
AbSciCon
2019

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

2
00:00:12,200 --> 00:00:09,100
[Applause]

3
00:00:13,850 --> 00:00:12,210
so I'm going to try to wrap up the

4
00:00:17,030 --> 00:00:13,860
session quickly so we can all get to

5
00:00:18,769 --> 00:00:17,040
lunch but Laurie and Pete both did a

6
00:00:21,040 --> 00:00:18,779
great job of explaining by

7
00:00:23,690 --> 00:00:21,050
electrochemical systems and they're

8
00:00:26,510 --> 00:00:23,700
especially the relevance to astrobiology

9
00:00:32,300 --> 00:00:26,520
and I'll talk about one of our systems

10
00:00:34,550 --> 00:00:32,310
so first I'd like to acknowledge my lab

11
00:00:39,140 --> 00:00:34,560
group I'm a postdoc at the Naval

12
00:00:41,000 --> 00:00:39,150
Research Lab Sara Glavine is my PI Bryan

13
00:00:43,580 --> 00:00:41,010

Eddie and Anthony Malinowski help with

14
00:00:45,680 --> 00:00:43,590
bioinformatics and Matt Yates and Lonnie

15
00:00:46,880 --> 00:00:45,690
tender are electro chemists and so

16
00:00:49,910 --> 00:00:46,890
there's a lot of us that have come

17
00:00:53,840 --> 00:00:49,920
together to characterize the system I'll

18
00:00:56,959 --> 00:00:53,850
talk to you about today and so again we

19
00:00:58,700 --> 00:00:56,969
heard from both Lori and Pete about bio

20
00:01:01,099 --> 00:00:58,710
electrochemical systems and I really

21
00:01:03,139 --> 00:01:01,109
like what Pete had to say that all life

22
00:01:06,290 --> 00:01:03,149
is sort of a bio electrochemical system

23
00:01:09,050 --> 00:01:06,300
in the environment but again we're

24
00:01:12,800 --> 00:01:09,060
looking at bio electrochemical systems

25
00:01:14,840 --> 00:01:12,810
basically as a way to culture organisms

26
00:01:18,020 --> 00:01:14,850
or communities and we can look directly

27
00:01:20,149 --> 00:01:18,030
at electron transfer and see what energy

28
00:01:24,380 --> 00:01:20,159
is required and what energy is moving

29
00:01:26,510 --> 00:01:24,390
through the system and so here I have a

30
00:01:29,270 --> 00:01:26,520
benthic microbial fuel cell which is

31
00:01:32,030 --> 00:01:29,280
benthic is at the bottom of the ocean or

32
00:01:34,399 --> 00:01:32,040
a river and typically we have one

33
00:01:36,280 --> 00:01:34,409
electrode that's in the sediment and at

34
00:01:38,230 --> 00:01:36,290
this electrode micro rna's

35
00:01:41,080 --> 00:01:38,240
microorganisms are capable of oxidizing

36
00:01:45,200 --> 00:01:41,090
organics and those electrons are moved

37
00:01:47,330 --> 00:01:45,210
pushed onto that electrode the electrons

38
00:01:50,080 --> 00:01:47,340

can move through the system to another

39
00:01:53,480 --> 00:01:50,090
electrode in the overlying seawater and

40
00:01:56,389 --> 00:01:53,490
here other microorganisms are capable of

41
00:01:59,560 --> 00:01:56,399
use utilizing those electrons for

42
00:02:04,310 --> 00:01:59,570
reduction reactions and so there's

43
00:02:07,219 --> 00:02:04,320
generally two types of BES where you

44
00:02:09,139 --> 00:02:07,229
keep either an electrode at an anodic

45
00:02:11,820 --> 00:02:09,149
potential and you have electricity

46
00:02:15,360 --> 00:02:11,830
production or you keep the electrode at

47
00:02:17,730 --> 00:02:15,370
a cathodic potential and you use the

48
00:02:22,770 --> 00:02:17,740
microorganisms use that those electrons

49
00:02:24,630 --> 00:02:22,780
for reduction reactions and so again as

50
00:02:27,620 --> 00:02:24,640
Pete and Laurie showed us there's many

51
00:02:30,510 --> 00:02:27,630
applications of BES with relevance to

