Thank You

- Dr. Loren Williams
  - Williams' group
    - Dr. Anton Petrov
    - Dr. Chad Bernier
- Institute of Bioscience and Bioengineering
- Georgia Tech
- AbGradCon 2015

1
00:00:12,619 --> 00:00:09,680
so um good morning everyone that was a

2
00:00:16,339 --> 00:00:12,629
great introduction by dr. waters so we

3
00:00:18,109 --> 00:00:16,349
think my job much easier okay so my name

4
00:00:20,659 --> 00:00:18,119
is Nicola watch I am a bioinformatics

5
00:00:23,269 --> 00:00:20,669
PhD student at the Georgia Institute of

6
00:00:26,120 --> 00:00:23,279
Technology biome format assist is

7
00:00:29,870 --> 00:00:26,130
someone who looked at biology using

8
00:00:32,299 --> 00:00:29,880
computers in statistics so my advisor is

9
00:00:35,979 --> 00:00:32,309
dr. lauren williams and my presentation

10
00:00:39,080 --> 00:00:35,989
today is on evolution of protein folding

11
00:00:42,170 --> 00:00:39,090
so to begin with like dr. waters is

12
00:00:44,540 --> 00:00:42,180
saying the ribosome takes nucleic acid

13
00:00:47,960 --> 00:00:44,550

which encodes information and turns it

14
00:00:50,120 --> 00:00:47,970
into protein which is function so yep

15
00:00:52,790 --> 00:00:50,130
that's the ribosome right there and it's

16
00:00:54,620 --> 00:00:52,800
taking deal well the RNA that comes from

17
00:00:58,580 --> 00:00:54,630
DNA and it turns it into protein and the

18
00:01:01,220 --> 00:00:58,590
ribosome itself is a large back row

19
00:01:04,729 --> 00:01:01,230
molecular structure of RNA and protein

20
00:01:06,469 --> 00:01:04,739
and it does its function so when you

21
00:01:08,870 --> 00:01:06,479
look at these phylogenetic trees that

22
00:01:11,029 --> 00:01:08,880
relate bacteria to archaea and

23
00:01:14,330 --> 00:01:11,039
eukaryotes and you look at like all

24
00:01:17,270 --> 00:01:14,340
animals are distantly related to fungi

25
00:01:20,209 --> 00:01:17,280
and plants that's by looking at the

26
00:01:23,569 --> 00:01:20,219
sequence of the ribosome on the DNA so

27
00:01:25,699 --> 00:01:23,579
the ribosome encodes species

28
00:01:28,249 --> 00:01:25,709
relationship and which is why we kind of

29
00:01:33,289 --> 00:01:28,259
say that the world started with the RNA

30
00:01:35,239 --> 00:01:33,299
RNA world hypothesis when you take the

31
00:01:36,620 --> 00:01:35,249
ribosome and you look at the size of it

32
00:01:38,959 --> 00:01:36,630
and you look at the size of it within

33
00:01:41,569 --> 00:01:38,969
the organisms on the tree of life you

34
00:01:43,309 --> 00:01:41,579
can see that prokaryotes have really

35
00:01:45,080 --> 00:01:43,319
small ribosomes that i have here

36
00:01:48,139 --> 00:01:45,090
represented by released small little

37
00:01:52,339 --> 00:01:48,149
circles and that simple york eukaryotes

38
00:01:54,679 --> 00:01:52,349

have larger ribosomes metazoans animals

39
00:01:57,169 --> 00:01:54,689
have even larger and then mammalian

40
00:02:00,620 --> 00:01:57,179
ribosomes are the largest found in

41
00:02:05,239 --> 00:02:00,630
nature and which very interesting is

42
00:02:08,300 --> 00:02:05,249
that these mammalian ribosomes contain

43
00:02:10,130 --> 00:02:08,310
the ribosomes of these animals and the

44
00:02:12,410 --> 00:02:10,140
ribosomes these animals contain within

45
00:02:14,539 --> 00:02:12,420
them the ribosomes of these yeast or

46
00:02:15,970 --> 00:02:14,549
simple eukaryotes and these simple

47
00:02:18,760 --> 00:02:15,980
eukaryotes the ribosomes of those

48
00:02:23,050 --> 00:02:18,770
contain the ribosomes

49
00:02:25,660 --> 00:02:23,060
prokaryotes and so when you look at that

50
00:02:28,330 --> 00:02:25,670
of the ribosomes of extent life and look

51
