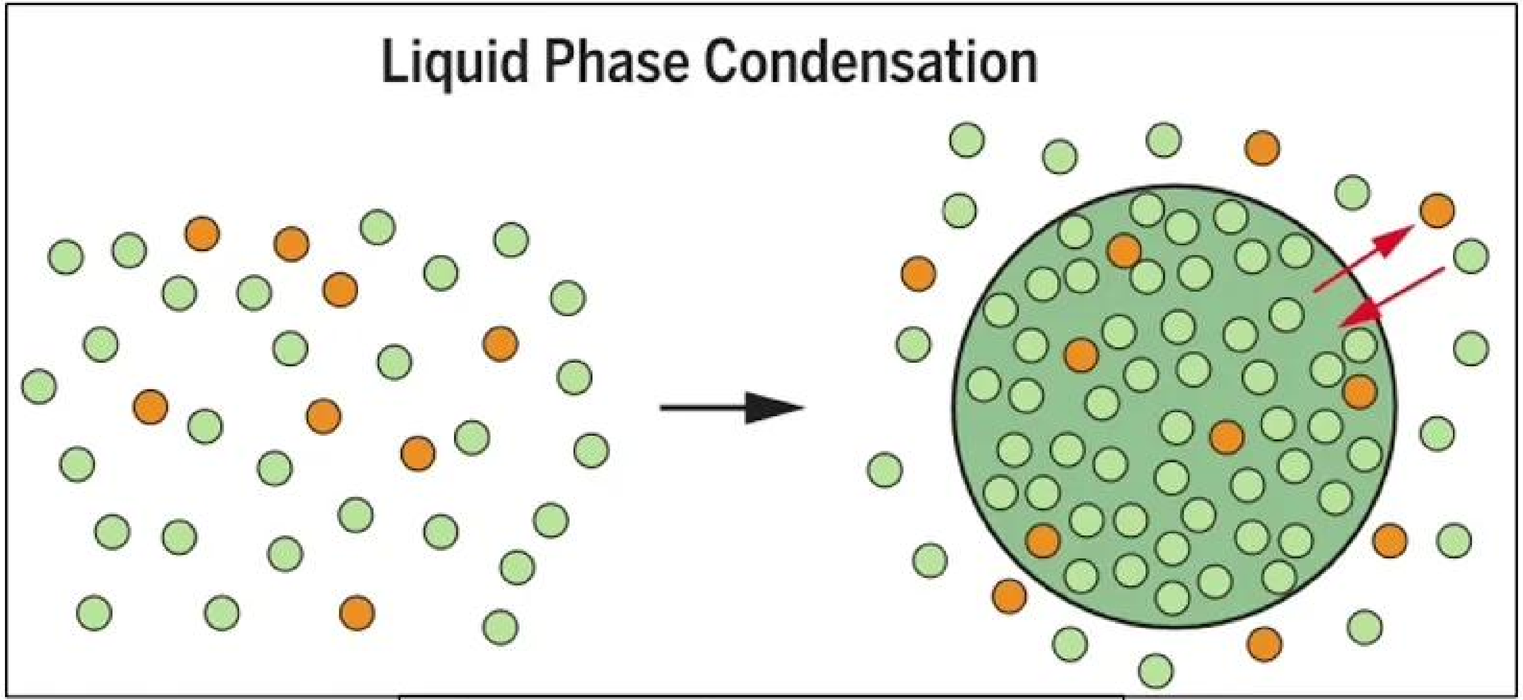
# Compartmentalization is essential for prebiotic chemistry




Shin *et al.*, *Science* **357**, 1253 (2017)