52
00:02:32,730 --> 00:02:30,520
astrobiology specifically if we want to

53
00:02:36,360 --> 00:02:32,740
look at how electron transfer is working

54
00:02:39,990 --> 00:02:36,370
in unique communities and so Laurie

55
00:02:43,770 --> 00:02:40,000
showed some hydrothermal vents there's

56
00:02:46,890 --> 00:02:43,780
also some applications of microbial fuel

57
00:02:49,800 --> 00:02:46,900
cells to life detection in this case

58
00:02:53,070 --> 00:02:49,810
current production would be correlated

59
00:02:57,630 --> 00:02:53,080
with photo or chemo with autotrophic

60
00:03:00,480 --> 00:02:57,640
microorganisms BES in general have a lot

61
00:03:02,520 --> 00:03:00,490
of use in wastewater treatment nutrient

62
00:03:04,640 --> 00:03:02,530
recycling and so they're also looked at

63
00:03:07,860 --> 00:03:04,650

as potential life support systems for

64
00:03:11,700 --> 00:03:07,870
both the ISS and for long-term space

65
00:03:13,950 --> 00:03:11,710
travel and so the system I'm going to

66
00:03:15,680 --> 00:03:13,960
talk to you about today is a unique

67
00:03:18,770 --> 00:03:15,690
system where we were trying to make a

68
00:03:21,660 --> 00:03:18,780
rechargeable battery so many my

69
00:03:23,790 --> 00:03:21,670
microbial electrochemical systems can be

70
00:03:26,640 --> 00:03:23,800
thought of as batteries as Laurie barge

71
00:03:29,490 --> 00:03:26,650
mentioned but what we wanted to do here

72
00:03:33,120 --> 00:03:29,500
instead of having a set anode and a set

73
00:03:36,120 --> 00:03:33,130
cathode in the ocean sediment and in the

74
00:03:39,150 --> 00:03:36,130
overlying sea water and having power

75
00:03:41,930 --> 00:03:39,160
production from oxidation of organics at

76
00:03:45,540 --> 00:03:41,940
the anode we wanted to see if we could

77
00:03:48,750 --> 00:03:45,550
basically switch this anode to a cathode

78
00:03:51,840 --> 00:03:48,760
and push power into the system we wanted

79
00:03:54,470 --> 00:03:51,850
to be able to push power into the

80
00:03:57,660 --> 00:03:54,480
sediment have organisms utilize those

81
00:03:59,400 --> 00:03:57,670
electrons and store that charge in

82
00:04:02,180 --> 00:03:59,410
charge carrying molecules in the

83
00:04:06,020 --> 00:04:02,190
sediment we'd be able to use this later

84
00:04:13,860 --> 00:04:08,790
fueling instruments at the bottom of the

85
00:04:16,409 --> 00:04:13,870
ocean or submersibles for example and so

86
00:04:19,700 --> 00:04:16,419
what we did is we took an initial

87
00:04:22,920 --> 00:04:19,710
inoculum from a river sediment and we

88
00:04:24,820 --> 00:04:22,930

put it we brought it into a lab scale

89
00:04:27,429 --> 00:04:24,830
environment and we used a typical

90
00:04:29,469 --> 00:04:27,439
age cell by electrochemical reactor and

91
00:04:31,390 --> 00:04:29,479
so here we don't have a sediment

92
00:04:33,640 --> 00:04:31,400
electrode but we have a counter

93
00:04:35,350 --> 00:04:33,650
electrode and a working electrode the

94
00:04:36,999 --> 00:04:35,360
working electrode is the one that we're

95
00:04:40,149 --> 00:04:37,009
going to switch the potential back and

96
00:04:42,879 --> 00:04:40,159
forth to see if we can both produce

97
00:04:46,179 --> 00:04:42,889
power and consume power depending on our

98
00:04:48,610 --> 00:04:46,189
needs and so our NOC um was a river

99
00:04:51,640 --> 00:04:48,620
sediment we used anaerobic artificial

100
00:04:53,469 --> 00:04:51,650
seawater as a culture medium and the

101
00:04:56,890 --> 00:04:53,479
working electrode was a piece of carbon

102