00:02:31,360 --> 00:02:28,340
at the way that they've evolved since

52
00:02:34,590 --> 00:02:31,370
the last Universal common ancestor 3.53

53
00:02:37,840 --> 00:02:34,600
point Oh 3.5 or 3.8 billion years ago

54
00:02:40,780 --> 00:02:37,850
and we just use the same mechanisms that

55
00:02:45,580 --> 00:02:40,790
we hypothesize that they've been growing

56
00:02:47,080 --> 00:02:45,590
since since then well yeah so okay Lucas

57
00:02:52,270 --> 00:02:47,090
here extend Webster here sorry about

58
00:02:53,980 --> 00:02:52,280
that we can see you can see exact same

59
00:02:55,450 --> 00:02:53,990
mechanisms that the ribosome that

60
00:02:58,450 --> 00:02:55,460
relates ribosome of all species in

61
00:03:00,130 --> 00:02:58,460
extant life today we'll just reuse that

62
00:03:02,590 --> 00:03:00,140
we can just deconstruct the ribosome and

63
00:03:04,420 --> 00:03:02,600

go back in time and see where life

64
00:03:06,850 --> 00:03:04,430
started with just the very first piece

65
00:03:09,220 --> 00:03:06,860
of RNA and these very first pieces of

66
00:03:12,220 --> 00:03:09,230
RNA are the catalytic centers I the

67
00:03:15,190 --> 00:03:12,230
ribosome and so that's where proteins

68
00:03:19,420 --> 00:03:15,200
are formed right at these little pieces

69
00:03:22,600 --> 00:03:19,430
of RNA and so but we hypothesize is that

70
00:03:24,760 --> 00:03:22,610
the ribosome very early on in the

71
00:03:27,760 --> 00:03:24,770
beginning of life was making small

72
00:03:30,610 --> 00:03:27,770
little pieces of proteins and as it as

73
00:03:32,770 --> 00:03:30,620
more pieces of RNA kind of stuck onto

74
00:03:36,490 --> 00:03:32,780
the ribosome its ability to synthesize

75
00:03:38,140 --> 00:03:36,500
proteins of increasing complexity just

76
00:03:40,120 --> 00:03:38,150
started happening and so we eventually

77
00:03:43,480 --> 00:03:40,130
ended up with a very functional ribosome

78
00:03:46,470 --> 00:03:43,490
back in code that can make very nice and

79
00:03:49,420 --> 00:03:46,480
complex proteins needed for life today

80
00:03:51,130 --> 00:03:49,430
so I've been talking about the RNA of

81
00:03:53,620 --> 00:03:51,140
the ribosome so far and I want to talk

82
00:03:55,210 --> 00:03:53,630
about the proteins of the ribosome so

83
00:03:58,900 --> 00:03:55,220
when you look at the prokaryotic

84
00:04:00,940 --> 00:03:58,910
ribosomes wheat there are 29 ribosomal

85
00:04:02,230 --> 00:04:00,950
proteins in just the large subunit i'll

86
00:04:04,240 --> 00:04:02,240
be talking about just a large subunit

87
00:04:07,060 --> 00:04:04,250
today there's off this also applies to

88
00:04:08,620 --> 00:04:07,070

the small subunit so there's 29 are

89
00:04:10,870 --> 00:04:08,630
those little proteins of the e.coli

90
00:04:13,870 --> 00:04:10,880
ribosome and what's very interesting

91
00:04:16,240 --> 00:04:13,880
about these proteins is that a lot of

92
00:04:19,000 --> 00:04:16,250
them have these globular like spherical

93
00:04:21,190 --> 00:04:19,010
domains that sit on the exterior of the

94
00:04:24,430 --> 00:04:21,200
ribosome and those look like proteins

95
00:04:26,290 --> 00:04:24,440
that we find in life today but they have

96
00:04:28,510 --> 00:04:26,300
these really weird segments that we just

97
00:04:30,850 --> 00:04:28,520
don't really find anywhere else these

98
00:04:32,070 --> 00:04:30,860
tail segments and they penetrate deep

99
00:04:35,369 --> 00:04:32,080
down into the

100
00:04:37,679 --> 00:04:35,379
core the ribosome close to where peptide

101
00:04:39,360 --> 00:04:37,689
bonds are actually made where proteins

102
00:04:43,740 --> 00:04:39,370
are actually synthesized by the ribosome

103
