NExSS & NFoLD

STANDARDS OF EVIDENCE FOR LIFE DETECTION COMMUNITY WORKSHOP

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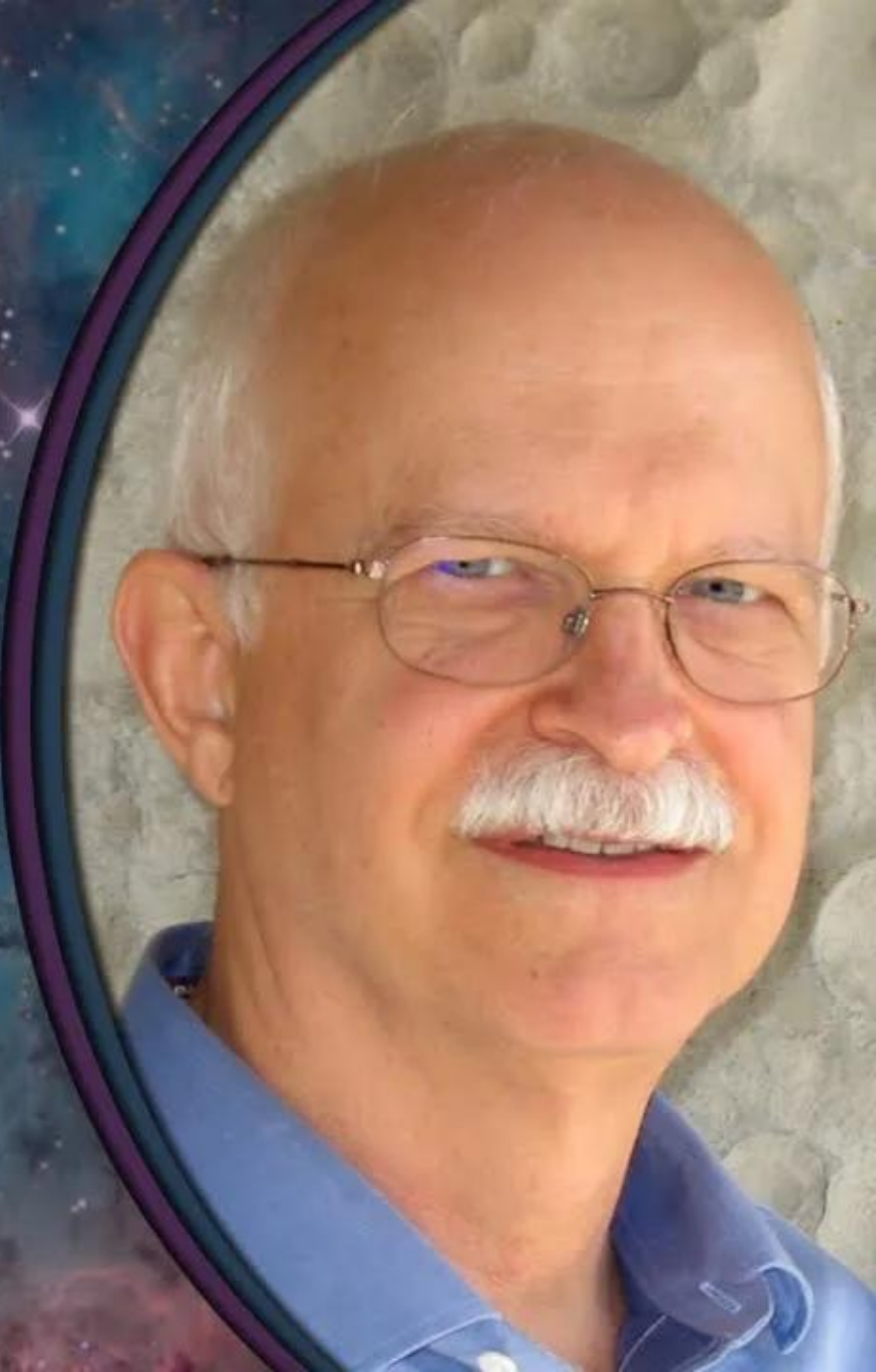
IN SITU BIOSIGNATURES: AN OVERVIEW



