
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:11,470 --> 00:00:09,120
[Applause]

3
00:00:14,260 --> 00:00:11,480
thank you guys for coming thanks for

4
00:00:15,880 --> 00:00:14,270
inviting me you guys I'd like to

5
00:00:19,030 --> 00:00:15,890
announce that the next apps icon is

6
00:00:20,710 --> 00:00:19,040
going to be at Georgia Tech and it's

7
00:00:23,530 --> 00:00:20,720
gonna save us a lot of money and air

8
00:00:26,019 --> 00:00:23,540
fares and hotels these are all the

9
00:00:29,940 --> 00:00:26,029
Georgia Tech people at this meeting or a

10
00:00:34,569 --> 00:00:32,109
okay I'm gonna talk about biopolymers

11
00:00:35,560 --> 00:00:34,579
and you guys my time doesn't start yet

12
00:00:40,150 --> 00:00:35,570
because it's kind of background

13
00:00:40,750 --> 00:00:40,160

information the the this this new

14
00:00:42,670 --> 00:00:40,760
mission

15
00:00:44,740 --> 00:00:42,680
you know the dragonfly this is like so

16
00:00:48,670 --> 00:00:44,750
good for us right this is we're going to

17
00:00:50,650 --> 00:00:48,680
a planet with polymers and organic

18
00:00:53,620 --> 00:00:50,660
chemistry this is going to be really

19
00:00:55,900 --> 00:00:53,630
exciting for all of us here okay so I

20
00:00:58,180 --> 00:00:55,910
want to talk about polymers you know

21
00:01:01,090 --> 00:00:58,190
like does biology actually need polymers

22
00:01:04,439 --> 00:01:01,100
and our biopolymers special among

23
00:01:07,270 --> 00:01:04,449
polymers and what can we learn about

24
00:01:08,770 --> 00:01:07,280
biopolymers you know about the origin of

25
00:01:10,450 --> 00:01:08,780
life what do biopolymers actually tell

26
00:01:12,010 --> 00:01:10,460
us about the origin of life and when you

27
00:01:14,649 --> 00:01:12,020
think about biopolymers of course this

28
00:01:16,570 --> 00:01:14,659
is sort of where we start which is

29
00:01:18,550 --> 00:01:16,580
really you know this is information flow

30
00:01:22,720 --> 00:01:18,560
in biology right there's sequences of

31
00:01:26,080 --> 00:01:22,730
DNA that's information is is transcribed

32
00:01:28,240 --> 00:01:26,090
to RNA it's translated to protein and

33
00:01:30,219 --> 00:01:28,250
then protein actually does things with

34
00:01:32,890 --> 00:01:30,229
that information so this is all about

35
00:01:36,250 --> 00:01:32,900
information and information is sequences

36
00:01:39,399 --> 00:01:36,260
of monomers that are linked that's

37
00:01:43,210 --> 00:01:39,409
really essentially what polymers are

38
00:01:45,370 --> 00:01:43,220

about so isn't it really important to me

39
00:01:48,090 --> 00:01:45,380
feature polymers is that they are all

40
00:01:50,920 --> 00:01:48,100
made by dehydration condensation okay

41
00:01:53,410 --> 00:01:50,930
everybody Universal bio polymer is made

42
00:01:55,240 --> 00:01:53,420
by essentially the same chemistry which

43
00:01:57,190 --> 00:01:55,250
is you take two monomers you put them

44
00:02:00,010 --> 00:01:57,200
together and a water molecule comes out

45
00:02:01,120 --> 00:02:00,020
and there's a lot of other things that

46
00:02:02,740 --> 00:02:01,130
are universal they all go through

47
00:02:04,570 --> 00:02:02,750
phosphorylated intermediates they're all

48
00:02:06,160 --> 00:02:04,580
made by possessives motors that use

49
00:02:08,380 --> 00:02:06,170
divalent cations there's a there's a

50
00:02:10,270 --> 00:02:08,390
whole lot of universalities in bio

51
00:02:15,789 --> 00:02:10,280
polymer synthesis but i want to focus on

52
00:02:17,949 --> 00:02:15,799
this water element here this is the way

53
00:02:20,770 --> 00:02:17,959
i think about it which i think you

54
