Rebecca Rapf

Session 2 Warm-up Talk: Chemistry & Geology

1
00:00:16,220 --> 00:00:14,390
I always like to start with with the

2
00:00:18,140 --> 00:00:16,230
timeline for sort of where we can place

3
00:00:20,870 --> 00:00:18,150
ourselves in the context of sort of the

4
00:00:24,230 --> 00:00:20,880
early Earth and I have adapted this from

5
00:00:25,910 --> 00:00:24,240
Steven Freeland who gave a really great

6
00:00:28,550 --> 00:00:25,920
talk and who I really like this picture

7
00:00:29,690 --> 00:00:28,560
of sort of our timeline of the early

8
00:00:32,930 --> 00:00:29,700
Earth because I think it really puts

9
00:00:34,430 --> 00:00:32,940
into perspective how quickly or how far

10
00:00:35,930 --> 00:00:34,440
back in time we're talking when we talk

11
00:00:37,459 --> 00:00:35,940
about prebiotic chemistry so I'm just

12
00:00:39,380 --> 00:00:37,469
gonna walk through this really quickly

13
00:00:42,259 --> 00:00:39,390

the disclaimer being I am a chemist I'm

14
00:00:47,860 --> 00:00:42,269
not a geologist but I'll do my best

15
00:00:51,110 --> 00:00:47,870
so we've got the we've got the various

16
00:00:52,970 --> 00:00:51,120
geologic time scales here and so if we

17
00:00:56,809 --> 00:00:52,980
just add in a few things here we've got

18
00:01:00,290 --> 00:00:56,819
the extinction of the dinosaurs right up

19
00:01:03,200 --> 00:01:00,300
here so very close to today the Cambrian

20
00:01:06,140 --> 00:01:03,210
explosion is right about here and then

21
00:01:09,230 --> 00:01:06,150
our very early earliest multicellular

22
00:01:13,450 --> 00:01:09,240
fossils are just right here at I think

23
00:01:16,670 --> 00:01:13,460
about 73 no I'm not gonna say a number

24
00:01:18,920 --> 00:01:16,680
early it's multicellular fossils are

25
00:01:21,170 --> 00:01:18,930
right about here and then sort of so

26
00:01:24,110 --> 00:01:21,180
that's all very very recent in terms of

27
00:01:26,900 --> 00:01:24,120
the timescales that most of us are

28
00:01:28,340 --> 00:01:26,910
thinking about in terms of I think this

29
00:01:29,870 --> 00:01:28,350
afternoon we're transitioning a little

30
00:01:32,960 --> 00:01:29,880
bit more into sort of prebiotic

31
00:01:34,910 --> 00:01:32,970
chemistry and that kind of thing and so

32
00:01:37,670 --> 00:01:34,920
if we continue sort of walking back in

33
00:01:42,260 --> 00:01:37,680
time we've got this great oxidation or

34
00:01:45,200 --> 00:01:42,270
great Oxana auxin oxygenation event and

35
00:01:46,850 --> 00:01:45,210
obviously the exact placement of this

36
00:01:48,290 --> 00:01:46,860
and where all of that happened and

37
00:01:51,170 --> 00:01:48,300
whether there were whiffs of oxygen a

38
00:01:52,580 --> 00:01:51,180

little earlier all comes into play but

39
00:01:56,180 --> 00:01:52,590
we really didn't have much in the way of

40
00:01:59,570 --> 00:01:56,190
oxygen in the atmosphere until about 2.4

41
00:02:02,810 --> 00:01:59,580
billion years ago and keeping going back

42
00:02:05,450 --> 00:02:02,820
at about 3.5 billion years ago we had

43
00:02:07,580 --> 00:02:05,460
our oldest micro fossils so that's our

44
00:02:10,460 --> 00:02:07,590
oldest sort of direct evidence for life

45
00:02:12,530 --> 00:02:10,470
and then we've got indirect evidence

46
00:02:14,360 --> 00:02:12,540
for life that stretches back to

47
00:02:17,240 --> 00:02:14,370
depending on who you talk to and

48
00:02:20,030 --> 00:02:17,250
depending on who you believe about 3.8

49
00:02:25,130 --> 00:02:20,040
to maybe even four or 4.1 billion years

50
00:02:27,890 --> 00:02:25,140
ago I have no particular opinions on

51
00:02:30,410 --> 00:02:27,900
that but there are various timelines for

52
00:02:32,660 --> 00:02:30,420
that and then we also have this period

53
00:02:35,180 --> 00:02:32,670
