



1
00:00:11,110 --> 00:00:08,710
good afternoon welcome to nasa

2
00:00:13,589 --> 00:00:11,120
headquarters i'm dr michael new i'm the

3
00:00:15,589 --> 00:00:13,599
astrobiology discipline scientist here

4
00:00:17,750 --> 00:00:15,599
and it's really my pleasure and honor to

5
00:00:19,750 --> 00:00:17,760
introduce our speaker for today dr ron

6
00:00:20,950 --> 00:00:19,760
ormlund who's the senior research

7
00:00:23,590 --> 00:00:20,960
scientist at the united states

8
00:00:25,349 --> 00:00:23,600
geological survey

9
00:00:27,750 --> 00:00:25,359
to give you his sort of scientific vital

10
00:00:28,870 --> 00:00:27,760
statistics ron has published over 150

11
00:00:30,950 --> 00:00:28,880
papers

12
00:00:34,150 --> 00:00:30,960
on topics such as methanogenesis which

13
00:00:37,510 --> 00:00:34,160

is how microorganisms generate methane

14

00:00:38,869 --> 00:00:37,520

he's also published on a large amount on

15

00:00:41,990 --> 00:00:38,879

how metals

16

00:00:44,150 --> 00:00:42,000

are cycled in the earth using about by

17

00:00:46,549 --> 00:00:44,160

microorganisms

18

00:00:47,830 --> 00:00:46,559

he's done most of his work in places

19

00:00:49,590 --> 00:00:47,840

that

20

00:00:51,510 --> 00:00:49,600

you wouldn't necessarily expect there to

21

00:00:54,069 --> 00:00:51,520

be a lot of life places like big soda

22

00:00:57,110 --> 00:00:54,079

lake nevada searles lake and mono lake

23

00:00:59,270 --> 00:00:57,120

these are very very salty very alkaline

24

00:01:00,869 --> 00:00:59,280

lakes full of metals and yet there's a

25

00:01:03,990 --> 00:01:00,879

lot of life there

26

00:01:05,910 --> 00:01:04,000

ron has spent much of his career

27

00:01:07,270 --> 00:01:05,920

cataloging the diversity of this life

28

00:01:09,590 --> 00:01:07,280

and how

29

00:01:12,469 --> 00:01:09,600

it makes its living using these

30

00:01:14,310 --> 00:01:12,479

supposedly toxic metals

31

00:01:16,469 --> 00:01:14,320

he i didn't know this until today but he

32

00:01:18,469 --> 00:01:16,479

has five patents to his name about

33

00:01:21,990 --> 00:01:18,479

bioremediation and how you can use

34

00:01:24,070 --> 00:01:22,000

microorganisms to help our world

35

00:01:26,789 --> 00:01:24,080

he was has a singular honor of having

36

00:01:29,270 --> 00:01:26,799

been elected both a fellow of the agu

37

00:01:30,950 --> 00:01:29,280

and voted by popular science magazine as

38

00:01:33,350 --> 00:01:30,960

having one of the 10 worst jobs in

39

00:01:37,030 --> 00:01:33,360

science because of the

40

00:01:38,950 --> 00:01:37,040

odor first vapors of his field sites

41

00:01:41,109 --> 00:01:38,960

he asked me to make sure to point out

42

00:01:42,789 --> 00:01:41,119

that the these vapors have probably

43

00:01:43,670 --> 00:01:42,799

affected his brain because today seems

44

00:01:45,830 --> 00:01:43,680

to think

45

00:01:47,749 --> 00:01:45,840

he is a major general or at least he's

46

00:02:01,990 --> 00:01:47,759

the admiral of the monolake

47

00:02:02,000 --> 00:02:09,350

next slide please

48

00:02:09,360 --> 00:02:13,589

there it is

49

00:02:13,599 --> 00:02:17,190

no back up

50

00:02:20,869 --> 00:02:19,350

that's the intro slide

51

00:02:24,790 --> 00:02:20,879

major general

52

00:02:26,070 --> 00:02:24,800

yes yes i am the very model of a modern

53

00:02:28,070 --> 00:02:26,080

major general i have information

54

00:02:29,589 --> 00:02:28,080

vegetable animal and mineral i know the

55

00:02:31,430 --> 00:02:29,599

king's in england and i quote the fights

56

00:02:33,110 --> 00:02:31,440

historical from marathon to waterloo and

57

00:02:34,790 --> 00:02:33,120

order categorical

58

00:02:36,470 --> 00:02:34,800

i'm very well acquainted too with matt

59

00:02:38,550 --> 00:02:36,480

is mathematical i understand equations

60

00:02:40,630 --> 00:02:38,560

both simple and quadratical about

61

00:02:42,710 --> 00:02:40,640

binomial theorem i'm teaming with a lot

62

00:02:44,309 --> 00:02:42,720

of news

63

00:02:45,990 --> 00:02:44,319

and some very cheerful facts about the

64

00:02:47,110 --> 00:02:46,000

square of the hypotenuse

65

00:02:48,229 --> 00:02:47,120

i'm very good at integral and

66

00:02:49,509 --> 00:02:48,239

differential calculus i know the

67

00:02:51,350 --> 00:02:49,519

scientific names of beings out on the

68

00:02:53,589 --> 00:02:51,360

malculus and exactly matters vegetable

69

00:02:55,270 --> 00:02:53,599

animal and mineral i am the very model

70

00:02:58,390 --> 00:02:55,280

of a modern major general everybody sing

71

00:03:01,190 --> 00:02:59,830

before you think i've really gone over

72

00:03:02,630 --> 00:03:01,200

the edge there's a thread here that i

73

00:03:04,550 --> 00:03:02,640

want you to follow

74

00:03:07,910 --> 00:03:04,560

that of course is the

75

00:03:10,390 --> 00:03:07,920

song of general stanley

76

00:03:12,630 --> 00:03:10,400

and the pirates of penzance

77

00:03:14,710 --> 00:03:12,640

the operator of gilbert and sullivan

78

00:03:17,509 --> 00:03:14,720

these two creative geniuses

79

00:03:19,750 --> 00:03:17,519

that had their heyday in london

80

00:03:21,750 --> 00:03:19,760

in the 1880s

81

00:03:23,910 --> 00:03:21,760

uh where they staged these at the savoy

82

00:03:26,550 --> 00:03:23,920

theater along with uh

83

00:03:28,869 --> 00:03:26,560

hms pinafore and mercado they were the

84

00:03:31,350 --> 00:03:28,879

toast of the town these urbane creative

85

00:03:33,589 --> 00:03:31,360

geniuses that brought joy

86

00:03:36,070 --> 00:03:33,599

to london society and to the world

87

00:03:37,430 --> 00:03:36,080

continually now in fact in san francisco

88

00:03:38,869 --> 00:03:37,440

they did this

89

00:03:40,630 --> 00:03:38,879

uh

90

00:03:42,229 --> 00:03:40,640

performance of the pirates of penzance

91

00:03:45,030 --> 00:03:42,239

by the lamplighters theater group an

92

00:03:47,350 --> 00:03:45,040

amateur group it's these

93

00:03:50,229 --> 00:03:47,360

a wonderful contribution

94

00:03:53,190 --> 00:03:50,239

all starting in the 1880s

95

00:03:55,750 --> 00:03:53,200

a contemporary of theirs

96

00:03:58,949 --> 00:03:55,760

was this gentleman here

97

00:04:02,229 --> 00:03:58,959

dimitri mendeleev

98

00:04:05,509 --> 00:04:02,239

and you can tell by the expression

99

00:04:07,429 --> 00:04:05,519

he was reclusive in brooding

100

00:04:09,429 --> 00:04:07,439

a loner

101
00:04:11,350 --> 00:04:09,439
well he grew up in siberia and he

102
00:04:14,149 --> 00:04:11,360
majored in those things in the wilds of

103
00:04:16,069 --> 00:04:14,159
siberia along with frostbite and

104
00:04:17,349 --> 00:04:16,079
eventually became a professor of

105
00:04:18,949 --> 00:04:17,359
chemistry

106
00:04:21,749 --> 00:04:18,959
at uh

107
00:04:24,390 --> 00:04:21,759
saint petersburg university

108
00:04:28,390 --> 00:04:24,400
and he was obsessed

109
00:04:32,550 --> 00:04:30,629
and

110
00:04:35,590 --> 00:04:32,560
in one of the creative leaps of

111
00:04:39,350 --> 00:04:37,590
this gentleman

112
00:04:41,430 --> 00:04:39,360
saw order

113
00:04:43,350 --> 00:04:41,440

in the arrangements of the chemical

114

00:04:44,710 --> 00:04:43,360

elements according to their mass and

115

00:04:46,950 --> 00:04:44,720

reactivity

116

00:04:48,469 --> 00:04:46,960

that really created

117

00:04:50,390 --> 00:04:48,479

a scaffolding

118

00:04:53,430 --> 00:04:50,400

for much of

119

00:04:55,030 --> 00:04:53,440

the incredible advances in physics and

120

00:04:57,110 --> 00:04:55,040

chemistry

121

00:04:59,270 --> 00:04:57,120

that went on in the late 19th century

122

00:05:00,230 --> 00:04:59,280

into the 20th century and into the 21st

123

00:05:01,110 --> 00:05:00,240

century

124

00:05:02,629 --> 00:05:01,120

uh

125

00:05:04,710 --> 00:05:02,639

an incredible leap that i really don't

126

00:05:05,990 --> 00:05:04,720

think he is fully appreciated even to

127

00:05:07,749 --> 00:05:06,000

this day this is sort of something we

128

00:05:10,469 --> 00:05:07,759

all take for granted it was always a

129

00:05:12,950 --> 00:05:10,479

periodic table that's not true

130

00:05:16,230 --> 00:05:12,960

until he saw order

131

00:05:20,790 --> 00:05:18,390

until he was able to establish chemistry

132

00:05:22,950 --> 00:05:20,800

as a real science from its roots in

133

00:05:24,629 --> 00:05:22,960

alchemy

134

00:05:27,110 --> 00:05:24,639

he really did quite

135

00:05:29,110 --> 00:05:27,120

quite something in fact i i can't help

136

00:05:32,150 --> 00:05:29,120

but think of uh uh

137

00:05:33,749 --> 00:05:32,160

spencer tracy putting uh frederick march

138

00:05:35,749 --> 00:05:33,759

on the stand

139

00:05:38,150 --> 00:05:35,759

in uh inherit the wind in the famous

140

00:05:40,710 --> 00:05:38,160

scopes trial and he looks at him and he

141

00:05:43,110 --> 00:05:40,720

says how do you know god didn't speak

142

00:05:44,870 --> 00:05:43,120

to charles darwin

143

00:05:46,950 --> 00:05:44,880

it's a very moving scene and how do you

144

00:05:48,550 --> 00:05:46,960

know god didn't speak

145

00:05:50,790 --> 00:05:48,560

to dmitry

146

00:06:06,070 --> 00:05:50,800

dimitri

147

00:06:11,189 --> 00:06:09,270

and there's how it all happened

148

00:06:14,309 --> 00:06:11,199

so

149

00:06:17,110 --> 00:06:14,319

about 75 years later another

150

00:06:18,150 --> 00:06:17,120

creative genius appeared on the scene

151
00:06:20,230 --> 00:06:18,160
this guy

152
00:06:22,950 --> 00:06:20,240
and

153
00:06:28,550 --> 00:06:26,469
was deconstruct the order of the uh

154
00:06:30,070 --> 00:06:28,560
periodic table of the elements in the

155
00:06:31,909 --> 00:06:30,080
late 50s

156
00:06:34,550 --> 00:06:31,919
and

157
00:06:37,029 --> 00:06:34,560
combined it with the music

158
00:06:38,790 --> 00:06:37,039
of gilbert and sullivan for general

159
00:06:40,790 --> 00:06:38,800
stanley's song

160
00:06:43,029 --> 00:06:40,800
to give us the song of the elements

161
00:06:44,550 --> 00:06:43,039
which is my introduction to this talk

162
00:06:45,909 --> 00:06:44,560
because it goes as follows i'm not going

163
00:06:48,629 --> 00:06:45,919

to do the whole thing

164

00:06:50,950 --> 00:06:48,639

maybe later over a scotch but not now

165

00:06:52,629 --> 00:06:50,960

there's antimony arsenic aluminum

166

00:06:54,629 --> 00:06:52,639

selenium and hydrogen oxygen and

167

00:06:56,950 --> 00:06:54,639

nitrogen and radium in nickel neodymium

168

00:06:59,029 --> 00:06:56,960

neutrinium germanium iron americium

169

00:07:01,350 --> 00:06:59,039

ruthenium uranium europium zirconium

170

00:07:03,990 --> 00:07:01,360

lutecium vanadium lanthanum and osmium

171

00:07:05,909 --> 00:07:04,000

and acetaminophen gold protactinium and

172

00:07:07,430 --> 00:07:05,919

indium and gallium

173

00:07:08,870 --> 00:07:07,440

and iodine and thorium and thulium

174

00:07:12,550 --> 00:07:08,880

enthalpy there's a tree in germany

175

00:07:17,189 --> 00:07:12,560

that's enough already uh the point is

176

00:07:19,029 --> 00:07:17,199

if you study the what he did he took

177

00:07:20,309 --> 00:07:19,039

it where's oprah

178

00:07:22,629 --> 00:07:20,319

uh

179

00:07:24,469 --> 00:07:22,639

he arranged the elements in in in

180

00:07:27,110 --> 00:07:24,479

patterns of four that rhymed on the

181

00:07:28,830 --> 00:07:27,120

fourth and the eighth

182

00:07:31,749 --> 00:07:28,840

and the first

183

00:07:34,230 --> 00:07:31,759

floor are actually three of those four

184

00:07:35,029 --> 00:07:34,240

or could have the next slide please

185

00:07:36,629 --> 00:07:35,039

are

186

00:07:39,670 --> 00:07:36,639

of particular meaning to me there's

187

00:07:41,430 --> 00:07:39,680

antimony arsenic aluminum selenium

188

00:07:43,350 --> 00:07:41,440

arsenic according to tom lehrer maybe

189

00:07:46,070 --> 00:07:43,360

not to the mendeleev but according to

190

00:07:49,029 --> 00:07:46,080

tom lehrer who is my personal god

191

00:07:51,270 --> 00:07:49,039

uh is the second most important element

192

00:07:52,710 --> 00:07:51,280

in the song of the periodic table and is

193

00:07:54,550 --> 00:07:52,720

therefore the most important element

194

00:07:57,350 --> 00:07:54,560

that i'm going to speak about today

195

00:07:59,430 --> 00:07:57,360

but three of the four of the first four

196

00:08:02,230 --> 00:07:59,440

are group 15

197

00:08:04,390 --> 00:08:02,240

and group 16 elements is antimony

198

00:08:06,309 --> 00:08:04,400

arsenic aluminum man forget about that

199

00:08:07,270 --> 00:08:06,319

selenium but tellurium these guys down

200

00:08:09,510 --> 00:08:07,280

here

201
00:08:11,510 --> 00:08:09,520
are the are the elements

202
00:08:13,350 --> 00:08:11,520
that

203
00:08:15,909 --> 00:08:13,360
i've been concerned with and interested

204
00:08:17,990 --> 00:08:15,919
and fascinated by for the last 25 years

205
00:08:18,869 --> 00:08:18,000
and my colleagues uh that i work with as

206
00:08:23,670 --> 00:08:18,879
well

207
00:08:30,469 --> 00:08:27,830
old dimitri did not understand why

208
00:08:32,709 --> 00:08:30,479
they share similar chemical properties

209
00:08:35,269 --> 00:08:32,719
but the 15 elements all have five

210
00:08:36,709 --> 00:08:35,279
electrons in their outer shell

211
00:08:38,310 --> 00:08:36,719
and therefore they have chemical

212
00:08:41,589 --> 00:08:38,320
similarities and biochemical

213
00:08:43,589 --> 00:08:41,599

similarities and they will do anything

214

00:08:46,949 --> 00:08:43,599

beg borrow steel alone to get to the

215

00:08:48,710 --> 00:08:46,959

magic quantum number of eight

216

00:08:50,389 --> 00:08:48,720

sixteen elements

217

00:08:52,550 --> 00:08:50,399

have six electrons

218

00:08:55,670 --> 00:08:52,560

and they need two and they'll beg borrow

219

00:08:57,910 --> 00:08:55,680

steel alone to get to that magic number

220

00:08:59,750 --> 00:08:57,920

so

221

00:09:01,030 --> 00:08:59,760

selenium which is what started this

222

00:09:02,949 --> 00:09:01,040

whole mess

223

00:09:05,829 --> 00:09:02,959

exists in four oxidation states in

224

00:09:07,990 --> 00:09:05,839

nature cylinate selenite

225

00:09:11,509 --> 00:09:08,000

the native elemental state and selanhide

226

00:09:15,990 --> 00:09:13,990

we got into this work

227

00:09:17,750 --> 00:09:16,000

in the 80s because there was a selenium

228

00:09:19,590 --> 00:09:17,760

contamination problem in the central

229

00:09:21,590 --> 00:09:19,600

valley of california

230

00:09:23,590 --> 00:09:21,600

and in the process of fiddling around

231

00:09:25,590 --> 00:09:23,600

and futzing around we discovered

232

00:09:27,110 --> 00:09:25,600

that there's bacteria in the sediments

233

00:09:29,190 --> 00:09:27,120

anaerobes

234

00:09:31,509 --> 00:09:29,200

that breathe the stuff

235

00:09:33,350 --> 00:09:31,519

this is a really really toxic element

236

00:09:35,750 --> 00:09:33,360

it's toxic because it's an analog of

237

00:09:37,430 --> 00:09:35,760

sulfur and where sulfur should go if

238

00:09:39,030 --> 00:09:37,440

there's too much selenium it denatures

239

00:09:41,110 --> 00:09:39,040

those enzymes

240

00:09:43,190 --> 00:09:41,120

but we found bugs that breathe it

241

00:09:44,870 --> 00:09:43,200

they oxidize carbon

242

00:09:47,910 --> 00:09:44,880

and they reduce

243

00:09:49,430 --> 00:09:47,920

uh the selenate to elemental selenium

244

00:09:50,949 --> 00:09:49,440

and actually gets the selenium out of

245

00:09:53,750 --> 00:09:50,959

this out of the water because it can be

246

00:09:55,750 --> 00:09:53,760

used for purification purposes

247

00:09:57,350 --> 00:09:55,760

as time went by we started isolating

248

00:10:00,150 --> 00:09:57,360

these microorganisms and jody

249

00:10:02,710 --> 00:10:00,160

switzer-blum came in into my lab with a

250

00:10:04,630 --> 00:10:02,720

specific purpose to start finding these

251
00:10:06,790 --> 00:10:04,640
bugs microbes

252
00:10:07,630 --> 00:10:06,800
and the first one that she pulled out

253
00:10:10,069 --> 00:10:07,640
was

254
00:10:13,030 --> 00:10:10,079
sulfurospurilum barnsie named after the

255
00:10:15,829 --> 00:10:13,040
late ivan barnes at the usgs

256
00:10:19,509 --> 00:10:15,839
and it grew very nicely on selenade and

257
00:10:21,509 --> 00:10:19,519
reduced it to the elemental state

258
00:10:22,790 --> 00:10:21,519
when she was on one of her maternity

259
00:10:25,190 --> 00:10:22,800
leaves and i don't remember there were

260
00:10:27,750 --> 00:10:25,200
three of them

261
00:10:29,030 --> 00:10:27,760
and neet levman came to my lab because i

262
00:10:30,829 --> 00:10:29,040
had noticed when

263
00:10:33,269 --> 00:10:30,839

jody was no longer there if i put

264

00:10:36,069 --> 00:10:33,279

arsenate into the test tube i came back

265

00:10:38,069 --> 00:10:36,079

in a day it was turbid

266

00:10:40,230 --> 00:10:38,079

arsenic

267

00:10:41,590 --> 00:10:40,240

was supporting the respiratory growth of

268

00:10:42,870 --> 00:10:41,600

these same bugs

269

00:10:44,949 --> 00:10:42,880

microbes

270

00:10:47,590 --> 00:10:44,959

and

271

00:10:49,829 --> 00:10:47,600

we it took off in a bunch of uh labs

272

00:10:52,389 --> 00:10:49,839

primarily uh the folks at mit

273

00:10:55,590 --> 00:10:52,399

uh uh with francois morell actually uh

274

00:10:58,949 --> 00:10:55,600

uh were the first to describe it

275

00:11:00,389 --> 00:10:58,959

and then we continued on uh with the

276

00:11:01,750 --> 00:11:00,399

story of arsenic

277

00:11:04,069 --> 00:11:01,760

uh

278

00:11:07,190 --> 00:11:04,079

sean found microbes that can breathe

279

00:11:08,790 --> 00:11:07,200

oxyanions of tellurium and uh tom

280

00:11:11,430 --> 00:11:08,800

copenhagen is working on the antimony

281

00:11:13,269 --> 00:11:11,440

story arsenic exists in four oxidation

282

00:11:14,949 --> 00:11:13,279

states

283

00:11:17,509 --> 00:11:14,959

eight the plus five

284

00:11:20,870 --> 00:11:17,519

the plus three is arsenite elemental

285

00:11:23,590 --> 00:11:20,880

arsenite arsenic and arsine i'm really

286

00:11:25,430 --> 00:11:23,600

just going to talk about these two

287

00:11:27,910 --> 00:11:25,440

uh today and the microbes that make a

288

00:11:28,710 --> 00:11:27,920

living by these redox reactions either

289

00:11:30,550 --> 00:11:28,720

by

290

00:11:33,350 --> 00:11:30,560

pulling off electrons

291

00:11:35,590 --> 00:11:33,360

from arsenic iii using it as food

292

00:11:37,590 --> 00:11:35,600

for chemoautotrophic growth that is they

293

00:11:39,750 --> 00:11:37,600

get their electrons and energy from this

294

00:11:41,030 --> 00:11:39,760

oxidation and they get their carbon from

295

00:11:42,790 --> 00:11:41,040

co₂

296

00:11:44,949 --> 00:11:42,800

or the back reaction

297

00:11:47,910 --> 00:11:44,959

of microbes that respire breathe

298

00:11:49,910 --> 00:11:47,920

arsenate and spit out arsenite in the

299

00:11:52,949 --> 00:11:49,920

environment now this is really important

300

00:11:54,790 --> 00:11:52,959

for environmental region reasons because

301
00:11:57,829 --> 00:11:54,800
arsenate

302
00:12:00,870 --> 00:11:57,839
adsorbs to more minerals

303
00:12:03,670 --> 00:12:00,880
than does arsenite and therefore

304
00:12:07,430 --> 00:12:03,680
is hydrologically less mobile while

305
00:12:09,750 --> 00:12:07,440
arsenite is more toxic and more mobile

306
00:12:11,990 --> 00:12:09,760
now the

307
00:12:13,670 --> 00:12:12,000
the reason why arsenic is toxic if you

308
00:12:15,430 --> 00:12:13,680
read the textbooks

309
00:12:18,150 --> 00:12:15,440
in the form of arsenate it's an analog

310
00:12:19,990 --> 00:12:18,160