00:04:46,770 --> 00:04:43,750
and so looking at these proteins in what

104
00:04:48,689 --> 00:04:46,780
they contact of the ribosomal RNA so a

105
00:04:51,059 --> 00:04:48,699
very beginning you saw that I had one

106
00:04:53,790 --> 00:04:51,069
piece of RNA and then as was growing

107
00:04:58,020 --> 00:04:53,800
throughout the evolution of life we can

108
00:05:00,420 --> 00:04:58,030
see that more RNA was conglomerating

109
00:05:04,260 --> 00:05:00,430
onto it and if we look at the proteins

110
00:05:06,860 --> 00:05:04,270
of the ribosome and which pieces of RNA

111
00:05:10,589 --> 00:05:06,870
they contact we can cut we can see a

112
00:05:12,540 --> 00:05:10,599
timeline of ribosomal evolution or in

113
00:05:13,920 --> 00:05:12,550

just run resume approaching evolution

114
00:05:15,959 --> 00:05:13,930
and just protein evolution for that

115
00:05:17,610 --> 00:05:15,969
matter so at the very beginning we only

116
00:05:20,790 --> 00:05:17,620
had small little peptides that we're

117
00:05:23,070 --> 00:05:20,800
sticking on there but as ribosome grew

118
00:05:25,559 --> 00:05:23,080
the proteins that could stick on to it

119
00:05:27,089 --> 00:05:25,569
we're growing as well and I'm going to

120
00:05:29,700 --> 00:05:27,099
look at the structure of these proteins

121
00:05:33,300 --> 00:05:29,710
and see how it's changed since the

122
00:05:36,930 --> 00:05:33,310
origin play okay so a lot of these

123
00:05:38,790 --> 00:05:36,940
proteins are very positively charged

124
00:05:40,709 --> 00:05:38,800
because RNA is very negatively charged

125
00:05:44,700 --> 00:05:40,719
so we see a lot of arginine and lysine

126
00:05:46,350 --> 00:05:44,710
and hypothesize that well we know that

127
00:05:48,659 --> 00:05:46,360
they kind just hold the RNA together

128
00:05:53,879 --> 00:05:48,669
they kind of just act as a glue so

129
00:05:56,399 --> 00:05:53,889
they're needed for the ribosome okay and

130
00:05:58,110 --> 00:05:56,409
then so my background is in biochemistry

131
00:06:01,200 --> 00:05:58,120
so I want to give you a brief background

132
00:06:03,659 --> 00:06:01,210
on what a popular plot that biochemistry

133
00:06:05,579 --> 00:06:03,669
is called the ramachandran plot and so

134
00:06:08,010 --> 00:06:05,589
biochemists really like proteins and

135
00:06:10,260 --> 00:06:08,020
light protein structure and so in

136
00:06:12,420 --> 00:06:10,270
proteins that we find today we see a lot

137
00:06:15,930 --> 00:06:12,430
of approach like looking at the angles

138
00:06:18,360 --> 00:06:15,940

that the amino acids in the protein form

139
00:06:20,670 --> 00:06:18,370
with each other they typically just the

140
00:06:22,170 --> 00:06:20,680
way they just fold into the protein we

141
00:06:24,689 --> 00:06:22,180
typically find them in these centers

142
00:06:26,550 --> 00:06:24,699
right here in the red and so we see this

143
00:06:29,159 --> 00:06:26,560
alpha helix which is very common in

144
00:06:31,969 --> 00:06:29,169
proteins today and that's usually just

145
00:06:33,869 --> 00:06:31,979
looking at the angles of those buns

146
00:06:36,180 --> 00:06:33,879
usually find them right in this red

147
00:06:37,769 --> 00:06:36,190
region and we also see a lot of beta

148
00:06:40,199 --> 00:06:37,779
sheets that's another common secondary

149
00:06:42,600 --> 00:06:40,209
structure of proteins and that usually

150
00:06:45,089 --> 00:06:42,610
falls within this red region and then

151
00:06:46,330 --> 00:06:45,099
all these like white area over here we

152
00:06:50,710 --> 00:06:46,340
don't find too many

153
00:06:52,090 --> 00:06:50,720
um amino acids in there but that's kind

154
00:06:53,860 --> 00:06:52,100