1
00:00:04,390 --> 00:00:02,710
in this talk i'd like to discuss two

2
00:00:05,749 --> 00:00:04,400
ever-present challenges in life

3
00:00:08,310 --> 00:00:05,759
detection

4
00:00:09,030 --> 00:00:08,320
where to look in this case on a planet's

5
00:00:12,549 --> 00:00:09,040
surface

6
00:00:14,390 --> 00:00:12,559
look for

7
00:00:15,589 --> 00:00:14,400
and that would be recognizing potential

8
00:00:18,150 --> 00:00:15,599
biosignatures in

9
00:00:19,990 --> 00:00:18,160
unfamiliar terrain and throughout this

10
00:00:22,230 --> 00:00:20,000
talk i'd like to use examples from the

11
00:00:22,710 --> 00:00:22,240
mars exploration program which can be

12
00:00:26,230 --> 00:00:22,720
quite

13
00:00:28,429 --> 00:00:26,240

illustrative to start with

14
00:00:29,669 --> 00:00:28,439
mars rover missions are necessarily

15
00:00:31,669 --> 00:00:29,679
multi-disciplinary

16
00:00:34,229 --> 00:00:31,679
in nature and that of course is to

17
00:00:38,310 --> 00:00:34,239
optimize the amount of science return

18
00:00:40,709 --> 00:00:38,320
against the cost an important point is

19
00:00:44,310 --> 00:00:40,719
that extraordinary success of the follow

20
00:00:44,790 --> 00:00:44,320
the water theme which is was addressed

21
00:00:47,830 --> 00:00:44,800
right

22
00:00:51,189 --> 00:00:47,840
shortly after the year 2000 or so uh

23
00:00:53,670 --> 00:00:51,199
really transformed mars science and that

24
00:00:54,630 --> 00:00:53,680
is because the focus on habitability

25
00:00:56,630 --> 00:00:54,640
assessments

26
00:00:58,709 --> 00:00:56,640
has made missions more interdisciplinary

27
00:01:01,510 --> 00:00:58,719
so the major disciplines

28
00:01:02,630 --> 00:01:01,520
are geology astrobiology and atmospheric

29
00:01:05,109 --> 00:01:02,640
science

30
00:01:06,310 --> 00:01:05,119
that have really come together more

31
00:01:08,149 --> 00:01:06,320
completely

32
00:01:10,310 --> 00:01:08,159
if you look here under geologic

33
00:01:11,030 --> 00:01:10,320
environments you can see that many of

34
00:01:13,270 --> 00:01:11,040
the

35
00:01:15,510 --> 00:01:13,280
environments of interest sedimentary

36
00:01:16,950 --> 00:01:15,520
systems hydrothermal deep subsurface

37
00:01:19,590 --> 00:01:16,960
groundwater sumerian

38
00:01:21,510 --> 00:01:19,600

ignis many of those are candidate

39
00:01:25,109 --> 00:01:21,520
habitable environments

40
00:01:27,590 --> 00:01:25,119
and therefore a key aspect here

41
00:01:28,630 --> 00:01:27,600
is not only to characterize geologic

42
00:01:30,950 --> 00:01:28,640
processes

43
00:01:32,390 --> 00:01:30,960
but to assess past habitability in these

44
00:01:33,670 --> 00:01:32,400
environments

45
00:01:35,670 --> 00:01:33,680
and this is really important for

46
00:01:38,230 --> 00:01:35,680
astrobiology because assessments of

47
00:01:40,230 --> 00:01:38,240
geologic processes and paleoclimate

48
00:01:41,990 --> 00:01:40,240
provide an essential context for

49
00:01:44,950 --> 00:01:42,000
characterizing the environment

50
00:01:46,149 --> 00:01:44,960
and even recognizing potential bias

51
00:01:49,510 --> 00:01:46,159
signatures

52
00:01:51,350 --> 00:01:49,520
so how do we sort of determine what the

53
00:01:53,749 --> 00:01:51,360
requirements for habitability

54
00:01:55,830 --> 00:01:53,759
are well you start with the basic

55
00:01:57,830 --> 00:01:55,840
concept of life's attributes what it

56
00:01:58,149 --> 00:01:57,840
what's it what are fundamental aspects

57
00:02:01,270 --> 00:01:58,159
of

58
00:02:01,590 --> 00:02:01,280
life that need to happen in order for it

59
00:02:04,870 --> 00:02:01,600
to

60
00:02:08,070 --> 00:02:04,880
persist and of course this then

61
00:02:09,910 --> 00:02:08,080
translates to the attributes for

62
00:02:11,830 --> 00:02:09,920
uh that define the requirements for

63
00:02:13,910 --> 00:02:11,840

habitable environments

64
00:02:15,670 --> 00:02:13,920
first of all we have information storage

65
00:02:18,390 --> 00:02:15,680
and replication

66
00:02:19,110 --> 00:02:18,400
a complex suite of components that

67
00:02:22,229 --> 00:02:19,120
collectively

68
00:02:24,550 --> 00:02:22,239
constitute what we call an automaton uh

69
00:02:25,750 --> 00:02:24,560
it was conceptualized by fond neumann in

70
00:02:29,110 --> 00:02:25,760
the early

71
00:02:31,430 --> 00:02:29,120
20th century and this is the machinery

72
00:02:33,990 --> 00:02:31,440
necessary for cell replication

73
00:02:35,990 --> 00:02:34,000
so you need that and this involves some

74
00:02:38,150 --> 00:02:36,000
pretty complicated molecules

75
00:02:39,670 --> 00:02:38,160
to be functional secondly of course you

76
00:02:42,470 --> 00:02:39,680
need a source of energy

77
00:02:43,589 --> 00:02:42,480
and harvesting free energy help enables

78
00:02:45,750 --> 00:02:43,599
metabolism

79
00:02:48,070 --> 00:02:45,760
and to maintain that information content

80
00:02:50,150 --> 00:02:48,080
in your automaton

81
00:02:51,270 --> 00:02:50,160
third you need organic biosynthesis of

82
00:02:53,430 --> 00:02:51,280
course

83
00:02:55,589 --> 00:02:53,440
and it needs nutrient sources in order

84
00:02:58,149 --> 00:02:55,599
to make the stuff of life

85
00:03:01,030 --> 00:02:58,159
and a key point also is that you need

86
00:03:03,270 --> 00:03:01,040
kinetically enhanced reactions

87
00:03:04,949 --> 00:03:03,280
that facilitate the self-regulation of

88
00:03:08,470 --> 00:03:04,959

this entire system

89
00:03:11,430 --> 00:03:08,480
and also to out-compete

90
00:03:13,350 --> 00:03:11,440
abiotic reactions for that source of

91
00:03:15,350 --> 00:03:13,360
energy that you want

92
00:03:17,270 --> 00:03:15,360
but the key point with all this is that

93
00:03:18,630 --> 00:03:17,280
some really key molecules are chemically

94
00:03:20,790 --> 00:03:18,640
rather fragile

95
00:03:22,630 --> 00:03:20,800