of phosphate and it inhibits oxidative

311
00:12:22,310 --> 00:12:20,000
phosphorylation

312
00:12:23,269 --> 00:12:22,320
arsenite is even more toxic because it

313
00:12:26,470 --> 00:12:23,279

binds

314

00:12:28,150 --> 00:12:26,480

with sulfur and sulfhydryl groups and it

315

00:12:31,590 --> 00:12:28,160

activates enzymes they take critical

316

00:12:36,710 --> 00:12:34,310

once upon a time when the earth first

317

00:12:39,350 --> 00:12:36,720

accreted

318

00:12:40,710 --> 00:12:39,360

we think there was more arsenic

319

00:12:43,110 --> 00:12:40,720

on the earth's surface than there is

320

00:12:43,990 --> 00:12:43,120

today but arsenic is a chalcophilic

321

00:12:46,629 --> 00:12:44,000

element

322

00:12:49,269 --> 00:12:46,639

it likes to bind with sulfur

323

00:12:51,269 --> 00:12:49,279

and metals to form things like arsenal

324

00:12:53,590 --> 00:12:51,279

pyrite that are very dense

325

00:12:55,190 --> 00:12:53,600

and are brought down

326

00:12:56,790 --> 00:12:55,200

into the mantle as the earth slowly

327

00:12:58,389 --> 00:12:56,800

differentiated

328

00:13:00,629 --> 00:12:58,399

uh

329

00:13:02,230 --> 00:13:00,639

there's some evidence for this

330

00:13:03,829 --> 00:13:02,240

even in meteorites that are rich in

331

00:13:05,509 --> 00:13:03,839

phosphorus were also very rich in

332

00:13:07,350 --> 00:13:05,519

arsenic so when the stuff was first

333

00:13:08,870 --> 00:13:07,360

forming the earth it was probably a lot

334

00:13:10,550 --> 00:13:08,880

of arsenic around

335

00:13:12,069 --> 00:13:10,560

and when our when life got going there

336

00:13:14,150 --> 00:13:12,079

was probably a lot more arsenic around

337

00:13:16,470 --> 00:13:14,160

on the surface than there is today the

338

00:13:19,430 --> 00:13:16,480

reason we see arsenic

339

00:13:21,750 --> 00:13:19,440

is because volcanic forces

340

00:13:23,829 --> 00:13:21,760

at plate boundaries

341

00:13:26,870 --> 00:13:23,839

bring stuff up from the mantle and

342

00:13:28,710 --> 00:13:26,880

distill uh metals and metalloids up

343

00:13:30,790 --> 00:13:28,720

together and that's what forms

344

00:13:33,509 --> 00:13:30,800

deposits of precious metals for example

345

00:13:37,910 --> 00:13:33,519

uh in california nevada and associated

346

00:13:37,920 --> 00:13:41,269

next slide please

347

00:13:45,030 --> 00:13:43,430

arsenic in the form of arsenate is

348

00:13:46,949 --> 00:13:45,040

a reasonably good accident i'm not going

349

00:13:48,629 --> 00:13:46,959

to give you the exact numbers but if you

350

00:13:49,750 --> 00:13:48,639

wanted to burn in this case molecular

351

00:13:52,069 --> 00:13:49,760

hydrogen

352

00:13:54,949 --> 00:13:52,079

we can go down this scale this was uh

353

00:13:57,189 --> 00:13:54,959

calculated in a review by diane newman a

354

00:13:59,110 --> 00:13:57,199

number of years ago

355

00:14:01,269 --> 00:13:59,120

but oxygen is the strongest going down

356

00:14:04,550 --> 00:14:01,279

to nitrate selenates roughly about the

357

00:14:07,189 --> 00:14:04,560

same arsenate and iron hydroxides are

358

00:14:09,509 --> 00:14:07,199

roughly about the same way below that is

359

00:14:11,350 --> 00:14:09,519

sulfate reduction uh this is as

360

00:14:13,590 --> 00:14:11,360

kilojoules per mole electrons and way

361

00:14:15,430 --> 00:14:13,600

below that is methanogenesis so it's

362

00:14:17,030 --> 00:14:15,440

reasonably respectable

363

00:14:18,790 --> 00:14:17,040

in terms of its

364

00:14:20,790 --> 00:14:18,800

ability

365

00:14:23,030 --> 00:14:20,800

to oxidize

366

00:14:26,310 --> 00:14:23,040

organic carbon and in this case hydrogen

367

00:14:32,470 --> 00:14:29,189

well jody went on to

368

00:14:35,110 --> 00:14:32,480

examine the diversity

369

00:14:37,030 --> 00:14:35,120

of uh bacteria that can make a living by

370

00:14:37,990 --> 00:14:37,040

respiring arsenic

371

00:14:39,350 --> 00:14:38,000

and

372

00:14:41,110 --> 00:14:39,360

we had been working at motorway for a

373

00:14:42,870 --> 00:14:41,120

number of years and

374

00:14:44,550 --> 00:14:42,880

we're aware that indeed there's a lot of

375

00:14:46,629 --> 00:14:44,560

arsenic in this lake let's see we can

376

00:14:48,870 --> 00:14:46,639

get out but we really went for the

377

00:14:51,110 --> 00:14:48,880

purpose of getting selenium bugs

378

00:14:53,030 --> 00:14:51,120

microbes that can respire selenium

379

00:14:55,590 --> 00:14:53,040

because they'd be adapted to the

380

00:14:57,910 --> 00:14:55,600

saline and alkaline conditions of

381

00:14:59,910 --> 00:14:57,920

wastewater ponds in the san joaquin

382

00:15:02,629 --> 00:14:59,920

valley and she did these this is an

383

00:15:05,509 --> 00:15:02,639

example of uh

384

00:15:06,629 --> 00:15:05,519

bacillus or senescence celinatus but it

385

00:15:07,430 --> 00:15:06,639

also can

386

00:15:09,110 --> 00:15:07,440

grow

387

00:15:11,110 --> 00:15:09,120

by respiring arsenide and this is just

388

00:15:12,470 --> 00:15:11,120

the growth curve to say well any bug

389

00:15:14,870 --> 00:15:12,480

that can do this does this sort of a

390

00:15:17,750 --> 00:15:14,880

thing they in this case it oxidizes

391

00:15:20,310 --> 00:15:17,760

lactate to acetate and co2 and the

392

00:15:22,150 --> 00:15:20,320

electrons that are generated are passed

393

00:15:23,910 --> 00:15:22,160

to arsenate

394

00:15:25,509 --> 00:15:23,920

and they make arsenide if you take away

395

00:15:26,550 --> 00:15:25,519

the arsenate they don't grow under these

396

00:15:31,189 --> 00:15:26,560

conditions

397

00:15:35,990 --> 00:15:33,110

now there were

398

00:15:38,870 --> 00:15:36,000

people working on arsenic metabolism by

399

00:15:41,189 --> 00:15:38,880

microorganisms for quite some time

400

00:15:43,990 --> 00:15:41,199

when we came on the scene

401
00:15:46,629 --> 00:15:44,000
simon silver and barry rosen

402
00:15:49,350 --> 00:15:46,639
worked out the intricacies of how

403
00:15:51,670 --> 00:15:49,360
microorganisms various microorganisms

404
00:15:53,430 --> 00:15:51,680
are resistant to high concentrations of

405
00:15:55,189 --> 00:15:53,440
arsenic you put them in media or

406
00:15:57,110 --> 00:15:55,199
surrounding that has a lot of arsenic

407
00:15:58,949 --> 00:15:57,120
the arsenic gets into the cell and they

408
00:16:01,430 --> 00:15:58,959
spit the arsenic back out and that

409
00:16:04,389 --> 00:16:01,440
requires atp that's an energy requiring

410
00:16:06,150 --> 00:16:04,399
process and that's known as uh

411
00:16:08,550 --> 00:16:06,160
the rc system there's an arsenic

412
00:16:10,790 --> 00:16:08,560
reductase that comes in as arsenate

413
00:16:12,470 --> 00:16:10,800

and it goes out as austenite they don't

414

00:16:14,069 --> 00:16:12,480

gain anything they actually lose energy

415

00:16:17,509 --> 00:16:14,079

from this the cell wants to get rid of

416

00:16:20,829 --> 00:16:17,519

the arsenic it's bad it kills us

417

00:16:25,590 --> 00:16:23,430

uh in fact

418

00:16:30,870 --> 00:16:25,600

it kills us rather effectively

419

00:16:35,829 --> 00:16:33,350

it's was used as a poisoning agent so

420

00:16:38,150 --> 00:16:35,839

widespread in 18th century france become

421

00:16:43,189 --> 00:16:38,160

known it became known as inheritance

422

00:16:43,199 --> 00:16:45,749

mike

423

00:16:50,790 --> 00:16:47,749

then there you are this is was sealed

424

00:16:54,470 --> 00:16:51,910

but then

425

00:16:56,629 --> 00:16:54,480

in the 19th century tests were made

426

00:16:58,870 --> 00:16:56,639

that advanced forensic science that

427

00:17:00,230 --> 00:16:58,880

could detect arsenic and tissue and now

428

00:17:02,949 --> 00:17:00,240

you know if you're having

429

00:17:04,710 --> 00:17:02,959

second thoughts about this

430

00:17:06,390 --> 00:17:04,720

speak to me afterwards we can maybe work

431

00:17:08,789 --> 00:17:06,400

something out but

432

00:17:11,829 --> 00:17:08,799

what we were involved in uh were the

433

00:17:14,230 --> 00:17:11,839

energy generating processes uh in this

434

00:17:16,150 --> 00:17:14,240

case arsenic oxidation partially three

435

00:17:18,470 --> 00:17:16,160

oxidations arsenic five

436

00:17:20,230 --> 00:17:18,480

and arsenate reduction processes that

437

00:17:23,429 --> 00:17:20,240

occur on the periphery of the cell in

438

00:17:25,669 --> 00:17:23,439

the in the membranes uh where arsenic 3

439

00:17:27,990 --> 00:17:25,679

is oxidized to arsenic 5 in the

440

00:17:30,150 --> 00:17:28,000

electrons eventually coupled to oxygen

441

00:17:31,110 --> 00:17:30,160

and carbon comes from co₂

442

00:17:33,110 --> 00:17:31,120

or

443

00:17:35,909 --> 00:17:33,120

uh the breathing of arsenate in

444

00:17:38,230 --> 00:17:35,919

anaerobic environments where arsenate is

445

00:17:40,390 --> 00:17:38,240

reduced to arsenite and the electrons

446

00:17:42,230 --> 00:17:40,400

come from burning of organic matter or

447

00:17:44,230 --> 00:17:42,240

hydrogen or what have you inside the

448

00:17:46,150 --> 00:17:44,240

cell next slide please just want to be

449

00:17:48,630 --> 00:17:46,160

able to differentiate between those

450

00:17:50,470 --> 00:17:48,640

processes now the the enzymes that are

451
00:17:52,710 --> 00:17:50,480
involved in these processes are

452
00:17:55,430 --> 00:17:52,720
molybdenum containing

453
00:17:58,789 --> 00:17:55,440
enzymes of the family of dmsO reductases

454
00:18:02,230 --> 00:17:58,799
can everybody say that now one more time

455
00:18:05,350 --> 00:18:02,240
very good uh and they look and taste and

456
00:18:06,549 --> 00:18:05,360
smell alike they're both heterodimers

457
00:18:07,909 --> 00:18:06,559
they all have

458
00:18:09,510 --> 00:18:07,919
a molybdenum

459
00:18:11,110 --> 00:18:09,520
uh in their reactive centers they have

460
00:18:13,669 --> 00:18:11,120
these iron sulfur

461
00:18:15,029 --> 00:18:13,679
uh side groups and iron sulfur crystals

462
00:18:16,950 --> 00:18:15,039
here but they're thought to be

463
00:18:19,750 --> 00:18:16,960

unidirectional

464

00:18:21,750 --> 00:18:19,760

so that in the case of arsenic oxidation

465

00:18:23,909 --> 00:18:21,760

uh arsenic 3

466

00:18:26,230 --> 00:18:23,919

the electrons are pulled this way

467

00:18:28,789 --> 00:18:26,240

through this high potential

468

00:18:31,270 --> 00:18:28,799

cofactor and to the oxygen eventually

469

00:18:32,789 --> 00:18:31,280

through cytochromes and here

470

00:18:34,789 --> 00:18:32,799

it's pushed

471

00:18:36,630 --> 00:18:34,799

through to arsenate and arsenide on the

472

00:18:38,230 --> 00:18:36,640

outside of the cell

473

00:18:39,270 --> 00:18:38,240

that's the paradigm we're going to find

474

00:18:41,190 --> 00:18:39,280

out that it's

475

00:18:42,950 --> 00:18:41,200

it's not quite true

476

00:18:44,870 --> 00:18:42,960

uh next slide please

477

00:18:48,390 --> 00:18:44,880

in fact these enzymes don't look like

478

00:18:49,750 --> 00:18:48,400

hot water bottles that was a big finding

479

00:18:51,430 --> 00:18:49,760

they look like

480

00:18:52,870 --> 00:18:51,440

plates of pasta with little meatballs on

481

00:18:55,350 --> 00:18:52,880

them and

482

00:18:56,950 --> 00:18:55,360

this is what arsenite oxidase looks like

483

00:18:59,270 --> 00:18:56,960

this is what

484

00:19:02,230 --> 00:18:59,280

the arsenic reductase from alkali

485

00:19:04,390 --> 00:19:02,240

limnicola or lickey eye looks like

486

00:19:07,110 --> 00:19:04,400

and this is from a review by john stulls

487

00:19:10,150 --> 00:19:07,120

this year earlier this year

488

00:19:12,150 --> 00:19:10,160

yeah that appeared in microbes

489

00:19:14,150 --> 00:19:12,160

and this we are going to

490

00:19:15,270 --> 00:19:14,160

spend a little bit of time on

491

00:19:17,510 --> 00:19:15,280

this guy

492

00:19:19,350 --> 00:19:17,520

because it upset the paradigm next slide

493

00:19:22,390 --> 00:19:19,360

please

494

00:19:25,190 --> 00:19:22,400

well when john and i wrote the uh review

495

00:19:29,430 --> 00:19:25,200

in science back in 2003

496

00:19:32,950 --> 00:19:29,440

he assembled uh phylogenetically

497

00:19:34,950 --> 00:19:32,960

in a tree uh what are the microbes

498

00:19:37,590 --> 00:19:34,960

that can make a living by breathing

499

00:19:39,590 --> 00:19:37,600

arsenic or in the form of arsenate or

500

00:19:41,990 --> 00:19:39,600

oxidizing arsenite

501
00:19:43,190 --> 00:19:42,000
and that gave us this tree and the blue

502
00:19:44,470 --> 00:19:43,200
dots

503
00:19:46,870 --> 00:19:44,480
are uh

504
00:19:48,789 --> 00:19:46,880
anaerobic respirers of arsenate

505
00:19:51,029 --> 00:19:48,799
including some uh

506
00:19:54,630 --> 00:19:51,039
pyrobacula in the archaea

507
00:19:57,190 --> 00:19:54,640
and the red squares are autotrophic

508
00:19:59,110 --> 00:19:57,200
arsenite oxidizers

509
00:20:00,710 --> 00:19:59,120
and a couple of things stand out right

510
00:20:02,710 --> 00:20:00,720
away

511
00:20:04,870 --> 00:20:02,720
it's diverse

512
00:20:06,870 --> 00:20:04,880
it's pretty much all over

513
00:20:08,789 --> 00:20:06,880

the microbial map and it's gotten more

514

00:20:11,590 --> 00:20:08,799

diverse and as people have been

515

00:20:14,390 --> 00:20:11,600

isolating these microbes over the past

516

00:20:17,909 --> 00:20:17,029

so how does that happen

517

00:20:20,390 --> 00:20:17,919

is it

518

00:20:23,270 --> 00:20:20,400

an ancient process

519

00:20:24,149 --> 00:20:23,280

going back several mil billion years

520

00:20:26,470 --> 00:20:24,159

uh

521

00:20:29,029 --> 00:20:26,480

to the beginning of life on the earth

522

00:20:31,590 --> 00:20:29,039

and that it this represents divergence

523

00:20:32,870 --> 00:20:31,600

with time of the same theme

524

00:20:37,350 --> 00:20:32,880

or

525

00:20:40,630 --> 00:20:39,430

conjugation

526

00:20:43,430 --> 00:20:40,640

what we call

527

00:20:45,430 --> 00:20:43,440

lateral gene transfer uh

528

00:20:46,710 --> 00:20:45,440

in the microbial world

529

00:20:49,510 --> 00:20:46,720

and you might want to try that as a

530

00:20:52,950 --> 00:20:49,520

pickup line at a bar or honey

531

00:20:55,270 --> 00:20:52,960

but really is it is this a recent thing

532

00:20:56,950 --> 00:20:55,280

or is this an ancient process

533

00:21:01,190 --> 00:20:56,960

you can't come to a conclusion on that

534

00:21:05,909 --> 00:21:03,190

another word

535

00:21:06,630 --> 00:21:05,919

these arsenate respirers

536

00:21:20,310 --> 00:21:06,640

they

537

00:21:23,909 --> 00:21:20,320

use arsenate except for one guy

538

00:21:27,029 --> 00:21:23,919

strain mlms isolated by shelley hoft

539

00:21:28,870 --> 00:21:27,039

which is an obligate arsenate respire

540

00:21:30,950 --> 00:21:28,880

which only uses

541

00:21:32,549 --> 00:21:30,960

hydrogen sulfide as its electron donor

542

00:21:34,710 --> 00:21:32,559

it's a chemoautotroph isolated from

543

00:21:37,110 --> 00:21:34,720

monolake

544

00:21:41,430 --> 00:21:37,120

the other critter that she isolated is

545

00:21:43,830 --> 00:21:41,440

strain mlhe1 alkali limnicolor erlickii

546

00:21:47,110 --> 00:21:43,840

named after henry ehrlich one of the

547

00:21:48,789 --> 00:21:47,120

gods of chief microbiology

548

00:21:51,590 --> 00:21:48,799

and it makes a living by oxidizing

549

00:21:53,830 --> 00:21:51,600

arsenic 3 to arsenic 5 but not with

550

00:21:55,750 --> 00:21:53,840

oxygen it uses nitrate so it's an

551
00:21:58,870 --> 00:21:55,760
anaerobe

552
00:22:00,230 --> 00:21:58,880
next slide please

553
00:22:02,549 --> 00:22:00,240
well

554
00:22:04,310 --> 00:22:02,559
one thing we have out in california and

555
00:22:06,149 --> 00:22:04,320
nevada is

556
00:22:08,789 --> 00:22:06,159
we've got lots of arsenic out there it's

557
00:22:10,230 --> 00:22:08,799
a great place for this soul to work

558
00:22:12,549 --> 00:22:10,240
you don't have too much of that back

559
00:22:19,350 --> 00:22:12,559
here

560
00:22:21,510 --> 00:22:19,360
and seals lake uh are the two that

561
00:22:24,070 --> 00:22:21,520
really stick out here mono lake has

562
00:22:27,430 --> 00:22:24,080
200 micromolar arsenic right in the form

563
00:22:29,510 --> 00:22:27,440

of arsenate in its waters its salinity

564

00:22:31,110 --> 00:22:29,520

is about 90 grams per liter and the

565

00:22:32,310 --> 00:22:31,120

composition of those salts are much

566

00:22:34,549 --> 00:22:32,320

different than sea salt so there's

567

00:22:37,590 --> 00:22:34,559

mainly a sodium carbonate system sodium

568

00:22:39,270 --> 00:22:37,600

bicarbonate system rich in sulfate and

569

00:22:41,669 --> 00:22:39,280

very alkaline ph

570

00:22:43,590 --> 00:22:41,679

of these lakes is 9.8 there's a lot of

571

00:22:45,029 --> 00:22:43,600

boron in them

572

00:22:47,350 --> 00:22:45,039

if you evaporate

573

00:22:49,110 --> 00:22:47,360

monolake you wind up with seals lake

574

00:22:51,590 --> 00:22:49,120

which has three to four million molar

575

00:22:53,590 --> 00:22:51,600

arsenate in its waters and its waters

576

00:22:56,070 --> 00:22:53,600

are saturated brines

577

00:22:57,830 --> 00:22:56,080

you can't get any more salt on him

578

00:23:00,470 --> 00:22:57,840

next slide please

579

00:23:01,990 --> 00:23:00,480

and this is a shot of cyril's lake down

580

00:23:04,149 --> 00:23:02,000

in the mojave desert

581

00:23:06,950 --> 00:23:04,159

this is my colleague larry miller this

582

00:23:09,909 --> 00:23:06,960

is my colleague tom culp

583

00:23:12,310 --> 00:23:09,919

and this was published in science uh

584

00:23:13,909 --> 00:23:12,320

five years ago

585

00:23:16,710 --> 00:23:13,919

what these guys are standing on you

586

00:23:17,990 --> 00:23:16,720

notice there's no lake here

587

00:23:21,110 --> 00:23:18,000

and it looks like they're standing on

588

00:23:23,830 --> 00:23:21,120

ice they're not they're standing on

589

00:23:25,750 --> 00:23:23,840

a salt crust about yay thick

590

00:23:28,070 --> 00:23:25,760

and underneath the salt crust

591

00:23:30,950 --> 00:23:28,080

is about yay much

592

00:23:33,029 --> 00:23:30,960

salt saturated brine under which there's

593

00:23:34,870 --> 00:23:33,039

sediment anoxic sediment and they were

594

00:23:37,270 --> 00:23:34,880

sampling they were actually they're not

595

00:23:39,270 --> 00:23:37,280

fishing uh in minnesota and when they're

596

00:23:42,310 --> 00:23:39,280

there it's 100 or so degrees here and

597

00:23:44,390 --> 00:23:42,320

they're chipping through the uh the salt

598

00:23:46,630 --> 00:23:44,400

to get to the sediments to do

599

00:23:49,590 --> 00:23:46,640

various experiments that convinced us

600

00:23:51,350 --> 00:23:49,600

uh that there was a full biological

601
00:23:53,669 --> 00:23:51,360
cycle of arsenic

602
00:23:55,830 --> 00:23:53,679
going on in this length lake both

603
00:23:58,789 --> 00:23:55,840
reduction and oxidation and jody

604
00:24:00,310 --> 00:23:58,799
switzerland isolated a bacterium

605
00:24:03,750 --> 00:24:00,320
from the lake that grows under these

606
00:24:07,190 --> 00:24:05,350
next slide please

607
00:24:09,430 --> 00:24:07,200
but let's go to mona lake because it's a

608
00:24:10,470 --> 00:24:09,440
it's a lot more fun uh in fact i i don't

609
00:24:13,190 --> 00:24:10,480
go to

610
00:24:16,470 --> 00:24:13,200
searle's lake because i'm i'm a

611
00:24:18,710 --> 00:24:16,480
these guys do it moto lake i like

612
00:24:20,390 --> 00:24:18,720
if you've never been there this is about

613
00:24:24,149 --> 00:24:20,400

15 miles across

614

00:24:28,470 --> 00:24:27,190

this is the current lake

615

00:24:30,549 --> 00:24:28,480