00:02:21,760 --> 00:02:20,780
should think about it which is that you

55
00:02:24,340 --> 00:02:21,770
know I'm at AB

56
00:02:26,050 --> 00:02:24,350
is a small molecule that is either used

57
00:02:28,990 --> 00:02:26,060
as a substrate or a product in an

58
00:02:31,120 --> 00:02:29,000
enzymatic reaction and water is clearly

59
00:02:34,360 --> 00:02:31,130
the most abundant and frequent and

60
00:02:36,790 --> 00:02:34,370
universal metabolite in all biology you

61
00:02:40,210 --> 00:02:36,800
use over your body mass of water in

62
00:02:44,050 --> 00:02:40,220
chemical reactions every day so water is

63
00:02:46,960 --> 00:02:44,060

the primary metabolite of biology what

64
00:02:48,310 --> 00:02:46,970
does that mean if we think about the

65
00:02:51,340 --> 00:02:48,320
surface of the land now I'm talking

66
00:02:54,490 --> 00:02:51,350
about NIC HUD kind of ideas here that's

67
00:02:57,240 --> 00:02:54,500
so where they come from is the activity

68
00:03:01,240 --> 00:02:57,250
of water on so on the entire planet

69
00:03:03,910 --> 00:03:01,250
cycles every day so reactions that take

70
00:03:06,340 --> 00:03:03,920
up and and release water are pushed and

71
00:03:09,250 --> 00:03:06,350
pulled on the entire planet every day

72
00:03:11,620 --> 00:03:09,260
except in certain places and that's in

73
00:03:13,060 --> 00:03:11,630
large bodies of water that is that that

74
00:03:15,580 --> 00:03:13,070
is a place where the activity of water

75
00:03:17,170 --> 00:03:15,590
is constant and and we're not going to

76
00:03:20,500 --> 00:03:17,180
be able to push in pull reactions by

77
00:03:23,230 --> 00:03:20,510
this process so the abiotic synthesis of

78
00:03:26,500 --> 00:03:23,240
polymers by the cycling of water is a

79
00:03:27,850 --> 00:03:26,510
metabolic process and think about what

80
00:03:31,450 --> 00:03:27,860
Moran was saying if you were here for

81
00:03:33,880 --> 00:03:31,460
her talk early you take monomers you dry

82
00:03:35,680 --> 00:03:33,890
them down you make polymers and you

83
00:03:37,810 --> 00:03:35,690
bring them back up into solution and

84
00:03:39,550 --> 00:03:37,820
there kinetically trapped so what you've

85
00:03:41,650 --> 00:03:39,560
done is you've taken sunlight

86
00:03:44,350 --> 00:03:41,660
effectively and you have incorporated

87
00:03:46,030 --> 00:03:44,360
that energy into chemical bonds okay so

88
00:03:47,920 --> 00:03:46,040

that that is basically what the dry down

89
00:03:49,930 --> 00:03:47,930
root reaction does it's taking

90
00:03:51,610 --> 00:03:49,940
environmental energy and it's putting it

91
00:03:53,680 --> 00:03:51,620
into chemical bonds and you repeat this

92
00:03:55,900 --> 00:03:53,690
process and you can keep adding more and

93
00:03:58,930 --> 00:03:55,910
more energy into chemical bonds okay so

94
00:04:00,700 --> 00:03:58,940
this is this is metabolism to me and

95
00:04:03,130 --> 00:04:00,710
it's it's kind of funny I remember in

96
00:04:05,440 --> 00:04:03,140
the old days Steve and people would have

97
00:04:09,790 --> 00:04:05,450
these arguments about what was first

98
00:04:11,290 --> 00:04:09,800
nucleic acids or or metabolism and the

99
00:04:13,270 --> 00:04:11,300
problem with those discussions I think

100
00:04:16,330 --> 00:04:13,280
was that the way people were thinking

101
00:04:18,039 --> 00:04:16,340
about metabolism was in terms of the

102
00:04:19,360 --> 00:04:18,049
krebs cycle running in Reverse and

103
00:04:21,370 --> 00:04:19,370
things like that but if you think about

104
00:04:24,180 --> 00:04:21,380
metabolism in this way I think it

105
00:04:26,320 --> 00:04:24,190
changes the argument I think Steve might

106