of the late heavy bombardment although

54
00:02:38,480 --> 00:02:35,190
again I believe that is also somewhat up

55
00:02:40,220 --> 00:02:38,490
for the extent and how heavy the late

56
00:02:43,810 --> 00:02:40,230
heavy bombardment is is also right

57
00:02:45,860 --> 00:02:43,820
around 3.9 or 4 billion years ago and

58
00:02:47,390 --> 00:02:45,870
when we're really thinking about

59
00:02:49,190 --> 00:02:47,400
prebiotic chemistry we're really

60
00:02:50,690 --> 00:02:49,200
thinking about this time obviously

61
00:02:52,550 --> 00:02:50,700
before there was life right we have to

62
00:02:54,199 --> 00:02:52,560
have chemistry happening before there's

63
00:02:56,180 --> 00:02:54,209

life for it to be prebiotic chemistry

64
00:02:57,530 --> 00:02:56,190
and part of the reason why I think

65
00:03:01,010 --> 00:02:57,540
prebiotic chemistry is such an

66
00:03:04,220 --> 00:03:01,020
interesting field is because it's really

67
00:03:05,780 --> 00:03:04,230
the place where we have very little in

68
00:03:08,240 --> 00:03:05,790
the way of geology that's sort of

69
00:03:10,760 --> 00:03:08,250
shaping our understanding of what the

70
00:03:12,770 --> 00:03:10,770
constraints were because with plate

71
00:03:14,930 --> 00:03:12,780
tectonics and everything we've recycled

72
00:03:17,840 --> 00:03:14,940
a lot of the material that was present

73
00:03:19,580 --> 00:03:17,850
on the early earth and so right around

74
00:03:22,220 --> 00:03:19,590
this time period right around when we

75
00:03:24,229 --> 00:03:22,230
think life was kicking off we really run

76
00:03:26,750 --> 00:03:24,239
out of any constraints you know we don't

77
00:03:29,949 --> 00:03:26,760
really have much in the way of a rock

78
00:03:32,540 --> 00:03:29,959
record and so it's really hard to know

79
00:03:34,790 --> 00:03:32,550
what the constraints were and everything

80
00:03:36,770 --> 00:03:34,800
and and even if you like your you know

81
00:03:38,690 --> 00:03:36,780
detrital zircons and things like that

82
00:03:40,520 --> 00:03:38,700
they're these tiny little micro things

83
00:03:43,160 --> 00:03:40,530
and we're extrapolating an entire

84
00:03:45,949 --> 00:03:43,170
planets conditions from a very small

85
00:03:47,810 --> 00:03:45,959
microscopic thing and that's great it's

86
00:03:49,850 --> 00:03:47,820
the evidence that we have but it's I

87
00:03:52,580 --> 00:03:49,860
mean given the diversity of environments

88
00:03:55,160 --> 00:03:52,590

that exist on earth today to the extent

89
00:03:57,350 --> 00:03:55,170
to which you know the isotopic evidence

90
00:03:59,960 --> 00:03:57,360
of a small zircon can really be used to

91
00:04:01,699 --> 00:03:59,970
extrapolate the plat planet conditions

92
00:04:03,740 --> 00:04:01,709
is I think interesting and so I think

93
00:04:07,100 --> 00:04:03,750
that's what makes prebiotic chemistry

94
00:04:10,789 --> 00:04:07,110
such an interesting environment to sort

95
00:04:12,949 --> 00:04:10,799
of play around in yeah and so like I was

96
00:04:15,080 --> 00:04:12,959
saying earlier you know our era of

97
00:04:16,640 --> 00:04:15,090
prebiotic chemistry you can push it you

98
00:04:17,990 --> 00:04:16,650
know sort of whatever the dates you you

99
00:04:19,370 --> 00:04:18,000
really want to pick on or your favorite

100
00:04:21,159 --> 00:04:19,380
as far as I'm concerned you could pick

101
00:04:22,840 --> 00:04:21,169
them

102
00:04:24,310 --> 00:04:22,850
I would say that especially given you

103
00:04:26,050 --> 00:04:24,320
know the lack of the rock record and the

104
00:04:27,640 --> 00:04:26,060
lack of some of those things that a lot

105
00:04:29,890 --> 00:04:27,650
of those conditions are not particularly

106
00:04:33,220 --> 00:04:29,900
well constrained and so we're gonna have

107
