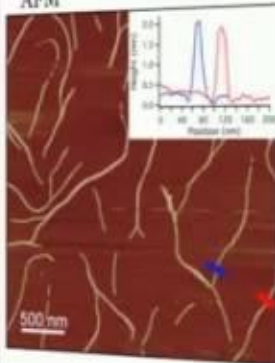


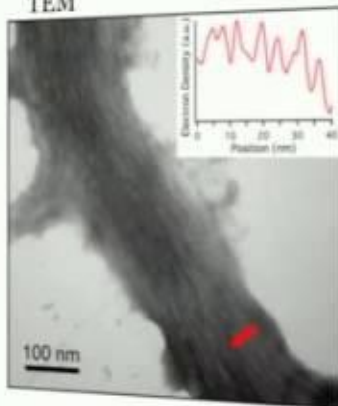
Microscopy suggests long assemblies of stacked rosettes



AFM



TEM



1
00:00:11,440 --> 00:00:10,299
assemble at the monomer level so we went

2
00:00:13,090 --> 00:00:11,450
back we looked at the different

3
00:00:14,410 --> 00:00:13,100
different building blocks these

4
00:00:17,350 --> 00:00:14,420
molecular recognition units the

5
00:00:19,660 --> 00:00:17,360
appearance of primitives and out of 27

6
00:00:21,160 --> 00:00:19,670
molecules that are purines that have

7
00:00:23,019 --> 00:00:21,170
substitution for the two six or eight

8
00:00:24,700 --> 00:00:23,029
position only one comes out and that's

9
00:00:26,139 --> 00:00:24,710
the one we just heard about wanna see an

10
00:00:27,970 --> 00:00:26,149
able to form self structures in the

11
00:00:30,639 --> 00:00:27,980
presence of ions actually that need to

12
00:00:32,830 --> 00:00:30,649
be coordinating these structures and if

13
00:00:36,010 --> 00:00:32,840

we look at all the possibilities for the

14

00:00:38,290 --> 00:00:36,020

perimeters what we have is 54 related

15

00:00:40,509 --> 00:00:38,300

molecules where we substitute at the 2 4

16

00:00:42,160 --> 00:00:40,519

5 6 positions and those are you see that

17

00:00:44,169 --> 00:00:42,170

I'm curing all Kuehl permitting molecule

18

00:00:46,419 --> 00:00:44,179

over there let's do those of the means

19

00:00:48,939 --> 00:00:46,429

carbonyl groups are hydrogen we now have

20

00:00:50,590 --> 00:00:48,949

pity for related molecules and then if

21

00:00:52,989 --> 00:00:50,600

we also include another molecule that

22

00:00:55,869 --> 00:00:52,999

comes out of many prebiotic model

23

00:00:58,389 --> 00:00:55,879

reactions and has been found on on

24

00:01:01,090 --> 00:00:58,399

molecule molecules in space coming down

25

00:01:03,610 --> 00:01:01,100

from meteorites we see that there is

26

00:01:06,340 --> 00:01:03,620

about 10 more possibilities for these

27

00:01:08,080 --> 00:01:06,350

molecules that might have been present

28

00:01:10,359 --> 00:01:08,090

in a periodic inventory that could

29

00:01:12,730 --> 00:01:10,369

potentially assemble however of these

30

00:01:15,130 --> 00:01:12,740

molecules only four of them have been

31

00:01:17,050 --> 00:01:15,140

found to assemble in organic solutions

32

00:01:18,880 --> 00:01:17,060

so this is actually sort of carrying

33

00:01:21,639 --> 00:01:18,890

over from the field of super molecular

34

00:01:23,020 --> 00:01:21,649

assembly so we wanted to see if these

35

00:01:24,219 --> 00:01:23,030

molecules which are potentially

36

00:01:27,190 --> 00:01:24,229

prebiotic and three of these haven't

37

00:01:28,330 --> 00:01:27,200

found in model reactions could present

38

00:01:33,969 --> 00:01:28,340

Lisa seem into something that's

39

00:01:36,700 --> 00:01:33,979

similar to a duplex or a polymer that

40

00:01:39,310 --> 00:01:36,710

is able to store information so choosing

41

00:01:42,130 --> 00:01:39,320

two of these try me in a primitive which

42

00:01:43,810 --> 00:01:42,140

is here and blue and cyanuric acid you

43

00:01:46,630 --> 00:01:43,820

can see that they assemble actually in

44

00:01:49,359 --> 00:01:46,640

this rosette hex at formation and what

45

00:01:51,039 --> 00:01:49,369

it should be immediately evident is that

46

00:01:51,940 --> 00:01:51,049

you see that these hydrogen bonding

47

00:01:53,469 --> 00:01:51,950

interaction these are very specific

48

00:01:54,789 --> 00:01:53,479

hydrogen bond interactions you have two

49

00:01:56,709 --> 00:01:54,799

faces instead of just the one phase

50

00:02:00,130 --> 00:01:56,719