of unstructured they usually don't like

155
00:06:55,860 --> 00:06:53,870
hydrogen bond with each other you can't

156
00:07:00,450 --> 00:06:55,870
it's just don't really form any like

157
00:07:04,930 --> 00:07:00,460
functional catalytic parts typically

158
00:07:07,780 --> 00:07:04,940
okay so looking at the secondary

159
00:07:09,189 --> 00:07:07,790
structure of ribosomal proteins so in

160
00:07:10,870 --> 00:07:09,199
the very beginning you could see that I

161
00:07:15,070 --> 00:07:10,880
had this little peptide earlier on two

162
00:07:18,280 --> 00:07:15,080
slides ago that was like composed of I

163
00:07:20,890 --> 00:07:18,290

think 12 amino acids and approximately

164
00:07:25,420 --> 00:07:20,900
one third of them fell within these red

165
00:07:29,110 --> 00:07:25,430
regions then we look at when the next

166
00:07:30,580 --> 00:07:29,120
little phase of evolution a few more of

167
00:07:33,820 --> 00:07:30,590
the amino acids are starting to fall

168
00:07:37,150 --> 00:07:33,830
into these red regions and as we keep on

169
00:07:39,400 --> 00:07:37,160
going through we can see that more and

170
00:07:41,020 --> 00:07:39,410
more of these amino acids the bonds

171
00:07:45,279 --> 00:07:41,030
between them we're falling into these

172
00:07:47,290 --> 00:07:45,289
red regions so when the ribosomes

173
00:07:50,080 --> 00:07:47,300
started producing proteins they weren't

174
00:07:54,159 --> 00:07:50,090
really structured but as drivers ohm

175
00:07:56,680 --> 00:07:54,169
evolved so did its ability to synthesize

176
00:07:59,680 --> 00:07:56,690
proteins of increasing complexity and

177
00:08:01,960 --> 00:07:59,690
now they have these structures that we

178
00:08:03,969 --> 00:08:01,970
find in life and many of them not within

179
00:08:09,550 --> 00:08:03,979
the ribosome but these structures are

180
00:08:11,770 --> 00:08:09,560
often catalytic okay so what about like

181
00:08:15,370 --> 00:08:11,780
hydrogen bonds within the ribosomal

182
00:08:17,260 --> 00:08:15,380
proteins so I brought up earlier beta

183
00:08:19,629 --> 00:08:17,270
sheets and alpha helix ease and they

184
00:08:23,409 --> 00:08:19,639
have a lot of hydrogen bonds and so when

185
00:08:25,659 --> 00:08:23,419
I look at the the phases of ribosomal

186
00:08:27,909 --> 00:08:25,669
evolution from the origin of life until

187
00:08:29,920 --> 00:08:27,919
last Universal common as sensitive right

188
00:08:32,290 --> 00:08:29,930

over here we can see that the hydrogen

189
00:08:35,140 --> 00:08:32,300
bonds per residue are increasing so

190
00:08:37,240 --> 00:08:35,150
these proteins are just folding more and

191
00:08:40,000 --> 00:08:37,250
more compact and they're just looking

192
00:08:42,070 --> 00:08:40,010
more and more like proteins that we find

193
00:08:43,810 --> 00:08:42,080
an extent like today and then when we

194
00:08:46,660 --> 00:08:43,820
look at the surface area of them by just

195
00:08:48,370 --> 00:08:46,670
a computational method of just pretty

196
00:08:51,010 --> 00:08:48,380
much just rolling a ball around the

197
00:08:53,710 --> 00:08:51,020
ribosomal proteins we can see that their

198
00:08:55,720 --> 00:08:53,720
their surface area is going down and we

199
00:08:57,850 --> 00:08:55,730
just see that they're just folding more

200
00:08:58,809 --> 00:08:57,860
compactly and that they're just looking

201
00:09:02,889 --> 00:08:58,819
more in

202
00:09:05,799 --> 00:09:02,899
more like proteins we find today so I

203
00:09:08,529 --> 00:09:05,809
believe that is what I have for today so

204
00:09:10,809 --> 00:09:08,539
my name is watch my name is Nicholas

205
00:09:13,090 --> 00:09:10,819
kawatche and I'd like I working dr.