00:04:35,800 --> 00:04:33,230
a couple talks that I'm broadly putting

108
00:04:37,060 --> 00:04:35,810
a sort of what was there or what could

109
00:04:39,640 --> 00:04:37,070
be there and so here we're thinking

110
00:04:41,260 --> 00:04:39,650
about what would be a possible bio

111
00:04:42,850 --> 00:04:41,270
signature so Maria is going to be

112
00:04:45,040 --> 00:04:42,860
talking about that in terms of sort of

113
00:04:47,890 --> 00:04:45,050

what are some of the analyses of pyrite

114
00:04:49,540 --> 00:04:47,900
that we could look at to sort of maybe

115
00:04:51,310 --> 00:04:49,550
have bio signatures maybe not exactly

116
00:04:52,930 --> 00:04:51,320
for the early Earth but thinking you

117
00:04:55,180 --> 00:04:52,940
know beyond that what can we take away

118
00:04:56,860 --> 00:04:55,190
from what we know here and then Chris is

119
00:04:59,020 --> 00:04:56,870
going to be talking about well how do we

120
00:05:01,120 --> 00:04:59,030
how maybe can we tell what the pH

121
00:05:03,480 --> 00:05:01,130
conditions were like and what where are

122
00:05:06,670 --> 00:05:03,490
those proxies valid and things like that

123
00:05:08,050 --> 00:05:06,680
and then again I'm chemists so I like to

124
00:05:09,879 --> 00:05:08,060
think about it and I think you know in

125
00:05:11,890 --> 00:05:09,889
its simplest case that chemical

126
00:05:15,219 --> 00:05:11,900
evolution is broadly speaking the

127
00:05:17,800 --> 00:05:15,229
journey from simple to complex and it's

128
00:05:21,129 --> 00:05:17,810
not a simple arrow but you know we have

129
00:05:22,629 --> 00:05:21,139
to present it somehow and so I think one

130
00:05:25,390 --> 00:05:22,639
of the things that's really important is

131
00:05:27,010 --> 00:05:25,400
when we say the word complex we really

132
00:05:30,550 --> 00:05:27,020
have to know what we mean by complex

133
00:05:31,930 --> 00:05:30,560
right and and maybe it's semantics but I

134
00:05:33,790 --> 00:05:31,940
think it's kind of funny so we heard a

135
00:05:35,890 --> 00:05:33,800
lot this morning about how in

136
00:05:37,990 --> 00:05:35,900
astrochemistry something complex is

137
00:05:40,360 --> 00:05:38,000
anything with greater than six carbons

138
00:05:42,340 --> 00:05:40,370

and that's great but I will remind you

139
00:05:44,770 --> 00:05:42,350
that the astronomers periodic chart is

140
00:05:46,750 --> 00:05:44,780
hydrogen helium and a whole bunch of

141
00:05:51,370 --> 00:05:46,760
metals so this afternoon we're going to

142
00:05:53,920 --> 00:05:51,380
be working in a slightly more in a

143
00:05:57,400 --> 00:05:53,930
slightly more complex region of

144
00:05:59,200 --> 00:05:57,410
complexity and to do that when

145
00:06:00,969 --> 00:05:59,210
especially as we start to get into

146
00:06:03,460 --> 00:06:00,979
bigger molecules and this is a warm-up

147
00:06:06,909 --> 00:06:03,470
talk and so I apologize to those in the

148
00:06:09,520 --> 00:06:06,919
room for whom this is not new but it's

149
00:06:11,200 --> 00:06:09,530
always good to remember our skeleton

150
00:06:13,360 --> 00:06:11,210
structures on how to speak chemistry

151
00:06:15,760 --> 00:06:13,370
especially as we get to these bigger

152
00:06:18,159 --> 00:06:15,770
molecules and so chemists really like

153
00:06:20,140 --> 00:06:18,169
skeletal structures like this and so

154
00:06:23,140 --> 00:06:20,150
this is one hexene you might also see it

155
00:06:24,580 --> 00:06:23,150
as c6 h-12 and you know you're gonna see

156
00:06:27,580 --> 00:06:24,590
a lot of molecules like this that kind

157
00:06:30,520 --> 00:06:27,590
of look like little snakes and just to

158
00:06:32,070 --> 00:06:30,530
translate for those of you who organic

159
00:06:33,140 --> 00:06:32,080
chemistry was a really long time ago

160