and they also depend on mutual

96
00:03:23,589 --> 00:03:22,640
non-covalent interactions with each

97
00:03:26,789 --> 00:03:23,599
other and all these

98
00:03:29,750 --> 00:03:26,799
place constraints on the environment

99
00:03:32,710 --> 00:03:29,760
so let's be a little more explicit about

100
00:03:34,470 --> 00:03:32,720
then the requirements to sustain life

101
00:03:36,149 --> 00:03:34,480
this is a figure that tory holder came

102
00:03:38,949 --> 00:03:36,159
up with some time ago

103
00:03:40,789 --> 00:03:38,959
and the key four elements are four

104
00:03:42,149 --> 00:03:40,799
aspects that are identified here are the

105
00:03:45,270 --> 00:03:42,159
raw materials

106
00:03:48,070 --> 00:03:45,280
the energy source the solvent and

107
00:03:49,670 --> 00:03:48,080
the clement conditions that can support

108
00:03:51,670 --> 00:03:49,680
life

109
00:03:52,830 --> 00:03:51,680
and the key thing is that all of these

110
00:03:55,670 --> 00:03:52,840
have to be present

111
00:03:57,429 --> 00:03:55,680
simultaneously to create what we call a

112
00:03:59,110 --> 00:03:57,439
habitable environment

113
00:04:00,789 --> 00:03:59,120

hence that h that's in the middle of the

114
00:04:03,750 --> 00:04:00,799
diagram

115
00:04:04,470 --> 00:04:03,760
now if you start to investigate these

116
00:04:06,949 --> 00:04:04,480
things you can

117
00:04:08,070 --> 00:04:06,959
uh it allows quantitative assessments

118
00:04:10,789 --> 00:04:08,080
and comparisons

119
00:04:11,830 --> 00:04:10,799
of environments to be made and since the

120
00:04:13,830 --> 00:04:11,840
follow the water

121
00:04:15,990 --> 00:04:13,840
theme was so successful in finding so

122
00:04:17,110 --> 00:04:16,000
many places on mars there were water was

123
00:04:19,110 --> 00:04:17,120
once present

124
00:04:20,870 --> 00:04:19,120
how do you pick between them to

125
00:04:22,069 --> 00:04:20,880
determine which ones are the most

126
00:04:24,230 --> 00:04:22,079
promising

127
00:04:26,310 --> 00:04:24,240
well one key approach is to quantify the

128
00:04:29,350 --> 00:04:26,320
abundances and the constraints

129
00:04:30,790 --> 00:04:29,360
upon these resources so for example in

130
00:04:32,870 --> 00:04:30,800
the case of raw materials

131
00:04:34,870 --> 00:04:32,880
it's not just their abundances but it's

132
00:04:37,110 --> 00:04:34,880
their solubility their availability for

133
00:04:40,790 --> 00:04:37,120
organisms so i'm thinking of iron

134
00:04:41,749 --> 00:04:40,800
as an element in particular in terms of

135
00:04:44,710 --> 00:04:41,759
energy

136
00:04:45,990 --> 00:04:44,720
you have to have a supply that exceeds

137
00:04:48,550 --> 00:04:46,000
what the demand

138
00:04:49,430 --> 00:04:48,560

is placed on the organism and just to

139
00:04:52,629 --> 00:04:49,440
survive

140
00:04:53,909 --> 00:04:52,639
so the supply demand ratio is really

141
00:04:55,909 --> 00:04:53,919
important

142
00:04:58,150 --> 00:04:55,919
under with solvent it's not just the

143
00:05:00,950 --> 00:04:58,160
abundance of water but it's chemical

144
00:05:02,310 --> 00:05:00,960
activity if it's so salty that life

145
00:05:04,550 --> 00:05:02,320
can't use it

146
00:05:06,230 --> 00:05:04,560
then it's a constraint on habitability

147
00:05:07,990 --> 00:05:06,240
and then finally of course the clement

148
00:05:09,990 --> 00:05:08,000
conditions

149
00:05:12,390 --> 00:05:10,000
two key points that point out here is a

150
00:05:15,110 --> 00:05:12,400
duration of those conditions matters

151
00:05:16,070 --> 00:05:15,120
and secondly uh if you have extremes in

152
00:05:19,350 --> 00:05:16,080
temperature ph

153
00:05:20,310 --> 00:05:19,360
or salinity this imposes energy costs on

154
00:05:22,230 --> 00:05:20,320
the organism

155
00:05:23,590 --> 00:05:22,240
and that's a good example of how these

156
00:05:25,670 --> 00:05:23,600
factors these four

157
00:05:27,270 --> 00:05:25,680
areas interact with each other and

158
00:05:29,270 --> 00:05:27,280
collectively determine

159
00:05:30,550 --> 00:05:29,280
the suitability the habitability of an

160
00:05:33,350 --> 00:05:30,560
environment

161
00:05:34,150 --> 00:05:33,360
so these are all things that can be

162
00:05:37,670 --> 00:05:34,160
pursued

163
00:05:40,230 --> 00:05:37,680

to help us evaluate some sites against

164
00:05:42,870 --> 00:05:40,240
others and make the optimal choice

165
00:05:43,909 --> 00:05:42,880
uh this is not just an idle numerical

166
00:05:47,029 --> 00:05:43,919
exercise

167
00:05:49,590 --> 00:05:47,039
this is actually um born some fruit

168
00:05:51,510 --> 00:05:49,600
from the curiosity rover mission uh

169
00:05:53,510 --> 00:05:51,520
which basically identified an ancient

170
00:05:56,150 --> 00:05:53,520
persisted stratified lake

171
00:05:59,270 --> 00:05:56,160
in gale crater mars it's not there now

172
00:06:02,390 --> 00:05:59,280
but it was there billions of years ago

173
00:06:04,550 --> 00:06:02,400
the observations of

174
00:06:06,469 --> 00:06:04,560
multiple layers of sedimentary rocks

175
00:06:08,469 --> 00:06:06,479
that were formed under water

176
00:06:10,309 --> 00:06:08,479
indicates the former presence of a

177
00:06:12,469 --> 00:06:10,319
persistent water body

178
00:06:13,430 --> 00:06:12,479
the mineralogy and other chemical

179
00:06:15,430 --> 00:06:13,440
measurements

180
00:06:17,670 --> 00:06:15,440
indicated that the ph of that water was

181
00:06:18,469 --> 00:06:17,680
pretty moderate that the salinity was

182
00:06:21,029 --> 00:06:18,479
relatively

183
00:06:22,230 --> 00:06:21,039
low and that the key key elements for

184
00:06:25,270 --> 00:06:22,240
life were available

185
00:06:26,710 --> 00:06:25,280
and not only that as indicated by this

186
00:06:28,230 --> 00:06:26,720
oxen reductant

187
00:06:30,469 --> 00:06:28,240
gradient in the water column there are

188