206
00:09:15,429 --> 00:09:13,100
Warren Williams lab and I really like to

207
00:09:18,969 --> 00:09:15,439
thank dr. Anton Petrov and dr. chadbourn

208
00:09:21,549 --> 00:09:18,979
yer who are having my mentors and I

209
00:09:23,769 --> 00:09:21,559
would just like to thank a grad calm in

210
00:09:37,329 --> 00:09:23,779
Georgia Tech and the IBB at Georgia Tech

211
00:09:39,489 --> 00:09:37,339
for providing my funding hi I was

212
00:09:42,129 --> 00:09:39,499
wondering what like you know what the

213
00:09:45,369 --> 00:09:42,139

minimum number of residues like a

214
00:09:47,049 --> 00:09:45,379
polypeptide or I guess a short protein

215
00:09:49,479 --> 00:09:47,059
if you define it that way would have to

216
00:09:51,909 --> 00:09:49,489
have to like start exhibiting some type

217
00:09:57,009 --> 00:09:51,919
of defined structure um there is

218
00:09:59,259 --> 00:09:57,019
recently a paper we're just through like

219
00:10:02,349 --> 00:09:59,269
just directed evolution i think it was i

220
00:10:04,869 --> 00:10:02,359
think was like 12 amino acids they could

221
00:10:08,649 --> 00:10:04,879
make a functional protein when there are

222
00:10:10,929 --> 00:10:08,659
about 20 amino acids found today in all

223
00:10:13,269 --> 00:10:10,939
of life and those 12 a lot of them i

224
00:10:14,919 --> 00:10:13,279
think almost all of them were actually

225
00:10:17,289 --> 00:10:14,929
the same amino acids found the

226
00:10:19,329 --> 00:10:17,299
miller-urey experiment which we

227
00:10:24,969 --> 00:10:19,339
hypothesize owe their very first amino

228
00:10:26,379 --> 00:10:24,979
acids of life I think you might have

229
00:10:28,329 --> 00:10:26,389
just answered my question but I was

230
00:10:30,249 --> 00:10:28,339
gonna ask how did you determine the

231
00:10:33,669 --> 00:10:30,259
sequence of proteins for your early

232
00:10:36,069 --> 00:10:33,679
proteins um well I was just looking at

233
00:10:38,979 --> 00:10:36,079
the crystal structures of available of

234
00:10:41,340 --> 00:10:38,989
the ribosome today so we have crystal

235
00:10:43,779 --> 00:10:41,350
structures of the e.coli ribosome yeast

236
00:10:47,049 --> 00:10:43,789
drosophila human in a few other species

237
00:10:49,389 --> 00:10:47,059
and I was just taking the sequences

238
00:11:00,650 --> 00:10:49,399

found within those proteins of those

239
00:11:04,889 --> 00:11:03,600
yeah thanks a great talk I find it

240
00:11:06,930 --> 00:11:04,899
interesting this idea that species

241
00:11:09,540 --> 00:11:06,940
complexity is related to the size of the

242
00:11:11,370 --> 00:11:09,550
ribosome is that possibly because we

243
00:11:13,410 --> 00:11:11,380
have a lack of data on ribosomes that

244
00:11:16,500 --> 00:11:13,420
are out there yet or is this not been

245
00:11:19,410 --> 00:11:16,510
shown across the board so far I mean for

246
00:11:20,790 --> 00:11:19,420
i'm looking at crystal structures and I

247
00:11:23,490 --> 00:11:20,800
mean there's just not that many of them

248
00:11:25,530 --> 00:11:23,500
available just yet I mean the very first

249
00:11:27,120 --> 00:11:25,540
one was like we crystallized or of his

250
00:11:29,850 --> 00:11:27,130
own like in the early 2000s so there's

251
00:11:32,340 --> 00:11:29,860
not that many of them but we can look at

252
00:11:34,680 --> 00:11:32,350
the genes of that encode for these

253
00:11:35,850 --> 00:11:34,690
ribosomes in species you know really

254
00:11:38,910 --> 00:11:35,860