00:06:35,570 --> 00:06:33,150
what

161
00:06:38,210 --> 00:06:35,580
we represent molecules like this the

162
00:06:41,210 --> 00:06:38,220
little edges here the corners are a

163
00:06:43,130 --> 00:06:41,220

carbon and we just redact the hydrogen's

164
00:06:44,570 --> 00:06:43,140
so if we were to draw it all out we've

165
00:06:46,310 --> 00:06:44,580
got a whole bunch of carbons we've got

166
00:06:48,680 --> 00:06:46,320
six carbons and then we've got all of

167
00:06:50,690 --> 00:06:48,690
these dangling hydrogen's off of here so

168
00:06:53,540 --> 00:06:50,700
if you're just seeing this guy or any

169
00:06:55,040 --> 00:06:53,550
skeleton structure that's like it just

170
00:06:57,350 --> 00:06:55,050
remember that all the hydrogen's exist

171
00:06:59,840 --> 00:06:57,360
there too and the carbons are just in

172
00:07:01,880 --> 00:06:59,850
there and I simplification but I always

173
00:07:03,110 --> 00:07:01,890
think it's it's good to know what we're

174
00:07:06,650 --> 00:07:03,120
looking at because not everybody speaks

175
00:07:07,850 --> 00:07:06,660
exactly the same language also in terms

176
00:07:09,620 --> 00:07:07,860
of speaking chemistry we're gonna be

177
00:07:11,810 --> 00:07:09,630
talking a lot about molecules and so

178
00:07:13,460 --> 00:07:11,820
here this is pyruvic acid which is a

179
00:07:15,050 --> 00:07:13,470
molecule that is near to it near and

180
00:07:16,730 --> 00:07:15,060
dear to my heart a lot of you will know

181
00:07:18,740 --> 00:07:16,740
it as pyruvate which is the deprotonated

182
00:07:22,370 --> 00:07:18,750
form and when we're thinking about

183
00:07:24,290 --> 00:07:22,380
something that's acidic when we raise it

184
00:07:26,030 --> 00:07:24,300
in two basic conditions we lose a

185
00:07:27,380 --> 00:07:26,040
hydrogen and we D protonate the

186
00:07:29,330 --> 00:07:27,390
molecules so you're probably gonna hear

187
00:07:31,040 --> 00:07:29,340
words like protonate and d protonate I

188
00:07:33,650 --> 00:07:31,050

just point this out because I gave an

189
00:07:35,330 --> 00:07:33,660
hour grad cotton talked once and like at

190
00:07:37,700 --> 00:07:35,340
dinner two days later they were like

191
00:07:39,500 --> 00:07:37,710
great but what does deprotonate mean so

192
00:07:42,230 --> 00:07:39,510
I just want to you know make sure we're

193
00:07:43,790 --> 00:07:42,240
talking the same language and also we

194
00:07:45,020 --> 00:07:43,800
can have things like when we take this

195
00:07:47,570 --> 00:07:45,030
molecule and we dissolve it in water

196
00:07:49,400 --> 00:07:47,580
things can happen where we can add a

197
00:07:51,260 --> 00:07:49,410
water molecule we can hydrate the

198
00:07:54,020 --> 00:07:51,270
molecule and we get a whole bunch of

199
00:07:56,990 --> 00:07:54,030
different structures that can occur and

200
00:07:59,540 --> 00:07:57,000
so this is just you know various things

201
00:08:02,000 --> 00:07:59,550
pH dependent it's basically how

202
00:08:03,710 --> 00:08:02,010
protonated or deprotonated something is

203
00:08:06,140 --> 00:08:03,720
in different chemistry occurs under

204
00:08:09,470 --> 00:08:06,150
those conditions and so that's sort of

205
00:08:11,330 --> 00:08:09,480
our basic chemistry interlude and then

206
00:08:13,250 --> 00:08:11,340
we can start to think about the

207
00:08:15,170 --> 00:08:13,260
different types of complexity so like I

208
00:08:18,260 --> 00:08:15,180
said we're moving beyond the six carbons

209
00:08:19,640 --> 00:08:18,270
as our definition of complexity and I

210
00:08:21,110 --> 00:08:19,650
like to divide it into a couple

211
00:08:23,690 --> 00:08:21,120
different types so I think there's

212
00:08:26,120 --> 00:08:23,700
molecular complexity it's sort of how

213
00:08:29,000 --> 00:08:26,130