1
00:00:04,630 --> 00:00:03,110
hello my name is ella mullikin and i'm a

2
00:00:06,710 --> 00:00:04,640
graduate student at penn state

3
00:00:08,230 --> 00:00:06,720
university in the united states

4
00:00:10,150 --> 00:00:08,240
the work i'm going to describe to you

5
00:00:11,270 --> 00:00:10,160
today concerns the possibility of the

6
00:00:13,190 --> 00:00:11,280
origin of life

7
00:00:14,390 --> 00:00:13,200
at hydrothermal events involving metal

8
00:00:16,310 --> 00:00:14,400
sulfide catalysts

9
00:00:19,029 --> 00:00:16,320
as well as coastal droplets which may

10
00:00:20,390 --> 00:00:19,039
act as prebiotic compartments

11
00:00:21,710 --> 00:00:20,400
the premise for this idea is the

12
00:00:23,429 --> 00:00:21,720
well-accepted concept that

13
00:00:25,109 --> 00:00:23,439

compartmentalization is essential for

14
00:00:27,189 --> 00:00:25,119
prebiotic chemistry

15
00:00:29,029 --> 00:00:27,199
in general increasing the concentration

16
00:00:31,189 --> 00:00:29,039
of chemical reactants will increase

17
00:00:32,590 --> 00:00:31,199
reaction kinetics and speed up the rate

18
00:00:34,150 --> 00:00:32,600
of reaction

19
00:00:35,670 --> 00:00:34,160
compartmentalization is a way of

20
00:00:37,270 --> 00:00:35,680
decreasing volume and therefore

21
00:00:38,950 --> 00:00:37,280
increasing concentration

22
00:00:41,510 --> 00:00:38,960
making reactions between probiotic

23
00:00:43,590 --> 00:00:41,520
precursors for example more likely

24
00:00:45,670 --> 00:00:43,600
liquid liquid phase separation or liquid

25
00:00:47,670 --> 00:00:45,680
phase condensation is one way of forming

26
00:00:49,590 --> 00:00:47,680
a compartment

27
00:00:51,510 --> 00:00:49,600
if prebiotic precursors are dispersed

28
00:00:52,709 --> 00:00:51,520
throughout the entire early earth ocean

29
00:00:54,229 --> 00:00:52,719
it would be much too dilute for

30
00:00:55,350 --> 00:00:54,239
biochemistry-like reactions to be

31
00:00:57,029 --> 00:00:55,360
feasible

32
00:00:59,029 --> 00:00:57,039
on the other hand compartments like

33
00:01:01,110 --> 00:00:59,039
coastervates could sequester prebiotic

34
00:01:05,109 --> 00:01:01,120
molecules and gather a small volume

35
00:01:09,030 --> 00:01:06,870
the coastal rates that i'm interested in

36
00:01:10,390 --> 00:01:09,040
specifically are associative or complex

37
00:01:12,230 --> 00:01:10,400
coaster rates

38
00:01:13,830 --> 00:01:12,240

meaning that the constituents associate

39
00:01:14,870 --> 00:01:13,840
with each other through electrostatic

40
00:01:16,710 --> 00:01:14,880
interactions

41
00:01:19,830 --> 00:01:16,720
and form a dense polyelectrolyte rich

42
00:01:21,830 --> 00:01:19,840
phase within a dilute aqueous phase

43
00:01:23,590 --> 00:01:21,840
due to the release of counter ions when

44
00:01:24,950 --> 00:01:23,600
the two polyelectrolytes come together

45
00:01:27,030 --> 00:01:24,960
to form a complex

46
00:01:28,710 --> 00:01:27,040
this process is entropy driven and

47
00:01:30,469 --> 00:01:28,720
occurs spontaneously under the right

48
00:01:34,870 --> 00:01:30,479
conditions including ph

49
00:01:38,710 --> 00:01:36,630
coastervates were first proposed as a

50
00:01:40,550 --> 00:01:38,720
player in the origins of life by oparin

51
00:01:42,550 --> 00:01:40,560
in the early 20th century

52
00:01:44,069 --> 00:01:42,560
aparra noted the ability of coastervase

53
00:01:45,590 --> 00:01:44,079