which allows you to go into this larger

51
00:02:02,849 --> 00:02:00,140
structure and so just like watson-crick

52
00:02:04,539 --> 00:02:02,859
base pairing you have the two main

53
00:02:05,289 --> 00:02:04,549
energetic terms that are bringing these

54
00:02:07,510 --> 00:02:05,299
things together through molecular

55
00:02:10,240 --> 00:02:07,520
recognition is the hydrogen bonding and

56
00:02:12,100 --> 00:02:10,250
also the PI pi stacking to form this

57
00:02:13,600 --> 00:02:12,110
larger structure so we were asking is

58
00:02:15,850 --> 00:02:13,610
this the ancestry of watching creek base

59
00:02:17,970 --> 00:02:15,860
pair another another reason we really

60
00:02:20,980 --> 00:02:17,980
like this is because of theoretical

61
00:02:22,810 --> 00:02:20,990
investigations into sort of what is the

62
00:02:24,750 --> 00:02:22,820
minimum size you need to drive that you

63
00:02:27,100 --> 00:02:24,760

have the hydrophobic effect drive

64

00:02:29,680 --> 00:02:27,110

assemblies and this is worth it was done

65

00:02:32,440 --> 00:02:29,690

by a David Chandler and they're in the

66

00:02:34,450 --> 00:02:32,450

about that's seven eight years ago he is

67

00:02:36,370 --> 00:02:34,460

other groups of recently experimentally

68

00:02:38,650 --> 00:02:36,380

shown that you need to get up over this

69

00:02:39,700 --> 00:02:38,660

size of about one nanometer and once

70

00:02:42,430 --> 00:02:39,710

you're over that size about one

71

00:02:44,620 --> 00:02:42,440

nanometer water you can really get the

72

00:02:48,430 --> 00:02:44,630

hydrophobic effect to kick in and to

73

00:02:51,760 --> 00:02:48,440

allow for the assembly of through the

74

00:02:53,140 --> 00:02:51,770

hydrophobic effect and the heck's that

75

00:02:54,790 --> 00:02:53,150

has this you can see it's got a much

76

00:02:56,110 --> 00:02:54,800

larger surface area than it duplex but

77

00:02:58,690 --> 00:02:56,120

the duplex does not have this isn't

78

00:02:59,949 --> 00:02:58,700

cross this minimum threshold and from

79

00:03:01,750 --> 00:02:59,959

these calculations you have about thirty

80

00:03:03,850 --> 00:03:01,760

kcal per mole and that's actually a lot

81

00:03:05,530 --> 00:03:03,860

of energy for exposing that surface so

82

00:03:08,350 --> 00:03:05,540

that's why you want to bury these these

83

00:03:11,500 --> 00:03:08,360

surfaces forming very long polymers and

84

00:03:13,530 --> 00:03:11,510

I'll get to that a second so you know

85

00:03:16,660 --> 00:03:13,540

keeping this in mind we went after a

86

00:03:18,460 --> 00:03:16,670

very simple system to first brew the

87

00:03:19,810 --> 00:03:18,470

concept that the the alternative basis

88

00:03:22,240 --> 00:03:19,820

might be able to allow for the formation

89

00:03:24,370 --> 00:03:22,250

of polymers and so what we did is we

90

00:03:26,770 --> 00:03:24,380

took trimming a primitive added a

91

00:03:29,020 --> 00:03:26,780

aliphatic acid tail to it sort of blocks

92

00:03:32,620 --> 00:03:29,030

of face and what you were calling tap is

93

00:03:34,120 --> 00:03:32,630

hear the name came from my boss it was a

94

00:03:37,270 --> 00:03:34,130

way for like eight months in Barcelona

95

00:03:38,860 --> 00:03:37,280

so during that time we Calot thats not

96

00:03:41,530 --> 00:03:38,870

the actual correct I you pack name but

97

00:03:44,710 --> 00:03:41,540

it we kept to it and we kept going with

98

00:03:47,170 --> 00:03:44,720

it so each o cyanuric acid in you go

99

00:03:48,850 --> 00:03:47,180

into a rosette this hex I'd then stacks

100

00:03:49,840 --> 00:03:48,860

on top of each other and what's cool

101
00:03:51,610 --> 00:03:49,850
about this is you just throw them in