you go from a simple molecule like your

214
00:08:32,450 --> 00:08:29,010
fatty acids or your single amino acids

215
00:08:35,420 --> 00:08:32,460
and form covalent bonds to form peptides

216
00:08:37,760 --> 00:08:35,430
and to form you know phospholipids and

217
00:08:39,920 --> 00:08:37,770
the the useful molecules of biology and

218
00:08:41,270 --> 00:08:39,930
so what environments do we need to do

219
00:08:43,130 --> 00:08:41,280
that and specifically how do we do that

220
00:08:46,050 --> 00:08:43,140
without biology so Amy is going to be

221
00:08:49,910 --> 00:08:46,060
telling us about one possible way of

222
00:08:52,470 --> 00:08:49,920
tied formation which is by delivery from

223
00:08:55,500 --> 00:08:52,480
exogenous sources rather than happening

224
00:08:57,360 --> 00:08:55,510
on the earth itself

225
00:08:59,670 --> 00:08:57,370
so there's molecular complexity there's

226
00:09:02,519 --> 00:08:59,680
also chemical complexity that got messed

227
00:09:05,130 --> 00:09:02,529
up where we've just got a whole bunch of

228
00:09:06,900 --> 00:09:05,140
mixtures of species right so we're not

229
00:09:08,610 --> 00:09:06,910
necessarily saying something about the

230
00:09:09,960 --> 00:09:08,620
nature of the molecules themselves but

231
00:09:12,810 --> 00:09:09,970
that there are these mixtures and

232
00:09:14,370 --> 00:09:12,820
there's a lot of work recently on messy

233
00:09:15,900 --> 00:09:14,380
chemistry and what are the interesting

234
00:09:19,079 --> 00:09:15,910
and emergent properties that can happen

235
00:09:21,090 --> 00:09:19,089
with messy chemistry itself but also

236
00:09:24,090 --> 00:09:21,100
sometimes having this big mixture is

237
00:09:26,490 --> 00:09:24,100
detrimental and so John is going to be

238
00:09:28,740 --> 00:09:26,500

talking about sort of what are the ways

239
00:09:30,480 --> 00:09:28,750
that we can emerge like that

240
00:09:33,360 --> 00:09:30,490
chiral asymmetry and things like that

241
00:09:35,280 --> 00:09:33,370
can emerge as we're transitioning from

242
00:09:37,350 --> 00:09:35,290
non-life to life and sort of how do we

243
00:09:39,120 --> 00:09:37,360
maybe not that everybody would agree you

244
00:09:41,490 --> 00:09:39,130
need to escape but at some point escape

245
00:09:44,490 --> 00:09:41,500
this sort of messy chemical complexity

246
00:09:46,530 --> 00:09:44,500
which is just a mixture of species and

247
00:09:48,720 --> 00:09:46,540
then of course there's supra molecular

248
00:09:51,120 --> 00:09:48,730
complexity which is sort of how do we

249
00:09:53,490 --> 00:09:51,130
think about the larger 3d organization

250
00:09:56,190 --> 00:09:53,500
of molecules and sort of getting towards

251
00:09:57,540 --> 00:09:56,200
functionality so there's molecules that

252
00:09:59,250 --> 00:09:57,550
are coming together and they're

253
00:10:00,630 --> 00:09:59,260
organizing themselves into

254
00:10:04,230 --> 00:10:00,640
three-dimensional structures so a

255
00:10:05,040 --> 00:10:04,240
protein folding or the double helix or

256
00:10:07,740 --> 00:10:05,050
something like that

257
00:10:09,990 --> 00:10:07,750
there's also having a coordination

258
00:10:11,700 --> 00:10:10,000
between two different molecules that are

259
00:10:14,220 --> 00:10:11,710
complexing with each other

260
00:10:15,450 --> 00:10:14,230
there's putting things inside of

261
00:10:16,770 --> 00:10:15,460
compartments what is the role of

262
00:10:18,780 --> 00:10:16,780
confinement and where does that

263
00:10:21,210 --> 00:10:18,790

self-assembly occur and how do you get

264
00:10:23,400 --> 00:10:21,220
vesicles and all that kind of stuff and

265
00:10:25,860 --> 00:10:23,410
we're going to have three really nice

266
00:10:27,930 --> 00:10:25,870
talks on sort of that aspect of super