00:06:32,790 --> 00:06:30,479

even chemical energy sources available

189
00:06:33,670 --> 00:06:32,800
and of course potentially sunlight as

190
00:06:36,230 --> 00:06:33,680
well so this

191
00:06:38,070 --> 00:06:36,240
was an ancient habitable environment not

192
00:06:40,790 --> 00:06:38,080
to say it was inhabited

193
00:06:42,070 --> 00:06:40,800
but it was habitable so that's a nice

194
00:06:44,230 --> 00:06:42,080
demonstration

195
00:06:46,150 --> 00:06:44,240
of this multi-dimensional approach to

196
00:06:47,909 --> 00:06:46,160
assessing habitability

197
00:06:50,390 --> 00:06:47,919
so now let's turn our attention to

198
00:06:52,230 --> 00:06:50,400
biosignatures

199
00:06:53,670 --> 00:06:52,240
this is a definition that has been in

200
00:06:55,350 --> 00:06:53,680
use now for

201
00:06:57,510 --> 00:06:55,360
quite a while in the astrobiology

202
00:06:58,550 --> 00:06:57,520
program and also in the mars exploration

203
00:07:00,870 --> 00:06:58,560
program

204
00:07:02,950 --> 00:07:00,880
and that is a biosignature consists of

205
00:07:04,070 --> 00:07:02,960
objects substances patterns or

206
00:07:06,390 --> 00:07:04,080
activities

207
00:07:10,710 --> 00:07:06,400
or ensembles of these features whose

208
00:07:15,270 --> 00:07:10,720
origin requires a biological agent

209
00:07:16,710 --> 00:07:15,280
so that's basically the definition but

210
00:07:17,830 --> 00:07:16,720
then we have to acknowledge the

211
00:07:20,469 --> 00:07:17,840
challenges

212
00:07:21,589 --> 00:07:20,479
uh in the actual missions we have the

213
00:07:24,070 --> 00:07:21,599

challenge of

214
00:07:25,830 --> 00:07:24,080
interpreting something that's not a bias

215
00:07:27,189 --> 00:07:25,840
signature and that would be called a

216
00:07:29,270 --> 00:07:27,199
false positive

217
00:07:30,950 --> 00:07:29,280
if we thought it was evidence of life

218
00:07:32,870 --> 00:07:30,960
and then you have the problem of false

219
00:07:33,510 --> 00:07:32,880
negatives and that is the last thing she

220
00:07:35,430 --> 00:07:33,520
was there

221
00:07:36,629 --> 00:07:35,440
but you just did not detect it for

222
00:07:39,670 --> 00:07:36,639
whatever reason

223
00:07:43,110 --> 00:07:39,680
so these are important challenges um

224
00:07:46,309 --> 00:07:43,120
and as a court accordingly uh the term

225
00:07:49,029 --> 00:07:46,319
potential bias signatures has been

226
00:07:50,550 --> 00:07:49,039
has come into common use and again the

227
00:07:52,469 --> 00:07:50,560
definition is similar with a key

228
00:07:53,189 --> 00:07:52,479
difference a potential biosignature

229
00:07:55,430 --> 00:07:53,199
consists of

230
00:07:57,110 --> 00:07:55,440
objects substances patterns or

231
00:07:59,110 --> 00:07:57,120
activities

232
00:08:01,029 --> 00:07:59,120
or ensembles of these features that

233
00:08:03,670 --> 00:08:01,039
potentially provide evidence

234
00:08:05,110 --> 00:08:03,680
of past or present life so the key thing

235
00:08:07,589 --> 00:08:05,120
here is potentially provide

236
00:08:09,670 --> 00:08:07,599
evidence it doesn't really mean that you

237
00:08:12,390 --> 00:08:09,680
have found it

238
00:08:14,629 --> 00:08:12,400

the key point here is that the

239
00:08:15,990 --> 00:08:14,639
usefulness of a potential bias insurer

240
00:08:16,869 --> 00:08:16,000
is determined not only by the

241
00:08:19,909 --> 00:08:16,879
probability

242
00:08:22,070 --> 00:08:19,919
that life produced it but also by the

243
00:08:23,830 --> 00:08:22,080
improbability that non-biological

244
00:08:26,150 --> 00:08:23,840
processes produced it

245
00:08:27,350 --> 00:08:26,160
and again with that the key challenges

246
00:08:29,990 --> 00:08:27,360
of false positives

247
00:08:31,270 --> 00:08:30,000
and false negatives so let's explore a

248
00:08:34,310 --> 00:08:31,280
little bit further

249
00:08:35,990 --> 00:08:34,320
uh these potential bias signatures

250
00:08:37,509 --> 00:08:36,000
in these categories of objects

251
00:08:39,829 --> 00:08:37,519
substances patterns

252
00:08:41,909 --> 00:08:39,839
and activity and with that we go to the

253
00:08:43,750 --> 00:08:41,919
next slide where we

254
00:08:45,190 --> 00:08:43,760
have an illustration of the known bias

255
00:08:47,509 --> 00:08:45,200
signature categories

256
00:08:49,750 --> 00:08:47,519
this figure came from the a mars

257
00:08:50,949 --> 00:08:49,760
exploration study called again the imo

258
00:08:53,829 --> 00:08:50,959
study

259
00:08:55,590 --> 00:08:53,839
addressing sample return we have the

260
00:08:56,470 --> 00:08:55,600
well-known organic matter as bio

261
00:08:58,550 --> 00:08:56,480
signatures

262
00:09:00,470 --> 00:08:58,560
and of course these are substances and

263
00:09:02,470 --> 00:09:00,480

if you look at assemblages of these

264
00:09:04,870 --> 00:09:02,480
molecules you have the potential to

265
00:09:06,949 --> 00:09:04,880
discern interesting patterns

266
00:09:08,630 --> 00:09:06,959
the traditional ones the structures and

267
00:09:09,829 --> 00:09:08,640
textures like stromatolites and

268
00:09:12,550 --> 00:09:09,839
microfossils

269
00:09:15,110 --> 00:09:12,560
objects which again if you do population

270
00:09:16,870 --> 00:09:15,120
assessments could give you patterns

271
00:09:19,590 --> 00:09:16,880
other kinds of chemistry in organic

272
00:09:20,630 --> 00:09:19,600
chemistry again you could use substances

273
00:09:23,509 --> 00:09:20,640
and patterns

274
00:09:24,389 --> 00:09:23,519
between them to potentially identify

275
00:09:27,350 --> 00:09:24,399
interesting

276
00:09:28,470 --> 00:09:27,360
potential indicators of life over on the

277
00:09:31,430 --> 00:09:28,480
right side

278
00:09:31,910 --> 00:09:31,440
certain minerals could be diagnostic and

279
00:09:33,910 --> 00:09:31,920
again

280
00:09:36,630 --> 00:09:33,920
when you think about the magnetite