00:04:28,570 --> 00:04:26,330
haven't talked to him about this but I

107
00:04:31,810 --> 00:04:28,580
think he might accept that metabolism

108
00:04:34,090 --> 00:04:31,820
could take a lead before biopolymers if

109
00:04:35,830 --> 00:04:34,100
we define metabolism like this

110
00:04:38,740 --> 00:04:35,840
you don't have to say anything I'll ask

111
00:04:40,870 --> 00:04:38,750
you later over beers okay so now let's

112
00:04:45,130 --> 00:04:40,880
talk about actually it's kind of ironic

113
00:04:46,900 --> 00:04:45,140

that the people who finally discovered

114
00:04:51,040 --> 00:04:46,910
this metabolic process where nucleic

115
00:04:53,020 --> 00:04:51,050
acid people they were naked and and ROM

116
00:04:54,820 --> 00:04:53,030
Krishnamurti and people like that so

117
00:04:57,550 --> 00:04:54,830
that the people who are focused on

118
00:04:59,560 --> 00:04:57,560
metabolism are really interested in the

119
00:05:00,310 --> 00:04:59,570
Krebs cycle and redox chemistry and

120
00:05:01,930 --> 00:05:00,320
things like that

121
00:05:04,600 --> 00:05:01,940
and they really weren't paying attention

122
00:05:06,580 --> 00:05:04,610
to simple chemistry which is hydration

123
00:05:08,920 --> 00:05:06,590
dehydration which is near equilibrium

124
00:05:10,540 --> 00:05:08,930
processes on the surface of the earth so

125
00:05:13,180 --> 00:05:10,550
if we look there then we can see that

126
00:05:16,650 --> 00:05:13,190
it's really easy to imagine metabolism

127
00:05:20,290 --> 00:05:16,660
and biopolymers you know coming together

128
00:05:23,170 --> 00:05:20,300
okay so this is a polymer polymers are

129
00:05:24,340 --> 00:05:23,180
amazing they're magic okay polymers are

130
00:05:28,090 --> 00:05:24,350
magic that's the thing you have to

131
00:05:30,100 --> 00:05:28,100
realize they're undescribable amazing so

132
00:05:31,990 --> 00:05:30,110
if you look inside those things what you

133
00:05:34,480 --> 00:05:32,000
can see this beautiful self

134
00:05:36,610 --> 00:05:34,490
complementarity all biopolymers our self

135
00:05:38,410 --> 00:05:36,620
complimentary if you look at cellulose

136
00:05:40,180 --> 00:05:38,420
all the donors donate and all the

137
00:05:42,310 --> 00:05:40,190
acceptors except if you look in the

138
00:05:44,410 --> 00:05:42,320

center of a protein the donors and

139
00:05:45,970 --> 00:05:44,420
acceptors are beautifully aligned and of

140
00:05:48,250 --> 00:05:45,980
course if you look in nucleic acids

141
00:05:50,020 --> 00:05:48,260
nucleic acid chemists are used to

142
00:05:51,490 --> 00:05:50,030
talking about complementarity but that

143
00:05:54,840 --> 00:05:51,500
complementarity extends to all

144
00:05:57,730 --> 00:05:54,850
biopolymers okay every biopolymer is

145
00:06:00,790 --> 00:05:57,740
itself complementary you can see a Alpha

146
00:06:03,250 --> 00:06:00,800
anti parallel beta sheets and parallel

147
00:06:05,710 --> 00:06:03,260
beta sheets and alpha helixes everything

148
00:06:08,020 --> 00:06:05,720
is beautiful everything is perfect okay

149
00:06:12,070 --> 00:06:08,030
the problem is the same thing is true in

150
00:06:13,090 --> 00:06:12,080
ice if we take a water molecule and we

151
00:06:15,580 --> 00:06:13,100
crystallize that you look in that

152
00:06:17,440 --> 00:06:15,590
crystal you'll see the same thing small

153
00:06:19,420 --> 00:06:17,450
molecules when they form crystals are

154
00:06:21,550 --> 00:06:19,430
also self complimentary all the donors

155
00:06:23,920 --> 00:06:21,560
donate and all the acceptors accept so

156
00:06:26,890 --> 00:06:23,930
the question is really what what is

157
00:06:30,100 --> 00:06:26,900