to sequester molecules

54
00:01:47,749 --> 00:01:45,600
which could then undergo reactions

55
00:01:51,030 --> 00:01:47,759
within the corrosivate and the ability

56
00:01:52,950 --> 00:01:51,040
of coastervates to increase in size

57
00:01:54,950 --> 00:01:52,960
he compared these metabolism and

58
00:01:56,230 --> 00:01:54,960
growth-like properties to the protoplasm

59
00:01:58,069 --> 00:01:56,240
of modern cells

60
00:01:59,749 --> 00:01:58,079
which is not a very good comparison and

61
00:02:01,350 --> 00:01:59,759
caused the idea of coaster rates in

62
00:02:03,990 --> 00:02:01,360
origins of life scenarios

63
00:02:05,590 --> 00:02:04,000

to be discarded for a while however we

64
00:02:07,429 --> 00:02:05,600
now know that while coaster bates are

65
00:02:09,109 --> 00:02:07,439
not similar to salt protoplasm

66
00:02:11,910 --> 00:02:09,119
they are similar to biomolecular

67
00:02:13,830 --> 00:02:11,920
condensates or membraneless organelles

68
00:02:15,350 --> 00:02:13,840
also there are features of corrosivates

69
00:02:17,430 --> 00:02:15,360
which make them worthwhile to consider

70
00:02:19,190 --> 00:02:17,440
as players in the origins of life

71
00:02:20,390 --> 00:02:19,200
including varying behavior in different

72
00:02:22,710 --> 00:02:20,400
environmental conditions like

73
00:02:25,110 --> 00:02:22,720
temperature or salt concentration

74
00:02:27,110 --> 00:02:25,120
sequestration of biomolecules and the

75
00:02:29,030 --> 00:02:27,120
ability to harness natural gradients and

76
00:02:31,910 --> 00:02:29,040
act as reaction and organizational

77
00:02:34,869 --> 00:02:33,270
now we will return to the environment

78
00:02:36,229 --> 00:02:34,879
that this project is focused on which is

79
00:02:38,070 --> 00:02:36,239
hydrothermal vents

80
00:02:39,830 --> 00:02:38,080
the images here are from the lost city

81
00:02:41,270 --> 00:02:39,840
vents which have moderate temperatures

82
00:02:42,229 --> 00:02:41,280
compared to white smoker and black

83
00:02:43,589 --> 00:02:42,239
smoker vents

84
00:02:46,150 --> 00:02:43,599
which get up to hundreds of degrees

85
00:02:48,309 --> 00:02:46,160
celsius the reason the lost city vents

86
00:02:49,990 --> 00:02:48,319
are cooler is because they're off axis

87
00:02:52,229 --> 00:02:50,000
so the vent fluid does not come into

88
00:02:53,990 --> 00:02:52,239

direct contact with magma

89
00:02:55,270 --> 00:02:54,000
in contrast to black smoke events which

90
00:02:58,070 --> 00:02:55,280
have acidic effluent

91
00:02:59,750 --> 00:02:58,080
losses events are alkaline finally the

92
00:03:00,470 --> 00:02:59,760
mineral composition of the chimneys is

93
00:03:02,550 --> 00:03:00,480
different

94
00:03:05,270 --> 00:03:02,560
with velocity events being ultramafic

95
00:03:07,430 --> 00:03:05,280
and mostly magnesium and iron olivine

96
00:03:09,430 --> 00:03:07,440
these minerals undergo serpentinization

97
00:03:11,589 --> 00:03:09,440
and produce hydrogen gas

98
00:03:14,070 --> 00:03:11,599
in contrast to the vent fluid the early

99
00:03:17,670 --> 00:03:14,080
earth ocean was cool and slightly acidic

100
00:03:19,509 --> 00:03:17,680
containing dissolved co2 and metal ions

101
00:03:21,589 --> 00:03:19,519
one important feature of black smoker

102
00:03:23,589 --> 00:03:21,599
vents in particular is that they contain

103
00:03:25,670 --> 00:03:23,599
hydrogen sulfide in vent fluid