267
00:10:29,310 --> 00:10:27,940
molecular complexity we're going to be

268
00:10:31,020 --> 00:10:29,320
thinking about sort of the assembly and

269
00:10:33,360 --> 00:10:31,030
the coordination Krishnas going to be

270
00:10:35,640 --> 00:10:33,370
telling us about how Co a might be

271
00:10:37,140 --> 00:10:35,650
linked with RNA we're also going to be

272
00:10:38,910 --> 00:10:37,150
thinking again about self assembling and

273
00:10:40,470 --> 00:10:38,920
compartmentalization with Toni

274
00:10:42,390 --> 00:10:40,480
who's going to be telling us about these

275
00:10:45,750 --> 00:10:42,400
micro droplet compartments and how those

276
00:10:47,579 --> 00:10:45,760
might emerge from a mixture and we're

277
00:10:49,440 --> 00:10:47,589
also going to be talking about binding

278
00:10:52,350 --> 00:10:49,450
and functionality and sort of how

279
00:10:54,260 --> 00:10:52,360
proteins and things can bind metals to

280
00:10:57,030 --> 00:10:54,270
maybe ultimately get to functional

281
00:10:59,880 --> 00:10:57,040
biomolecules

282
00:11:01,710 --> 00:10:59,890
and then I always like to point out as

283
00:11:03,690 --> 00:11:01,720
you're going from simple to complex you

284
00:11:04,860 --> 00:11:03,700
also have to think about there are all

285
00:11:07,860 --> 00:11:04,870
the forces that are driving you

286
00:11:10,620 --> 00:11:07,870
backwards and so it's not a simple

287
00:11:12,150 --> 00:11:10,630
matter of pushing in a straight line

288
00:11:14,580 --> 00:11:12,160

towards complexity I think it's really

289
00:11:17,370 --> 00:11:14,590
easy with any sort of evolutionary

290
00:11:19,410 --> 00:11:17,380
perspective to think of it as a straight

291
00:11:20,970 --> 00:11:19,420
line and just to complexity but you also

292
00:11:23,570 --> 00:11:20,980
have to be in a condition where the back

293
00:11:26,490 --> 00:11:23,580
reaction is less favorable than the

294
00:11:30,990 --> 00:11:26,500
forward reaction and so that's the thing

295
00:11:33,450 --> 00:11:31,000
to keep in mind as well and sort of when

296
00:11:35,310 --> 00:11:33,460
we're thinking about this we need input

297
00:11:37,770 --> 00:11:35,320
of energy or something that's driving us

298
00:11:39,570 --> 00:11:37,780
to maintain these out of equilibrium

299
00:11:41,720 --> 00:11:39,580
structures you know life is sort of

300
00:11:45,360 --> 00:11:41,730
inherently out of equilibrium as soon as

301
00:11:47,520 --> 00:11:45,370
as soon as we become part of equilibrium

302
00:11:49,710 --> 00:11:47,530
that means that we're dead right we are

303
00:11:52,380 --> 00:11:49,720
no longer living and so we need this

304
00:11:54,960 --> 00:11:52,390
input of energy and how are we sustained

305
00:11:56,310 --> 00:11:54,970
of equilibria systems so you could have

306
00:11:58,620 --> 00:11:56,320
an input and energy in terms of

307
00:12:00,150 --> 00:11:58,630
photochemistry you can do wet/dry cycles

308
00:12:02,190 --> 00:12:00,160
there are any number of ways of getting

309
00:12:04,050 --> 00:12:02,200
there but I think it's really important

310
00:12:07,730 --> 00:12:04,060
to not forget that they're always back

311
00:12:09,690 --> 00:12:07,740
reactions driving us backwards and so

312
00:12:12,180 --> 00:12:09,700
and then the other thing is just that

313
00:12:13,560 --> 00:12:12,190

the environment and the conditions of

314
00:12:15,630 --> 00:12:13,570
the chemistry I think are really

315
00:12:18,750 --> 00:12:15,640
important and I think the fundamental

316
00:12:20,760 --> 00:12:18,760
chemical constraints are really also

317
00:12:23,910 --> 00:12:20,770
driven by what environments they find

318
00:12:26,670 --> 00:12:23,920
themselves in and so with that we're

319
00:12:31,940 --> 00:12:26,680
gonna move on and happy to welcome John