the lake's been there about a million

616

00:24:32,310 --> 00:24:30,559

years it's a closed basin lake water

617

00:24:33,830 --> 00:24:32,320

flows in but not out it goes out by

618

00:24:36,070 --> 00:24:33,840

evaporation and there's an evapo

619

00:24:37,590 --> 00:24:36,080

concentrative effect in this desert

620

00:24:40,789 --> 00:24:37,600

region

621

00:24:42,789 --> 00:24:40,799

that sounds good doesn't it uh but

622

00:24:45,029 --> 00:24:42,799

climate has changed considerably over

623

00:24:48,230 --> 00:24:45,039

the roughly million years

624

00:24:51,190 --> 00:24:48,240

his of its existence in fact back in the

625

00:24:53,350 --> 00:24:51,200

pleistocene roughly 20 000 years ago

626

00:24:54,870 --> 00:24:53,360

the lake covered five times the area

627

00:24:56,789 --> 00:24:54,880

that it does today

628

00:24:58,710 --> 00:24:56,799

and had 18 times more water on it and

629

00:25:01,190 --> 00:24:58,720

now it's in the contractive phase

630

00:25:03,510 --> 00:25:01,200

it's surrounded by active volcanoes so

631

00:25:05,750 --> 00:25:03,520

the hot springs

632

00:25:07,750 --> 00:25:05,760

put arsenic laden water into the lake

633

00:25:09,029 --> 00:25:07,760

and it stays in solution that's why

634

00:25:12,549 --> 00:25:09,039

there's so much

635

00:25:14,149 --> 00:25:12,559

arsenic dissolved in the wool lake water

636

00:25:15,190 --> 00:25:14,159

there are volcanic features through the

637

00:25:17,990 --> 00:25:15,200

lake

638

00:25:19,750 --> 00:25:18,000

peoha island which mark twain actually

639

00:25:21,669 --> 00:25:19,760

wrote about in uh

640

00:25:23,990 --> 00:25:21,679

uh roughing it i it's a wonderful book

641

00:25:26,070 --> 00:25:24,000

in a wonderful chapter and hilarious

642

00:25:27,669 --> 00:25:26,080

and there's hot springs

643

00:25:28,870 --> 00:25:27,679

uh on the south part that i'm going to

644

00:25:30,710 --> 00:25:28,880

show you

645

00:25:34,549 --> 00:25:30,720

where we did some of the current work

646

00:25:38,470 --> 00:25:36,950

that arsenic respiring bacteria are

647

00:25:40,710 --> 00:25:38,480

important in the ecology of the lake

648

00:25:42,390 --> 00:25:40,720

they burn up about 14

649

00:25:45,269 --> 00:25:42,400

of the phytoplankton

650

00:25:47,190 --> 00:25:45,279

organic carbon from primary productivity

651
00:25:49,590 --> 00:25:47,200
so arsenic in this case

652
00:25:51,590 --> 00:25:49,600
uh is important as an ecological oxidant

653
00:25:53,750 --> 00:25:51,600
for mineralization of carbon

654
00:25:56,149 --> 00:25:53,760
so then we got involved trying to figure

655
00:25:57,990 --> 00:25:56,159
out what microorganisms are actually

656
00:25:59,990 --> 00:25:58,000
doing this and we collaborated with tim

657
00:26:02,630 --> 00:26:00,000
hollibaugh and his crew at the

658
00:26:04,470 --> 00:26:02,640
university of georgia uh and of course

659
00:26:06,549 --> 00:26:04,480
we got

660
00:26:09,190 --> 00:26:06,559
entirely different result

661
00:26:10,870 --> 00:26:09,200
jody no shelly

662
00:26:12,390 --> 00:26:10,880
huffed

663
00:26:13,669 --> 00:26:12,400

discovered a microorganism from the

664

00:26:16,390 --> 00:26:13,679

water column

665

00:26:18,950 --> 00:26:16,400

alkaline limnicolor herlick ai that can

666

00:26:22,789 --> 00:26:18,960

oxidize arsenic 3 with nitrate and grow

667

00:26:24,390 --> 00:26:22,799

as a chemoautotroph next slide please

668

00:26:25,350 --> 00:26:24,400

and this is its growth curve that was

669

00:26:26,230 --> 00:26:25,360

published

670

00:26:28,950 --> 00:26:26,240

uh

671

00:26:30,710 --> 00:26:28,960

arsenite goes to arsenate nitrate goes

672

00:26:32,630 --> 00:26:30,720

to nitrite and there's more examples of

673

00:26:35,430 --> 00:26:32,640

this uh in the regular world it's not

674

00:26:36,950 --> 00:26:35,440

just confined to modal lake

675

00:26:40,310 --> 00:26:36,960

if you take away the arsenite it doesn't

676
00:26:43,830 --> 00:26:40,320
grow next slide please

677
00:26:46,870 --> 00:26:43,840
well john stahl sent uh uh

678
00:26:49,830 --> 00:26:46,880
we we sent the cells off to uh

679
00:26:55,190 --> 00:26:52,789
get their genome done by doe

680
00:26:56,149 --> 00:26:55,200
and the annotation came back and he

681
00:26:58,470 --> 00:26:56,159
called me

682
00:26:59,909 --> 00:26:58,480
and said are you sitting down

683
00:27:01,190 --> 00:26:59,919
i said i always sit down tell me

684
00:27:05,990 --> 00:27:01,200
something else you'll be lying down what

685
00:27:10,149 --> 00:27:08,230
we isolated this critter by giving it

686
00:27:12,230 --> 00:27:10,159
arsenic 3 and it grows by giving it

687
00:27:13,909 --> 00:27:12,240
arsenite and it makes arsenate

688
00:27:15,190 --> 00:27:13,919

but it has no

689

00:27:16,310 --> 00:27:15,200

annotated

690

00:27:18,710 --> 00:27:16,320

arsenite

691

00:27:20,389 --> 00:27:18,720

oxidase it ain't there

692

00:27:23,029 --> 00:27:20,399

it's the genome it's not there search

693

00:27:25,510 --> 00:27:23,039

the genome no arsenite oxidase

694

00:27:28,310 --> 00:27:25,520

but what it has

695

00:27:31,110 --> 00:27:28,320

are not one but two homologues of

696

00:27:32,549 --> 00:27:31,120

respiratory arsenic reductases

697

00:27:35,510 --> 00:27:32,559

but it doesn't

698

00:27:36,549 --> 00:27:35,520

respire arsenate

699

00:27:38,549 --> 00:27:36,559

why

700

00:27:39,350 --> 00:27:38,559

how does this work i don't understand

701
00:27:45,990 --> 00:27:39,360
this

702
00:27:47,990 --> 00:27:46,000
set

703
00:27:51,190 --> 00:27:48,000
that we're getting on our genome

704
00:27:53,669 --> 00:27:51,200
annotations of cells of communities of

705
00:27:56,789 --> 00:27:53,679
people we really have to do

706
00:27:58,789 --> 00:27:56,799
the basic classical physiology to

707
00:28:00,070 --> 00:27:58,799
determine whether these things are real

708
00:28:01,990 --> 00:28:00,080
or they're homologs or they're just

709
00:28:05,190 --> 00:28:02,000
pieces of dna but this is a really

710
00:28:07,510 --> 00:28:05,200
interesting story because what

711
00:28:09,269 --> 00:28:07,520
john's lab went on to show

712
00:28:10,389 --> 00:28:09,279
is that

713
00:28:12,789 --> 00:28:10,399

these are

714

00:28:15,750 --> 00:28:12,799

although they're annotated as arsenate

715

00:28:18,789 --> 00:28:15,760

reductases they're actually acting

716

00:28:20,950 --> 00:28:18,799

in vivo as arsenide oxidases remember i

717

00:28:22,310 --> 00:28:20,960

showed you they kind of look alike

718

00:28:24,230 --> 00:28:22,320

they're reversible

719

00:28:26,070 --> 00:28:24,240

and they're acting in the opposite

720

00:28:27,909 --> 00:28:26,080

direction but they're anaerobic

721

00:28:31,190 --> 00:28:27,919

arsenide oxidases as opposed to the

722

00:28:34,070 --> 00:28:31,200

aerobic ones next please

723

00:28:36,789 --> 00:28:34,080

and in further collaborations with chad

724

00:28:38,230 --> 00:28:36,799

soltikov and cameron zager

725

00:28:41,830 --> 00:28:38,240

who is his

726

00:28:43,350 --> 00:28:41,840

ph.d student they did knock out mutants

727

00:28:45,110 --> 00:28:43,360

and showed

728

00:28:47,029 --> 00:28:45,120

that if you knock out the gene one of

729

00:28:49,190 --> 00:28:47,039

the genes not both of them turns out one

730

00:28:51,590 --> 00:28:49,200

is irrelevant but one of them if you

731

00:28:54,389 --> 00:28:51,600

knock it out it does not grow

732

00:28:57,110 --> 00:28:54,399

under these conditions uh and it's

733

00:29:00,789 --> 00:28:57,120

critical it's acting as the arsenite

734

00:29:02,389 --> 00:29:00,799

oxidase next slide please

735

00:29:04,070 --> 00:29:02,399

and this is where it fell out it turns

736

00:29:05,750 --> 00:29:04,080

out the branching

737

00:29:06,789 --> 00:29:05,760

of the proteins

738

00:29:08,549 --> 00:29:06,799

for

739

00:29:10,149 --> 00:29:08,559

respiratory arsenate or duct tapes all

740

00:29:11,190 --> 00:29:10,159

these guys are although all of these are

741

00:29:14,630 --> 00:29:11,200

from

742

00:29:16,470 --> 00:29:14,640

microbes that can respire arsenate

743

00:29:17,590 --> 00:29:16,480

the ones from alkali alumina color or

744

00:29:19,190 --> 00:29:17,600

licking eye

745

00:29:20,310 --> 00:29:19,200

fall out

746

00:29:23,510 --> 00:29:20,320

a little bit

747

00:29:27,110 --> 00:29:25,269

down here

748

00:29:29,909 --> 00:29:27,120

are the arsenite oxidases that are

749

00:29:32,310 --> 00:29:29,919

associated with the aerobic oxidation

750

00:29:34,950 --> 00:29:32,320

of arsenic iii these

751
00:29:36,549 --> 00:29:34,960
two one only one of which actually works

752
00:29:39,029 --> 00:29:36,559
are associated with

753
00:29:40,710 --> 00:29:39,039
anaerobic oxidation of arsenic iii next

754
00:29:41,990 --> 00:29:40,720
slide please

755
00:29:43,750 --> 00:29:42,000
so let's go back to monolith because

756
00:29:45,510 --> 00:29:43,760
we've got pretty pictures now this one

757
00:29:46,950 --> 00:29:45,520
was taken by larry miller

758
00:29:49,269 --> 00:29:46,960
looking east

759
00:29:51,269 --> 00:29:49,279
over peoha island to the snow covered

760
00:29:55,029 --> 00:29:51,279
sierras in the background

761
00:29:57,350 --> 00:29:55,039
i think was made on the cover of esnt

762
00:29:59,269 --> 00:29:57,360
next slide please

763
00:30:00,870 --> 00:29:59,279

well if you go to those hot springs on

764

00:30:02,470 --> 00:30:00,880

peoha island

765

00:30:03,269 --> 00:30:02,480

on the south side this is what it looks

766

00:30:05,190 --> 00:30:03,279

like

767

00:30:07,750 --> 00:30:05,200

nice steam coming out of the water

768

00:30:09,750 --> 00:30:07,760

nice hydrogen sulfide smell

769

00:30:11,590 --> 00:30:09,760

bubbles of methane all over the place

770

00:30:14,470 --> 00:30:11,600

the lake actually has a natural gas

771

00:30:16,950 --> 00:30:14,480

deposit underneath it that

772

00:30:18,789 --> 00:30:16,960

just bubbles like pepsi cola sometimes

773

00:30:21,510 --> 00:30:18,799

next slide please don't smoke if you go

774

00:30:24,310 --> 00:30:22,710

and

775

00:30:26,070 --> 00:30:24,320

if you go ashore

776

00:30:27,909 --> 00:30:26,080

coming out of these hot springs you see

777

00:30:30,070 --> 00:30:27,919

these biofilms

778

00:30:31,269 --> 00:30:30,080

in many cases these beautiful

779

00:30:33,830 --> 00:30:31,279

layers of

780

00:30:35,110 --> 00:30:33,840

purple photosynthetic bacteria that are

781

00:30:36,549 --> 00:30:35,120

are growing

782

00:30:37,909 --> 00:30:36,559

under these warm springs next slide

783

00:30:39,830 --> 00:30:37,919

please

784

00:30:41,750 --> 00:30:39,840

and sometimes they form these nice big

785

00:30:43,669 --> 00:30:41,760

ponds

786

00:30:45,029 --> 00:30:43,679

of photosynthetic bacteria

787

00:30:46,710 --> 00:30:45,039

so what are they growing on besides

788

00:30:48,310 --> 00:30:46,720

light and co2

789

00:30:50,789 --> 00:30:48,320

there are three oxidants i have three

790

00:30:51,830 --> 00:30:50,799

reductants next slide please

791

00:30:53,830 --> 00:30:51,840

they also

792

00:30:55,990 --> 00:30:53,840

sometimes we have these green ones as

793

00:30:58,149 --> 00:30:56,000

well next slide

794

00:31:02,950 --> 00:30:58,159

but the red one the red ponds

795

00:31:02,960 --> 00:31:07,909

cheers

796

00:31:13,750 --> 00:31:10,149

they're anoxic

797

00:31:15,909 --> 00:31:13,760

they have plenty of arsenite in them

798

00:31:18,230 --> 00:31:15,919

there's also sulfide ammonia methane

799

00:31:20,149 --> 00:31:18,240

ethane

800

00:31:20,870 --> 00:31:20,159

but we wanted to see

801
00:31:23,509 --> 00:31:20,880
if

802
00:31:26,389 --> 00:31:23,519
arsenic 3 could drive the photosynthetic

803
00:31:28,789 --> 00:31:26,399
reaction so can these microbes use

804
00:31:30,710 --> 00:31:28,799
arsenic 3 to sustain an oxygenic

805
00:31:31,830 --> 00:31:30,720
photosynthesis we know they can use

806
00:31:33,909 --> 00:31:31,840
sulfide

807
00:31:36,149 --> 00:31:33,919
next slide please

808
00:31:39,750 --> 00:31:36,159
and what is the system composed of it's

809
00:31:41,590 --> 00:31:39,760
mainly composed of ectothyroid aspara

810
00:31:42,470 --> 00:31:41,600
photosynthetic bacteria that's not a big

811
00:31:43,269 --> 00:31:42,480
brain

812
00:31:46,870 --> 00:31:43,279
uh

813
00:31:49,110 --> 00:31:46,880

critters there there's other anaerobes

814

00:31:51,909 --> 00:31:49,120

there but the main ninety percent or so

815

00:31:53,350 --> 00:31:51,919

as was determined by uh uh brian

816

00:31:54,630 --> 00:31:53,360

lenoil's lab

817

00:31:56,630 --> 00:31:54,640

uh and

818

00:31:58,310 --> 00:31:56,640

ahsoki and han

819

00:32:00,470 --> 00:31:58,320

showed that the main component really is

820

00:32:04,470 --> 00:32:00,480

echo thyroid asperate type

821

00:32:04,480 --> 00:32:07,669

so tom kolp

822

00:32:12,630 --> 00:32:09,669

scraped these biofilms and incubated

823

00:32:14,630 --> 00:32:12,640

them under anaerobic conditions

824

00:32:16,149 --> 00:32:14,640

and with arsenic three in the light

825

00:32:18,710 --> 00:32:16,159

uh arsenic iii

826

00:32:20,789 --> 00:32:18,720

was completely converted uh to arsenic

827

00:32:23,350 --> 00:32:20,799

five and if you put him in the dark or

828

00:32:25,110 --> 00:32:23,360

if you kill him nothing happens

829

00:32:28,310 --> 00:32:25,120

next slide

830

00:32:30,310 --> 00:32:28,320

and if you keep on adding more arsenic 3

831

00:32:32,549 --> 00:32:30,320

at higher and higher doses

832

00:32:34,630 --> 00:32:32,559

they make more and more arsenic 5. this

833

00:32:36,389 --> 00:32:34,640

was a ruined weekend for tom he started

834

00:32:38,310 --> 00:32:36,399

the experiment over here

835

00:32:39,750 --> 00:32:38,320

on a long weekend it was actually

836

00:32:42,149 --> 00:32:39,760

columbus day weekend and i said i don't

837

00:32:44,310 --> 00:32:42,159

know what your plans are but you're

838

00:32:45,830 --> 00:32:44,320

coming in this weekend through monday

839

00:32:47,029 --> 00:32:45,840

and make the time up next week because

840

00:32:47,830 --> 00:32:47,039

we don't know if these guys are going to

841

00:32:48,789 --> 00:32:47,840

last

842

00:32:51,909 --> 00:32:48,799

actually

843

00:32:53,830 --> 00:32:51,919

they maintain uh viability for months

844

00:32:54,830 --> 00:32:53,840

and months if we keep them in the fridge

845

00:32:58,549 --> 00:32:54,840

next slide

846

00:33:03,029 --> 00:32:58,559

please then shelly huffed

847

00:33:05,590 --> 00:33:03,039

isolated strain phs1 from that milieu

848

00:33:07,990 --> 00:33:05,600

of a photosynthetic bacterium that grows

849

00:33:10,950 --> 00:33:08,000

on arsenite about the same time

850

00:33:12,549 --> 00:33:10,960

independently tim halabaugh's group uh

851
00:33:14,630 --> 00:33:12,559
isolated from

852
00:33:16,230 --> 00:33:14,640
a winogradski column an enrichment

853
00:33:18,389 --> 00:33:16,240
culture that seemed to do the same thing

854
00:33:20,630 --> 00:33:18,399
and then we ran into each other

855
00:33:23,350 --> 00:33:20,640
we had posters next to each other at agu

856
00:33:25,750 --> 00:33:23,360
and we said well let's put our

857
00:33:28,230 --> 00:33:25,760
forces together and and grind this thing

858
00:33:30,070 --> 00:33:28,240
out this is the next slide please

859
00:33:30,950 --> 00:33:30,080
uh these are the growth curves uh they

860
00:33:31,990 --> 00:33:30,960
grow

861
00:33:36,789 --> 00:33:32,000
uh

862
00:33:38,470 --> 00:33:36,799
arsenic five you the trick is you have

863
00:33:40,149 --> 00:33:38,480

to pulse your additions if you give them

864

00:33:41,350 --> 00:33:40,159

too much you'll kill them but if you

865

00:33:42,870 --> 00:33:41,360

should give them

866

00:33:45,110 --> 00:33:42,880

just the right amount they'll keep on

867

00:33:47,590 --> 00:33:45,120

growing and you just have to resupply it

868

00:33:49,669 --> 00:33:47,600

next slide

869

00:33:51,269 --> 00:33:49,679

and

870

00:33:53,190 --> 00:33:51,279

as i mentioned it's a member of the

871

00:33:54,389 --> 00:33:53,200

ectothyroid aspera

872

00:33:56,149 --> 00:33:54,399

not too far

873

00:33:58,789 --> 00:33:56,159

away

874

00:34:05,190 --> 00:34:02,630

strain mlhe1 phylogenetically

875

00:34:05,200 --> 00:34:08,550

and it's

876

00:34:13,430 --> 00:34:11,990

it doesn't have an arsenide oxidase

877

00:34:15,430 --> 00:34:13,440

it has

878

00:34:16,470 --> 00:34:15,440

an arsenic reductase

879

00:34:17,750 --> 00:34:16,480

that is

880

00:34:20,389 --> 00:34:17,760

aligned

881

00:34:22,310 --> 00:34:20,399

with the arsenate reductase of

882

00:34:23,430 --> 00:34:22,320

alkalinity color or lickeye in other

883

00:34:25,909 --> 00:34:23,440

words

884

00:34:28,470 --> 00:34:25,919

this guy this anaerobe is also oxidizing

885

00:34:29,190 --> 00:34:28,480

arsenic 3 in reverse

886

00:34:31,510 --> 00:34:29,200

by

887

00:34:32,790 --> 00:34:31,520

something the genome meditation says is

888

00:34:35,510 --> 00:34:32,800

a reductase

889

00:34:38,149 --> 00:34:35,520

next slide

890

00:34:39,190 --> 00:34:38,159

if you take these scrapings

891

00:34:41,909 --> 00:34:39,200

and

892

00:34:43,990 --> 00:34:41,919

them in a bottle

893

00:34:45,349 --> 00:34:44,000

in the light

894

00:34:47,349 --> 00:34:45,359

arsenic 3

895

00:34:48,550 --> 00:34:47,359

goes to arsenic 5 quantitatively there's

896

00:34:50,790 --> 00:34:48,560

no light if you kill them nothing

897

00:34:53,270 --> 00:34:50,800

happens but when you

898

00:34:55,109 --> 00:34:53,280

turn the lights off

899

00:34:57,589 --> 00:34:55,119

just the opposite happens

900

00:34:59,829 --> 00:34:57,599

all the arsenate goes to arsenite

901
00:35:01,750 --> 00:34:59,839
and what is occurring here

902
00:35:03,030 --> 00:35:01,760
is a centrifuge between different

903
00:35:04,710 --> 00:35:03,040
populations

904
00:35:07,829 --> 00:35:04,720
of photosynthetic bacteria that can

905
00:35:09,910 --> 00:35:07,839
oxidize the arsenic 3 to arsenic 5 and

906
00:35:13,270 --> 00:35:09,920
the arsenate respirers that are very

907
00:35:15,990 --> 00:35:13,280
closely related to them physically

908
00:35:18,310 --> 00:35:16,000
and we have coupled arsenite oxidation

909
00:35:21,829 --> 00:35:18,320
arsenate reduction so the arsenite

910
00:35:24,630 --> 00:35:21,839
oxidase advisors are creating a niche

911
00:35:26,470 --> 00:35:24,640
for the arsenate respirers

912
00:35:29,349 --> 00:35:26,480
and you can see how this is demonstrated

913
00:35:33,349 --> 00:35:29,359

ecologically in these hot springs

914

00:35:38,550 --> 00:35:36,550

arsenate reduction is being fueled by

915

00:35:40,950 --> 00:35:38,560

inorganic electron donors organics

916

00:35:43,030 --> 00:35:40,960

didn't work in this system but hydrogen

917

00:35:44,390 --> 00:35:43,040

and sulfide did i won't go into this in

918

00:35:46,230 --> 00:35:44,400

great detail but that's the take home

919

00:35:47,510 --> 00:35:46,240

message here and they're chemo

920

00:35:50,230 --> 00:35:47,520

autotrophs

921

00:35:54,950 --> 00:35:52,470

this is a terrible slide but there are

922

00:35:56,470 --> 00:35:54,960

arsenate reductases here that

923

00:35:58,630 --> 00:35:56,480

most of them align with those of the

924

00:36:00,950 --> 00:35:58,640

ectothroid aspera but there's others

925

00:36:03,910 --> 00:36:00,960

that are more associated with

926
00:36:06,390 --> 00:36:03,920
the respiratory type arsenal reductases

927
00:36:10,870 --> 00:36:08,390
and if you try and feed organics in this

928
00:36:12,950 --> 00:36:10,880
case acetate

929
00:36:14,390 --> 00:36:12,960
it doesn't fuel arsenic reduction what