special about a polymer how is that how

158
00:06:31,540 --> 00:06:30,110
is an Ice Cube different from a polymer

159
00:06:34,650 --> 00:06:31,550
what is the fundamental difference

160
00:06:39,700 --> 00:06:37,720
okay this is this is the difference if I

161
00:06:43,990 --> 00:06:39,710
take I say I take a mixture of 20 amino

162
00:06:46,420 --> 00:06:44,000
acids and I very slowly cool it they

163
00:06:48,280 --> 00:06:46,430

will resolve okay this is called

164
00:06:49,930 --> 00:06:48,290
recrystallization people make money off

165
00:06:51,909 --> 00:06:49,940
of this right this is how you purify

166
00:06:54,460 --> 00:06:51,919
things you recrystallize them because

167
00:06:57,550 --> 00:06:54,470
monomers will resolve in two simple

168
00:06:59,980 --> 00:06:57,560
systems biology doesn't want that right

169
00:07:01,480 --> 00:06:59,990
biology wants enzymes informational

170
00:07:03,640 --> 00:07:01,490
molecules it wants to

171
00:07:05,890 --> 00:07:03,650
it wants to through evolutionary process

172
00:07:08,260 --> 00:07:05,900
put functional groups at specific places

173
00:07:09,400 --> 00:07:08,270
in three-dimensional space okay that is

174
00:07:12,070 --> 00:07:09,410
not allowed here everything is

175
00:07:14,320 --> 00:07:12,080
determined by this small molecule so

176
00:07:18,000 --> 00:07:14,330
there there's no control of that that

177
00:07:21,040 --> 00:07:18,010
biology requires so we want to do this

178
00:07:24,250 --> 00:07:21,050
but nature doesn't let us do that okay

179
00:07:26,620 --> 00:07:24,260
if I take 20 amino acids and I try to

180
00:07:28,540 --> 00:07:26,630
assemble them I can't do it if I take

181
00:07:31,840 --> 00:07:28,550
guanine and cytosine together in water

182
00:07:34,270 --> 00:07:31,850
they don't form base pairs unless

183
00:07:37,050 --> 00:07:34,280
they're polymerized okay the magic is in

184
00:07:41,170 --> 00:07:37,060
the polymerization so this doesn't work

185
00:07:43,300 --> 00:07:41,180
but this works okay with linking things

186
00:07:45,070 --> 00:07:43,310
together and the linkage is really

187
00:07:46,630 --> 00:07:45,080
important okay it does it two things

188
00:07:49,150 --> 00:07:46,640

first there's the proximity it keeps

189
00:07:51,310 --> 00:07:49,160
things close together so the entropy is

190
00:07:53,890 --> 00:07:51,320
much less forming this thing because

191
00:07:55,270 --> 00:07:53,900
these things are already constrained to

192
00:07:57,070 --> 00:07:55,280
be close together in space so there's a

193
00:07:59,440 --> 00:07:57,080
big entropy argument but the other thing

194
00:08:01,690 --> 00:07:59,450
is this you know in biopolymers these

195
00:08:03,900 --> 00:08:01,700
are not flexible strings right these are

196
00:08:07,630 --> 00:08:03,910
very specific for example a peptide

197
00:08:09,969 --> 00:08:07,640
highly restrained pre-organized and and

198
00:08:13,900 --> 00:08:09,979
really already pushing very hard for

199
00:08:15,700 --> 00:08:13,910
this assemble thing in fact any RNA you

200
00:08:17,740 --> 00:08:15,710
make any sequence of RNA except for a

201
00:08:20,350 --> 00:08:17,750
homo polymer and it will assemble right

202
00:08:22,420 --> 00:08:20,360
RNA just wants to assemble so bad you

203
00:08:24,880 --> 00:08:22,430
can't stop it and any sequence of

204
00:08:26,650 --> 00:08:24,890
polypeptide will form beta structures

205
00:08:29,560 --> 00:08:26,660
right so the assembly of these molecules

206
00:08:31,960 --> 00:08:29,570
is built into the backbone in many ways

207
00:08:34,240 --> 00:08:31,970
and it's just totally inescapable um

208
00:08:36,610 --> 00:08:34,250