102
00:03:52,930 --> 00:03:51,620
right away any form a gel that's the

103
00:03:55,210 --> 00:03:52,940
first thing we saw we threw these both

104
00:03:57,970 --> 00:03:55,220
molecules in and spontaneously a gel

105
00:04:00,009 --> 00:03:57,980
forms this is indicative of long

106
00:04:01,570 --> 00:04:00,019
polymers that are cross-linked we want

107
00:04:04,240 --> 00:04:01,580
to get more information about these

108
00:04:07,030 --> 00:04:04,250
polymers which are cross-linked so we

109
00:04:09,190 --> 00:04:07,040
looked at we use microscopy and here we

110
00:04:11,289 --> 00:04:09,200
have an AFM and a TEM and the AFM is

111
00:04:12,490 --> 00:04:11,299
atomic force microscopy and if you see

112
00:04:14,830 --> 00:04:12,500
the blue and the red or the cross

113
00:04:16,630 --> 00:04:14,840

sections and you can get a height and

114

00:04:18,699 --> 00:04:16,640

the heights going to be pretty good for

115

00:04:20,259 --> 00:04:18,709

telling you how large it is in each of

116

00:04:21,699 --> 00:04:20,269

these come to about two nanometers and

117

00:04:23,560 --> 00:04:21,709

that's the actual predicted size of one

118

00:04:25,870 --> 00:04:23,570

of these rosettes so we see that we are

119

00:04:27,370 --> 00:04:25,880

forming stacked rosettes we also have

120

00:04:30,670 --> 00:04:27,380

some other spectroscopic evidence of

121

00:04:31,660 --> 00:04:30,680

that but these pre are prettier so you

122

00:04:34,390 --> 00:04:31,670

see that we're forming

123

00:04:36,580 --> 00:04:34,400

a long polymers as well and we also see

124

00:04:38,230 --> 00:04:36,590

this in the TM transmission electron

125

00:04:40,780 --> 00:04:38,240

microscope and these are actually

126
00:04:43,210 --> 00:04:40,790
laterally assembled and again you have

127
00:04:46,120 --> 00:04:43,220
the two ain't the two nanometers as the

128
00:04:47,620 --> 00:04:46,130
size of the width so what's really just

129
00:04:49,060 --> 00:04:47,630
about these is how long they are again

130
00:04:51,160 --> 00:04:49,070
it's because of that hydrophobic effect

131
00:04:52,780 --> 00:04:51,170
you don't want to expose these surfaces

132
00:04:54,310 --> 00:04:52,790
so you form very long polymers but this

133
00:04:57,340 --> 00:04:54,320
polymer here which is a little bit over

134
00:04:59,770 --> 00:04:57,350
a micron contains about 20,000 highly

135
00:05:03,210 --> 00:04:59,780
ordered nucleobases that are positioned

136
00:05:05,740 --> 00:05:03,220
right next to each other in solution so

137
00:05:07,210 --> 00:05:05,750
what we see from self assemblies we see

138
00:05:10,570 --> 00:05:07,220

that it overcomes from these problems

139

00:05:11,680 --> 00:05:10,580

such as base selection in a very complex

140

00:05:12,820 --> 00:05:11,690

mixture and we've actually thrown an

141

00:05:14,230 --> 00:05:12,830

other nucleobase and we see that it

142

00:05:16,140 --> 00:05:14,240

preferentially only these are

143

00:05:18,640 --> 00:05:16,150

incorporated into these assemblies

144

00:05:21,460 --> 00:05:18,650

connectivity you're now pre organizing

145

00:05:23,140 --> 00:05:21,470

for corrects coupling we are forming

146

00:05:24,460 --> 00:05:23,150

very long polymers but of course the

147

00:05:26,410 --> 00:05:24,470

next step is to link them together these

148

00:05:29,290 --> 00:05:26,420

are all non covalent assemblies while

149

00:05:31,170 --> 00:05:29,300

they will enhance the ability to form

150

00:05:33,100 --> 00:05:31,180

ligation between them because the

151
00:05:34,480 --> 00:05:33,110
concentration local concentration is so

152
00:05:37,600 --> 00:05:34,490
high when you put them next to each

153