930
00:36:16,069 --> 00:36:14,400
it actually fuels

931
00:36:18,790 --> 00:36:16,079
is photosynthetic

932
00:36:21,430 --> 00:36:18,800
arsenic photosynthetic and oxygenic

933
00:36:23,430 --> 00:36:21,440
photosynthesis these bugs can also

934
00:36:25,990 --> 00:36:23,440
strip electrons from acetate that's

935
00:36:27,829 --> 00:36:26,000
rather well known and that goes on uh

936
00:36:29,510 --> 00:36:27,839
very well in the light but not the dark

937
00:36:30,790 --> 00:36:29,520
so it's sort of like different

938
00:36:32,950 --> 00:36:30,800

than what you're thinking about a marine

939

00:36:35,910 --> 00:36:32,960

sediment or mud you acetate it's going

940

00:36:39,750 --> 00:36:35,920

to go to CO_2 and methane not here

941

00:36:39,760 --> 00:36:43,349

so in summary

942

00:36:49,030 --> 00:36:45,589

there's a complete cycle biogeochemical

943

00:36:51,349 --> 00:36:49,040

cycle of arsenic in the environment

944

00:36:52,950 --> 00:36:51,359

if we start out with arsenate

945

00:36:54,710 --> 00:36:52,960

it can be reduced

946

00:36:56,630 --> 00:36:54,720

to arsenite

947

00:37:00,310 --> 00:36:56,640

at the

948

00:37:06,630 --> 00:37:00,320

organic matter to CO_2

949

00:37:11,349 --> 00:37:09,030

but inorganic electron donors could also

950

00:37:13,829 --> 00:37:11,359

fuel this process including hydrogen and

951
00:37:16,310 --> 00:37:13,839
sulfide

952
00:37:18,950 --> 00:37:16,320
on the oxidative side of the cycle

953
00:37:21,270 --> 00:37:18,960
arsenic 3 can go back to arsenic 5

954
00:37:23,670 --> 00:37:21,280
through microbial action

955
00:37:25,510 --> 00:37:23,680
by coupling with strong oxidants like

956
00:37:29,030 --> 00:37:25,520
oxygen or nitrate

957
00:37:31,030 --> 00:37:29,040
and this is a chemoautotrophic process

958
00:37:32,630 --> 00:37:31,040
but

959
00:37:35,030 --> 00:37:32,640
an oxygenic photosynthesis

960
00:37:37,109 --> 00:37:35,040
short-circuits this

961
00:37:39,510 --> 00:37:37,119
so all you need is light

962
00:37:41,190 --> 00:37:39,520
and you can go from arsenic 3 to arsenic

963
00:37:41,990 --> 00:37:41,200

5. and if you think back

964

00:37:43,670 --> 00:37:42,000

maybe

965

00:37:45,030 --> 00:37:43,680

4 billion years

966

00:37:46,710 --> 00:37:45,040

when life is first getting going and

967

00:37:49,589 --> 00:37:46,720

there's all these reductants coming out

968

00:37:50,470 --> 00:37:49,599

of the ground like sulfide like arsenic

969

00:37:52,390 --> 00:37:50,480

iii

970

00:37:54,870 --> 00:37:52,400

all you need is a microbe that can

971

00:37:56,870 --> 00:37:54,880

oxidize arsenic 3 to arsenic 5 with a

972

00:37:59,109 --> 00:37:56,880

little bit of light

973

00:38:00,390 --> 00:37:59,119

and it creates arsenic 5 and makes an

974

00:38:02,230 --> 00:38:00,400

immediate niche

975

00:38:05,349 --> 00:38:02,240

for the appearance of respiratory

976

00:38:07,829 --> 00:38:05,359

arsenic reducing bacteria or archaea in

977

00:38:10,150 --> 00:38:07,839

the same place and they start working in

978

00:38:12,310 --> 00:38:10,160

centrifuge and feeding off each other next

979

00:38:14,150 --> 00:38:12,320

slide please

980

00:38:16,950 --> 00:38:14,160

so this is that

981

00:38:19,109 --> 00:38:16,960

a refined version of the slide i showed

982

00:38:21,109 --> 00:38:19,119

you before coming out of chad salter

983

00:38:23,750 --> 00:38:21,119

calls lab it hasn't been published yet

984

00:38:26,550 --> 00:38:23,760

but it will be submitted soon

985

00:38:29,270 --> 00:38:26,560

of the dmso reductases molybdenum and

986

00:38:30,390 --> 00:38:29,280

the that's not an easy element

987

00:38:32,550 --> 00:38:30,400

to say

988

00:38:35,109 --> 00:38:32,560

here are the anaerobic

989

00:38:36,310 --> 00:38:35,119

uh arsenate reductases here are the

990

00:38:38,230 --> 00:38:36,320

aerobic

991

00:38:39,670 --> 00:38:38,240

uh arsenite oxidases and here's that

992

00:38:41,829 --> 00:38:39,680

branch and now we've got a lot more

993

00:38:45,030 --> 00:38:41,839

clones and cultures in here

994

00:38:47,510 --> 00:38:45,040

that appear to have this anaerobic

995

00:38:50,470 --> 00:38:47,520

arsenite oxidase

996

00:38:53,670 --> 00:38:50,480

we call it ar x now to distinguish it

997

00:38:58,829 --> 00:38:53,680

between ar uh a

998

00:39:01,109 --> 00:38:58,839

a-r-r-a and a-o-x it's a-r-x and

999

00:39:02,470 --> 00:39:01,119

here's all right alkaline lemon color

1000

00:39:04,870 --> 00:39:02,480

erlicky i

1001
00:39:06,710 --> 00:39:04,880
here are the photosynthetic bacteria

1002
00:39:08,950 --> 00:39:06,720
that shelly has in culture as well as

1003
00:39:11,109 --> 00:39:08,960
clones from the environment and there

1004
00:39:13,910 --> 00:39:11,119
are a number of hits from the shoreline

1005
00:39:16,310 --> 00:39:13,920
of moto lake as well as from hot creek

1006
00:39:18,710 --> 00:39:16,320
which is an arsenic rich fresh water

1007
00:39:20,230 --> 00:39:18,720
environment about 30 miles away

1008
00:39:22,630 --> 00:39:20,240
which might imply that this is a lot

1009
00:39:23,670 --> 00:39:22,640
more widespread

1010
00:39:25,430 --> 00:39:23,680
than

1011
00:39:28,230 --> 00:39:25,440
just mono lake

1012
00:39:30,710 --> 00:39:28,240
there's another way to cycle arsenic 3

1013
00:39:32,470 --> 00:39:30,720

back to arsenic 5 anaerobically next

1014

00:39:34,150 --> 00:39:32,480

slide please

1015

00:39:35,829 --> 00:39:34,160

so what does this have to do

1016

00:39:38,790 --> 00:39:35,839

with

1017

00:39:41,030 --> 00:39:38,800

that slide i showed you earlier about

1018

00:39:43,430 --> 00:39:41,040

the diversity of arsenic metabolizing

1019

00:39:45,510 --> 00:39:43,440

microbes and the history of arsenic in

1020

00:39:49,190 --> 00:39:45,520

the biogeochemistry of

1021

00:39:51,030 --> 00:39:49,200

biogeochemical evolution of the earth

1022

00:39:53,349 --> 00:39:51,040

well if life got going about four

1023

00:39:56,870 --> 00:39:53,359

billion years ago

1024

00:39:59,589 --> 00:39:56,880

and the first microfossils are like 3.5

1025

00:40:01,910 --> 00:39:59,599

3.6 billion years old and some of them

1026
00:40:04,470 --> 00:40:01,920
seem to be photosynthetic communities

1027
00:40:07,430 --> 00:40:04,480
it's reasonable to suggest that

1028
00:40:10,550 --> 00:40:07,440
arsenic 3 biofilms were important

1029
00:40:13,030 --> 00:40:10,560
components of those primitive microbial

1030
00:40:15,109 --> 00:40:13,040
communities and maybe that process has

1031
00:40:17,109 --> 00:40:15,119
been around uh quite a while and as soon

1032
00:40:20,309 --> 00:40:17,119
as you get that going

1033
00:40:21,829 --> 00:40:20,319
you get the arsenate respire going

1034
00:40:24,710 --> 00:40:21,839
because you created arsenate and made

1035
00:40:26,069 --> 00:40:24,720
that immediate niche and if we can back

1036
00:40:28,150 --> 00:40:26,079
up one slide

1037
00:40:31,829 --> 00:40:28,160
please

1038
00:40:35,829 --> 00:40:33,670

in the course of evolution all you had

1039

00:40:38,710 --> 00:40:35,839

to do was switch the side group around

1040

00:40:42,309 --> 00:40:38,720

and you wind up with these not that big

1041

00:40:45,829 --> 00:40:42,319

a deal when oxygen picked up later

1042

00:40:46,630 --> 00:40:45,839

these guys arose so next slide please

1043

00:40:48,150 --> 00:40:46,640

so

1044

00:40:49,990 --> 00:40:48,160

it wasn't until

1045

00:40:51,670 --> 00:40:50,000

the goe event that we can really start

1046

00:40:54,150 --> 00:40:51,680

talking about aerobic

1047

00:40:55,589 --> 00:40:54,160

arsenide oxidation

1048

00:40:58,470 --> 00:40:55,599

and we had a good

1049

00:41:00,150 --> 00:40:58,480

billion years or so of anaerobic arsenic

1050

00:41:01,430 --> 00:41:00,160

cycling before that came along so it's

1051

00:41:03,750 --> 00:41:01,440

an ancient process is what i'm

1052

00:41:06,630 --> 00:41:03,760

contending uh and that's why we see this

1053

00:41:07,990 --> 00:41:06,640

diversity that we do today that's uh the

1054

00:41:10,069 --> 00:41:08,000

hypothesis

1055

00:41:12,150 --> 00:41:10,079

later on we had goa as opposed to the

1056

00:41:14,710 --> 00:41:12,160

goe event goa's

1057

00:41:16,470 --> 00:41:14,720

garlic onions and anchovies on pizza

1058

00:41:18,550 --> 00:41:16,480

next slide please

1059

00:41:20,069 --> 00:41:18,560

and this is that phylogenetic tree you

1060

00:41:21,589 --> 00:41:20,079

can see now it's even more diverse it's

1061

00:41:24,950 --> 00:41:21,599

not showing up very well so let's go to

1062

00:41:28,309 --> 00:41:26,069

okay

1063

00:41:30,069 --> 00:41:28,319

this is the money payoff this is what uh

1064

00:41:34,390 --> 00:41:30,079

all the hoopla was about for the last

1065

00:41:38,710 --> 00:41:36,390

milo i've been working on arsenic and

1066

00:41:41,030 --> 00:41:38,720

selenium and tellurium and things that

1067

00:41:43,349 --> 00:41:41,040

go bump in the night for quite some time

1068

00:41:45,190 --> 00:41:43,359

and i kept on bumping in to

1069

00:41:47,190 --> 00:41:45,200

felicia wolfe simon

1070

00:41:49,750 --> 00:41:47,200

at the gordon research conferences on

1071

00:41:52,069 --> 00:41:49,760

environmental bio inorganic chemistry

1072

00:41:54,069 --> 00:41:52,079

that have unfortunately been abolished

1073

00:41:56,390 --> 00:41:54,079

and she

1074

00:41:58,069 --> 00:41:56,400

was always persistent i mean she and her

1075

00:41:59,589 --> 00:41:58,079

husband were there and

1076
00:42:02,470 --> 00:41:59,599
they were from oberlin college and so

1077
00:42:05,510 --> 00:42:02,480
they had rings and things and orange

1078
00:42:07,270 --> 00:42:05,520
hair and felicia who had it had it too

1079
00:42:10,390 --> 00:42:07,280
uh and uh

1080
00:42:12,790 --> 00:42:10,400
she kept on talking about arsenic

1081
00:42:13,829 --> 00:42:12,800
substituting for phosphorus

1082
00:42:16,870 --> 00:42:13,839
and

1083
00:42:21,190 --> 00:42:16,880
argument became a little bit more

1084
00:42:22,230 --> 00:42:21,200
complicated a little bit more compelling

1085
00:42:23,910 --> 00:42:22,240
until

1086
00:42:25,589 --> 00:42:23,920
a couple of years ago i

1087
00:42:28,069 --> 00:42:25,599
said look

1088
00:42:29,510 --> 00:42:28,079

i don't think this is going to work but

1089

00:42:34,630 --> 00:42:29,520

it might

1090

00:42:37,270 --> 00:42:34,640

all you would have to do

1091

00:42:39,829 --> 00:42:37,280

is make a simple defined organ inorganic

1092

00:42:41,670 --> 00:42:39,839

media give it glucose

1093

00:42:43,829 --> 00:42:41,680

take away the phosphate give it a couple

1094

00:42:45,829 --> 00:42:43,839

of vitamins and give it a little bit of

1095

00:42:47,829 --> 00:42:45,839

nitrogen and give it a lot of arsenic

1096

00:42:50,950 --> 00:42:47,839

and see if anything grows

1097

00:42:54,150 --> 00:42:50,960

now this gets back to the idea that

1098

00:42:55,670 --> 00:42:54,160

life may be composed of a bit more in

1099

00:42:58,470 --> 00:42:55,680

terms of the elements

1100

00:43:00,150 --> 00:42:58,480

than what we're used to being taught

1101

00:43:01,990 --> 00:43:00,160

and thinking about because you know you

1102

00:43:04,069 --> 00:43:02,000

look in the textbook it's

1103

00:43:05,670 --> 00:43:04,079

carbon nitrogen phosphorus oxygen sulfur

1104

00:43:07,510 --> 00:43:05,680

hydrogen and they're arranged in their

1105

00:43:09,589 --> 00:43:07,520

periodic order here so these are the 15

1106

00:43:12,390 --> 00:43:09,599

elements these are the 16 elements why

1107

00:43:14,790 --> 00:43:12,400

is that true because lenninger

1108

00:43:16,550 --> 00:43:14,800

in this textbook said and the

1109

00:43:18,069 --> 00:43:16,560

earlier textbook said that they all said

1110

00:43:21,190 --> 00:43:18,079

it and we all know we're composing this

1111

00:43:24,069 --> 00:43:21,200

stuff so what's the argument right

1112

00:43:25,990 --> 00:43:24,079

well star trek

1113

00:43:27,670 --> 00:43:26,000

silica instead of carbon it's right

1114

00:43:29,670 --> 00:43:27,680

below i mean that would be wonderful for

1115

00:43:31,670 --> 00:43:29,680

the astrophysicist community because

1116

00:43:33,430 --> 00:43:31,680

we've got all now all these exoplanets

1117

00:43:34,950 --> 00:43:33,440

but they're usually circulating close to

1118

00:43:36,309 --> 00:43:34,960

the sun they're hot but they can have

1119

00:43:40,150 --> 00:43:36,319

rocks

1120

00:43:42,309 --> 00:43:40,160

silica instead of carbon wouldn't that

1121

00:43:43,589 --> 00:43:42,319

be terrific

1122

00:43:45,349 --> 00:43:43,599

but

1123

00:43:47,589 --> 00:43:45,359

the chemistry is not right

1124

00:43:48,950 --> 00:43:47,599

it doesn't form the myriads of compounds

1125

00:43:50,870 --> 00:43:48,960

so what the what are the rocks going to

1126
00:43:52,829 --> 00:43:50,880
eat it just doesn't seem to work what

1127
00:43:54,470 --> 00:43:52,839
are they going to poop out

1128
00:43:55,990 --> 00:43:54,480
and

1129
00:43:58,550 --> 00:43:56,000
but it's great for science fiction they

1130
00:44:01,349 --> 00:43:58,560
were the old hoarder uh episodes of star

1131
00:44:03,990 --> 00:44:01,359
trek spock what is it doing

1132
00:44:05,750 --> 00:44:04,000
spot you know the over acting uh

1133
00:44:09,670 --> 00:44:05,760
community uh

1134
00:44:11,270 --> 00:44:09,680
emoting emote you emote too much

1135
00:44:13,270 --> 00:44:11,280
and i don't think anybody seriously

1136
00:44:14,470 --> 00:44:13,280
considered lithium substituting for

1137
00:44:15,829 --> 00:44:14,480
hydrogen

1138
00:44:17,430 --> 00:44:15,839

in life because

1139

00:44:19,430 --> 00:44:17,440

how do you get it out of an aqueous or

1140

00:44:21,430 --> 00:44:19,440

even an organic solvent they all have

1141

00:44:23,750 --> 00:44:21,440

hydrogen uh how is that going to work

1142

00:44:26,150 --> 00:44:23,760

how are you going to test that but

1143

00:44:28,470 --> 00:44:26,160

if you go down to group 15 and the group

1144

00:44:31,109 --> 00:44:28,480

16 elements we got these two

1145

00:44:32,630 --> 00:44:31,119

these are actually testable

1146

00:44:34,150 --> 00:44:32,640

so i said come on out fellas so what do

1147

00:44:36,710 --> 00:44:34,160

we got to lose well you got to lose your

1148

00:44:39,030 --> 00:44:36,720

whole career but i got nothing to lose

1149

00:44:41,589 --> 00:44:39,040

and so we appealed to nasa and they love

1150

00:44:43,670 --> 00:44:41,599

the idea this is what i love about nasa

1151
00:44:45,750 --> 00:44:43,680
a long shot

1152
00:44:47,589 --> 00:44:45,760
is not that big a deal

1153
00:44:50,150 --> 00:44:47,599
whether you're going

1154
00:44:51,990 --> 00:44:50,160
to venus or mars or jupiter or saturn we

1155
00:44:54,069 --> 00:44:52,000
might find out something and we always

1156
00:44:55,990 --> 00:44:54,079
usually do if the dang things don't

1157
00:44:58,630 --> 00:44:56,000
break down

1158
00:45:00,230 --> 00:44:58,640
and this compared to a mars mission

1159
00:45:01,990 --> 00:45:00,240
is boopkis you're talking about a

1160
00:45:03,589 --> 00:45:02,000
postdoc salary

1161
00:45:05,750 --> 00:45:03,599
and they pay him a lot less than the

1162
00:45:08,230 --> 00:45:05,760
usgs postdocs i'll just put that in

1163
00:45:10,950 --> 00:45:08,240

there she works for half the price

1164

00:45:12,870 --> 00:45:10,960

so there's been a huge amount of hoopla

1165

00:45:14,309 --> 00:45:12,880

about this in the media you think this

1166

00:45:16,230 --> 00:45:14,319

was a billion dollar

1167

00:45:17,990 --> 00:45:16,240

multi-gigantic thing no it's just

1168

00:45:20,309 --> 00:45:18,000

felicia puts it away in the lab with

1169

00:45:23,109 --> 00:45:20,319

this culture

1170

00:45:25,510 --> 00:45:23,119

for a very small amount of money

1171

00:45:28,790 --> 00:45:26,950

everybody knows how to make a small

1172

00:45:34,150 --> 00:45:28,800

fortune in california

1173

00:45:36,950 --> 00:45:35,349

but

1174

00:45:38,230 --> 00:45:36,960

so she started this experiment and this

1175

00:45:39,829 --> 00:45:38,240

is you know the meaning of life our

1176
00:45:43,510 --> 00:45:39,839
snake in the meaning of life i get that

1177
00:45:46,390 --> 00:45:43,520
from monty python next slide please

1178
00:45:47,270 --> 00:45:46,400
and her contention was

1179
00:45:49,430 --> 00:45:47,280
uh

1180
00:45:51,910 --> 00:45:49,440
it doesn't show up very well here but

1181
00:45:55,430 --> 00:45:51,920
these are arsenic uh

1182
00:45:59,109 --> 00:45:55,440
arsenate molecules binding the ribose

1183
00:46:00,390 --> 00:45:59,119
uh sugars together in the dna helix on

1184
00:46:02,309 --> 00:46:00,400
both sides

1185
00:46:03,829 --> 00:46:02,319
now that's a pretty big deal if that's

1186
00:46:07,670 --> 00:46:03,839
really true

1187
00:46:09,750 --> 00:46:07,680
and i think we now have decent evidence

1188
00:46:11,190 --> 00:46:09,760

that supports this

1189

00:46:12,390 --> 00:46:11,200

next slide

1190

00:46:14,630 --> 00:46:12,400

so

1191

00:46:16,870 --> 00:46:14,640

from this media

1192

00:46:19,190 --> 00:46:16,880

things started growing

1193

00:46:20,390 --> 00:46:19,200

and well you're carrying over phosphorus

1194

00:46:22,870 --> 00:46:20,400

from there's a lot of phosphorus in

1195

00:46:24,470 --> 00:46:22,880

monolight mud keep on transferring it

1196

00:46:27,109 --> 00:46:24,480

well you're going through eight

1197

00:46:29,109 --> 00:46:27,119

transfers 10 transfers

1198

00:46:30,550 --> 00:46:29,119

all right something's in there but

1199

00:46:33,190 --> 00:46:30,560

there's got to be phosphorus in there

1200

00:46:34,069 --> 00:46:33,200

put it on plates pick colonies and put

1201
00:46:35,510 --> 00:46:34,079
it back

1202
00:46:37,510 --> 00:46:35,520
into the media it's not going to grow

1203
00:46:40,150 --> 00:46:37,520
the group

1204
00:46:42,550 --> 00:46:40,160
but the growth was marginal

1205
00:46:44,390 --> 00:46:42,560
compared to controls or it was way below

1206
00:46:46,069 --> 00:46:44,400
phosphorus and then on our own she

1207
00:46:47,510 --> 00:46:46,079
figured out two things one we need to

1208
00:46:49,510 --> 00:46:47,520
keep these guys

1209
00:46:51,270 --> 00:46:49,520
at constant temperature

1210
00:46:53,670 --> 00:46:51,280
at 28 degrees

1211
00:46:56,230 --> 00:46:53,680
because the usgs has a very very

1212
00:46:58,390 --> 00:46:57,589
temperature control in the building i'm

1213
00:47:08,069 --> 00:46:58,400

in

1214

00:47:09,270 --> 00:47:08,079

and it fluctuates on a 24-hour cycle and

1215

00:47:10,630 --> 00:47:09,280

on weekends

1216

00:47:11,990 --> 00:47:10,640

all bets are off

1217

00:47:14,230 --> 00:47:12,000

so the bugs

1218

00:47:15,750 --> 00:47:14,240

our microbes are exposed to these things

1219

00:47:17,109 --> 00:47:15,760

so i said all right

1220

00:47:19,349 --> 00:47:17,119

let's take some money let's buy a bunch

1221

00:47:21,349 --> 00:47:19,359

of incubators then she found out that it

1222

00:47:23,430 --> 00:47:21,359

grows really well

1223

00:47:26,549 --> 00:47:23,440

at extraordinarily high arsenal

1224

00:47:30,710 --> 00:47:26,559

concentration is 20 to 40 millimolar now

1225

00:47:33,270 --> 00:47:30,720

the but it grows very well on phosphorus

1226

00:47:35,910 --> 00:47:33,280

clearly no question about that that's

1227

00:47:38,549 --> 00:47:35,920

only about one to two millimolar

1228

00:47:39,829 --> 00:47:38,559

but it grows very well very respectably

1229

00:47:41,990 --> 00:47:39,839

on arsenate

1230

00:47:44,150 --> 00:47:42,000

if you don't have arsenate

1231

00:47:46,870 --> 00:47:44,160

and if you don't have phosphate

1232

00:47:49,510 --> 00:47:46,880

it does not grow and that is this and we