281
00:09:38,470 --> 00:09:36,640
crystals formed in certain bacteria

282
00:09:40,710 --> 00:09:38,480
they have certain diagnostic features

283
00:09:43,269 --> 00:09:40,720
that could be uh useful

284
00:09:44,550 --> 00:09:43,279
and then of course activities obviously

285
00:09:47,190 --> 00:09:44,560
uh you know the

286
00:09:48,070 --> 00:09:47,200
if you actually detect active things

287
00:09:51,110 --> 00:09:48,080
happening

288
00:09:53,350 --> 00:09:51,120

uh that's the life detection

289
00:09:55,030 --> 00:09:53,360
experiments in viking attempted to do

290
00:09:57,350 --> 00:09:55,040
that course could be another

291
00:09:59,509 --> 00:09:57,360
type of biosignature and then finally

292
00:10:01,110 --> 00:09:59,519
stable isotopes

293
00:10:02,949 --> 00:10:01,120
and that is that ratios of stable

294
00:10:03,990 --> 00:10:02,959
isotopes of the biologically important

295
00:10:07,269 --> 00:10:04,000
elements

296
00:10:08,150 --> 00:10:07,279
could by virtue of the patterns you see

297
00:10:10,630 --> 00:10:08,160
between different

298
00:10:12,470 --> 00:10:10,640
compounds or substances could in itself

299
00:10:14,710 --> 00:10:12,480
constitute a biosignature

300
00:10:16,550 --> 00:10:14,720
the key point here is that coordinated

301
00:10:18,630 --> 00:10:16,560
analyses of multiple

302
00:10:20,710 --> 00:10:18,640
features in a category as well as

303
00:10:21,829 --> 00:10:20,720
multiple categories of potential bias

304
00:10:23,990 --> 00:10:21,839
signatures

305
00:10:26,150 --> 00:10:24,000
greatly strengthen the interpretations

306
00:10:28,949 --> 00:10:26,160
of their origins and significance

307
00:10:29,430 --> 00:10:28,959
and that's why all of these categories

308
00:10:32,790 --> 00:10:29,440
are

309
00:10:35,269 --> 00:10:32,800
listed in plural form in the

310
00:10:36,870 --> 00:10:35,279
biosignature definition because you

311
00:10:39,750 --> 00:10:36,880
probably need assemblages

312
00:10:42,949 --> 00:10:39,760
of observations of features in order to

313
00:10:45,430 --> 00:10:42,959

become more demonstrative of life

314
00:10:46,389 --> 00:10:45,440
so biosignatures of past life again

315
00:10:48,870 --> 00:10:46,399
these this is

316
00:10:51,030 --> 00:10:48,880
a list and part of a study that was done

317
00:10:51,750 --> 00:10:51,040
by imos this international mars sample

318
00:10:54,069 --> 00:10:51,760
return

319
00:10:55,990 --> 00:10:54,079
objectives and samples team the key

320
00:10:57,590 --> 00:10:56,000
question being are there detectable bias

321
00:10:58,790 --> 00:10:57,600
signatures in any of the returned

322
00:11:00,949 --> 00:10:58,800
samples

323
00:11:02,949 --> 00:11:00,959
and basically you want to assay for the

324
00:11:03,829 --> 00:11:02,959
presence of biosignatures of past life

325
00:11:06,150 --> 00:11:03,839
at sites

326
00:11:07,030 --> 00:11:06,160
that hosted habitable environments and

327
00:11:10,790 --> 00:11:07,040
could have

328
00:11:13,990 --> 00:11:10,800
preserved any bias signatures

329
00:11:16,710 --> 00:11:14,000
and so basically this imo study

330
00:11:19,030 --> 00:11:16,720
uh assess strategies for in-situ

331
00:11:19,590 --> 00:11:19,040
investigations and for the selection of

332
00:11:23,190 --> 00:11:19,600
return

333
00:11:25,110 --> 00:11:23,200
samples to assess preservation of

334
00:11:26,389 --> 00:11:25,120
potential biosignatures and of course to

335
00:11:29,110 --> 00:11:26,399
investigate the range

336
00:11:29,829 --> 00:11:29,120
of potential by signatures types while

337
00:11:32,150 --> 00:11:29,839
also

338
00:11:33,430 --> 00:11:32,160

simultaneously is part of the mission

339
00:11:36,230 --> 00:11:33,440
characterizing key

340
00:11:37,350 --> 00:11:36,240
geologic processes so i'd like briefly

341
00:11:39,430 --> 00:11:37,360
to go through

342
00:11:40,870 --> 00:11:39,440
each of these things indicated in the in

343
00:11:42,949 --> 00:11:40,880
the pink box

344
00:11:44,630 --> 00:11:42,959
and just say a few more words about them

345
00:11:46,310 --> 00:11:44,640
so the first one is preservation and

346
00:11:48,389 --> 00:11:46,320
degradation

347
00:11:50,550 --> 00:11:48,399
that is to search for the most favorable

348
00:11:52,389 --> 00:11:50,560
conditions for preservation

349
00:11:54,629 --> 00:11:52,399
and the key game here is you have

350
00:11:57,190 --> 00:11:54,639
preservers and degraders with respect to

351
00:12:00,389 --> 00:11:57,200
bio signatures the preservers

352
00:12:00,949 --> 00:12:00,399
could be relatively rapid burial into

353
00:12:01,910 --> 00:12:00,959
rocks

354
00:12:04,069 --> 00:12:01,920
in other words you get them out of

355
00:12:05,990 --> 00:12:04,079
harm's way as quickly as you can

356
00:12:07,910 --> 00:12:06,000
secondly you have certain phases which

357
00:12:10,790 --> 00:12:07,920
on earth has been have been very not

358
00:12:12,230 --> 00:12:10,800
good for preserving biosignatures silica

359
00:12:16,069 --> 00:12:12,240
carbohydrates

360
00:12:18,389 --> 00:12:16,079
evaporates

361
00:12:20,310 --> 00:12:18,399
reducing conditions are favorable and

362
00:12:21,430 --> 00:12:20,320
then of course low temperatures and low

363
00:12:24,629 --> 00:12:21,440

pressures

364
00:12:25,590 --> 00:12:24,639
after burial the bad guys are the

365
00:12:27,750 --> 00:12:25,600
oxidation

366
00:12:28,870 --> 00:12:27,760
react radiation and metamorphism

367
00:12:31,990 --> 00:12:28,880
processes

368
00:12:34,150 --> 00:12:32,000
and these are uh

369
00:12:36,870 --> 00:12:34,160
all potentially capable of destroying

370
00:12:39,110 --> 00:12:36,880
your bias by a signature

371
00:12:39,990 --> 00:12:39,120
and so we basically need to perform

372
00:12:42,230 --> 00:12:40,000
measurements

373
00:12:43,829 --> 00:12:42,240
to characterize the the good guys the

374