people complain that they make random

209
00:08:38,709 --> 00:08:36,620
sequences of polypeptide and it always

210
00:08:41,290 --> 00:08:38,719
comes out of solution the reason is that

211
00:08:42,760 --> 00:08:41,300
it forms beautiful beta structures right

212
00:08:44,890 --> 00:08:42,770
those aren't just random precipitates

213
00:08:47,140 --> 00:08:44,900

right those are those are assemblies

214
00:08:51,450 --> 00:08:47,150
that have been designed by Nature over

215
00:08:55,620 --> 00:08:51,460
long evolution how much time do I got oh

216
00:08:58,000 --> 00:08:55,630
okay good so we talked about proteins

217
00:09:00,370 --> 00:08:58,010
spontaneously folding right you take a

218
00:09:03,010 --> 00:09:00,380
protein in solution and it will

219
00:09:05,350 --> 00:09:03,020
spontaneously fold but the only reason

220
00:09:07,810 --> 00:09:05,360
for that is that you're cheating on the

221
00:09:09,760 --> 00:09:07,820
accounting if you really add everything

222
00:09:12,880 --> 00:09:09,770
up like how much did it cost to make the

223
00:09:14,769 --> 00:09:12,890
amino acids how much did you invest in

224
00:09:17,470 --> 00:09:14,779
selecting for the right sequence and

225
00:09:20,200 --> 00:09:17,480
then of course for making the bonds in

226
00:09:22,269 --> 00:09:20,210
an aqueous media proteins do not

227
00:09:23,920 --> 00:09:22,279
spontaneously fold right they only

228
00:09:27,670 --> 00:09:23,930
spontaneously fold is because you're

229
00:09:28,690 --> 00:09:27,680
starting with the polymer okay so and

230
00:09:33,070 --> 00:09:28,700
that's kind of cheating

231
00:09:34,560 --> 00:09:33,080
thermodynamically so this is I think the

232
00:09:37,300 --> 00:09:34,570
way to think about it

233
00:09:40,269 --> 00:09:37,310
this is what nature can do really easily

234
00:09:42,460 --> 00:09:40,279
and what nature has done is it has

235
00:09:44,829 --> 00:09:42,470
separated the cost of the assembly

236
00:09:47,260 --> 00:09:44,839
Nature wants complex assemblies it wants

237
00:09:51,010 --> 00:09:47,270
informational biopolymers it wants

238
00:09:53,949 --> 00:09:51,020

catalytic sites and it has separated the

239
00:09:56,769 --> 00:09:53,959
cost of that assembly from the making of

240
00:09:59,250 --> 00:09:56,779
the assembly so the sequence of this

241
00:10:02,050 --> 00:09:59,260
thing and the backbone has been designed

242
00:10:04,600 --> 00:10:02,060
by billions of years of evolution right

243
00:10:07,540 --> 00:10:04,610
that is an investment that Nature has

244
00:10:09,340 --> 00:10:07,550
made in this polymer it has selected the

245
00:10:10,750 --> 00:10:09,350
side chains it has selected the sequence

246
00:10:13,120 --> 00:10:10,760
and then what it actually does the

247
00:10:14,769 --> 00:10:13,130
polymerization of course it uses ATP and

248
00:10:16,900 --> 00:10:14,779
high-blood so there's an enormous amount

249
00:10:20,530 --> 00:10:16,910
of energy that is put and the reason

250
00:10:22,960 --> 00:10:20,540
that energy is invested is in order to

251
00:10:28,810 --> 00:10:22,970
make assemblies and so this is this is

252
00:10:30,250 --> 00:10:28,820
the analogy I use money if you don't

253
00:10:32,710 --> 00:10:30,260
have to pay for stuff you can have

254
00:10:36,010 --> 00:10:32,720
everything right and that's what Nature

255
00:10:39,610 --> 00:10:36,020
has done it has invested so much in the

256
00:10:40,930 --> 00:10:39,620
past that assemblies are free and so the

257
00:10:44,230 --> 00:10:40,940
way to think about it is if you have

258
00:10:46,420 --> 00:10:44,240
saved your whole life for your kid to go

259
00:10:47,710 --> 00:10:46,430
to college then you can send your