00:05:39,460 --> 00:05:37,610
other they are different we also have

154
00:05:42,040 --> 00:05:39,470
glycosidic bond formation that is

155
00:05:43,810 --> 00:05:42,050
actually pretty pretty good in high

156
00:05:45,250 --> 00:05:43,820
yields with these with some of these

157
00:05:50,020 --> 00:05:45,260
assembly molecules and we just submitted

158
00:05:52,230 --> 00:05:50,030
this work so it should be AB soon but if

159
00:05:54,640 --> 00:05:52,240
we were to accept that these nucleobases

160
00:05:56,680 --> 00:05:54,650
predated the nucleobases in life today

161
00:06:00,160 --> 00:05:56,690
we must also accept that then there was

162
00:06:04,510 --> 00:06:00,170
an evolution from a a proto system a

163
00:06:06,160 --> 00:06:04,520

proto RNA or a prerna into the into the

164

00:06:08,020 --> 00:06:06,170

structure that we have today and i'm

165

00:06:10,150 --> 00:06:08,030

going to use the the ship of theseus

166

00:06:13,390 --> 00:06:10,160

this is a paradox put up I plutarch to

167

00:06:15,820 --> 00:06:13,400

sort of give an idea of our ideas on how

168

00:06:17,470 --> 00:06:15,830

this transfer turn doesn't happens he

169

00:06:19,630 --> 00:06:17,480

postulated that if you take a ship and

170

00:06:21,340 --> 00:06:19,640

you deconstruct it and then change all

171

00:06:23,740 --> 00:06:21,350

its parts and then put it back together

172

00:06:25,240 --> 00:06:23,750

is it still the same ship and I mean we

173

00:06:26,380 --> 00:06:25,250

could argue one way or the other but I

174

00:06:28,630 --> 00:06:26,390

think we'd all argue that it has still

175

00:06:30,550 --> 00:06:28,640

at the same function the ship is still

176

00:06:33,160 --> 00:06:30,560

going to be able to maneuver the Seas in

177

00:06:34,960 --> 00:06:33,170

the work the same way how about if you

178

00:06:36,670 --> 00:06:34,970

actually change just one part of the

179

00:06:38,080 --> 00:06:36,680

ship at a time sort of that ship is sort

180

00:06:40,090 --> 00:06:38,090

of involved in order to fit a certain

181

00:06:41,890 --> 00:06:40,100

scenario certain need then you might

182

00:06:43,510 --> 00:06:41,900

have several ships that are going to

183

00:06:44,770 --> 00:06:43,520

come in at different times to facilitate

184

00:06:46,840 --> 00:06:44,780

a different need where

185

00:06:48,160 --> 00:06:46,850

you would have a canoe maybe to start

186

00:06:49,660 --> 00:06:48,170

with you want it to just navigate a

187

00:06:51,970 --> 00:06:49,670

creek but you couldn't do that with this

188

00:06:53,500 --> 00:06:51,980

very large ship here however you still

189

00:06:55,720 --> 00:06:53,510

are conserving some basic principles

190

00:06:57,640 --> 00:06:55,730

such as a whole or a sale depending on

191

00:06:59,710 --> 00:06:57,650

what is it required and we see that

192

00:07:01,840 --> 00:06:59,720

already from just the the change if we

193

00:07:05,379 --> 00:07:01,850

were to accept the RNA world the change

194

00:07:07,240 --> 00:07:05,389

going from RNA to DNA where you actually

195

00:07:09,340 --> 00:07:07,250

have a change to the architecture in the

196

00:07:10,690 --> 00:07:09,350

the two position here you don't have

197

00:07:12,129 --> 00:07:10,700

this hydroxyl which is good because that

198

00:07:13,240 --> 00:07:12,139

light leads the strand cleavage and

199

00:07:17,560 --> 00:07:13,250

that's why people keep talking about how

200

00:07:18,820 --> 00:07:17,570

RNA so so pesky to have around so you

201
00:07:20,920 --> 00:07:18,830
you have actually changes in the

202
00:07:22,840 --> 00:07:20,930
physical architecture that went to a DNA

203
00:07:25,060 --> 00:07:22,850