1233

00:47:51,190 --> 00:47:49,520

did this two ways this is ods

1234

00:47:52,870 --> 00:47:51,200

and this is

1235

00:47:54,230 --> 00:47:52,880

acronym orange direct counts you're

1236

00:47:55,990 --> 00:47:54,240

sitting there under a microscope

1237

00:47:58,950 --> 00:47:56,000

counting counting counting counting

1238

00:47:59,750 --> 00:47:58,960

counting laborious but you really

1239

00:48:02,309 --> 00:47:59,760

have

1240

00:48:06,150 --> 00:48:03,349

this

1241

00:48:07,670 --> 00:48:06,160

is the crux of the entire story if there

1242

00:48:11,270 --> 00:48:07,680

is not arsenic

1243

00:48:13,349 --> 00:48:11,280

or phosphate added they don't grow

1244

00:48:15,670 --> 00:48:13,359

now there's a smidgen of phosphorus in

1245

00:48:16,710 --> 00:48:15,680

the medium it's coming from impurities

1246

00:48:18,549 --> 00:48:16,720

in the

1247

00:48:20,470 --> 00:48:18,559

reagents

1248

00:48:21,589 --> 00:48:20,480

it's about two micromolar

1249

00:48:23,270 --> 00:48:21,599

and we

1250

00:48:24,069 --> 00:48:23,280

didn't do anything fancy to get rid of

1251
00:48:25,430 --> 00:48:24,079
that

1252
00:48:27,510 --> 00:48:25,440
uh so

1253
00:48:29,349 --> 00:48:27,520
they're probably or maybe or there could

1254
00:48:31,190 --> 00:48:29,359
be some phosphorus

1255
00:48:33,349 --> 00:48:31,200
incorporated into the places where

1256
00:48:35,990 --> 00:48:33,359
phosphorus should be going but it's not

1257
00:48:37,270 --> 00:48:36,000
enough to sustain growth it's very clear

1258
00:48:38,870 --> 00:48:37,280
next slide please

1259
00:48:42,390 --> 00:48:38,880
and

1260
00:48:43,990 --> 00:48:42,400
well we we took a look at these things

1261
00:48:45,670 --> 00:48:44,000
and this is

1262
00:48:49,589 --> 00:48:45,680
phosphorus grown cells and they're nice

1263
00:48:51,910 --> 00:48:49,599

and happy and thin and fast and immortal

1264

00:48:53,430 --> 00:48:51,920

when you put them on arsenic they get

1265

00:48:55,190 --> 00:48:53,440

bloated

1266

00:48:56,309 --> 00:48:55,200

and they're the staining is a little bit

1267

00:48:57,910 --> 00:48:56,319

odd

1268

00:48:59,109 --> 00:48:57,920

but they're still modal

1269

00:49:01,030 --> 00:48:59,119

and they're still making copies of

1270

00:49:03,750 --> 00:49:01,040

themselves they're still growing rather

1271

00:49:05,109 --> 00:49:03,760

well and if you cut those these guys up

1272

00:49:07,190 --> 00:49:05,119

you there's vacuoles in there and

1273

00:49:09,270 --> 00:49:07,200

they're not in in the uh phosphate grown

1274

00:49:10,549 --> 00:49:09,280

ones so something is going on here

1275

00:49:12,069 --> 00:49:10,559

biologically

1276

00:49:14,309 --> 00:49:12,079

between these two conditions that we're

1277

00:49:18,230 --> 00:49:14,319

just seeing uh the beginning of next

1278

00:49:24,309 --> 00:49:21,910

this was icp work uh of uh the cells

1279

00:49:26,470 --> 00:49:24,319

uh done on phosphate grown cells and

1280

00:49:29,430 --> 00:49:26,480

arsenate grown cells and the take up

1281

00:49:30,790 --> 00:49:29,440

home story here it was done in asu is

1282

00:49:32,630 --> 00:49:30,800

that cells that were grown on our snake

1283

00:49:33,910 --> 00:49:32,640

have a lot of arsenic in them and cells

1284

00:49:35,829 --> 00:49:33,920

that were grown on phosphorus have a lot

1285

00:49:39,510 --> 00:49:35,839

of phosphorus on them now the paper has

1286

00:49:44,870 --> 00:49:42,710

this is where the criticism has been

1287

00:49:46,630 --> 00:49:44,880

hardest at this point is that what are

1288

00:49:48,069 --> 00:49:46,640

these numbers this little this is a

1289

00:49:48,870 --> 00:49:48,079

little bit sloppy

1290

00:49:52,950 --> 00:49:48,880

uh

1291

00:49:54,150 --> 00:49:52,960

well the cells

1292

00:49:55,670 --> 00:49:54,160

ain't as healthy when they're growing

1293

00:49:56,870 --> 00:49:55,680

they probably leak a bit when you sense

1294

00:49:59,109 --> 00:49:56,880

your fusion down and wash them in

1295

00:50:00,470 --> 00:49:59,119

centrifuge in washington uh

1296

00:50:02,309 --> 00:50:00,480

the numbers aren't precise they don't

1297

00:50:04,069 --> 00:50:02,319

quite work but if you do some rough

1298

00:50:05,990 --> 00:50:04,079

calculations and i say these are only

1299

00:50:07,670 --> 00:50:06,000

rough calculations

1300

00:50:09,349 --> 00:50:07,680

you can say there's not enough

1301

00:50:11,589 --> 00:50:09,359

phosphorus in the system to sustain it

1302

00:50:14,069 --> 00:50:11,599

you saw the growth they ain't not

1303

00:50:16,230 --> 00:50:14,079

but there's enough

1304

00:50:18,230 --> 00:50:16,240

arsenic there to to

1305

00:50:20,069 --> 00:50:18,240

keep them going so let's look at it a

1306

00:50:22,390 --> 00:50:20,079

little bit further

1307

00:50:24,710 --> 00:50:22,400

next slide please

1308

00:50:26,390 --> 00:50:24,720

so we did some radio label experiments

1309

00:50:29,510 --> 00:50:26,400

with radioactive arsenic and this was

1310

00:50:31,430 --> 00:50:29,520

where tom kulp uh helped us and this was

1311

00:50:33,109 --> 00:50:31,440

really a pain in the tucus

1312

00:50:35,510 --> 00:50:33,119

but

1313

00:50:37,190 --> 00:50:35,520

we eventually got them to take up the

1314

00:50:38,549 --> 00:50:37,200

radioactive arsenic

1315

00:50:43,829 --> 00:50:38,559

and

1316

00:50:47,109 --> 00:50:43,839

based on the extractions uh a lot of the

1317

00:50:48,870 --> 00:50:47,119

radioisotope was associated with

1318

00:50:50,549 --> 00:50:48,880

what we would normally

1319

00:50:52,790 --> 00:50:50,559

call the protein fraction the small

1320

00:50:55,510 --> 00:50:52,800

metabolite fractions like something like

1321

00:50:58,870 --> 00:50:55,520

uh acetyl-coa maybe

1322

00:50:59,750 --> 00:50:58,880

acetyl phosphate and things like that

1323

00:51:07,589 --> 00:50:59,760

and

1324

00:51:09,589 --> 00:51:07,599

now this doesn't really prove they're

1325

00:51:11,990 --> 00:51:09,599

there but it's consistent with the

1326

00:51:14,150 --> 00:51:12,000

labeling pattern and and there's

1327

00:51:15,430 --> 00:51:14,160

a bit of slough here but it's it's where

1328

00:51:17,589 --> 00:51:15,440

we would kind of expect these things to

1329

00:51:20,150 --> 00:51:17,599

be so next slide please that

1330

00:51:22,390 --> 00:51:20,160

prompted us to uh say we need some

1331

00:51:23,510 --> 00:51:22,400

better analysis we need to get in touch

1332

00:51:24,710 --> 00:51:23,520

with folks

1333

00:51:26,390 --> 00:51:24,720

uh

1334

00:51:27,910 --> 00:51:26,400

that could

1335

00:51:29,829 --> 00:51:27,920

make a more convincing evidence because

1336

00:51:32,870 --> 00:51:29,839

we're getting ourselves

1337

00:51:35,030 --> 00:51:32,880

out of the uh the doubting stage

1338

00:51:36,309 --> 00:51:35,040

and is this an artifact to do we really

1339

00:51:37,910 --> 00:51:36,319

have something we really might have

1340

00:51:39,990 --> 00:51:37,920

something and

1341

00:51:41,750 --> 00:51:40,000

we can't it can't it can't be

1342

00:51:44,150 --> 00:51:41,760

it really can't be

1343

00:51:46,710 --> 00:51:44,160

but it looks and then we she brought

1344

00:51:49,109 --> 00:51:46,720

cells over uh to slack stanford linear

1345

00:51:52,150 --> 00:51:49,119

accelerator the x-ray spectroscopy and

1346

00:51:53,670 --> 00:51:52,160

sam webb and

1347

00:51:56,870 --> 00:51:53,680

the results

1348

00:51:59,270 --> 00:51:56,880

sam jumped out of his out of his pants

1349

00:52:02,870 --> 00:51:59,280

and that was before we saw the results

1350

00:52:07,829 --> 00:52:05,510

it fits arsenic

1351
00:52:09,990 --> 00:52:07,839
in the dna helix with a little wiggle

1352
00:52:11,990 --> 00:52:10,000
room there for binding to uh various

1353
00:52:15,030 --> 00:52:12,000
amino acids

1354
00:52:17,030 --> 00:52:15,040
it's it's not arsenic iron arsenides

1355
00:52:19,670 --> 00:52:17,040
and it's not arsenic sulfides clearly

1356
00:52:20,549 --> 00:52:19,680
and it's as arsenic five it's consistent

1357
00:52:23,190 --> 00:52:20,559
with

1358
00:52:25,109 --> 00:52:23,200
arsenic being present in the dna

1359
00:52:27,589 --> 00:52:25,119
at that point we said

1360
00:52:30,069 --> 00:52:27,599
let's write a draft to science

1361
00:52:31,190 --> 00:52:30,079
and while that was going on

1362
00:52:35,750 --> 00:52:31,200
uh

1363
00:52:37,910 --> 00:52:35,760

pedridge came back to lawrence livermore

1364

00:52:39,349 --> 00:52:37,920

with her nano sims array

1365

00:52:41,510 --> 00:52:39,359

and

1366

00:52:43,030 --> 00:52:41,520

felicia brought out samples uh to

1367

00:52:46,790 --> 00:52:43,040

lawrence livermore

1368

00:52:48,630 --> 00:52:46,800

of extracted dna on gels from

1369

00:52:50,870 --> 00:52:48,640

arsenic grown cells and phosphorus grown

1370

00:52:52,950 --> 00:52:50,880

cells and a bunch of other cells uh and

1371

00:52:55,109 --> 00:52:52,960

they i don't have those slides but the

1372

00:52:56,950 --> 00:52:55,119

take home message is that dna from

1373

00:52:59,510 --> 00:52:56,960

arsenic ground cells

1374

00:53:01,589 --> 00:52:59,520

has arsenic and dna from phosphorus gone

1375

00:53:03,910 --> 00:53:01,599

cells has phosphorus

1376
00:53:05,589 --> 00:53:03,920
and at that point we said we've got

1377
00:53:07,510 --> 00:53:05,599
compelling evidence that

1378
00:53:08,790 --> 00:53:07,520
this is here now we we don't have

1379
00:53:11,030 --> 00:53:08,800
everything

1380
00:53:13,430 --> 00:53:11,040
we don't people where's the nmr of

1381
00:53:15,030 --> 00:53:13,440
crystallized proteins we

1382
00:53:16,950 --> 00:53:15,040
don't have that and that's going to take

1383
00:53:18,950 --> 00:53:16,960
years to get to

1384
00:53:20,309 --> 00:53:18,960
and we don't have an nmr we need to

1385
00:53:22,150 --> 00:53:20,319
collaborate with people who know how to

1386
00:53:24,630 --> 00:53:22,160
do this to make that a bit more

1387
00:53:26,630 --> 00:53:24,640
convincing what about the metabolites

1388
00:53:28,470 --> 00:53:26,640

the numbers don't quite jive and they

1389

00:53:30,069 --> 00:53:28,480

don't i'll be the first to admit it

1390

00:53:31,910 --> 00:53:30,079

they're rough they're back they're not

1391

00:53:34,069 --> 00:53:31,920

even back at the envelope calculations

1392

00:53:35,270 --> 00:53:34,079

they're inside the envelope calculations

1393

00:53:38,230 --> 00:53:35,280

uh that were

1394

00:53:40,470 --> 00:53:38,240

used in an argument to make us try these

1395

00:53:42,790 --> 00:53:40,480

analyses to convince us that this was

1396

00:53:44,870 --> 00:53:42,800

worth doing

1397

00:53:46,950 --> 00:53:44,880

and i think this is rather compelling

1398

00:53:47,990 --> 00:53:46,960

that we now have an example

1399

00:53:49,990 --> 00:53:48,000

of uh

1400

00:53:52,150 --> 00:53:50,000

arsenic-based life where it's

1401
00:53:54,870 --> 00:53:52,160
substituting for phosphorus and this is

1402
00:53:56,630 --> 00:53:54,880
strained gfaj

1403
00:53:59,109 --> 00:53:56,640
and

1404
00:54:02,069 --> 00:53:59,119
here was another surprise uh i don't

1405
00:54:05,990 --> 00:54:02,079
think next slide please

1406
00:54:08,390 --> 00:54:06,000
uh next slide i think it's a okay

1407
00:54:11,829 --> 00:54:08,400
it's a member of the hallomono desi asa

1408
00:54:14,230 --> 00:54:11,839
hello monas hello monas it's uh common

1409
00:54:15,510 --> 00:54:14,240
in its alien environments they're not an

1410
00:54:16,790 --> 00:54:15,520
unusual we thought we're gonna get the

1411
00:54:19,510 --> 00:54:16,800
green monster

1412
00:54:20,309 --> 00:54:19,520
you know take us to your leader uh we

1413
00:54:22,150 --> 00:54:20,319

get

1414

00:54:23,190 --> 00:54:22,160

a strain of halimonas

1415

00:54:24,470 --> 00:54:23,200

and

1416

00:54:27,270 --> 00:54:24,480

halamonis

1417

00:54:30,150 --> 00:54:27,280

helimon eye hello monae they are known

1418

00:54:31,910 --> 00:54:30,160

arsenic accumulators

1419

00:54:33,829 --> 00:54:31,920

but nobody's ever looked at arsenic

1420

00:54:36,470 --> 00:54:33,839

substituting for phosphorus before so

1421

00:54:39,270 --> 00:54:36,480

they're in a well-established genome uh

1422

00:54:42,549 --> 00:54:39,280

well-established genus uh

1423

00:54:43,670 --> 00:54:42,559

uh that lives in uh salient environments

1424

00:54:45,430 --> 00:54:43,680

and you know we were kind of

1425

00:54:46,630 --> 00:54:45,440

disappointed at that we were

1426

00:54:48,390 --> 00:54:46,640

if you

1427

00:54:50,069 --> 00:54:48,400

create such a challenge to isolate the

1428

00:54:51,750 --> 00:54:50,079

organism in the first place shouldn't

1429

00:54:53,190 --> 00:54:51,760

you get something really nutty that

1430

00:54:55,190 --> 00:54:53,200

nobody's ever seen before and it turns

1431

00:54:57,430 --> 00:54:55,200

out to be fairly common it's like the e

1432

00:54:58,630 --> 00:54:57,440

coli of saline environments what's the

1433

00:55:04,230 --> 00:54:58,640

big whoop

1434

00:55:06,870 --> 00:55:04,240

maybe this phenomena is more common

1435

00:55:10,150 --> 00:55:06,880

than just this microbe

1436

00:55:12,230 --> 00:55:10,160

it's just that nobody's tested it

1437

00:55:14,630 --> 00:55:12,240

there's bugs in culture but there's a

1438

00:55:17,190 --> 00:55:14,640

lot more guys out there that might be

1439

00:55:19,349 --> 00:55:17,200

able to do it including members that are

1440

00:55:22,470 --> 00:55:19,359

in culture collections uh

1441

00:55:23,910 --> 00:55:22,480

of established habimona desii

1442

00:55:25,829 --> 00:55:23,920

so that's worth looking at and there may

1443

00:55:27,990 --> 00:55:25,839

be others

1444

00:55:30,470 --> 00:55:28,000

the trouble of modern science in

1445

00:55:32,630 --> 00:55:30,480

microbiology now is if it ain't in the

1446

00:55:35,109 --> 00:55:32,640

books or if it's not annotated in the

1447

00:55:37,030 --> 00:55:35,119

computer so i can really do these omics

1448

00:55:39,270 --> 00:55:37,040

games

1449

00:55:40,950 --> 00:55:39,280

this this is stuff pasteur was doing

1450

00:55:42,950 --> 00:55:40,960

come on we're beyond that now that we've

1451

00:55:45,030 --> 00:55:42,960

got these beautiful in silico data sets

1452

00:55:46,710 --> 00:55:45,040

we can figure out everything

1453

00:55:48,630 --> 00:55:46,720

horse manure

1454

00:55:50,710 --> 00:55:48,640

you haven't challenged

1455

00:55:52,309 --> 00:55:50,720

and thought in a creative way

1456

00:55:54,630 --> 00:55:52,319

it might be there's more examples of

1457

00:55:57,030 --> 00:55:54,640

arsenic-based life there might be forms

1458

00:55:58,710 --> 00:55:57,040

of arsenic based life that are allergic

1459

00:55:59,990 --> 00:55:58,720

to phosphorus

1460

00:56:01,510 --> 00:56:00,000

now that would be really something we

1461

00:56:02,549 --> 00:56:01,520

don't have any evidence for that but

1462

00:56:04,390 --> 00:56:02,559

it's possible

1463

00:56:06,390 --> 00:56:04,400

and that extends

1464

00:56:08,390 --> 00:56:06,400

what we know about the biome

1465

00:56:10,390 --> 00:56:08,400

and the composition of life and it also

1466

00:56:13,190 --> 00:56:10,400

raises the possibility that maybe

1467

00:56:15,270 --> 00:56:13,200

selenium might be worth testing for some

1468

00:56:16,870 --> 00:56:15,280

bold person who wants to get away from

1469

00:56:18,549 --> 00:56:16,880

the omics world

1470

00:56:20,549 --> 00:56:18,559

and try and figure out everything what

1471

00:56:21,430 --> 00:56:20,559

everything's doing and start to think

1472

00:56:23,670 --> 00:56:21,440

about

1473

00:56:25,349 --> 00:56:23,680

basic microbiology and once you get

1474

00:56:27,109 --> 00:56:25,359

something as really interesting as this

1475

00:56:30,549 --> 00:56:27,119

you can do all the really fancy stuff on

1476

00:56:32,150 --> 00:56:30,559

it i think the next generation

1477

00:56:35,030 --> 00:56:32,160

of

1478

00:56:38,230 --> 00:56:35,040

microbiologists are losing this creative

1479

00:56:40,150 --> 00:56:38,240

ability to culture new microorganisms

1480

00:56:41,589 --> 00:56:40,160

for new processes

1481

00:56:43,430 --> 00:56:41,599

they're becoming obsessed with the

1482

00:56:44,710 --> 00:56:43,440

technology because their mentors are

1483

00:56:46,150 --> 00:56:44,720

obsessed with the technology and made

1484

00:56:48,069 --> 00:56:46,160

their reputations on it and they're

1485

00:56:50,230 --> 00:56:48,079

getting further and further away from

1486

00:56:51,750 --> 00:56:50,240

this and some of that's good

1487

00:56:52,630 --> 00:56:51,760

and important

1488

00:56:54,710 --> 00:56:52,640

but

1489

00:56:56,230 --> 00:56:54,720

some of the basics are being lost the

1490

00:56:58,549 --> 00:56:56,240

simple stuff nobody's going to know what

1491

00:57:00,069 --> 00:56:58,559

a petri dish is you know in isolation

1492

00:57:02,470 --> 00:57:00,079

nobody's gonna know what cereal dilution

1493

00:57:03,510 --> 00:57:02,480

is from a natural environment nobody's

1494

00:57:05,270 --> 00:57:03,520

gonna know how to challenge

1495

00:57:08,069 --> 00:57:05,280

microorganisms and figure out how to

1496

00:57:11,430 --> 00:57:08,079

make the guy grow as derek lovely says

1497

00:57:14,710 --> 00:57:12,870

well

1498

00:57:17,030 --> 00:57:14,720

what are the ramifications here i talked

1499

00:57:18,950 --> 00:57:17,040

about weird forms of life you've heard a

1500

00:57:21,190 --> 00:57:18,960

lot about this last week

1501
00:57:21,990 --> 00:57:21,200
nasa certainly made a big hoopla about

1502
00:57:23,990 --> 00:57:22,000
it

1503
00:57:27,750 --> 00:57:24,000
uh there's other things

1504
00:57:32,309 --> 00:57:30,630
there's organo arsenal compounds

1505
00:57:35,190 --> 00:57:32,319
we're out there

1506
00:57:37,670 --> 00:57:35,200
it's not just all inorganic story

1507
00:57:40,430 --> 00:57:37,680
uh one of the common ones is an analog

1508
00:57:43,349 --> 00:57:40,440
of glycine betaine

1509
00:57:44,630 --> 00:57:43,359
trimethylglycine this is common

1510
00:57:46,630 --> 00:57:44,640
in marine

1511
00:57:47,750 --> 00:57:46,640
organisms it's an osmo regulatory

1512
00:57:50,470 --> 00:57:47,760
compound

1513
00:57:52,470 --> 00:57:50,480

that microbes and saline environments

1514

00:57:54,710 --> 00:57:52,480

use to pump themselves up internally to

1515

00:57:56,230 --> 00:57:54,720

be isotonic with their

1516

00:57:57,510 --> 00:57:56,240

environment so they keep the salts out

1517

00:58:00,150 --> 00:57:57,520

and they keep this stuff in and when

1518

00:58:03,349 --> 00:58:01,670

this stuff breaks off and becomes

1519

00:58:05,109 --> 00:58:03,359

trimethylamine and can be made into

1520

00:58:06,950 --> 00:58:05,119

methane and co2 and give you terrible

1521

00:58:09,069 --> 00:58:06,960

odors dead fish

1522

00:58:10,950 --> 00:58:09,079

the same thing with sulfur dimethyl

1523

00:58:12,789 --> 00:58:10,960

sulfoniopropionate can everybody say

1524

00:58:14,950 --> 00:58:12,799

that thyme methyl so

1525

00:58:16,950 --> 00:58:14,960

same sort of thing

1526
00:58:18,150 --> 00:58:16,960
but arsenic can substitute for nitrogen

1527
00:58:20,870 --> 00:58:18,160
now

1528
00:58:23,190 --> 00:58:20,880
and form arsenal betaine

1529
00:58:25,190 --> 00:58:23,200
it's an amino acid derivative

1530
00:58:26,230 --> 00:58:25,200
it's glycine with three methyl groups on

1531
00:58:28,470 --> 00:58:26,240
it and now

1532
00:58:32,549 --> 00:58:28,480
an arsenic what the heck is this stuff

1533
00:58:34,309 --> 00:58:32,559
doing and why do critters like lobster

1534
00:58:37,190 --> 00:58:34,319
have really high concentrations of