00:04:58,869 --> 00:04:56,900
cloth and basically we alternated the

103
00:05:01,200 --> 00:04:58,879
the potential of this working electrode

104
00:05:03,040 --> 00:05:01,210
from operating at a cathode where

105
00:05:05,350 --> 00:05:03,050
electrons are available to the

106
00:05:08,140 --> 00:05:05,360
microorganisms to operating as an anode

107
00:05:14,469 --> 00:05:08,150
where the electrode operates as an

108
00:05:18,010 --> 00:05:14,479
electron acceptor we did oopsie we used

109
00:05:21,249 --> 00:05:18,020
a twenty-minute charge/discharge cycle

110
00:05:23,200 --> 00:05:21,259
and so every 10 minutes the electrode

111
00:05:26,290 --> 00:05:23,210
potential would switch on the working

112
00:05:29,469 --> 00:05:26,300
electrode we also covered the reactors

113
00:05:32,740 --> 00:05:29,479

so that we could harvest or enrich for

114
00:05:35,200 --> 00:05:32,750
non photosynthetic organisms and so on

115
00:05:37,540 --> 00:05:35,210
this graph on the right its current

116
00:05:39,279 --> 00:05:37,550
density over time and basically at bolt

117
00:05:41,559 --> 00:05:39,289
when the electrode is operating at

118
00:05:45,579 --> 00:05:41,569
either potential a current is generated

119
00:05:48,309 --> 00:05:45,589
and as you can see around 10 days we

120
00:05:51,010 --> 00:05:48,319
start to see this symmetric increase and

121
00:05:53,529 --> 00:05:51,020
decrease in current and each data point

122
00:05:56,379 --> 00:05:53,539
is representative of 1 10 minute cycle

123
00:05:58,390 --> 00:05:56,389
and so every 10 minutes again this cycle

124
00:06:00,969 --> 00:05:58,400
is switching between a notic current and

125
00:06:04,029 --> 00:06:00,979
cathodic current and so this symmetric

126
00:06:06,760 --> 00:06:04,039
increase in both currents suggests that

127
00:06:08,980 --> 00:06:06,770
the same pathway or biochemical reaction

128
00:06:12,790 --> 00:06:08,990
is occurring to allow this reversibility

129
00:06:14,379 --> 00:06:12,800
of the system so what we wanted to

130
00:06:17,260 --> 00:06:14,389
figure out who's there and what are they

131
00:06:19,420 --> 00:06:17,270
doing we initially inoculated from a

132
00:06:21,219 --> 00:06:19,430
river sediment and so it's just a

133
00:06:25,869 --> 00:06:21,229
bacterial community that's been enriched

134
00:06:28,240 --> 00:06:25,879
for this reversibility so we did first a

135
00:06:31,269 --> 00:06:28,250
met a genomics analysis we retrieved

136
00:06:34,899 --> 00:06:31,279
initially 135 bins which could be

137
00:06:37,360 --> 00:06:34,909
potentially 135 different organisms only

138
00:06:38,800 --> 00:06:37,370

58 or those bins have at least 80%

139
00:06:41,020 --> 00:06:38,810
completeness

140
00:06:43,150 --> 00:06:41,030
there's at least 16 bins that are make

141
00:06:45,760 --> 00:06:43,160
up at least 1% relative abundance in the

142
00:06:49,210 --> 00:06:45,770
community and 10 of these bins are at

143
00:06:51,370 --> 00:06:49,220
least 92% complete 5 bins have at least

144
00:06:55,720 --> 00:06:51,380
relative have a relative abundance at

145
00:06:58,960 --> 00:06:55,730
least 6% and of these 5 2 bins are Delta

146
00:07:01,150 --> 00:06:58,970
proteobacteria and so for a bes this

147
00:07:02,620 --> 00:07:01,160
indicates relatively high diversity and

148
00:07:08,290 --> 00:07:02,630
the presence of sulfate-reducing

149
00:07:11,650 --> 00:07:08,300
bacteria and so in our metagenomics

150
00:07:15,340 --> 00:07:11,660
analysis we were also able to assign a

151
00:07:18,100 --> 00:07:15,350
taxonomy these are our what we're

152