00:12:47,269 --> 00:12:43,839
preservers that they're there

375
00:12:49,430 --> 00:12:47,279
and also uh to identify any evidence of

376
00:12:51,990 --> 00:12:49,440
post-depositional processes

377
00:12:53,350 --> 00:12:52,000
including cosmic radiation that might

378
00:12:55,110 --> 00:12:53,360
have degrade these

379
00:12:56,790 --> 00:12:55,120
all part of the assessment of finding

380
00:12:58,310 --> 00:12:56,800
the best places to look for

381
00:13:00,230 --> 00:12:58,320
biosignatures

382
00:13:02,470 --> 00:13:00,240
so let's just briefly go through some of

383
00:13:04,470 --> 00:13:02,480
these the key thing with organic

384
00:13:05,030 --> 00:13:04,480
molecules and deposits is to look for

385
00:13:07,590 --> 00:13:05,040
features

386
00:13:09,190 --> 00:13:07,600
arising from biosynthetic pathways and

387
00:13:11,110 --> 00:13:09,200
that might be indicators of key

388
00:13:12,710 --> 00:13:11,120

biological functions

389
00:13:15,350 --> 00:13:12,720
and for that we're basically in the game

390
00:13:17,350 --> 00:13:15,360
of interpreting molecular structures

391
00:13:19,750 --> 00:13:17,360
structures of individual molecules

392
00:13:21,750 --> 00:13:19,760
relative abundances of molecules

393
00:13:23,750 --> 00:13:21,760
molecular weight distributions and

394
00:13:24,310 --> 00:13:23,760
abundance of related species that

395
00:13:26,870 --> 00:13:24,320
contain

396
00:13:28,550 --> 00:13:26,880
these key biogenic elements so the

397
00:13:30,550 --> 00:13:28,560
measurement game is basically

398
00:13:31,670 --> 00:13:30,560
to measure molecules and characterize

399
00:13:34,870 --> 00:13:31,680
their structures

400
00:13:36,790 --> 00:13:34,880
but also to identify spatial

401
00:13:38,470 --> 00:13:36,800
relationships between the organic matter

402
00:13:40,150 --> 00:13:38,480
and associated minerals

403
00:13:42,710 --> 00:13:40,160
because minerals could be another type

404
00:13:44,550 --> 00:13:42,720
of biosignature potential biosignature

405
00:13:46,949 --> 00:13:44,560
and then ultimately between the organics

406
00:13:49,189 --> 00:13:46,959
and the history of the host rock

407
00:13:51,030 --> 00:13:49,199
so these are all aspects of just looking

408
00:13:53,829 --> 00:13:51,040
for organic molecules

409
00:13:56,629 --> 00:13:53,839
as potential biasing issues stabilized

410
00:13:58,629 --> 00:13:56,639
stock ratio patterns are sort of related

411
00:14:00,710 --> 00:13:58,639
patterns of isotopic discrimination

412
00:14:02,870 --> 00:14:00,720
arising from enzymatic catalysis

413
00:14:04,069 --> 00:14:02,880

and metabolic pathways could in

414
00:14:05,990 --> 00:14:04,079
themselves well

415
00:14:08,389 --> 00:14:06,000
in concert with organics and other

416
00:14:10,629 --> 00:14:08,399
things be diagnostic of life

417
00:14:12,790 --> 00:14:10,639
and the key aspect here for example

418
00:14:13,990 --> 00:14:12,800
would be to look for patterns of isotope

419
00:14:15,910 --> 00:14:14,000
values

420
00:14:17,910 --> 00:14:15,920
between substances that are linked by

421
00:14:19,269 --> 00:14:17,920
networks of chemical reaction pathways

422
00:14:21,350 --> 00:14:19,279
so basically

423
00:14:23,189 --> 00:14:21,360
can we see patterns between organic

424
00:14:24,710 --> 00:14:23,199
molecules in their isotopes

425
00:14:26,550 --> 00:14:24,720
that might suggest some kind of a

426
00:14:28,230 --> 00:14:26,560
biosynthetic network

427
00:14:30,150 --> 00:14:28,240
and of course for that we want to look

428
00:14:32,629 --> 00:14:30,160
at patterns isotopic patterns within

429
00:14:37,189 --> 00:14:32,639
individual organic molecules

430
00:14:39,030 --> 00:14:37,199
between classes of organic compounds

431
00:14:40,230 --> 00:14:39,040
and between oxidized and reduced

432
00:14:42,550 --> 00:14:40,240
compounds

433
00:14:44,710 --> 00:14:42,560
that again contain these biologically

434
00:14:47,030 --> 00:14:44,720
important elements

435
00:14:48,230 --> 00:14:47,040
and so basically that dictates what the

436
00:14:51,590 --> 00:14:48,240
measurements are

437
00:14:51,990 --> 00:14:51,600
to try to characterize these things and

438
00:14:54,629 --> 00:14:52,000

that

439
00:14:56,870 --> 00:14:54,639
basically is what we're interested in

440
00:14:58,629 --> 00:14:56,880
with the stable isotopes

441
00:15:01,030 --> 00:14:58,639
minerals of course which i've mentioned

442
00:15:03,350 --> 00:15:01,040
already we're interested in

443
00:15:04,069 --> 00:15:03,360
chemical compositions crystal structures

444
00:15:06,550 --> 00:15:04,079
and forms

445
00:15:07,189 --> 00:15:06,560
orientations whatever an interesting

446
00:15:12,230 --> 00:15:07,199
point

447
00:15:13,910 --> 00:15:12,240
biochemical processes may be responsible

448
00:15:15,910 --> 00:15:13,920
directly or indirectly from most of

449
00:15:17,829 --> 00:15:15,920
earth's known mineral species

450
00:15:19,110 --> 00:15:17,839
uh be very interesting to see to the

451
00:15:21,910 --> 00:15:19,120
extent to which

452
00:15:22,870 --> 00:15:21,920
you know mars would address the

453
00:15:24,389 --> 00:15:22,880
potential of that

454
00:15:26,790 --> 00:15:24,399
but that's why we got to go make the

455
00:15:28,550 --> 00:15:26,800
measurements and so the measurements

456
00:15:30,509 --> 00:15:28,560
would be to characterize minerals that

457
00:15:32,310 --> 00:15:30,519
on earth are compositionally or

458
00:15:34,310 --> 00:15:32,320
morphologically associated with

459
00:15:35,189 --> 00:15:34,320
biological activity or catalytic

460
00:15:36,870 --> 00:15:35,199
activity

461
00:15:38,790 --> 00:15:36,880
and that would begin to be preservers

462
00:15:40,949 --> 00:15:38,800
like the carbonates the sulfur minerals

463
00:15:44,310 --> 00:15:40,959

and the phosphates and phytosilicates

464
00:15:45,749 --> 00:15:44,320
but now also transition metal oxides