1535
00:58:38,789 --> 00:58:37,200
arsenic in their tissues in this format

1536
00:58:40,150 --> 00:58:38,799
against the concentration gradient of

1537
00:58:42,309 --> 00:58:40,160
the ocean there's not that much arsenic

1538
00:58:43,670 --> 00:58:42,319

in the ocean it's not model egg

1539

00:58:44,710 --> 00:58:43,680

they're bringing arsenic into their

1540

00:58:47,589 --> 00:58:44,720

cells

1541

00:58:49,910 --> 00:58:47,599

and making this weird compound

1542

00:58:50,870 --> 00:58:49,920

is it substituting for nitrogen are they

1543

00:58:53,510 --> 00:58:50,880

making

1544

00:58:55,670 --> 00:58:53,520

arsenic-based amino acids

1545

00:58:58,309 --> 00:58:55,680

fruit and proteins

1546

00:58:59,510 --> 00:58:58,319

that's that's crazy

1547

00:59:01,510 --> 00:58:59,520

no it's not

1548

00:59:03,349 --> 00:59:01,520

because 20 years ago they said selena

1549

00:59:05,910 --> 00:59:03,359

methionine is crazy and now that's the

1550

00:59:07,670 --> 00:59:05,920

21st amino acid

1551

00:59:10,150 --> 00:59:07,680

so that i would admit is a little bit on

1552

00:59:12,309 --> 00:59:10,160

the edge but it could be

1553

00:59:13,430 --> 00:59:12,319

that it's a repository for animals and

1554

00:59:15,030 --> 00:59:13,440

plants

1555

00:59:16,950 --> 00:59:15,040

to store

1556

00:59:18,870 --> 00:59:16,960

arsenic when they're starved of

1557

00:59:21,270 --> 00:59:18,880

phosphorus

1558

00:59:23,829 --> 00:59:21,280

because this stuff is innocuous

1559

00:59:25,990 --> 00:59:23,839

even though lobsters have lots and lots

1560

00:59:28,150 --> 00:59:26,000

of arsenic in their tissue when we eat

1561

00:59:30,150 --> 00:59:28,160

it it goes down the toilet

1562

00:59:31,589 --> 00:59:30,160

and i keep on telling my wife that it's

1563

00:59:33,109 --> 00:59:31,599

very dangerous you shouldn't be ordering

1564

00:59:34,710 --> 00:59:33,119

these expensive lobster dishes every

1565

00:59:36,549 --> 00:59:34,720

time we go out to eat because you're

1566

00:59:38,870 --> 00:59:36,559

gonna and no it goes down the toilet you

1567

00:59:40,069 --> 00:59:38,880

said it in your lecture so uh but it's

1568

00:59:41,990 --> 00:59:40,079

innocuous

1569

00:59:43,430 --> 00:59:42,000

but maybe in times of phosphorus

1570

00:59:47,510 --> 00:59:43,440

limitation

1571

00:59:49,670 --> 00:59:47,520

various microbes and animals and algae

1572

00:59:51,589 --> 00:59:49,680

could do this swap

1573

00:59:52,470 --> 00:59:51,599

next slide please

1574

00:59:54,789 --> 00:59:52,480

the

1575

00:59:56,390 --> 00:59:54,799

next thing is medical

1576

01:00:00,950 --> 00:59:56,400

and i didn't really touch on this but

1577

01:00:02,470 --> 01:00:00,960

this is a separate topic entirely of

1578

01:00:04,710 --> 01:00:02,480

i told you that arsenic is a

1579

01:00:07,030 --> 01:00:04,720

well-established poison for homicidal

1580

01:00:09,270 --> 01:00:07,040

purposes and for a few dollars more i'll

1581

01:00:11,109 --> 01:00:09,280

tell you more after the lecture

1582

01:00:12,069 --> 01:00:11,119

uh in private

1583

01:00:15,109 --> 01:00:12,079

but

1584

01:00:17,349 --> 01:00:15,119

this is a tragedy on a massive scale

1585

01:00:19,190 --> 01:00:17,359

worldwide

1586

01:00:20,549 --> 01:00:19,200

naturally occurring arsenic in

1587

01:00:22,950 --> 01:00:20,559

groundwaters

1588

01:00:25,510 --> 01:00:22,960

especially in places in south asia like

1589

01:00:27,670 --> 01:00:25,520

bangladesh and and west bengal india and

1590

01:00:28,870 --> 01:00:27,680

now it's being manifested and seen in

1591

01:00:31,270 --> 01:00:28,880

cambodia

1592

01:00:32,710 --> 01:00:31,280

and uh vietnam and

1593

01:00:34,470 --> 01:00:32,720

it's very common it's even common in the

1594

01:00:36,789 --> 01:00:34,480

united states but we can purify the

1595

01:00:39,670 --> 01:00:36,799

arsenic out of our waters while many of

1596

01:00:41,829 --> 01:00:39,680

these cultures can't

1597

01:00:43,430 --> 01:00:41,839

a condition known as arsenosis arises

1598

01:00:44,789 --> 01:00:43,440

from drinking water that has too much

1599

01:00:46,309 --> 01:00:44,799

arsenic in it

1600

01:00:48,470 --> 01:00:46,319

the arsenic

1601
01:00:51,030 --> 01:00:48,480
has to move out of your body and it's

1602
01:00:52,630 --> 01:00:51,040
the forms of methylated arsenic that

1603
01:00:54,870 --> 01:00:52,640
the body

1604
01:00:57,109 --> 01:00:54,880
metabolizes are nasty corrosive

1605
01:00:59,270 --> 01:00:57,119
chemicals and eventually people die and

1606
01:01:00,950 --> 01:00:59,280
have cancers and and these terrible

1607
01:01:02,870 --> 01:01:00,960
terrible lesions it's not a fun thing

1608
01:01:04,549 --> 01:01:02,880
it's a terrible terrible tragedy on a

1609
01:01:05,510 --> 01:01:04,559
massive scale something like 50 million

1610
01:01:08,069 --> 01:01:05,520
people

1611
01:01:09,750 --> 01:01:08,079
in just in south asia alone

1612
01:01:12,069 --> 01:01:09,760
are drinking water like this and the

1613
01:01:13,030 --> 01:01:12,079

incidence of arsenic psychosis is very

1614

01:01:14,309 --> 01:01:13,040

high

1615

01:01:18,390 --> 01:01:14,319

but

1616

01:01:21,589 --> 01:01:20,150

chairman mao

1617

01:01:23,109 --> 01:01:21,599

during his

1618

01:01:24,549 --> 01:01:23,119

reign

1619

01:01:26,069 --> 01:01:24,559

uh uh

1620

01:01:30,309 --> 01:01:26,079

terror

1621

01:01:34,870 --> 01:01:32,230

he had great affection for the peasants

1622

01:01:37,190 --> 01:01:34,880

because the peasants hid the red army

1623

01:01:38,470 --> 01:01:37,200

uh during the revolution and during uh

1624

01:01:39,750 --> 01:01:38,480

world war ii

1625

01:01:41,270 --> 01:01:39,760

and

1626

01:01:44,630 --> 01:01:41,280

in his life among them

1627

01:01:46,069 --> 01:01:44,640

he thought they actually had some

1628

01:01:48,230 --> 01:01:46,079

important things to bring to the

1629

01:01:49,510 --> 01:01:48,240

forefront of society and and since he

1630

01:01:52,870 --> 01:01:49,520

was a tyrant

1631

01:01:54,390 --> 01:01:52,880

he took the intelligentsia

1632

01:01:56,470 --> 01:01:54,400

living in the cities like beijing and

1633

01:01:58,870 --> 01:01:56,480

said you're going out into the fields

1634

01:02:00,309 --> 01:01:58,880

for the next 10 15 years to learn from

1635

01:02:01,510 --> 01:02:00,319

the peasants

1636

01:02:03,990 --> 01:02:01,520

i don't care if you're a doctor lawyer

1637

01:02:05,670 --> 01:02:04,000

indian chief awad you're going out there

1638

01:02:07,349 --> 01:02:05,680

and those that

1639

01:02:08,950 --> 01:02:07,359

did not die

1640

01:02:10,630 --> 01:02:08,960

uh learned a few things and one of the

1641

01:02:12,630 --> 01:02:10,640

few things they learned

1642

01:02:14,309 --> 01:02:12,640

was there was a peasant cure for uh i

1643

01:02:16,470 --> 01:02:14,319

believe it was cancers it was a

1644

01:02:19,510 --> 01:02:16,480

concoction

1645

01:02:21,510 --> 01:02:19,520

of mercury salts and arsenic

1646

01:02:23,109 --> 01:02:21,520

that seemed to have some effect

1647

01:02:24,710 --> 01:02:23,119

a beneficial effect on the patients that

1648

01:02:25,990 --> 01:02:24,720

didn't outright die from exposure to

1649

01:02:27,910 --> 01:02:26,000

these things

1650

01:02:31,430 --> 01:02:27,920

uh

1651

01:02:34,150 --> 01:02:31,440

when mao exited the scene and

1652

01:02:35,589 --> 01:02:34,160

china became more rational

1653

01:02:37,029 --> 01:02:35,599

they started looking into this in a more

1654

01:02:38,470 --> 01:02:37,039

reasonable way

1655

01:02:41,510 --> 01:02:38,480

and they were able to say it's not the

1656

01:02:43,910 --> 01:02:41,520

mercury it's the arsenic is doing it has

1657

01:02:45,589 --> 01:02:43,920

some sort of anti-cancer properties

1658

01:02:46,710 --> 01:02:45,599

and they started working with western

1659

01:02:49,430 --> 01:02:46,720

science

1660

01:02:51,670 --> 01:02:49,440

western medicine and now

1661

01:02:53,589 --> 01:02:51,680

arsenic is used as a treatment a

1662

01:02:55,829 --> 01:02:53,599

chemotherapeutic treatment for certain

1663

01:02:57,750 --> 01:02:55,839

types of neoplasias cancers

1664

01:03:00,549 --> 01:02:57,760

tumors early stages

1665

01:03:03,589 --> 01:03:00,559

with some effectiveness

1666

01:03:05,910 --> 01:03:03,599

but this is an empirical

1667

01:03:07,670 --> 01:03:05,920

basis i mean medicine just sort of goes

1668

01:03:09,349 --> 01:03:07,680

by trial it's hard to

1669

01:03:11,670 --> 01:03:09,359

uh understand the mechanism and if you

1670

01:03:13,190 --> 01:03:11,680

go back to the mechanism well it must be

1671

01:03:15,589 --> 01:03:13,200

acting as an analog

1672

01:03:17,589 --> 01:03:15,599

of oxidative phosphorylation that's what

1673

01:03:20,710 --> 01:03:17,599

the textbook says

1674

01:03:24,309 --> 01:03:22,630

that in

1675

01:03:26,710 --> 01:03:24,319

fast-growing cells that are growing out

1676
01:03:28,230 --> 01:03:26,720
of control in the human body or animal

1677
01:03:31,190 --> 01:03:28,240
bodies

1678
01:03:33,750 --> 01:03:31,200
they may need every molecule of

1679
01:03:37,349 --> 01:03:33,760
phosphorus they can get hold on hold of

1680
01:03:38,710 --> 01:03:37,359
and if you administer to them arsenic

1681
01:03:40,710 --> 01:03:38,720
they'll see the arsenic instead and

1682
01:03:43,109 --> 01:03:40,720
screw up their dna whether it's in the

1683
01:03:45,750 --> 01:03:43,119
nucleus or their uh mitochondria or

1684
01:03:47,829 --> 01:03:45,760
whatever but it doesn't work as well

1685
01:03:50,150 --> 01:03:47,839
and things go haywire in the haywire

1686
01:03:51,430 --> 01:03:50,160
cells and it might be that

1687
01:03:53,510 --> 01:03:51,440
the normal

1688
01:03:55,510 --> 01:03:53,520

immune systems reabsorb the cancer and

1689

01:03:57,750 --> 01:03:55,520

the patient goes into remission i'm just

1690

01:04:00,870 --> 01:03:57,760

making this as a speculation but i think

1691

01:04:03,430 --> 01:04:00,880

there may be medical ramifications uh to

1692

01:04:06,150 --> 01:04:03,440

this finding uh if it's fully accepted

1693

01:04:07,829 --> 01:04:06,160

and reproduced by our colleagues out

1694

01:04:09,510 --> 01:04:07,839

out in the world there and i encourage

1695

01:04:11,510 --> 01:04:09,520

everybody to do that

1696

01:04:13,190 --> 01:04:11,520

so next slide please so we're getting to

1697

01:04:15,029 --> 01:04:13,200

the end here

1698

01:04:17,190 --> 01:04:15,039

this is my final bow i'm actually trying

1699

01:04:20,870 --> 01:04:17,200

to yank a core a couple years ago from

1700

01:04:26,150 --> 01:04:23,109

folks on my project over the years and

1701

01:04:27,589 --> 01:04:26,160

many years larry miller shelly hoff jody

1702

01:04:32,230 --> 01:04:27,599

switzer-blum

1703

01:04:34,470 --> 01:04:32,240

sean baseman tom kulp phyllis wolf simon

1704

01:04:37,750 --> 01:04:34,480

chuck culbertson and mike rosen at the

1705

01:04:39,670 --> 01:04:37,760

district office in carson city

1706

01:04:40,470 --> 01:04:39,680

we've had a lot of interaction

1707

01:04:43,109 --> 01:04:40,480

with

1708

01:04:45,190 --> 01:04:43,119

colleagues in academia

1709

01:04:48,150 --> 01:04:45,200

most notably john stahls john stahls is

1710

01:04:50,470 --> 01:04:48,160

also funded on the same proposal i am

1711

01:04:52,950 --> 01:04:50,480

with nasa exobiology and has been so for

1712

01:04:55,589 --> 01:04:52,960

a long time

1713

01:04:58,549 --> 01:04:55,599

chad soltikov just over the hill uh and

1714

01:05:00,950 --> 01:04:58,559

uc santa cruz uh

1715

01:05:03,829 --> 01:05:00,960

and his his students and and postdocs

1716

01:05:06,470 --> 01:05:03,839

well students brian lenoil uh sookie and

1717

01:05:09,109 --> 01:05:06,480

hans tim hollibaugh jen fisher mike

1718

01:05:12,789 --> 01:05:09,119

madigan and and the list goes on

1719

01:05:14,710 --> 01:05:12,799

uh of course the usgs that uh uh pays my

1720

01:05:15,430 --> 01:05:14,720

salary and the salary of these people

1721

01:05:16,230 --> 01:05:15,440

and

1722

01:05:17,349 --> 01:05:16,240

uh

1723

01:05:19,190 --> 01:05:17,359

nasa

1724

01:05:21,029 --> 01:05:19,200

exobiology that gives us the extra

1725

01:05:23,430 --> 01:05:21,039

amount of money to

1726
01:05:25,270 --> 01:05:23,440
sustain curiosity-driven research along

1727
01:05:26,230 --> 01:05:25,280
these lines and

1728
01:05:28,950 --> 01:05:26,240
nasa

1729
01:05:31,990 --> 01:05:28,960
astrobiology

1730
01:05:33,670 --> 01:05:32,000
which in its various manifestations

1731
01:05:34,950 --> 01:05:33,680
keeps felicia

1732
01:05:37,109 --> 01:05:34,960
on a

1733
01:05:40,309 --> 01:05:37,119
marginal salary compared to the usgs

1734
01:05:41,349 --> 01:05:40,319
postdocs uh next slide please

1735
01:05:44,630 --> 01:05:41,359
so

1736
01:05:46,630 --> 01:05:44,640
i heard and met

1737
01:05:48,870 --> 01:05:46,640
folks from the carnegie institution that

1738
01:05:50,789 --> 01:05:48,880

came all the way down

1739

01:05:52,549 --> 01:05:50,799

from new york's west side

1740

01:05:54,789 --> 01:05:52,559

uh to be here they're in the front row

1741

01:05:55,589 --> 01:05:54,799

here i didn't smell any uh uh corned

1742

01:05:58,309 --> 01:05:55,599

beef

1743

01:06:01,270 --> 01:05:58,319

uh but uh i heard

1744

01:06:05,190 --> 01:06:01,280

uh that uh mike new is gonna

1745

01:06:06,870 --> 01:06:05,200

fry up some latkes and uh

1746

01:06:08,309 --> 01:06:06,880

matt kane brought some brisket and we're

1747

01:06:10,950 --> 01:06:08,319

going to celebrate hanukkah the writers

1748

01:06:13,270 --> 01:06:10,960

after this is over but the carnegie is

1749

01:06:15,510 --> 01:06:13,280

really an institution

1750

01:06:18,390 --> 01:06:15,520

i mean you speak carnegie

1751

01:06:20,069 --> 01:06:18,400

and this is where uh andrew got started

1752

01:06:20,950 --> 01:06:20,079

he was behind the counter slicing corned

1753

01:06:22,870 --> 01:06:20,960

beef

1754

01:06:24,870 --> 01:06:22,880

uh and this is where the fa they really

1755

01:06:26,549 --> 01:06:24,880

was karnawaski was the that was the name

1756

01:06:28,069 --> 01:06:26,559

and it got changed they branched out

1757

01:06:29,670 --> 01:06:28,079

into steel and stuff but this is what

1758

01:06:33,990 --> 01:06:29,680

funds you guys

1759

01:06:38,549 --> 01:06:35,829

that that is very important and that

1760

01:06:40,630 --> 01:06:38,559

keeps us fed and going uh that is very

1761

01:06:42,710 --> 01:06:40,640

much unappreciated i think in a modern

1762

01:06:45,430 --> 01:06:42,720

world in fact it's an institution

1763

01:06:48,230 --> 01:06:45,440

because if you ever saw the movie uh

1764

01:06:50,309 --> 01:06:48,240

broadway danny rose with woody allen uh

1765

01:06:52,390 --> 01:06:50,319

all the comedians

1766

01:06:53,910 --> 01:06:52,400

after their they do their shtick are

1767

01:06:55,750 --> 01:06:53,920

always depicted

1768

01:06:57,270 --> 01:06:55,760

uh in in the carnegie they're always

1769

01:06:58,950 --> 01:06:57,280

talking back there and this is where i

1770

01:07:00,710 --> 01:06:58,960

get to talk like jackie mason because he

1771

01:07:01,990 --> 01:07:00,720

was probably one of the people back

1772

01:07:03,190 --> 01:07:02,000

there he didn't like the sandwich the

1773

01:07:04,630 --> 01:07:03,200

portions used to be like this i don't

1774

01:07:06,710 --> 01:07:04,640

know what happened what's the matter

1775

01:07:08,309 --> 01:07:06,720

with this place anyway i think that's

1776

01:07:09,589 --> 01:07:08,319

all i have next slide is there anything

1777

01:07:13,990 --> 01:07:09,599

else

1778

01:07:16,710 --> 01:07:15,349

these are the people that really make it

1779

01:07:18,470 --> 01:07:16,720

go

1780

01:07:19,510 --> 01:07:18,480

the ones that should be getting all the

1781

01:07:20,870 --> 01:07:19,520

credit

1782

01:07:23,750 --> 01:07:20,880

and here it comes

1783

01:07:25,750 --> 01:07:23,760

rolling these are the true stars

1784

01:07:27,990 --> 01:07:25,760

and this is the biofilm

1785

01:07:28,710 --> 01:07:28,000

uh from that red biofilm that i showed

1786

01:07:33,670 --> 01:07:28,720

you

1787

01:07:35,349 --> 01:07:33,680

they're really fun to look at and

1788

01:07:37,270 --> 01:07:35,359

they're incredibly diverse you're seeing

1789

01:07:39,109 --> 01:07:37,280

all kinds of different things there

1790

01:07:42,309 --> 01:07:39,119

and

1791

01:07:45,349 --> 01:07:42,319

you lose the wonder

1792

01:07:46,870 --> 01:07:45,359

of these phenomena if you don't get more

1793

01:07:48,950 --> 01:07:46,880

intimately associated with these

1794

01:07:49,990 --> 01:07:48,960

microbes if you're just extracting the

1795

01:07:52,789 --> 01:07:50,000

dna

1796

01:07:54,069 --> 01:07:52,799

and doing meta genomics and proteomics

1797

01:07:56,069 --> 01:07:54,079

and

1798

01:07:57,670 --> 01:07:56,079

you become detached look at these guys

1799

01:07:59,750 --> 01:07:57,680

look at how diverse they are some are

1800

01:08:01,190 --> 01:07:59,760

mobile some are going like rockets

1801
01:08:02,950 --> 01:08:01,200
they're all different shapes and sizes

1802
01:08:05,589 --> 01:08:02,960
and yet even that primitive

1803
01:08:10,630 --> 01:08:07,589
analyses we had said well they're mostly

1804
01:08:12,870 --> 01:08:10,640
ectothyroid aspara and a few archaea

1805
01:08:15,349 --> 01:08:12,880
okay let's move on no the what your eyes

1806
01:08:17,110 --> 01:08:15,359
tell you something very different

1807
01:08:18,550 --> 01:08:17,120
so this is a fascinating place don't

1808
01:08:20,309 --> 01:08:18,560
lose the wonder

1809
01:08:22,630 --> 01:08:20,319
of a little kid looking under the

1810
01:08:24,470 --> 01:08:22,640
doctor's microscope it's always exciting

1811
01:08:26,470 --> 01:08:24,480
let's get back to some of the basics and

1812
01:08:28,229 --> 01:08:26,480
embellish it with the new stuff

1813
01:08:30,149 --> 01:08:28,239

so i thank you

1814

01:08:45,669 --> 01:08:30,159

and

1815

01:08:50,870 --> 01:08:48,309

so ron when you

1816

01:08:55,269 --> 01:08:50,880

extract dna from

1817

01:09:00,070 --> 01:08:57,430

i'm talking now about the ones

1818

01:09:03,990 --> 01:09:01,829

you're

1819

01:09:06,630 --> 01:09:04,000

detecting

1820

01:09:09,030 --> 01:09:06,640

arsenic in dna

1821

01:09:12,229 --> 01:09:09,040

when you extract dna from them

1822

01:09:13,669 --> 01:09:12,239

you also still detect some phosphorus

1823

01:09:16,309 --> 01:09:13,679

correct

1824

01:09:18,630 --> 01:09:16,319

so you can quantify dna

1825

01:09:20,550 --> 01:09:18,640

and you can quantify phosphorus

1826

01:09:23,110 --> 01:09:20,560

so you should be able to do for example

1827

01:09:25,269 --> 01:09:23,120

a simple back of the hand calculation of

1828

01:09:28,070 --> 01:09:25,279

how much phosphorus you would expect to

1829

01:09:30,630 --> 01:09:28,080

find in that much dna

1830

01:09:31,749 --> 01:09:30,640

and so if arsenic is replacing the

1831

01:09:36,149 --> 01:09:31,759

phosphorus

1832

01:09:38,470 --> 01:09:36,159

to be low right

1833

01:09:40,229 --> 01:09:38,480

so what do you get we get a low number i

1834

01:09:42,789 --> 01:09:40,239

can't give it to you off the top of my

1835

01:09:45,110 --> 01:09:42,799

head it conforms with that

1836

01:09:48,870 --> 01:09:45,120

notion but it's not perfect it's there's

1837

01:09:52,070 --> 01:09:48,880

this slush in that number the rastering

1838

01:09:53,430 --> 01:09:52,080

process as i understand it of nano sims

1839

01:09:55,430 --> 01:09:53,440

doesn't give you

1840

01:09:57,270 --> 01:09:55,440