00:07:20,800 --> 00:07:18,110
confident in assigning but you'll see

153
00:07:23,430 --> 00:07:20,810
that our average abundant our most

154
00:07:27,040 --> 00:07:23,440
abundant organisms about 22% abundant

155
00:07:30,310 --> 00:07:27,050
sorry across the 6 replicates and this

156
00:07:33,070 --> 00:07:30,320
maps to a sulfate-reducing the solver

157
00:07:37,060 --> 00:07:33,080
Occulus bar CI the next eight bins

158
00:07:39,310 --> 00:07:37,070
account for about 66 percent of the

159
00:07:41,920 --> 00:07:39,320
total abundance of the community and

160
00:07:45,820 --> 00:07:41,930
you'll also notice that i included two

161
00:07:47,710 --> 00:07:45,830
bins with very low abundance but you'll

162
00:07:51,159 --> 00:07:47,720
see that we have another sulfate reducer

163
00:07:57,100 --> 00:07:51,169

and two other possible sulfate reducers

164
00:08:00,219 --> 00:07:57,110
and so now if we switch to the activity

165
00:08:02,230 --> 00:08:00,229
looking at our meta transcriptomics the

166
00:08:04,300 --> 00:08:02,240
reason I included those two very low

167
00:08:07,450 --> 00:08:04,310
abundant been low abundance bins is

168
00:08:09,969 --> 00:08:07,460
because bin 127 is actually our most

169
00:08:13,719 --> 00:08:09,979
active bin and so this maps to the

170
00:08:17,350 --> 00:08:13,729
sulfur over bo alkali Phyllis and so it

171
00:08:20,920 --> 00:08:17,360
appears that we have some sulfate

172
00:08:24,310 --> 00:08:20,930
reducing organisms at work in the

173
00:08:27,190 --> 00:08:24,320
reversible system and so I'm gonna focus

174
00:08:29,620 --> 00:08:27,200
on our two most abundant and the most

175
00:08:31,600 --> 00:08:29,630
active organisms again we have the self

176
00:08:34,719 --> 00:08:31,610
Arceus bar CI which is the most abundant

177
00:08:37,029 --> 00:08:34,729
it's a sulfate reducer amezo file and

178
00:08:39,579 --> 00:08:37,039
has been shown to oxidize for me in

179
00:08:42,180 --> 00:08:39,589
acetate to carbon dioxide via the wood

180
00:08:44,710 --> 00:08:42,190
long dull pathway our most active

181
00:08:46,930 --> 00:08:44,720
organism is also our most interesting

182
00:08:50,650 --> 00:08:46,940
organism so it's technically classified

183
00:08:51,380 --> 00:08:50,660
as a sulfate reducer but in pure culture

184
00:08:55,040 --> 00:08:51,390
in the lab

185
00:08:57,949 --> 00:08:55,050
it has been shown to oxidize sulfide

186
00:09:00,170 --> 00:08:57,959
with a high expression of sulfate

187
00:09:02,000 --> 00:09:00,180
reduction genes so this organism

188
00:09:04,759 --> 00:09:02,010

actually doesn't have any genes for

189
00:09:09,019 --> 00:09:04,769
sulphide oxidation but in culture it

190
00:09:10,460 --> 00:09:09,029
oxidizes sulphide via possibly the

191
00:09:13,220 --> 00:09:10,470
sulfate reduction pathway

192
00:09:16,790 --> 00:09:13,230
it also has genes for carbon fixation

193
00:09:19,940 --> 00:09:16,800
and it has been associated with an anode

194
00:09:24,410 --> 00:09:19,950
in a sulfide oxidizing by

195
00:09:25,579 --> 00:09:24,420
electrochemical system and so we wanted

196
00:09:27,590 --> 00:09:25,589
to look at what genes were

197
00:09:29,210 --> 00:09:27,600
differentially expressed between our two

198
00:09:31,550 --> 00:09:29,220
different potentials so when the

199
00:09:33,079 --> 00:09:31,560
electrodes operating as an anode versus

200
00:09:36,199 --> 00:09:33,089
when is operating as a cathode and

201
00:09:40,519 --> 00:09:36,209
basically I highlighted in red that the

202
00:09:43,730 --> 00:09:40,529
most highly expressed genes are a bunch