465
00:15:48,069 --> 00:15:45,759
they might have characteristic

466
00:15:49,749 --> 00:15:48,079
signatures like those little magnetite

467
00:15:51,430 --> 00:15:49,759
crystals i mentioned

468
00:15:52,790 --> 00:15:51,440
map spatial relationship between

469
00:15:54,230 --> 00:15:52,800
minerals and formerly habitable

470
00:15:55,910 --> 00:15:54,240
environments and document course

471
00:15:59,269 --> 00:15:55,920
relationships between that

472
00:16:00,870 --> 00:15:59,279
and the histories of the source rocks

473
00:16:02,790 --> 00:16:00,880
so let's now go to structures and

474
00:16:04,870 --> 00:16:02,800
textures in a way these are the original

475
00:16:06,230 --> 00:16:04,880
first recognized bio signatures in the

476
00:16:08,710 --> 00:16:06,240
rock record

477
00:16:10,150 --> 00:16:08,720
and they involve various aspects of rot

478
00:16:13,829 --> 00:16:10,160
rock textures and also

479
00:16:15,189 --> 00:16:13,839
body fossils biofilms bio herbs and

480
00:16:17,990 --> 00:16:15,199
biofabrics

481
00:16:18,710 --> 00:16:18,000
and even trace fossils the key point

482
00:16:21,030 --> 00:16:18,720
here

483
00:16:22,629 --> 00:16:21,040
is that these are visual observations

484
00:16:24,470 --> 00:16:22,639
and that need to be conducted all the

485
00:16:26,629 --> 00:16:24,480
way from sub-micron scale

486
00:16:28,389 --> 00:16:26,639
to like for cells all the way up to

487
00:16:29,030 --> 00:16:28,399
potentially hundreds of meters if we're

488
00:16:31,430 --> 00:16:29,040

talking about

489
00:16:32,949 --> 00:16:31,440
reef type communities as we see in some

490
00:16:35,430 --> 00:16:32,959
places on the earth

491
00:16:36,230 --> 00:16:35,440
so there's a range of just visual

492
00:16:39,350 --> 00:16:36,240
observations

493
00:16:41,110 --> 00:16:39,360
that would be uh important for this one

494
00:16:42,550 --> 00:16:41,120
chemical features is sort of the

495
00:16:44,389 --> 00:16:42,560
additional category

496
00:16:46,710 --> 00:16:44,399
uh and this is one that really embodies

497
00:16:49,350 --> 00:16:46,720
a lot of the inorganic minerals

498
00:16:50,069 --> 00:16:49,360
inorganic elements elemental abundance

499
00:16:52,870 --> 00:16:50,079
patterns

500
00:16:54,470 --> 00:16:52,880
matters elevated organic concentrations

501
00:16:56,550 --> 00:16:54,480
uh redox boundaries

502
00:16:57,910 --> 00:16:56,560
which could be places where organisms

503
00:16:59,509 --> 00:16:57,920
could derive energy

504
00:17:01,670 --> 00:16:59,519
and of course then we would like to

505
00:17:04,150 --> 00:17:01,680
conduct measurements of abundances

506
00:17:05,029 --> 00:17:04,160
and these redox patterns associated with

507
00:17:07,750 --> 00:17:05,039
that

508
00:17:09,829 --> 00:17:07,760
so let's go to again an aspect of the

509
00:17:10,630 --> 00:17:09,839
imo study and that is to address the

510
00:17:13,669 --> 00:17:10,640
question

511
00:17:15,590 --> 00:17:13,679
why return sample studies are important

512
00:17:17,750 --> 00:17:15,600
and i should mention right off the top

513
00:17:20,470 --> 00:17:17,760

that the sample return

514
00:17:22,710 --> 00:17:20,480
option is a potential option for most

515
00:17:24,630 --> 00:17:22,720
in-situ mission destinations

516
00:17:27,669 --> 00:17:24,640
so the fact that you can send something

517
00:17:29,669 --> 00:17:27,679
there to the surface of a planet

518
00:17:30,870 --> 00:17:29,679
indicates it's not totally out of the

519
00:17:32,710 --> 00:17:30,880
question that you could bring the

520
00:17:33,750 --> 00:17:32,720
samples back to the earth so this is an

521
00:17:36,950 --> 00:17:33,760
option

522
00:17:38,390 --> 00:17:36,960
for in situ missions and mars sample

523
00:17:41,110 --> 00:17:38,400
return of course is

524
00:17:41,669 --> 00:17:41,120
uh the most shining and clear example of

525
00:17:43,590 --> 00:17:41,679
this

526
00:17:45,669 --> 00:17:43,600
because there is an imperative to

527
00:17:47,669 --> 00:17:45,679
actually identify and return samples to

528
00:17:49,590 --> 00:17:47,679
earth within the next decade

529
00:17:51,190 --> 00:17:49,600
so during the mission the in-situ

530
00:17:52,390 --> 00:17:51,200
mission you're exploring for the most

531
00:17:53,909 --> 00:17:52,400
promising sites

532
00:17:55,590 --> 00:17:53,919
and you're conducting in-situ

533
00:17:57,350 --> 00:17:55,600
measurements to select the most

534
00:17:59,110 --> 00:17:57,360
promising samples

535
00:18:01,029 --> 00:17:59,120
and then when you return the samples to

536
00:18:03,190 --> 00:18:01,039
earth led based laboratories

537
00:18:04,950 --> 00:18:03,200
you have what we call you enable what we

538
00:18:06,710 --> 00:18:04,960

call observation guided sample

539
00:18:08,310 --> 00:18:06,720
preparation and that is when you see the

540
00:18:10,150 --> 00:18:08,320
samples

541
00:18:11,830 --> 00:18:10,160
what you see actually guides how you

542
00:18:12,549 --> 00:18:11,840
would prepare them do you do thin

543
00:18:15,190 --> 00:18:12,559
sections do

544
00:18:15,669 --> 00:18:15,200
certain chemical separations and these

545
00:18:18,230 --> 00:18:15,679
of course

546
00:18:19,909 --> 00:18:18,240
greatly increase your diagnostic power

547
00:18:20,710 --> 00:18:19,919
we would love to be able to do thin

548
00:18:23,190 --> 00:18:20,720
sections and

549
00:18:23,990 --> 00:18:23,200
observe them in a remote mission to mars

550
00:18:25,510 --> 00:18:24,000
but that

551
00:18:27,669 --> 00:18:25,520
doesn't seem like that's possible in the

552
00:18:27,990 --> 00:18:27,679
near future and then the real punchline

553
00:18:29,909 --> 00:18:28,000
here

554
00:18:31,990 --> 00:18:29,919
is that you have laboratory consortia

555
00:18:32,390 --> 00:18:32,000
that can exchange samples to interrogate

556
00:18:36,310 --> 00:18:32,400
these

557