260
00:10:49,720 --> 00:10:47,720
college to your kid to college

261
00:10:51,880 --> 00:10:49,730
essentially free because you have that

262
00:10:53,160 --> 00:10:51,890
account and you're not you don't have to

263
00:10:55,900 --> 00:10:53,170

pay for it in real time

264
00:10:58,840 --> 00:10:55,910
that's what biology has done biology has

265
00:10:59,980 --> 00:10:58,850
been investing in in assemblies for

266
00:11:02,110 --> 00:10:59,990
billions of years

267
00:11:04,810 --> 00:11:02,120
and has made them spontaneous and it and

268
00:11:07,030 --> 00:11:04,820
free right this is why nature does such

269
00:11:09,130 --> 00:11:07,040
crazy things because it really doesn't

270
00:11:11,110 --> 00:11:09,140
have to pay for it right it's it's

271
00:11:13,600 --> 00:11:11,120
already paid that investment is a done

272
00:11:18,220 --> 00:11:13,610
deal and and everything it wants to do

273
00:11:23,530 --> 00:11:18,230
is essentially free so thank you guys

274
00:11:25,330 --> 00:11:23,540
this is my group and actually I have

275
00:11:27,700 --> 00:11:25,340
this is Moran who has done a lot of work

276
00:11:29,170 --> 00:11:27,710
on the DEP c-peptide stuff this is Anton

277
00:11:29,680 --> 00:11:29,180
who talks to me about these things all

278
00:11:31,240 --> 00:11:29,690
the time

279
00:11:39,520 --> 00:11:31,250
and the other member of my group are

280
00:11:41,260 --> 00:11:39,530
here thank you guys okay we can only do

281
00:11:43,660 --> 00:11:41,270
one quick one because I've been informed

282
00:11:46,900 --> 00:11:43,670
that we have another group coming in

283
00:11:48,700 --> 00:11:46,910
right after us okay so yeah usually

284
00:11:50,320 --> 00:11:48,710
disagree with Lawrence I hope you're

285
00:11:53,770 --> 00:11:50,330
going does he didn't say anything about

286
00:11:54,940 --> 00:11:53,780
human beings so it's I thought an

287
00:11:56,800 --> 00:11:54,950
interesting idea about the water

288
00:11:58,900 --> 00:11:56,810

activity being like the first metabolism

289
00:12:01,870 --> 00:11:58,910
when I talked to RNA world people they

290
00:12:04,210 --> 00:12:01,880
usually don't talk about metabolism in

291
00:12:06,970 --> 00:12:04,220
that world so you but you need some type

292
00:12:09,220 --> 00:12:06,980
of energy to replicate yourself so is

293
00:12:11,050 --> 00:12:09,230
that is water activity variation a

294
00:12:14,170 --> 00:12:11,060
candidate for the metabolism in an RNA

295
00:12:16,180 --> 00:12:14,180
world I would say no because RNA is so

296
00:12:18,580 --> 00:12:16,190
far from equilibrium that these

297
00:12:21,310 --> 00:12:18,590
processes in fact I would say RNA is a

298
00:12:23,200 --> 00:12:21,320
very derived polymer that comes from a

299
00:12:25,000 --> 00:12:23,210
lot of chemical evolution or if you look

300
00:12:25,720 --> 00:12:25,010
at peptides and sugars and other things

301
00:12:27,160 --> 00:12:25,730
you polymerize

302
00:12:29,410 --> 00:12:27,170
you can do them near equilibrium by

303
00:12:31,150 --> 00:12:29,420
dehydration it's very simple RNA because

304
00:12:32,770 --> 00:12:31,160
it's so far from equilibrium with that

305
00:12:34,930 --> 00:12:32,780
phosphate that's the only polymer that

306
00:12:36,460 --> 00:12:34,940
it doesn't work so I would I would argue

307
00:12:38,470 --> 00:12:36,470
based on that and some other things that

308
00:12:40,240 --> 00:12:38,480
already has a very derived polymer and

309
00:12:42,400 --> 00:12:40,250
it of the polymers we have it's the one

310
00:12:46,330 --> 00:12:42,410
that is farthest away from the sort of

311
00:12:49,129 --> 00:12:46,340
origins of chemical evolution alright