203
00:09:45,199 --> 00:09:43,740
of hetero disulfide reductases these

204
00:09:47,900 --> 00:09:45,209
were initially characterized in

205
00:09:51,850 --> 00:09:47,910
methanogens but in bacteria they're

206
00:09:55,030 --> 00:09:51,860
considered to replace the reverse

207
00:10:00,710 --> 00:09:55,040
dissimilatory sulfite reductase genes

208
00:10:03,050 --> 00:10:00,720
and so these genes are down regulated at

209
00:10:04,699 --> 00:10:03,060
a cathode and now we can sort of start

210
00:10:08,090 --> 00:10:04,709
thinking about what metabolism is

211
00:10:09,829 --> 00:10:08,100
occurring in our system but first we

212
00:10:12,319 --> 00:10:09,839
wanted to look at what genes were highly

213
00:10:14,420 --> 00:10:12,329

expressed at both conditions and so

214
00:10:18,230 --> 00:10:14,430
these genes were highly expressed both

215
00:10:22,100 --> 00:10:18,240
at an anode or at cathodic potential and

216
00:10:24,350 --> 00:10:22,110
we have the complete genes pathway for

217
00:10:27,650 --> 00:10:24,360
sulfate reduction and these genes are

218
00:10:30,470 --> 00:10:27,660
also actually correlated with our most

219
00:10:33,620 --> 00:10:30,480
active organism the sulfur Vibrio alkali

220
00:10:35,960 --> 00:10:33,630
Phyllis and so if we put all this

221
00:10:40,009 --> 00:10:35,970
together including looking through the

222
00:10:42,259 --> 00:10:40,019
literature at pure cultures of alkali

223
00:10:44,780 --> 00:10:42,269
Phylis what we think is happening is

224
00:10:49,670 --> 00:10:44,790
that when the electrode is operating as

225
00:10:51,740 --> 00:10:49,680
a cathode this is offering electrons to

226
00:10:53,300 --> 00:10:51,750
the microorganisms and we believe that

227
00:10:55,250 --> 00:10:53,310
sulfate reduction is taking place

228
00:10:57,829 --> 00:10:55,260
through the normal sulfate reduction

229
00:11:01,639 --> 00:10:57,839
pathway for which all of the genes are

230
00:11:04,340 --> 00:11:01,649
highly expressed however a tan

231
00:11:07,550 --> 00:11:04,350
we believe that sulphide oxidation is

232
00:11:10,210 --> 00:11:07,560
occurring again from our same highly

233
00:11:13,850 --> 00:11:10,220
active organism but through a proposed

234
00:11:16,759 --> 00:11:13,860
reversal of the normal sulfate reduction

235
00:11:20,150 --> 00:11:16,769
pathway and Thora pat all are the ones

236
00:11:23,090 --> 00:11:20,160
that had seen this sulfate reducer

237
00:11:25,129 --> 00:11:23,100
performing sulphide oxidation with high

238
00:11:29,600 --> 00:11:25,139

expression of the sulfate reduction

239
00:11:32,720 --> 00:11:29,610
genes and they proposed a new pathway

240
00:11:36,319 --> 00:11:32,730
for sulphide oxidation that is simply a

241
00:11:40,670 --> 00:11:36,329
reverse of the sulfite of the sulfate

242
00:11:44,180 --> 00:11:40,680
reduction pathway and so again since we

243
00:11:48,050 --> 00:11:44,190
also see our main or our main active

244
00:11:50,900 --> 00:11:48,060
organism at the anode of be ESS in other

245
00:11:54,610 --> 00:11:50,910
systems this is our current hypothesis

246
00:11:57,199 --> 00:11:54,620
and so to bring this back to

247
00:11:59,000 --> 00:11:57,209
astrobiology throughout the week we've

248
00:12:01,100 --> 00:11:59,010
heard a lot about following the energy

249
00:12:04,250 --> 00:12:01,110
sources and also a lot about what we

250
00:12:06,980 --> 00:12:04,260
don't know and so on as Laurie and Pete

251
00:12:10,699 --> 00:12:06,990
mentioned I think BES are a great way to

252
00:12:13,490 --> 00:12:10,709
culture either pure pure pure cultures