precise numbers it says there's a lot of

1841

01:09:58,630 --> 01:09:57,280

arsenic in this spot

1842

01:09:59,590 --> 01:09:58,640

there's a little less in this spot

1843

01:10:01,030 --> 01:09:59,600

there's a little more in this spot

1844

01:10:02,149 --> 01:10:01,040

there's a little bit of phosphorus there

1845

01:10:04,310 --> 01:10:02,159

there's a little bit more phosphorus

1846

01:10:06,310 --> 01:10:04,320

it's not a precise thing we should it

1847

01:10:08,390 --> 01:10:06,320

they did the same thing for uh vicki

1848

01:10:11,430 --> 01:10:08,400

orphan's work on on aerobic methane

1849

01:10:12,709 --> 01:10:11,440

oxidation for stable carbon uh

1850

01:10:14,709 --> 01:10:12,719

isotopes

1851

01:10:16,630 --> 01:10:14,719

this is minus sixty this is minus eighty

1852

01:10:19,030 --> 01:10:16,640

this is minus seven but it showed the

1853

01:10:20,149 --> 01:10:19,040

point and here we're just trying to do a

1854

01:10:22,390 --> 01:10:20,159

crude

1855

01:10:24,630 --> 01:10:22,400

point there's arsenic a lot of arsenic

1856

01:10:26,070 --> 01:10:24,640

in the dna not very much phosphorus and

1857

01:10:28,630 --> 01:10:26,080

that's really all we can say that's the

1858

01:10:31,669 --> 01:10:28,640

limitation well so you know there's a

1859

01:10:34,070 --> 01:10:31,679

arsenic associated with the dna but

1860

01:10:35,270 --> 01:10:34,080

actually showing it's in the dna

1861

01:10:37,590 --> 01:10:35,280

you know

1862

01:10:39,590 --> 01:10:37,600

is is

1863

01:10:41,510 --> 01:10:39,600

perhaps a little more complicated and so

1864

01:10:42,390 --> 01:10:41,520

that's what i'm trying to get at is

1865

01:10:44,390 --> 01:10:42,400

you know

1866

01:10:45,510 --> 01:10:44,400

do you have any idea for example what

1867

01:10:47,430 --> 01:10:45,520

percent

1868

01:10:49,910 --> 01:10:47,440

of the phosphorus molecules have been

1869

01:10:51,750 --> 01:10:49,920

replaced by arsenic in arsenal i can't

1870

01:10:53,669 --> 01:10:51,760

give you a number on that but i think

1871

01:10:54,790 --> 01:10:53,679

it's a very high number

1872

01:10:56,550 --> 01:10:54,800

a very high number because they don't

1873

01:10:57,990 --> 01:10:56,560

grow in phosphorus i mean they don't

1874

01:11:00,070 --> 01:10:58,000

grow in the absence of phosphorus and

1875

01:11:01,910 --> 01:11:00,080

there's not enough trace phosphorus

1876

01:11:04,390 --> 01:11:01,920

in the in the contaminants to sustain

1877

01:11:07,590 --> 01:11:04,400

this right so i think if you look

1878

01:11:10,950 --> 01:11:07,600

qualitatively at our data right it's

1879

01:11:13,750 --> 01:11:10,960

compelling if you want precise numbers

1880

01:11:15,830 --> 01:11:13,760

that say how much arsenic is in the dna

1881

01:11:17,910 --> 01:11:15,840

how much phosphorus is there

1882

01:11:19,590 --> 01:11:17,920

that's work that should be done down the

1883

01:11:22,070 --> 01:11:19,600

line that has to be done

1884

01:11:24,070 --> 01:11:22,080

but we cannot and people are asking and

1885

01:11:26,950 --> 01:11:24,080

really really looking at our data set

1886

01:11:29,030 --> 01:11:26,960

very closely uh we're getting

1887

01:11:30,950 --> 01:11:29,040

uh

1888

01:11:31,990 --> 01:11:30,960

we're trying to build

1889

01:11:33,669 --> 01:11:32,000

uh

1890

01:11:34,950 --> 01:11:33,679

a good argument and there's more that

1891

01:11:36,550 --> 01:11:34,960

needs to be done but people are throwing

1892

01:11:38,709 --> 01:11:36,560

stones at us and as soon as they throw

1893

01:11:41,030 --> 01:11:38,719

enough stones we're gonna build a decent

1894

01:11:43,350 --> 01:11:41,040

argument uh no seriously this is work

1895

01:11:45,350 --> 01:11:43,360

for the future we cannot answer

1896

01:11:47,750 --> 01:11:45,360

all these questions with the

1897

01:11:50,310 --> 01:11:47,760

uh precision that uh the critics are

1898

01:11:51,270 --> 01:11:50,320

saying now i will admit to that

1899

01:11:53,350 --> 01:11:51,280

easily

1900

01:11:55,830 --> 01:11:53,360

but i think it's it's compelling that

1901

01:11:57,910 --> 01:11:55,840

felicia has shown

1902

01:12:00,870 --> 01:11:57,920

there's arsenic in the dna and it looks

1903

01:12:02,470 --> 01:12:00,880

like a lot and they don't grow

1904

01:12:04,550 --> 01:12:02,480

with the amount of phosphorus that's

1905

01:12:05,990 --> 01:12:04,560

there so something very strange is going

1906

01:12:07,830 --> 01:12:06,000

on with arsenic

1907

01:12:10,470 --> 01:12:07,840

and we need to examine the dna more

1908

01:12:13,110 --> 01:12:10,480

closely of our synchron cells uh we need

1909

01:12:15,270 --> 01:12:13,120

to do endonucleases we need to do fancy

1910

01:12:16,550 --> 01:12:15,280

schmancy things and make a more

1911

01:12:17,910 --> 01:12:16,560

compelling evidence but these were the

1912

01:12:19,350 --> 01:12:17,920

tools we had

1913

01:12:21,590 --> 01:12:19,360

we had something

1914

01:12:23,910 --> 01:12:21,600

when it popped out of the test tube and

1915

01:12:26,630 --> 01:12:23,920

so i'm here and it's arsenic so what can

1916

01:12:27,590 --> 01:12:26,640

we do to convince ourselves besides the

1917

01:12:29,750 --> 01:12:27,600

growth

1918

01:12:31,350 --> 01:12:29,760

and besides some crude calculations

1919

01:12:35,110 --> 01:12:31,360

these three analyses

1920

01:12:38,149 --> 01:12:35,120

the radioisotopes the icp ms i mean the

1921

01:12:39,830 --> 01:12:38,159

uh uh the nanoscience and uh the xf

1922

01:12:41,990 --> 01:12:39,840

zanes we thought it was enough three

1923

01:12:43,910 --> 01:12:42,000

different techniques gave us arsenic and

1924

01:12:46,470 --> 01:12:43,920

dna of our synchron cells phosphorus and

1925

01:12:50,790 --> 01:12:46,480

phosphorus crown cells it's known that's

1926

01:12:56,229 --> 01:12:53,430

uh other cells are austenotrophic

1927

01:13:00,229 --> 01:12:58,149

you saw the definitions

1928

01:13:02,229 --> 01:13:00,239

uh these arsenic resistance what i'm

1929

01:13:04,630 --> 01:13:02,239

calling arsenic trophy are

1930

01:13:08,070 --> 01:13:04,640

microbes that make energy from arsenic

1931

01:13:09,990 --> 01:13:08,080

by oxidation or respiration these don't

1932

01:13:12,550 --> 01:13:10,000

but that doesn't mean

1933

01:13:14,390 --> 01:13:12,560

others don't do both

1934

01:13:16,630 --> 01:13:14,400

and we are looking towards that and we

1935

01:13:18,709 --> 01:13:16,640

have some candidates

1936

01:13:20,070 --> 01:13:18,719

in culture that are

1937

01:13:21,910 --> 01:13:20,080

anaerobes

1938

01:13:25,750 --> 01:13:21,920

that i can't talk more about right now

1939

01:13:31,430 --> 01:13:27,750

a good question

1940

01:13:35,830 --> 01:13:32,470

the audience

1941

01:13:37,430 --> 01:13:35,840

uh the peanut gallery uh in tv land

1942

01:13:39,030 --> 01:13:37,440

to

1943

01:13:41,110 --> 01:13:39,040

do these experiments on your own you can

1944

01:13:43,030 --> 01:13:41,120

do this in in your own lab

1945

01:13:45,189 --> 01:13:43,040

uh i don't think it's confined to mono

1946

01:13:47,350 --> 01:13:45,199

lake or an arsenic-rich environment i

1947

01:13:49,590 --> 01:13:47,360

think it's a common phenomena and people

1948

01:13:51,590 --> 01:13:49,600

are going to ha if this is true and i

1949

01:13:54,390 --> 01:13:51,600

believe we have compelling evidence but

1950

01:13:58,070 --> 01:13:54,400

others have to test it independently and

1951

01:14:02,390 --> 01:14:00,149

that i think it's going to happen it's

1952

01:14:03,590 --> 01:14:02,400

the way science works you

1953

01:14:05,350 --> 01:14:03,600

there's a community that says this is

1954

01:14:07,350 --> 01:14:05,360

great let's get it published

1955

01:14:08,790 --> 01:14:07,360

uh then the people who did the work

1956

01:14:11,669 --> 01:14:08,800

uh get the rocks thrown at them and

1957

01:14:13,350 --> 01:14:11,679

sometimes the rocks are very very nasty

1958

01:14:15,110 --> 01:14:13,360

einstein went through some terrible

1959

01:14:17,270 --> 01:14:15,120

stuff on a more personal level stan

1960

01:14:19,590 --> 01:14:17,280

proustner with prions

1961

01:14:22,070 --> 01:14:19,600

came up with this idea and he suffered

1962

01:14:23,830 --> 01:14:22,080

immensely i actually know him and he

1963

01:14:25,590 --> 01:14:23,840

said it forced him to elevate his his

1964

01:14:27,030 --> 01:14:25,600

work

1965

01:14:28,070 --> 01:14:27,040

to the point that everybody accepted it

1966

01:14:30,390 --> 01:14:28,080

and now everybody's jumped on the

1967

01:14:32,310 --> 01:14:30,400

pre-owned story i see dozens and dozens

1968

01:14:33,990 --> 01:14:32,320

of papers every month i'm pre-owned this

1969

01:14:35,030 --> 01:14:34,000

behind that it's in nature it's science

1970

01:14:39,030 --> 01:14:35,040

and he's not one of the authors he did

1971

01:14:39,040 --> 01:14:41,590

i hope

1972

01:14:45,990 --> 01:14:43,590

i was noticing in some of your early

1973

01:14:49,270 --> 01:14:46,000

slides you did a lot of kilt controls

1974

01:14:50,630 --> 01:14:49,280

did you consider doing kilt controls to

1975

01:14:52,630 --> 01:14:50,640

control for

1976

01:14:55,510 --> 01:14:52,640

non-specific binding during extractions

1977

01:14:57,350 --> 01:14:55,520

for your icbms work for instance

1978

01:14:59,189 --> 01:14:57,360

things like that i think uh killed

1979

01:15:02,229 --> 01:14:59,199

control in in this situation i think

1980

01:15:03,590 --> 01:15:02,239

felicia did some of those uh but

1981

01:15:05,910 --> 01:15:03,600

if you do

1982

01:15:07,510 --> 01:15:05,920

if how do you kill your control for icp

1983

01:15:08,550 --> 01:15:07,520

ms are you killing the just blown

1984

01:15:09,510 --> 01:15:08,560

everything apart what do you what are

1985

01:15:11,430 --> 01:15:09,520

you gonna do

1986

01:15:14,229 --> 01:15:11,440

i don't understand just take your your

1987

01:15:16,550 --> 01:15:14,239

normal bug without arsenic enrichment or

1988

01:15:18,229 --> 01:15:16,560

phosphate in richmond kill it put it

1989

01:15:21,110 --> 01:15:18,239

into the media and then extract from

1990

01:15:23,030 --> 01:15:21,120

that i think she did that uh i know she

1991

01:15:25,590 --> 01:15:23,040

did it for arsenic and phosphorus i'm

1992

01:15:26,630 --> 01:15:25,600

not sure she did it in that condition

1993

01:15:28,950 --> 01:15:26,640

but

1994

01:15:30,310 --> 01:15:28,960

where's my brisket

1995

01:15:32,470 --> 01:15:30,320

you look you look like you eat your

1996

01:15:34,310 --> 01:15:32,480

pastrami on white bread with

1997

01:15:38,550 --> 01:15:34,320

with mayonnaise and tomatoes get out of

1998

01:15:42,070 --> 01:15:40,950

no it's a decent question i didn't mean

1999

01:15:44,470 --> 01:15:42,080

to

2000

01:15:46,470 --> 01:15:44,480

actually have two questions um

2001

01:15:48,790 --> 01:15:46,480

what is the composition of the vacuoles

2002

01:15:50,070 --> 01:15:48,800

that you find in the cells that you've

2003

01:15:51,430 --> 01:15:50,080

enriched for

2004

01:15:53,990 --> 01:15:51,440

the arsenate

2005

01:15:58,070 --> 01:15:54,000

we don't know

2006

01:15:59,270 --> 01:15:58,080

could be polyhydroxybutyrate could be

2007

01:16:01,669 --> 01:15:59,280

something else we haven't done those

2008

01:16:03,830 --> 01:16:01,679

analyses we know they're there

2009

01:16:05,910 --> 01:16:03,840

but we don't know what they're made of

2010

01:16:07,910 --> 01:16:05,920

okay and how that is related to arsenic

2011

01:16:09,510 --> 01:16:07,920

we don't know but it might be different

2012

01:16:11,910 --> 01:16:09,520

polarity solvents who the hell knows

2013

01:16:15,110 --> 01:16:11,920

that stabilizes the arsenic and you know

2014

01:16:16,630 --> 01:16:15,120

those are things the decades of work

2015

01:16:19,510 --> 01:16:16,640

good good point though

2016

01:16:21,990 --> 01:16:19,520

um my my second question was that um

2017

01:16:24,630 --> 01:16:22,000

the arsenal life

2018

01:16:26,390 --> 01:16:24,640

and it is certainly testable

2019

01:16:28,470 --> 01:16:26,400

the average composition of organic

2020

01:16:29,830 --> 01:16:28,480

matter typically is your carbon nitrogen

2021

01:16:32,950 --> 01:16:29,840

oxygen hydrogen

2022

01:16:38,950 --> 01:16:35,590

but typically you don't find or see such

2023

01:16:40,709 --> 01:16:38,960

high levels of arsenic have you taken

2024

01:16:42,550 --> 01:16:40,719

samples from these hot springs and

2025

01:16:44,870 --> 01:16:42,560

actually looked to see if you have

2026
01:16:48,790 --> 01:16:44,880
very large concentrations of arsenic in

2027
01:16:51,510 --> 01:16:49,990
uh

2028
01:16:53,750 --> 01:16:51,520
this is

2029
01:16:55,430 --> 01:16:53,760
an area for future work

2030
01:16:57,030 --> 01:16:55,440
uh and don't forget

2031
01:16:58,470 --> 01:16:57,040
these systems also have very high

2032
01:17:00,870 --> 01:16:58,480
phosphate

2033
01:17:02,950 --> 01:17:00,880
there's about three to five times more

2034
01:17:04,229 --> 01:17:02,960
phosphorus in monolake waters than there

2035
01:17:05,510 --> 01:17:04,239
is arsenic

2036
01:17:07,590 --> 01:17:05,520
motor like waters are limited by

2037
01:17:09,110 --> 01:17:07,600
nitrogen not phosphorous they're rich in

2038
01:17:11,510 --> 01:17:09,120

light and phosphorus they're also rich

2039

01:17:15,030 --> 01:17:11,520

in arsenic so you get both

2040

01:17:17,590 --> 01:17:15,040

there are some environments the

2041

01:17:20,229 --> 01:17:17,600

endolithic communities that seem to be

2042

01:17:21,110 --> 01:17:20,239

largely dominated uh low in phosphorus

2043

01:17:22,390 --> 01:17:21,120

but

2044

01:17:24,390 --> 01:17:22,400

we didn't want to work with those

2045

01:17:27,430 --> 01:17:24,400

because mono lake is right next door

2046

01:17:28,870 --> 01:17:27,440

let's start out with a low-hanging fruit

2047

01:17:31,750 --> 01:17:28,880

but

2048

01:17:33,110 --> 01:17:31,760

a bit further down the road uh

2049

01:17:34,630 --> 01:17:33,120

there's there's different ways this work

2050

01:17:35,990 --> 01:17:34,640

can go

2051

01:17:38,310 --> 01:17:36,000

some of it should go to the molecular

2052

01:17:40,790 --> 01:17:38,320

level with with uh cultures where it's

2053

01:17:42,229 --> 01:17:40,800

been established like a

2054

01:17:44,709 --> 01:17:42,239

gfaj

2055

01:17:46,470 --> 01:17:44,719

and find out

2056

01:17:48,390 --> 01:17:46,480

to answer questions like matt kaine's

2057

01:17:49,350 --> 01:17:48,400

you know is it in the dna how much of it

2058

01:17:50,870 --> 01:17:49,360

is there

2059

01:17:53,270 --> 01:17:50,880

how is it structured what's the crystal

2060

01:17:55,110 --> 01:17:53,280

structure how does this work how does

2061

01:17:56,950 --> 01:17:55,120

transcription and translation work of an

2062

01:17:59,790 --> 01:17:56,960

arsenic encoded all that stuff what

2063

01:18:04,310 --> 01:17:59,800

about metabolites how how efficient is

2064

01:18:07,910 --> 01:18:04,320

ats versus atp and all that stuff

2065

01:18:10,470 --> 01:18:07,920

uh how does arsenic uh activate

2066

01:18:12,310 --> 01:18:10,480

uh uh biosynthesis and catabolism like

2067

01:18:13,669 --> 01:18:12,320

phosphate does

2068

01:18:14,630 --> 01:18:13,679

it's all open

2069

01:18:16,870 --> 01:18:14,640

uh

2070

01:18:18,229 --> 01:18:16,880

the other avenue is isolating more

2071

01:18:19,590 --> 01:18:18,239

examples

2072

01:18:21,189 --> 01:18:19,600

of this from the natural world and

2073

01:18:23,350 --> 01:18:21,199

testing cultures

2074

01:18:24,870 --> 01:18:23,360

from populations that are held in in

2075

01:18:27,590 --> 01:18:24,880

cultural collections

2076

01:18:28,630 --> 01:18:27,600

uh and examine the physiology of these

2077

01:18:30,870 --> 01:18:28,640

critics to show that it's more

2078

01:18:33,189 --> 01:18:30,880

widespread and may have significance

2079

01:18:34,870 --> 01:18:33,199

maybe back four billion years when there

2080

01:18:36,229 --> 01:18:34,880

was more arsenic available than perhaps

2081

01:18:38,229 --> 01:18:36,239

phosphorus

2082

01:18:39,669 --> 01:18:38,239

the third area is ecological and this is

2083

01:18:40,790 --> 01:18:39,679

where

2084

01:18:43,669 --> 01:18:40,800

i would address what you're talking

2085

01:18:47,110 --> 01:18:43,679

about can you take natural populations

2086

01:18:48,950 --> 01:18:47,120

and arsenic-rich systems and see uh xf

2087

01:18:51,350 --> 01:18:48,960

zanes

2088

01:18:52,790 --> 01:18:51,360

of natural populations that say

2089

01:18:54,470 --> 01:18:52,800

oh there's you know phosphorus

2090

01:18:56,470 --> 01:18:54,480

containing dna but there's signal here

2091

01:18:58,790 --> 01:18:56,480

also for rocks for

2092

01:19:01,430 --> 01:18:58,800

arsenic-containing dna or some other

2093

01:19:03,110 --> 01:19:01,440

fancy analytical uh approach to say that

2094

01:19:04,470 --> 01:19:03,120

this can actually occur in the

2095

01:19:06,310 --> 01:19:04,480

environment right now we just have it in

2096

01:19:08,790 --> 01:19:06,320

a manipulated test tube

2097

01:19:11,270 --> 01:19:08,800

and it works that's all we have

2098

01:19:12,709 --> 01:19:11,280

uh we don't have any of these other

2099

01:19:14,070 --> 01:19:12,719

other things yet

2100

01:19:15,750 --> 01:19:14,080

but those are directions for future

2101

01:19:24,790 --> 01:19:15,760

research

2102

01:19:29,510 --> 01:19:27,110

more of a compositional question that in

2103

01:19:31,189 --> 01:19:29,520

dna carbon nitrogen hydrogen phosphorus

2104

01:19:32,950 --> 01:19:31,199

is a particular ratio

2105

01:19:35,350 --> 01:19:32,960

so when you are looking at the material

2106

01:19:38,310 --> 01:19:35,360

is it in the dna or somewhere else you

2107

01:19:40,790 --> 01:19:38,320

can simply do ratios and from that ratio

2108

01:19:43,189 --> 01:19:40,800

you can tell the material is dna and not

2109

01:19:45,510 --> 01:19:43,199

even not knowing it's a dna or not have

2110

01:19:47,590 --> 01:19:45,520

you done ratio with nitrogen or carbon

2111

01:19:48,950 --> 01:19:47,600

or hydrogen there are ratios published

2112

01:19:52,149 --> 01:19:48,960

in the paper i think they were related

2113

01:19:55,189 --> 01:19:52,159

to carbon uh they're crude numbers

2114

01:19:58,310 --> 01:19:55,199

but they're not uh uh

2115

01:20:00,229 --> 01:19:58,320

really carefully done studies of sort of

2116

01:20:02,790 --> 01:20:00,239

like things that came off

2117

01:20:05,189 --> 01:20:02,800

the nano sims work for example

2118

01:20:06,870 --> 01:20:05,199

but they're not red field ratios

2119

01:20:08,149 --> 01:20:06,880

they're not we're not we don't take that

2120

01:20:10,390 --> 01:20:08,159

revenue those are things again that

2121

01:20:12,470 --> 01:20:10,400

could be looked at in the future uh you

2122

01:20:14,390 --> 01:20:12,480

know the red field ratio is canonized

2123

01:20:15,669 --> 01:20:14,400

it's in the textbook right this is what

2124

01:20:18,149 --> 01:20:15,679

it has to be because it's in the

2125

01:20:19,830 --> 01:20:18,159

textbook and the textbook before that

2126

01:20:21,350 --> 01:20:19,840

had it there and so did that textbook

2127

01:20:23,430 --> 01:20:21,360

have it there because redfield published

2128

01:20:25,430 --> 01:20:23,440

it was it 50 years ago it must be true

2129

01:20:27,350 --> 01:20:25,440

right because all the textbooks say that

2130

01:20:29,270 --> 01:20:27,360

but what if those ratios are not always

2131

01:20:31,030 --> 01:20:29,280

the same and they shift around a lot and