104
00:03:26,869 --> 00:03:25,680
which can react with aqueous iron in the

105
00:03:30,229 --> 00:03:26,879
early earth ocean

106
00:03:32,229 --> 00:03:30,239
to form iron sulfide minerals

107
00:03:34,229 --> 00:03:32,239
in the late 80s vectors housing proposed

108
00:03:35,509 --> 00:03:34,239
an iron sulfur world hypothesis of the

109
00:03:37,830 --> 00:03:35,519
origins of life

110
00:03:38,710 --> 00:03:37,840
where pyrite minerals catalyze prebiotic

111
00:03:40,869 --> 00:03:38,720
reactions

112
00:03:43,910 --> 00:03:40,879
and allow early biomolecules to arrange

113
00:03:45,509 --> 00:03:43,920

and associate on the mineral surfaces

114
00:03:46,949 --> 00:03:45,519
the other feature of hydrothermal vent

115
00:03:48,309 --> 00:03:46,959
chimneys that is interesting for this

116
00:03:50,789 --> 00:03:48,319
project is pores

117
00:03:52,710 --> 00:03:50,799
which you can see in this image and they

118
00:03:54,229 --> 00:03:52,720
can be tens or hundreds of microns in

119
00:03:56,070 --> 00:03:54,239
diameter

120
00:03:57,589 --> 00:03:56,080
these pores can facilitate reactions

121
00:03:59,509 --> 00:03:57,599
within small volumes

122
00:04:01,429 --> 00:03:59,519
which mix through diffusion rather than

123
00:04:02,390 --> 00:04:01,439
turbulent mixing due to the geometry of

124
00:04:04,229 --> 00:04:02,400
the pores

125
00:04:06,309 --> 00:04:04,239
and due to this also a large amount of

126
00:04:08,149 --> 00:04:06,319
the fluid is in close proximity to the

127
00:04:11,190 --> 00:04:08,159
minerals that make up the pore walls

128
00:04:11,830 --> 00:04:11,200
and may catalyze reactions because of

129
00:04:13,350 --> 00:04:11,840
the ph

130
00:04:15,509 --> 00:04:13,360
temperature and solute differences

131
00:04:17,670 --> 00:04:15,519
between vent fluid and ocean fluid

132
00:04:19,590 --> 00:04:17,680
these pores would also have ph

133
00:04:21,189 --> 00:04:19,600
temperature and chemical gradients that

134
00:04:23,189 --> 00:04:21,199
could provide energy for prebiotic

135
00:04:24,790 --> 00:04:23,199
reactions

136
00:04:27,350 --> 00:04:24,800
the different aspects of this scenario

137
00:04:28,790 --> 00:04:27,360
are represented in this small diagram

138
00:04:30,870 --> 00:04:28,800

where the acidic ocean fluid and

139
00:04:33,350 --> 00:04:30,880
alkaline vent fluid enter a microfluidic

140
00:04:35,749 --> 00:04:33,360
channel and travel with laminar flow

141
00:04:37,909 --> 00:04:35,759
reactants in the fluids undergo

142
00:04:38,710 --> 00:04:37,919
reactions catalyzed by the iron sulfur

143
00:04:40,550 --> 00:04:38,720
minerals

144
00:04:43,350 --> 00:04:40,560
and may produce polypeptides which can

145
00:04:45,189 --> 00:04:43,360
then form corrosivates within the force

146
00:04:46,310 --> 00:04:45,199
the pores have ph and temperature

147
00:04:48,710 --> 00:04:46,320
gradients due to the different

148
00:04:50,310 --> 00:04:48,720
conditions of the ocean and vent fluids

149
00:04:51,510 --> 00:04:50,320
which can further encourage reactions

150
00:04:53,909 --> 00:04:51,520
within the vent or within the

151
00:04:55,749 --> 00:04:53,919
corrosorates there

152
00:04:57,189 --> 00:04:55,759
the first aspect of this i'll focus on

153
00:04:58,310 --> 00:04:57,199
is the production of crosstalk

154
00:04:59,990 --> 00:04:58,320
components

155
00:05:01,590 --> 00:05:00,000
in order to look at the feasibility of