00:18:39,430 --> 00:18:36,320
course are state-of-the-art

558
00:18:41,510 --> 00:18:39,440
laboratories that actually in which you

559
00:18:43,110 --> 00:18:41,520
can actually develop a new methodology

560
00:18:45,430 --> 00:18:43,120
based on your observations of these

561
00:18:47,110 --> 00:18:45,440
samples new technology

562
00:18:49,029 --> 00:18:47,120
and then of course the punch line is you

563
00:18:51,510 --> 00:18:49,039

can archive some of these samples

564
00:18:53,909 --> 00:18:51,520
and save them for even better

565
00:18:55,909 --> 00:18:53,919
technologies in the future

566
00:18:56,950 --> 00:18:55,919
i'd like to then just spend a few

567
00:19:00,070 --> 00:18:56,960
comments on

568
00:19:02,310 --> 00:19:00,080
uh the question of is there evidence of

569
00:19:03,830 --> 00:19:02,320
extant martian life in any of the return

570
00:19:06,549 --> 00:19:03,840
samples actually

571
00:19:08,710 --> 00:19:06,559
living organisms that is to assess the

572
00:19:11,350 --> 00:19:08,720
possibility that any life forms detected

573
00:19:13,110 --> 00:19:11,360
are still alive but were recently alive

574
00:19:16,310 --> 00:19:13,120
i think again without getting into the

575
00:19:20,070 --> 00:19:16,320
detail in the purple box too much

576
00:19:21,750 --> 00:19:20,080
i think the key point here is that

577
00:19:23,909 --> 00:19:21,760
you would like to maybe to look for

578
00:19:25,110 --> 00:19:23,919
organic molecules which by virtue of

579
00:19:27,830 --> 00:19:25,120
their

580
00:19:29,750 --> 00:19:27,840
chemical sensitivity must have been of

581
00:19:31,909 --> 00:19:29,760
recent origin which pretty much means

582
00:19:33,830 --> 00:19:31,919
that there must have been life somewhere

583
00:19:35,830 --> 00:19:33,840
recently even if it's not right where

584
00:19:37,590 --> 00:19:35,840
you are taking the sample

585
00:19:39,590 --> 00:19:37,600
and secondly of course the standard

586
00:19:41,430 --> 00:19:39,600
stuff like what viking attempted

587
00:19:43,270 --> 00:19:41,440
assessing metabolic activity the

588
00:19:44,070 --> 00:19:43,280

potential for reproduction and all of

589
00:19:46,549 --> 00:19:44,080
that

590
00:19:47,990 --> 00:19:46,559
but i shouldn't leave this topic without

591
00:19:49,430 --> 00:19:48,000
of course raising the specter of

592
00:19:51,510 --> 00:19:49,440
contamination

593
00:19:52,630 --> 00:19:51,520
there has to be an incredibly rigorous

594
00:19:55,430 --> 00:19:52,640
effort to

595
00:19:56,870 --> 00:19:55,440
define and constrain and contain

596
00:19:59,029 --> 00:19:56,880
contamination

597
00:20:01,590 --> 00:19:59,039
that's really a key challenge in this

598
00:20:04,549 --> 00:20:01,600
topic of looking for extent life

599
00:20:06,710 --> 00:20:04,559
and so just like with the past life and

600
00:20:10,230 --> 00:20:06,720
the other types of biosignatures

601
00:20:10,710 --> 00:20:10,240
we still have very similar benefits we

602
00:20:13,029 --> 00:20:10,720
can

603
00:20:15,110 --> 00:20:13,039
list for why return sample studies are

604
00:20:16,870 --> 00:20:15,120
important

605
00:20:19,669 --> 00:20:16,880
you can imagine trying to characterize

606
00:20:21,669 --> 00:20:19,679
maybe small populations of

607
00:20:24,390 --> 00:20:21,679
requires instruments and protocols that

608
00:20:27,029 --> 00:20:24,400
are very large and complex

609
00:20:28,710 --> 00:20:27,039
again a special sample handling

610
00:20:31,510 --> 00:20:28,720
especially to avoid

611
00:20:33,590 --> 00:20:31,520
contamination and then an investigation

612
00:20:35,270 --> 00:20:33,600
pathway that's discovery dependent

613
00:20:37,029 --> 00:20:35,280

we really don't know what form life

614
00:20:38,950 --> 00:20:37,039
might take whether and whether it would

615
00:20:39,830 --> 00:20:38,960
be alive or even have the ability to

616
00:20:43,350 --> 00:20:39,840
grow

617
00:20:45,430 --> 00:20:43,360
and so these questions uh pose a guide

618
00:20:47,110 --> 00:20:45,440
as to how we might design experiments we

619
00:20:50,149 --> 00:20:47,120
hadn't even thought of yet

620
00:20:52,789 --> 00:20:50,159
and that's an aspect of course of uh

621
00:20:54,149 --> 00:20:52,799
sample return missions and so with that

622
00:20:56,950 --> 00:20:54,159
i'd just like to leave you

623
00:20:57,350 --> 00:20:56,960
with uh some critical open questions and

624
00:20:59,909 --> 00:20:57,360
these

625
00:21:01,110 --> 00:20:59,919
questions course apply to all efforts in

626
00:21:03,669 --> 00:21:01,120
life detection

627
00:21:04,470 --> 00:21:03,679
beyond the earth and you know what is

628
00:21:06,630 --> 00:21:04,480
the evidence

629
00:21:08,070 --> 00:21:06,640
for that and how confident are we in the

630
00:21:09,750 --> 00:21:08,080
results

631
00:21:11,590 --> 00:21:09,760
does life on earth or elsewhere share a

632
00:21:12,870 --> 00:21:11,600
common ancestor what are the universal

633
00:21:14,630 --> 00:21:12,880
requirements of life

634
00:21:16,710 --> 00:21:14,640
that second example could really help

635
00:21:18,470 --> 00:21:16,720
with that and does life elsewhere

636
00:21:20,470 --> 00:21:18,480
perform the processes that we presume

637
00:21:22,310 --> 00:21:20,480
are necessary for all life i mean when i

638
00:21:23,430 --> 00:21:22,320

started with this basic attributes of

639
00:21:25,590 --> 00:21:23,440
lifeslide

640
00:21:27,510 --> 00:21:25,600
uh that's life as we know it okay we

641
00:21:29,590 --> 00:21:27,520
could and we need to test that with a

642
00:21:31,270 --> 00:21:29,600
second discovery and then one of the

643
00:21:33,029 --> 00:21:31,280
physiologic and metabology

644
00:21:34,789 --> 00:21:33,039
metabolic strategies are for life on

645
00:21:36,630 --> 00:21:34,799
other plants sort of another way of

646
00:21:39,830 --> 00:21:36,640
looking at the same question