2132

01:20:33,110 --> 01:20:31,040

they may change a bit for

2133

01:20:34,629 --> 01:20:33,120

elements based on how much dna is there

2134

01:20:36,390 --> 01:20:34,639

maybe only a portion of the dna is

2135

01:20:37,910 --> 01:20:36,400

needed when they're grown on artists i

2136

01:20:40,070 --> 01:20:37,920

don't know

2137

01:20:41,510 --> 01:20:40,080

and maybe those ratios break down if you

2138

01:20:43,189 --> 01:20:41,520

can get things growing on our snake for

2139

01:20:44,950 --> 01:20:43,199

god's sakes

2140

01:20:46,390 --> 01:20:44,960

i don't think you know these ratios are

2141

01:20:47,990 --> 01:20:46,400

necessarily going to be whole they

2142

01:20:51,030 --> 01:20:48,000

should be looked at we need to find them

2143

01:20:53,350 --> 01:20:51,040

out but they shouldn't be canonized

2144

01:20:55,350 --> 01:20:53,360

the reason is it if it replacing just

2145

01:20:57,750 --> 01:20:55,360

first for us i think that probably will

2146

01:20:59,910 --> 01:20:57,760

be more likely than doing a major change

2147

01:21:01,830 --> 01:20:59,920

in the macromolecule because the

2148

01:21:03,990 --> 01:21:01,840

machinery of the cell is not going to

2149

01:21:06,310 --> 01:21:04,000

change that much in replication

2150

01:21:09,189 --> 01:21:06,320

transcription all those so

2151
01:21:11,030 --> 01:21:09,199
it general logic will be the replacement

2152
01:21:13,030 --> 01:21:11,040
is very conservative

2153
01:21:14,709 --> 01:21:13,040
if at all it will be very conservative

2154
01:21:16,950 --> 01:21:14,719
it is worth looking at and should be

2155
01:21:19,189 --> 01:21:16,960
looked at we haven't done it

2156
01:21:20,870 --> 01:21:19,199
i'm sorry we can't do everything but

2157
01:21:23,189 --> 01:21:20,880
somebody should do it

2158
01:21:25,110 --> 01:21:23,199
so um have you and your colleagues given

2159
01:21:28,310 --> 01:21:25,120
any thought to

2160
01:21:29,910 --> 01:21:28,320
synthetic dna making synthetic dna with

2161
01:21:31,750 --> 01:21:29,920
arsenic in it

2162
01:21:33,669 --> 01:21:31,760
felicia this is what brought her in

2163
01:21:35,910 --> 01:21:33,679

she's been obsessed with this and uh

2164

01:21:37,910 --> 01:21:35,920

steve banner had been talking about this

2165

01:21:40,310 --> 01:21:37,920

he he doesn't like this at all

2166

01:21:41,430 --> 01:21:40,320

because in his synthetic system arsenic

2167

01:21:42,870 --> 01:21:41,440

doesn't work

2168

01:21:43,910 --> 01:21:42,880

but he's not dealing with a cell he's

2169

01:21:45,110 --> 01:21:43,920

dealing with

2170

01:21:46,229 --> 01:21:45,120

solvents

2171

01:21:48,550 --> 01:21:46,239

and water

2172

01:21:50,550 --> 01:21:48,560

and it doesn't work it's unstable so he

2173

01:21:52,790 --> 01:21:50,560

infers if this is real and we believe it

2174

01:21:55,510 --> 01:21:52,800

is he needs to be convinced there must

2175

01:21:57,350 --> 01:21:55,520

be stabilizing mechanisms

2176

01:21:58,390 --> 01:21:57,360

to keep the arsenic working

2177

01:21:59,830 --> 01:21:58,400

and

2178

01:22:01,830 --> 01:21:59,840

let's look for them well you know i'm

2179

01:22:03,030 --> 01:22:01,840

also wondering if there aren't

2180

01:22:05,189 --> 01:22:03,040

ways of

2181

01:22:06,790 --> 01:22:05,199

at least amplifying

2182

01:22:08,870 --> 01:22:06,800

with pcr

2183

01:22:10,870 --> 01:22:08,880

arsenic containing even that would be a

2184

01:22:13,990 --> 01:22:10,880

fun thing to do is to instead of using

2185

01:22:16,070 --> 01:22:14,000

the phosphate and the pcr uh replace it

2186

01:22:17,990 --> 01:22:16,080

with arsenic but these are there's

2187

01:22:18,950 --> 01:22:18,000

dozens and dozens of things that could

2188

01:22:22,229 --> 01:22:18,960

be done

2189

01:22:23,669 --> 01:22:22,239

them

2190

01:22:25,030 --> 01:22:23,679

because in the interest of getting the

2191

01:22:26,550 --> 01:22:25,040

idea out

2192

01:22:28,149 --> 01:22:26,560

after we'd worked on it for a year which

2193

01:22:29,990 --> 01:22:28,159

is pretty dang good we thought we had

2194

01:22:30,790 --> 01:22:30,000

enough uh

2195

01:22:33,030 --> 01:22:30,800

the

2196

01:22:34,709 --> 01:22:33,040

radio label experiments were were very

2197

01:22:36,870 --> 01:22:34,719

difficult

2198

01:22:39,270 --> 01:22:36,880

they didn't

2199

01:22:41,669 --> 01:22:39,280

go as easily as we thought they would uh

2200

01:22:43,430 --> 01:22:41,679

based on what arsenic oxidation or

2201

01:22:44,470 --> 01:22:43,440

arsenic respiration is or like sulfate

2202

01:22:47,189 --> 01:22:44,480

reduction

2203

01:22:49,910 --> 01:22:47,199

it was it was a hard hard process

2204

01:22:50,790 --> 01:22:49,920

and i think we had enough

2205

01:22:52,470 --> 01:22:50,800

uh

2206

01:22:54,550 --> 01:22:52,480

to get the point out

2207

01:22:56,709 --> 01:22:54,560

and certainly the reviewers liked it and

2208

01:22:59,350 --> 01:22:56,719

now the community is

2209

01:23:00,950 --> 01:22:59,360

gonna judge but uh uh what are you gonna

2210

01:23:03,910 --> 01:23:00,960

see and then after it's formally

2211

01:23:06,310 --> 01:23:03,920

published the science is gonna have to

2212

01:23:08,950 --> 01:23:06,320

filter through the objectionable uh well

2213

01:23:11,110 --> 01:23:08,960

not the objectionable but the

2214

01:23:12,390 --> 01:23:11,120

the letters that are gonna bring up

2215

01:23:14,229 --> 01:23:12,400

these points and we're gonna have to

2216

01:23:15,750 --> 01:23:14,239

respond in a logical way but that really

2217

01:23:17,910 --> 01:23:15,760

doesn't settle anything those are

2218

01:23:19,669 --> 01:23:17,920

arguments about how many angels on the

2219

01:23:20,790 --> 01:23:19,679

head of a pin it really is

2220

01:23:21,750 --> 01:23:20,800

the only way this is going to get

2221

01:23:23,669 --> 01:23:21,760

settled

2222

01:23:26,310 --> 01:23:23,679

is if people reproduce these experiments

2223

01:23:28,229 --> 01:23:26,320

on their own or if we provide them with

2224

01:23:30,310 --> 01:23:28,239

the cells which we will probably do in

2225

01:23:31,830 --> 01:23:30,320

about a year we'll give them to a

2226

01:23:33,669 --> 01:23:31,840

culture collection

2227

01:23:35,189 --> 01:23:33,679

once we understand their physiology and

2228

01:23:36,870 --> 01:23:35,199

they know how to do it they're in the

2229

01:23:39,350 --> 01:23:36,880

public domain folks

2230

01:23:42,070 --> 01:23:39,360

this is taxpayer money

2231

01:23:44,790 --> 01:23:42,080

nasa and usgs provided this

2232

01:23:46,709 --> 01:23:44,800

enormous expense we went to this it cost

2233

01:23:48,709 --> 01:23:46,719

17.23

2234

01:23:50,550 --> 01:23:48,719

i'm sure they're arguing about that at

2235

01:23:53,270 --> 01:23:50,560

capitol hill right now but no i'm

2236

01:23:55,510 --> 01:23:53,280

serious uh it's in the public domain we

2237

01:23:58,149 --> 01:23:55,520

intend to deposit this

2238

01:24:00,870 --> 01:23:58,159

with at least two

2239

01:24:02,470 --> 01:24:00,880

cultural collections like atcc and dsmz

2240

01:24:04,229 --> 01:24:02,480

they'll be freely available to anybody

2241

01:24:05,430 --> 01:24:04,239

who wants to pursue them but the other

2242

01:24:07,350 --> 01:24:05,440

way

2243

01:24:09,189 --> 01:24:07,360

is to test cultures of

2244

01:24:12,310 --> 01:24:09,199

halamoni that are already in those

2245

01:24:15,590 --> 01:24:12,320

collections and see if they can do it or

2246

01:24:17,270 --> 01:24:15,600

go out on your own and isolate something

2247

01:24:19,510 --> 01:24:17,280

and get away from

2248

01:24:22,149 --> 01:24:19,520

being silico stuff and the stuff that

2249

01:24:24,149 --> 01:24:22,159

everybody's knows everything about and

2250

01:24:25,669 --> 01:24:24,159

have some adventure in your life okay so

2251

01:24:27,590 --> 01:24:25,679

i have one more question getting away

2252

01:24:31,350 --> 01:24:27,600

from the dna for a second you've got

2253

01:24:35,189 --> 01:24:32,870

now behave ron or you don't get your

2254

01:24:37,430 --> 01:24:35,199

lockies um

2255

01:24:39,189 --> 01:24:37,440

moving away from dna for a second

2256

01:24:41,510 --> 01:24:39,199

back to the first part of your talk when

2257

01:24:44,310 --> 01:24:41,520

you talked about both arsenic and

2258

01:24:46,790 --> 01:24:44,320

selenium and and organisms that can

2259

01:24:50,470 --> 01:24:46,800

metabolize them oxidize them or reduce

2260

01:24:55,110 --> 01:24:52,870

what i'm wondering is uh

2261

01:24:57,990 --> 01:24:55,120

are the has anybody ever looked to see

2262

01:25:00,070 --> 01:24:58,000

whether there's a chemotactic response

2263

01:25:01,830 --> 01:25:00,080

to some of these unusual like eric

2264

01:25:04,149 --> 01:25:01,840

lovely angio back there and yeah oh we

2265

01:25:05,030 --> 01:25:04,159

haven't uh it's certainly worth doing

2266

01:25:06,229 --> 01:25:05,040

it's

2267

01:25:08,790 --> 01:25:06,239

uh

2268

01:25:11,350 --> 01:25:08,800

a laundry list of things you know the

2269

01:25:12,790 --> 01:25:11,360

the arsenic selenium tellurium uh

2270

01:25:13,910 --> 01:25:12,800

antimony

2271

01:25:15,430 --> 01:25:13,920

are sort of at the bottom of the

2272

01:25:17,430 --> 01:25:15,440

periodic table there's not much further

2273

01:25:19,910 --> 01:25:17,440

you can go down there's bismuth and

2274

01:25:21,750 --> 01:25:19,920

there's polonium and

2275

01:25:23,990 --> 01:25:21,760

uh at the top of the periodic table is

2276

01:25:25,350 --> 01:25:24,000

where people have been focused that iron

2277

01:25:26,390 --> 01:25:25,360

and manganese have been around for a

2278

01:25:28,070 --> 01:25:26,400

long time

2279

01:25:28,790 --> 01:25:28,080

and big advances have been made there

2280

01:25:32,229 --> 01:25:28,800

but

2281

01:25:33,830 --> 01:25:32,239

uh there's been an uh for me an escape

2282

01:25:38,629 --> 01:25:33,840

to the areas that nobody's been working

2283

01:25:42,790 --> 01:25:40,790

competitors if you will but collegial

2284

01:25:44,629 --> 01:25:42,800

competitors that are fussing around with

2285

01:25:45,510 --> 01:25:44,639

this area it's not a big area

2286

01:25:46,870 --> 01:25:45,520

uh

2287

01:25:48,470 --> 01:25:46,880

because there's not that much antimony

2288

01:25:50,950 --> 01:25:48,480

out there there's nothing there's some

2289

01:25:53,110 --> 01:25:50,960

arsenic in certain places but if you go

2290

01:25:55,110 --> 01:25:53,120

to places like uh

2291

01:25:56,629 --> 01:25:55,120

aquifers where there's arsenic being

2292

01:25:58,709 --> 01:25:56,639

mobilized

2293

01:26:00,550 --> 01:25:58,719

uh and people are dying

2294

01:26:02,310 --> 01:26:00,560

it's still not a lot of arsenic

2295

01:26:04,229 --> 01:26:02,320

there's a heck of a lot more iron and

2296

01:26:07,430 --> 01:26:04,239

aluminum the most what's the most

2297

01:26:08,870 --> 01:26:07,440

abundant element in the earth's crust

2298

01:26:10,790 --> 01:26:08,880

anybody okay

2299

01:26:13,350 --> 01:26:10,800

time for one more question

2300

01:26:17,110 --> 01:26:15,110

thank you for giving me the mic it takes

2301

01:26:19,590 --> 01:26:17,120

a lot of courage sitting in an in an

2302

01:26:22,070 --> 01:26:19,600

auditorium field with scientists let me

2303

01:26:24,629 --> 01:26:22,080

confess to you i'm not a scientist i'm

2304

01:26:26,950 --> 01:26:24,639

an economist and an accountant

2305

01:26:29,189 --> 01:26:26,960

but when this news broke first

2306

01:26:30,790 --> 01:26:29,199

i already thought at nasa

2307

01:26:33,270 --> 01:26:30,800

and then i went home went back to the

2308

01:26:34,950 --> 01:26:33,280

internet and read some more about it

2309

01:26:37,189 --> 01:26:34,960

and ran into a theory that said the

2310

01:26:38,629 --> 01:26:37,199

white house called nasa to find out what

2311

01:26:41,189 --> 01:26:38,639

it is all about

2312

01:26:42,629 --> 01:26:41,199

that got my interest even higher and so

2313

01:26:45,030 --> 01:26:42,639

the announcement was made that you'll be

2314

01:26:47,590 --> 01:26:45,040

coming to talk to us today

2315

01:26:49,990 --> 01:26:47,600

i came in to see it to listen

2316

01:26:51,510 --> 01:26:50,000

and after hearing all this you made some

2317

01:26:53,990 --> 01:26:51,520

reference to

2318

01:26:56,070 --> 01:26:54,000

ancient textbooks old textbooks that

2319

01:26:59,189 --> 01:26:56,080

gave those six elements that you've all

2320

01:27:01,669 --> 01:26:59,199

accepted to be the basis of life from

2321

01:27:04,550 --> 01:27:01,679

carbon through to sulphur and then you

2322

01:27:06,390 --> 01:27:04,560

run into this new thing called arsenic

2323

01:27:08,070 --> 01:27:06,400

and you're wondering you seem so

2324

01:27:10,709 --> 01:27:08,080

surprised about it

2325

01:27:13,350 --> 01:27:10,719

what i as a non-scientist has ict and my

2326

01:27:15,350 --> 01:27:13,360

interest and curiosity picked

2327

01:27:18,790 --> 01:27:15,360

wondering is

2328

01:27:21,430 --> 01:27:18,800

would you all as scientists accept this

2329

01:27:22,870 --> 01:27:21,440

rather than being surprised accepted as

2330

01:27:25,189 --> 01:27:22,880

an invitation

2331

01:27:26,149 --> 01:27:25,199

that maybe you haven't even started the

2332

01:27:28,870 --> 01:27:26,159

journey

2333

01:27:31,910 --> 01:27:28,880

into untangling the mystery

2334

01:27:34,550 --> 01:27:31,920

of the richness of life itself that this

2335

01:27:36,149 --> 01:27:34,560

is your invitation to go further

2336

01:27:38,390 --> 01:27:36,159

explore

2337

01:27:39,510 --> 01:27:38,400

yes technology is wonderful like you've

2338

01:27:41,350 --> 01:27:39,520

mentioned

2339

01:27:43,990 --> 01:27:41,360

maybe scientists are drifting away from

2340

01:27:46,070 --> 01:27:44,000

the basics like you described

2341

01:27:47,750 --> 01:27:46,080

would you accept that this is maybe your

2342

01:27:49,750 --> 01:27:47,760

invitation to say hey

2343

01:27:51,669 --> 01:27:49,760

let's explore some more rather than

2344

01:27:53,990 --> 01:27:51,679

being surprised that you found this

2345

01:27:55,990 --> 01:27:54,000

wonderful new thing

2346

01:27:58,870 --> 01:27:56,000

that is that humbling invitation that

2347

01:28:00,950 --> 01:27:58,880

says let's go look deeply could you do

2348

01:28:03,750 --> 01:28:00,960

that i wish i were a scientist as a time

2349

01:28:05,990 --> 01:28:03,760

like this i wish i was a scientist

2350

01:28:08,229 --> 01:28:06,000

because i'd like to find out some what

2351

01:28:10,550 --> 01:28:08,239

in the world is going on here

2352

01:28:12,310 --> 01:28:10,560

and i have to look to you guys to do

2353

01:28:14,709 --> 01:28:12,320

that and this is really what i'm asking

2354

01:28:17,030 --> 01:28:14,719

you would you accept this invitation

2355

01:28:18,950 --> 01:28:17,040

rather than being surprised go and ask

2356

01:28:21,189 --> 01:28:18,960

some more questions to see what life

2357

01:28:23,030 --> 01:28:21,199

really is all about maybe it's more than

2358

01:28:25,990 --> 01:28:23,040

those six elements that you depend on

2359

01:28:29,750 --> 01:28:26,000

for all these years and textbooks

2360

01:28:33,910 --> 01:28:31,750

and i i'll ask you a question do you

2361

01:28:35,110 --> 01:28:33,920

should i buy gm now that it's on the

2362

01:28:38,229 --> 01:28:35,120

market

2363

01:28:40,390 --> 01:28:38,239

but no that was very very gracious uh uh

2364

01:28:43,430 --> 01:28:40,400

science works in a certain way it's it's

2365

01:28:45,430 --> 01:28:43,440

really human nature uh

2366

01:28:47,270 --> 01:28:45,440

it's resistant to change

2367

01:28:50,310 --> 01:28:47,280

and it's especially resistant to change

2368

01:28:51,669 --> 01:28:50,320

because if a new upsetting paradigm

2369

01:28:53,669 --> 01:28:51,679

comes in

2370

01:28:56,550 --> 01:28:53,679

there's strong pushback it has to work

2371

01:28:58,390 --> 01:28:56,560

this way so the the data coming in has

2372

01:29:00,790 --> 01:28:58,400

to break through that push back i think

2373

01:29:03,669 --> 01:29:00,800

we've crossed that threshold but there's

2374

01:29:05,030 --> 01:29:03,679

still going to be strong pushback over

2375

01:29:07,110 --> 01:29:05,040

time

2376

01:29:08,149 --> 01:29:07,120

that push back is going to be less

2377

01:29:10,149 --> 01:29:08,159

personal

2378

01:29:11,750 --> 01:29:10,159

and

2379

01:29:12,870 --> 01:29:11,760

more intriguing to the people who are

2380

01:29:14,229 --> 01:29:12,880

actually pushing back some of the

2381

01:29:17,030 --> 01:29:14,239

motivation

2382

01:29:19,110 --> 01:29:17,040

may be i'm going to prove him wrong

2383

01:29:21,990 --> 01:29:19,120

and i'm going to do it myself

2384

01:29:23,669 --> 01:29:22,000

and they may prove us wrong or

2385

01:29:25,430 --> 01:29:23,679

they may reproduce the results and find

2386

01:29:28,070 --> 01:29:25,440

new stuff that's just the way the

2387

01:29:30,070 --> 01:29:28,080

process works others

2388

01:29:31,510 --> 01:29:30,080

like it and may say i'm going to do this

2389

01:29:35,750 --> 01:29:31,520

right now along the lines we were

2390

01:29:38,790 --> 01:29:37,270

to anything that's really really

2391

01:29:41,270 --> 01:29:38,800

radically new

2392

01:29:43,830 --> 01:29:41,280

and it's part of the cleansing

2393

01:29:45,590 --> 01:29:43,840

process intellectually in science it has

2394

01:29:49,189 --> 01:29:45,600

to work this way

2395

01:29:50,709 --> 01:29:49,199

sometimes it's not exactly pleasant

2396

01:29:53,110 --> 01:29:50,719

in fact

2397

01:29:54,870 --> 01:29:53,120

i would have been very disappointed and

2398

01:29:56,229 --> 01:29:54,880

shocked if everybody said oh that's

2399

01:29:58,070 --> 01:29:56,239

really nice

2400

01:29:59,750 --> 01:29:58,080

they got a paper in science maybe they

2401
01:30:01,110 --> 01:29:59,760
have another paper let's go on and talk

2402
01:30:05,189 --> 01:30:01,120
about something else

2403
01:30:07,750 --> 01:30:05,830
and pushback

2404
01:30:09,030 --> 01:30:07,760
know when we got reviews back from

2405
01:30:11,110 --> 01:30:09,040
science

2406
01:30:13,030 --> 01:30:11,120
uh they were they were stellar

2407
01:30:16,470 --> 01:30:13,040
and i was very surprised but i'm not

2408
01:30:20,149 --> 01:30:16,480
surprised uh but by pushback from the

2409
01:30:22,629 --> 01:30:20,159
scientific community and and bloggers uh

2410
01:30:24,790 --> 01:30:22,639
that's part of the process uh but your

2411
01:30:27,030 --> 01:30:24,800
your comments are are very well taken

2412
01:30:28,950 --> 01:30:27,040
and really make me feel very warm thank

2413
01:30:31,270 --> 01:30:28,960

you sir

2414

01:30:32,709 --> 01:30:31,280

well let me uh switch gears here my name

2415

01:30:35,030 --> 01:30:32,719

is duane brown from the office of

2416

01:30:36,709 --> 01:30:35,040

communications and i happen to have the

2417

01:30:38,790 --> 01:30:36,719

honor of being the moderator for the

2418

01:30:40,470 --> 01:30:38,800

press conference that happened last week

2419

01:30:42,149 --> 01:30:40,480

and i want to thank ron can we give ron

2420

01:30:46,870 --> 01:30:42,159

another round of applause for coming

2421

01:30:51,510 --> 01:30:48,390

ron thank you for putting it in even a

2422

01:30:53,590 --> 01:30:51,520

bigger context and i can assure you uh

2423

01:30:55,669 --> 01:30:53,600

there will be more discussion on this

2424

01:30:57,189 --> 01:30:55,679

incredible finding and subject and

2425

01:30:58,550 --> 01:30:57,199

that's what scientists do and we thank