156
00:05:02,950 --> 00:05:01,600
producing these polypeptides in a

157
00:05:04,629 --> 00:05:02,960
hydrothermal vent setting

158
00:05:06,469 --> 00:05:04,639
we return to the iron sulfur world

159
00:05:08,310 --> 00:05:06,479
hypothesis of vector sauser

160
00:05:09,990 --> 00:05:08,320
and the iron nickel sulfide cluster

161
00:05:13,430 --> 00:05:10,000
catalyzed peptide bond formation

162
00:05:15,189 --> 00:05:13,440
mechanism shown here in the past this

163
00:05:16,950 --> 00:05:15,199

mechanism has been tested mainly with

164
00:05:18,550 --> 00:05:16,960
glycine and phenylalanine

165
00:05:20,629 --> 00:05:18,560
and starting with the simplest amino

166
00:05:23,430 --> 00:05:20,639
acid glycine we replicated the

167
00:05:25,110 --> 00:05:23,440
production of glycine dimers

168
00:05:26,629 --> 00:05:25,120
the next step is to use arginine and

169
00:05:28,629 --> 00:05:26,639
aspartic acid

170
00:05:29,909 --> 00:05:28,639
for the associative complex corrosivates

171
00:05:31,749 --> 00:05:29,919
that i'm interested in

172
00:05:33,430 --> 00:05:31,759
the constituents need to be oppositely

173
00:05:35,270 --> 00:05:33,440
charged so they will interact

174
00:05:36,870 --> 00:05:35,280
electrostatically

175
00:05:38,390 --> 00:05:36,880
commonly we work with a tender of a

176
00:05:40,790 --> 00:05:38,400
cationic amino acid

177
00:05:43,270 --> 00:05:40,800
like arginine and a tender of an anionic

178
00:05:44,550 --> 00:05:43,280
amino acid like aspartic acid

179
00:05:46,469 --> 00:05:44,560
here you can see the different charged

180
00:05:48,150 --> 00:05:46,479
states of arginine which has amine

181
00:05:50,310 --> 00:05:48,160
groups in its side chain and can have a

182
00:05:52,550 --> 00:05:50,320
maximum charge of plus two

183
00:05:54,870 --> 00:05:52,560
we work at a slightly basic ph where it

184
00:05:56,469 --> 00:05:54,880
has a single positive charge

185
00:05:58,469 --> 00:05:56,479
and then below you can see four

186
00:06:00,070 --> 00:05:58,479
different charge states of aspartic acid

187
00:06:02,629 --> 00:06:00,080
which can have at most a net charge of

188
00:06:04,870 --> 00:06:02,639

minus two but at slightly basic ph it

189
00:06:06,390 --> 00:06:04,880
has a single negative charge

190
00:06:07,909 --> 00:06:06,400
an interesting note for production of

191
00:06:09,510 --> 00:06:07,919
classified components

192
00:06:11,350 --> 00:06:09,520
is that the peptide bond formation

193
00:06:11,749 --> 00:06:11,360
mechanism that we are taking advantage

194
00:06:15,990 --> 00:06:11,759
of

195
00:06:17,670 --> 00:06:16,000
amino acid since arginine has extra

196
00:06:19,350 --> 00:06:17,680
amine groups in its side chain compared

197
00:06:21,110 --> 00:06:19,360
to something like glycine

198
00:06:23,350 --> 00:06:21,120
which only has a hydrogen instead of a

199
00:06:24,950 --> 00:06:23,360
true side chain it may be possible for

200
00:06:27,909 --> 00:06:24,960
this reaction to form branched

201
00:06:29,350 --> 00:06:27,919
peptides with arginine although this

202
00:06:31,430 --> 00:06:29,360
would be undesirable if when we're

203
00:06:32,390 --> 00:06:31,440
trying to produce biological peptides

204
00:06:34,230 --> 00:06:32,400
since we're interested in

205
00:06:35,110 --> 00:06:34,240
polyelectrolytes for coastal rate

206
00:06:39,350 --> 00:06:35,120
formation

207
00:06:42,870 --> 00:06:40,950