253
00:12:15,650 --> 00:12:13,500
of organisms or communities and look

254
00:12:18,769 --> 00:12:15,660
directly at electron transfer and what

255
00:12:23,030 --> 00:12:18,779
energy sources are required for those

256
00:12:24,650 --> 00:12:23,040
kinds of events and so I'll leave you

257
00:12:26,420 --> 00:12:24,660
with this slide and I'll take any

258
00:12:30,290 --> 00:12:26,430
questions if we have time or you can

259
00:12:36,320 --> 00:12:30,300
catch me on your way to lunch Thanks

260
00:12:44,000 --> 00:12:39,370
I have two questions the first did these

261
00:12:46,730 --> 00:12:44,010
reversible oxidation reduction occur

262
00:12:49,810 --> 00:12:46,740
equally in the light and the dark and

263
00:12:51,980 --> 00:12:49,820

then the second question would be

264
00:12:58,100 --> 00:12:51,990
relating back to the previous speaker in

265
00:13:01,970 --> 00:12:58,110
a comment you made how much how much can

266
00:13:03,740 --> 00:13:01,980
you store for future use and are you

267
00:13:06,200 --> 00:13:03,750
talking about the sea floor fervor for

268
00:13:08,300 --> 00:13:06,210
submersibles how it how would that

269
00:13:11,480 --> 00:13:08,310
affect the surrounding ecology of the

270
00:13:14,120 --> 00:13:11,490
sea floor so for the first question I

271
00:13:16,510 --> 00:13:14,130
don't we haven't looked at light versus

272
00:13:20,150 --> 00:13:16,520
dark we've just been looking at

273
00:13:22,040 --> 00:13:20,160
non-photosynthetic communities so i

274
00:13:24,080 --> 00:13:22,050
can't i'm unfortunately i can't answer

275
00:13:27,920 --> 00:13:24,090
that question but for the second

276
00:13:31,250 --> 00:13:27,930
question so were our initial goal was to

277
00:13:34,010 --> 00:13:31,260
try to create a localized fuel source in

278
00:13:36,980 --> 00:13:34,020
the sediment because what is often

279
00:13:39,890 --> 00:13:36,990
limiting at that point is mass transport

280
00:13:42,410 --> 00:13:39,900
of the organics to you know and

281
00:13:44,150 --> 00:13:42,420
oxidation to the electrode and so if we

282
00:13:46,150 --> 00:13:44,160
have a localized fuel source by the

283
00:13:50,930 --> 00:13:46,160
electrode where we can store these

284
00:13:53,270 --> 00:13:50,940
discharge it would be available later in

285
00:13:58,490 --> 00:13:53,280
data I haven't shown we've tried to

286
00:14:00,560 --> 00:13:58,500
increase the times time of the cycle so

287
00:14:02,960 --> 00:14:00,570
this here was just a 10 minute cycle

288
00:14:07,010 --> 00:14:02,970

back and forth we've gone up to 12 hours

289
00:14:11,890 --> 00:14:07,020
and the bacteria do not like that so we

290
00:14:16,340 --> 00:14:11,900
tried to mimic a diurnal cycle and

291
00:14:19,060 --> 00:14:16,350
basically it resulted in bacterial death

292
00:14:22,940 --> 00:14:19,070
that current was not produced and so

293
00:14:25,940 --> 00:14:22,950
this this system isn't actually in a

294
00:14:29,630 --> 00:14:25,950
river or ocean sediment we do have other

295
00:14:31,880 --> 00:14:29,640
actual systems that are in ocean

296
00:14:33,590 --> 00:14:31,890
sediment but I don't know the specific

297
00:14:35,240 --> 00:14:33,600
parameters of the that current

298
00:14:38,990 --> 00:14:35,250
generation or what their what they see

299
00:14:41,900 --> 00:14:39,000
at them but Lenny Tender is one of my

300
00:14:45,260 --> 00:14:41,910
co-authors and he has systems actually

301
00:14:50,890 --> 00:14:48,620
okay well thank you all for staying and

302
00:14:52,250 --> 00:14:50,900
have a nice lunch