which is a lot better for storing large

204
00:07:26,980 --> 00:07:25,070
genetic information like we have in life

205
00:07:29,500 --> 00:07:26,990
today there's also some changes to the

206
00:07:32,770 --> 00:07:29,510
nucleobases these are changes that are

207
00:07:35,710 --> 00:07:32,780
all although small impact the situation

208
00:07:38,530 --> 00:07:35,720
greatly so what could have predated

209
00:07:41,950 --> 00:07:38,540
these systems could be a polymer that is

210
00:07:44,500 --> 00:07:41,960
more amiable to self-assembly to being

211
00:07:47,500 --> 00:07:44,510
able to be spontaneously generated under

212
00:07:50,500 --> 00:07:47,510
geophysical conditions and there might

213
00:07:52,930 --> 00:07:50,510

have been more that that preceded these

214

00:07:54,730 --> 00:07:52,940

these structures and this this could be

215

00:07:56,469 --> 00:07:54,740

thought of as or Dale puts as a gloomy

216

00:08:00,430 --> 00:07:56,479

prospects if there are all these

217

00:08:02,350 --> 00:08:00,440

different scenarios what which one is

218

00:08:03,969 --> 00:08:02,360

right and is it really even good idea to

219

00:08:05,380 --> 00:08:03,979

go after them but you can start

220

00:08:06,370 --> 00:08:05,390

constraining things and many people have

221

00:08:08,200 --> 00:08:06,380

already started building different

222

00:08:09,460 --> 00:08:08,210

architectures changing out the base is

223

00:08:11,230 --> 00:08:09,470

changing out the backbone and change it

224

00:08:16,180 --> 00:08:11,240

at the phosphate and found that we can

225

00:08:17,710 --> 00:08:16,190

form structures that are just as good in

226

00:08:19,750 --> 00:08:17,720

certain scenarios such as just as good

227

00:08:21,580 --> 00:08:19,760

as assembling story information they can

228

00:08:22,570 --> 00:08:21,590

actually be catalysts to you going to

229

00:08:24,969 --> 00:08:22,580

form you can change the background

230

00:08:27,940 --> 00:08:24,979

remove the ribose and you can still have

231

00:08:29,590 --> 00:08:27,950

a catalyst that is that is the

232

00:08:33,969 --> 00:08:29,600

spontaneously emerges from a pool of

233

00:08:36,520 --> 00:08:33,979

other sequences so I just want to put

234

00:08:37,630 --> 00:08:36,530

this out there this really is something

235

00:08:38,770 --> 00:08:37,640

that we were talking about earlier could

236

00:08:44,350 --> 00:08:38,780

life also have taken a different path

237

00:08:46,750 --> 00:08:44,360

and again if it did it if it's not we're

238

00:08:49,030 --> 00:08:46,760

not at that the DNA or RNA and we don't

239

00:08:53,250 --> 00:08:49,040

see that in biology or see that in a

240

00:08:56,980 --> 00:08:53,260

biology paper we find it outside well

241

00:08:58,300 --> 00:08:56,990

it's not such a dire position like what

242

00:08:59,769 --> 00:08:58,310

what you

243

00:09:01,870 --> 00:08:59,779

really need to look for when we start

244

00:09:03,700 --> 00:09:01,880

looking for genetic systems that are not

245

00:09:04,840 --> 00:09:03,710

like our own and we can constrain that

246

00:09:07,930 --> 00:09:04,850

by understanding the physicochemical

247

00:09:11,110 --> 00:09:07,940

properties of these molecules that are

248

00:09:15,480 --> 00:09:11,120

able to sustain information storage or

249

00:09:17,710 --> 00:09:15,490

catalysis and with that acknowledgments

250

00:09:22,329 --> 00:09:17,720

Nick HUD Michael Shannon was an

251

00:09:24,340 --> 00:09:22,339

undergrad I worked with Diego NASA NSF

252

00:09:26,560 --> 00:09:24,350

the Center for chemical pollution which

253

00:09:32,950 --> 00:09:26,570

is based in Atlanta and if you have any

254

00:09:36,850 --> 00:09:32,960