the next part of this research is an

208
00:06:43,749 --> 00:06:42,880
investigation into how polypeptide

209
00:06:46,629 --> 00:06:43,759
coastal rates

210
00:06:48,469 --> 00:06:46,639
and iron sulfur minerals interact these

211
00:06:50,550 --> 00:06:48,479
microscope images are of equal charge

212
00:06:51,589 --> 00:06:50,560
ratios of arginine tender and aspartic

213
00:06:54,230 --> 00:06:51,599

acid temer

214
00:06:56,309 --> 00:06:54,240
with iron sulfur mineral the salt is

215
00:06:58,230 --> 00:06:56,319
relatively high to mimic ocean fluid and

216
00:06:59,189 --> 00:06:58,240
the solutions were mixed under argon gas

217
00:07:01,749 --> 00:06:59,199
to replicate

218
00:07:02,390 --> 00:07:01,759
the anoxic conditions of early earth as

219
00:07:03,830 --> 00:07:02,400
you can see

220
00:07:06,309 --> 00:07:03,840
the minerals seem to be encompassed

221
00:07:08,150 --> 00:07:06,319
within the corrosivates

222
00:07:10,150 --> 00:07:08,160
with higher mineral concentrations this

223
00:07:10,870 --> 00:07:10,160
scenario changes so mineral structures

224
00:07:12,550 --> 00:07:10,880
dominate

225
00:07:14,150 --> 00:07:12,560
and the coast surveys associate at the

226
00:07:15,589 --> 00:07:14,160
mineral surfaces

227
00:07:17,749 --> 00:07:15,599
this is a particularly interesting

228
00:07:20,390 --> 00:07:17,759
result from the next part of the project

229
00:07:21,589 --> 00:07:20,400
which is microfluidics an important part

230
00:07:23,510 --> 00:07:21,599
of the environment that we

231
00:07:25,430 --> 00:07:23,520
envision these interactions taking place

232
00:07:26,870 --> 00:07:25,440
in is the micron scale pores of the

233
00:07:28,870 --> 00:07:26,880
hydrothermal vents

234
00:07:30,790 --> 00:07:28,880
to replicate and study this in the lab

235
00:07:32,390 --> 00:07:30,800
we are using microfluidics

236
00:07:34,870 --> 00:07:32,400
currently we use simple y-shaped

237
00:07:36,710 --> 00:07:34,880
channels from one inlet we introduce the

238
00:07:38,230 --> 00:07:36,720

acidic ocean-like fluid containing

239
00:07:40,309 --> 00:07:38,240
iron-two cations

240
00:07:42,070 --> 00:07:40,319
and the cationic coastal a constituent

241
00:07:43,749 --> 00:07:42,080
which is arginine tenomer

242
00:07:45,589 --> 00:07:43,759
and from the other inlet we introduced

243
00:07:46,950 --> 00:07:45,599
the alkaline vent like fluid containing

244
00:07:48,950 --> 00:07:46,960
sulfur anions

245
00:07:51,110 --> 00:07:48,960
and the anionic coacific constituent

246
00:07:52,710 --> 00:07:51,120
which is aspartic acid tender

247
00:07:54,710 --> 00:07:52,720
the microfluidic devices are made of

248
00:07:56,550 --> 00:07:54,720
pdms and solutions are flowed through

249
00:07:58,309 --> 00:07:56,560
using a syringe pump

250
00:08:00,309 --> 00:07:58,319
due to the fluid dynamics and micron

251
00:08:01,670 --> 00:08:00,319
scale channels there is laminar flow

252
00:08:03,270 --> 00:08:01,680
which is important for us

253
00:08:06,550 --> 00:08:03,280
because the solutions will only mix by

254
00:08:08,469 --> 00:08:06,560
diffusion rather than turbulent mixing

255
00:08:10,070 --> 00:08:08,479
because of the charge on the pms wall

256
00:08:12,629 --> 00:08:10,080
and the parabolic nature of the flow

257
00:08:14,150 --> 00:08:12,639
speeds in such a channel charged species

258
00:08:15,350 --> 00:08:14,160
will be somewhat more concentrated at

