a little bit on the

335
00:14:51,900 --> 00:14:45,820
electron transport mechanism across the

336
00:14:55,379 --> 00:14:51,910
membrane a little bit so you know I mean

337
00:14:57,509 --> 00:14:55,389
we think that that there there's the

338
00:15:00,060 --> 00:14:57,519

cytochromes they're probably involved in

339
00:15:02,310 --> 00:15:00,070
shuttling electrons from the outer

340
00:15:04,410 --> 00:15:02,320
membrane or from that I mean we we're

341
00:15:07,110 --> 00:15:04,420
still I mean I should our models still

342
00:15:09,150 --> 00:15:07,120
based around a cyc - like proteins being

343
00:15:13,590 --> 00:15:09,160
that outer that does the initial contact

344
00:15:16,610 --> 00:15:13,600
with Fe - and oxidizes the FE 3 and that

345
00:15:19,160 --> 00:15:16,620
then those electrons are transferred and

346
00:15:21,300 --> 00:15:19,170
yeah so we don't find some of the

347
00:15:23,610 --> 00:15:21,310
canonical proteins that have been found

348
00:15:27,090 --> 00:15:23,620
for example in acidify Oh bacillus that

349
00:15:30,660 --> 00:15:27,100
are involved in that process you know we

350
00:15:32,550 --> 00:15:30,670
don't find necessarily the same systems

351
00:15:34,800 --> 00:15:32,560
it would be in some of the iron reducers

352
00:15:38,280 --> 00:15:34,810
which go in the other direction

353
00:15:40,579 --> 00:15:38,290
so you know whether this is some kind of

354
00:15:43,769 --> 00:15:40,589
a shuttle system where there's a soluble

355
00:15:46,889 --> 00:15:43,779
cytochrome that does that transfer or

356
00:15:48,300 --> 00:15:46,899
whether there's actually a he or chain

357
00:15:50,370 --> 00:15:48,310
of heenes or something like that but

358
00:15:52,889 --> 00:15:50,380
after the wire these organs have some

359
00:15:55,139 --> 00:15:52,899
fairly large gene groups in them but not

360
00:16:00,389 --> 00:15:55,149
as not as large as for example geo

361
00:16:03,269 --> 00:16:00,399
bacter we don't tend to find cytochromes

362
00:16:07,230 --> 00:16:03,279
that have say 30 or 40 your genes in

363
00:16:08,850 --> 00:16:07,240

them or cytokines and groups in them but

364
00:16:11,189 --> 00:16:08,860
they some of them have 10 to 20 but

365
00:16:12,900 --> 00:16:11,199
we're still that's we're trying to sort

366
00:16:14,340 --> 00:16:12,910
that out one thing I would say is I

367
00:16:16,439 --> 00:16:14,350
don't think there's any Universal

368
00:16:18,059 --> 00:16:16,449
mechanism here I think you know each

369
00:16:19,620 --> 00:16:18,069
system that each organism

370
00:16:20,550 --> 00:16:19,630
maybe not each organism but I think

371
00:16:24,329 --> 00:16:20,560
there's going to be quite a bit of

372
00:16:25,860 --> 00:16:24,339
modularity in this system thank you okay