questions have any time take them think

255

00:09:38,829 --> 00:09:36,860

we have time for learning to have you

256

00:09:41,140 --> 00:09:38,839

tried looking at the Assembly of these

257

00:09:44,579 --> 00:09:41,150

polymers under different conditions like

258

00:09:47,500 --> 00:09:44,589

different temperature over here yeah

259

00:09:49,570 --> 00:09:47,510

different temperature different pH I

260

00:09:51,640 --> 00:09:49,580

other things it's interesting to these

261

00:09:54,130 --> 00:09:51,650

polymers on there if there's some

262

00:09:56,019 --> 00:09:54,140

arguments about PKA also pH if your

263

00:09:59,230 --> 00:09:56,029

these all assemble at ph 7 really well

264

00:10:01,390 --> 00:09:59,240

moving away from the ph you have them

265

00:10:03,010 --> 00:10:01,400

start to fall apart which could be also

266

00:10:05,020 --> 00:10:03,020

you could you think of it was a way to

267

00:10:06,640 --> 00:10:05,030

maybe get around strand ambition or

268

00:10:09,490 --> 00:10:06,650

something work yet you guess which is

269

00:10:12,430 --> 00:10:09,500

temperature wise they are they do

270

00:10:14,410 --> 00:10:12,440

assemble through just they're not

271

00:10:16,510 --> 00:10:14,420

they're empathically a prone to assemble

272

00:10:18,130 --> 00:10:16,520

that are not entropically driven so at

273

00:10:19,810 --> 00:10:18,140

least for the initial assembly to form

274

00:10:26,440 --> 00:10:19,820

the rosette which means that coin it

275

00:10:29,530 --> 00:10:26,450

down you can get more assembled okay hi

276

00:10:31,390 --> 00:10:29,540

okay so my question and actually this

277

00:10:32,920 --> 00:10:31,400

was I read the paper but it's still

278

00:10:35,140 --> 00:10:32,930

unclear to me I'm so you've got the tip

279

00:10:36,340 --> 00:10:35,150

you've got your rosettes and so the blue

280

00:10:37,510 --> 00:10:36,350

is always on top of the red is always on

281

00:10:39,970 --> 00:10:37,520

top of the blue is always on top of the

282

00:10:43,540 --> 00:10:39,980

red how do you propose that a system

283

00:10:45,220 --> 00:10:43,550

like that becomes a system like RNA

284

00:10:46,720 --> 00:10:45,230

where the order of the basis is

285

00:10:50,890 --> 00:10:46,730

different and drives evolution like how

286

00:10:52,720 --> 00:10:50,900

does this how do you make these polymers

287

00:10:54,430 --> 00:10:52,730

that are all essentially the same evolve

288

00:10:55,870 --> 00:10:54,440

into something that's not the same yeah

289

00:10:58,030 --> 00:10:55,880

I mean that was actually just a drawing

290

00:11:00,220 --> 00:10:58,040

though so that was a problem that's what

291

00:11:02,320 --> 00:11:00,230

we chose and you know I've we've had to

292

00:11:03,970 --> 00:11:02,330

come up again like people assume that

293

00:11:05,470 --> 00:11:03,980

you have these that they're going to be

294

00:11:08,440 --> 00:11:05,480

stacked on top of each other a certain

295

00:11:09,579 --> 00:11:08,450

way this is a very greasy surface we

296

00:11:12,100 --> 00:11:09,589

don't actually have this atomic

297

00:11:13,990 --> 00:11:12,110

resolution but you

298

00:11:15,400 --> 00:11:14,000

expect and what we've done by throwing

299

00:11:17,019 --> 00:11:15,410

in chiral molecules they had a key

300

00:11:20,259 --> 00:11:17,029

little twist so they're off a little bit

301

00:11:21,819 --> 00:11:20,269

and we don't know exactly either stacked

302

00:11:24,699 --> 00:11:21,829

and that was a problem of my advisor

303

00:11:26,650 --> 00:11:24,709

using his software and not spacing them

304

00:11:30,940 --> 00:11:26,660

out in a way that's you know maybe or