259
00:08:17,749 --> 00:08:15,360
the walls

260
00:08:19,510 --> 00:08:17,759
also as the iron and sulfur ions happen

261
00:08:20,790 --> 00:08:19,520
to meet at the fluid interface at the

262
00:08:22,790 --> 00:08:20,800
center of the channel

263
00:08:24,550 --> 00:08:22,800

a metal membrane forms at the interface

264
00:08:26,070 --> 00:08:24,560
of the two solutions

265
00:08:27,909 --> 00:08:26,080
this will also be charged and will

266
00:08:29,589 --> 00:08:27,919
divide the channel into two again

267
00:08:31,510 --> 00:08:29,599
creating two new parabolic flows and

268
00:08:33,269 --> 00:08:31,520
concentration patterns

269
00:08:36,310 --> 00:08:33,279
because of the different ph's of the two

270
00:08:37,990 --> 00:08:36,320
solutions a ph gradient should form

271
00:08:39,509 --> 00:08:38,000
to get really close to what might happen

272
00:08:41,670 --> 00:08:39,519
in hydrothermal vent pores

273
00:08:43,029 --> 00:08:41,680
i also intend to design a device with a

274
00:08:45,110 --> 00:08:43,039
temperature gradient

275
00:08:46,710 --> 00:08:45,120
where the ocean fluid is cold and the

276
00:08:48,949 --> 00:08:46,720
vent fluid is warm

277
00:08:50,949 --> 00:08:48,959
as for crossovates if the fluorescence

278
00:08:52,230 --> 00:08:50,959
microscopy results i showed earlier or

279
00:08:53,990 --> 00:08:52,240
any indication

280
00:08:56,070 --> 00:08:54,000
the coaster base should also stick to

281
00:08:58,070 --> 00:08:56,080
that membrane and become a location for

282
00:08:59,030 --> 00:08:58,080
other interesting molecules such as rna

283
00:09:02,470 --> 00:08:59,040
in solution

284
00:09:04,230 --> 00:09:02,480
to accumulate near a mineral catalyst

285
00:09:05,670 --> 00:09:04,240
currently we are working on protocols to

286
00:09:07,829 --> 00:09:05,680
keep samples anoxic

287
00:09:09,910 --> 00:09:07,839
for a study with confocal microscopy

288
00:09:11,590 --> 00:09:09,920

raman microscopy x-ray diffraction and

289
00:09:13,030 --> 00:09:11,600
scanning electron microscopy

290
00:09:14,870 --> 00:09:13,040
to understand how they classify

291
00:09:18,150 --> 00:09:14,880
constituents and minerals interact

292
00:09:19,269 --> 00:09:18,160
in micron scale channels moving forward

293
00:09:20,949 --> 00:09:19,279
with this project

294
00:09:22,870 --> 00:09:20,959
the first aim is to produce charge

295
00:09:25,350 --> 00:09:22,880
polyelectrolytes through the iron sulfur

296
00:09:27,590 --> 00:09:25,360
mineral catalyzed peptide bond formation

297
00:09:28,550 --> 00:09:27,600
particularly using arginine and aspartic

298
00:09:30,230 --> 00:09:28,560
acid

299
00:09:32,230 --> 00:09:30,240
with both bulk and microfluidic

300
00:09:33,910 --> 00:09:32,240
experiments we need to characterize the

301
00:09:35,350 --> 00:09:33,920
iron sulfide minerals that are forming

302
00:09:37,190 --> 00:09:35,360
and determine their actual surface

303
00:09:38,389 --> 00:09:37,200
properties such as charge and catalytic

304
00:09:40,070 --> 00:09:38,399
activity

305
00:09:41,910 --> 00:09:40,080
part of the difficulty of this step is

306
00:09:44,070 --> 00:09:41,920
maintaining anoxic conditions

307
00:09:46,150 --> 00:09:44,080
since iron sulfides will quickly oxidize

308
00:09:49,030 --> 00:09:46,160
to iron oxides and hydroxides

309
00:09:50,230 --> 00:09:49,040
under ambient atmospheric conditions

310
00:09:51,990 --> 00:09:50,240
knowing the surface charge of the

311
00:09:53,910 --> 00:09:52,000
mineral particles or clusters

312
00:09:55,910 --> 00:09:53,920
we can then change the charge ratios of

313
00:09:57,030 --> 00:09:55,920

the polycations and anions that make up

314
00:09:58,870 --> 00:09:57,040
the phosphates

315
00:10:00,070 --> 00:09:58,880
to manipulate how they coastavate sweat

316
00:10:02,230 --> 00:10:00,080
to the minerals

317
00:10:04,150 --> 00:10:02,240
finally in the microfluidic system we

318
00:10:06,310 --> 00:10:04,160
will introduce and monitor ph

319
00:10:08,470 --> 00:10:06,320
redox and thermal gradients to more

320
00:10:10,150 --> 00:10:08,480
closely mimic hydrothermal vent pores

321
00:10:11,750 --> 00:10:10,160
and introduce prebiotic and biotic

322
00:10:13,350 --> 00:10:11,760
molecules like rna

323
00:10:14,630 --> 00:10:13,360
to see how these conditions combined

324
00:10:15,430 --> 00:10:14,640
with the presence of cross-servate

325
00:10:18,870 --> 00:10:15,440
compartments

326
00:10:20,550 --> 00:10:18,880
can create a type of functional system

327
00:10:22,389 --> 00:10:20,560
i'd like to conclude by returning to the

328
00:10:24,069 --> 00:10:22,399
bigger picture of how corrosivates can

329
00:10:26,230 --> 00:10:24,079
be an important piece of the origins of

330
00:10:27,590 --> 00:10:26,240
life at hydrothermal vents

331
00:10:29,430 --> 00:10:27,600
their ability to respond to

332
00:10:31,269 --> 00:10:29,440
environmental conditions and sequester

333
00:10:33,110 --> 00:10:31,279
specific prebiotic molecules

334
00:10:35,430 --> 00:10:33,120
allows for something akin to a selection

335
00:10:37,910 --> 00:10:35,440
process or at least transient processes

336
00:10:39,350 --> 00:10:37,920
involving uptake and release

337
00:10:41,190 --> 00:10:39,360
by becoming enriched in biotic

338
00:10:43,190 --> 00:10:41,200

precursors and by associating and

339
00:10:43,990 --> 00:10:43,200
interacting with mineral catalysts like

340
00:10:46,310 --> 00:10:44,000
pyrite

341
00:10:47,590 --> 00:10:46,320
they can enhance reaction rates by

342
00:10:49,509 --> 00:10:47,600
associating with minerals and

343
00:10:51,110 --> 00:10:49,519
hydrothermal vents particularly

344
00:10:53,110 --> 00:10:51,120
these corrosivates could prevent the

345
00:10:54,630 --> 00:10:53,120
escape of prebiotic reaction products

346
00:10:57,750 --> 00:10:54,640
into the dilute ocean

347
00:10:59,269 --> 00:10:57,760
and also take advantage of ph redox and

348
00:11:00,550 --> 00:10:59,279
temperature gradients found in vent

349
00:11:02,310 --> 00:11:00,560
pores

350
00:11:03,990 --> 00:11:02,320
coaster vapes may well have been one

351
00:11:05,750 --> 00:11:04,000
form of an early protocell

352
00:11:08,069 --> 00:11:05,760
within a larger system of prebiotic

353
00:11:11,829 --> 00:11:08,079
chemistry co-evolving with biomolecules

354
00:11:14,630 --> 00:11:13,350
of course none of this work would be

355
00:11:16,150 --> 00:11:14,640
possible without support from the

356
00:11:17,190 --> 00:11:16,160
keating group and the house group at

357
00:11:18,790 --> 00:11:17,200
penn state

358
00:11:20,470 --> 00:11:18,800
and i particularly want to acknowledge

359
00:11:20,870 --> 00:11:20,480
seihan che and andrew hyde for their

360
00:11:23,829 --> 00:11:20,880
direct

361
00:11:25,870 --> 00:11:23,839
involvement with the work presented here