easily we've been doing it for quite a

255
00:11:40,800 --> 00:11:38,920
while and so I that's the mile out

256
00:11:43,740 --> 00:11:40,810
knowledge i think these mammalian ones

257
00:11:45,569 --> 00:11:43,750
are the largest we've seen interesting

258
00:11:47,850 --> 00:11:45,579
here's the end up for a long time we

259
00:11:48,960 --> 00:11:47,860
thought that genome why's that we humans

260
00:11:50,280 --> 00:11:48,970
would be the best we'd have the most

261
00:11:51,960 --> 00:11:50,290
genes of anything and that's not the

262
00:11:54,690 --> 00:11:51,970
case and we've now found out that

263
00:11:56,040 --> 00:11:54,700

complexity in our little viewpoint of

264
00:11:57,900 --> 00:11:56,050
complexity isn't really related to

265
00:11:59,220 --> 00:11:57,910
genome size and so i was just wondering

266
00:12:02,670 --> 00:11:59,230
if that would be the case with ribosomes

267
00:12:04,620 --> 00:12:02,680
once we get more data as well yeah well

268
00:12:06,720 --> 00:12:04,630
what's interesting is that fly that

269
00:12:08,730 --> 00:12:06,730
ribosome work was based on a paper we

270
00:12:11,220 --> 00:12:08,740
had and we put it on someone pick it up

271
00:12:13,139 --> 00:12:11,230
on reddit and people were kind of

272
00:12:14,639 --> 00:12:13,149
getting like really like up in arms

273
00:12:17,220 --> 00:12:14,649
about like a big like discussions

274
00:12:18,840 --> 00:12:17,230
because we are just the biggest rivals

275
00:12:20,310 --> 00:12:18,850
own we've seen today is the human

276
00:12:21,870 --> 00:12:20,320
ribosome and then people we're just

277
00:12:23,880 --> 00:12:21,880
going off on like tangents about like

278
00:12:25,680 --> 00:12:23,890
why we're the most like the highest most

279
00:12:27,420 --> 00:12:25,690
dominant species because of that and

280
00:12:28,470 --> 00:12:27,430
just people were you know biologists are

281
00:12:34,639 --> 00:12:28,480
getting in there and getting mad and

282
00:12:41,220 --> 00:12:37,920
well so I've heard this idea before that

283
00:12:44,340 --> 00:12:41,230
you can see sort of the ribosomes of

284
00:12:46,230 --> 00:12:44,350
less complex species embedded in the

285
00:12:49,620 --> 00:12:46,240
ribosomes of more complex ones but

286
00:12:52,380 --> 00:12:49,630
obviously like you know if you take

287
00:12:53,910 --> 00:12:52,390
humans and like a fly for example those

288
00:12:56,370 --> 00:12:53,920

diverged in their evolution a really

289
00:12:58,800 --> 00:12:56,380
really long time ago so why would you

290
00:13:00,389 --> 00:12:58,810
necessarily find like a fly's ribosome

291
00:13:02,490 --> 00:13:00,399
embedded in there do you think that

292
00:13:05,130 --> 00:13:02,500
there's intrinsic sort of evolutionary

293
00:13:06,960 --> 00:13:05,140
bottlenecks that only the ribozyme can

294
00:13:08,249 --> 00:13:06,970
sort of get past and it has to evolve

295
00:13:10,439 --> 00:13:08,259
particular features

296
00:13:12,269 --> 00:13:10,449
or is it just oh you have to actually

297
00:13:14,669 --> 00:13:12,279
strip away some of these a lot evolved

298
00:13:16,530 --> 00:13:14,679
features to find like you know there's

299
00:13:19,979 --> 00:13:16,540
something on top of the fly ribosome

300
00:13:21,629 --> 00:13:19,989
that's not in the human one well I was

301
00:13:23,609 --> 00:13:21,639
looking at the structure and so like a

302
00:13:26,009 --> 00:13:23,619
lot of times like you can have like an

303
00:13:28,979 --> 00:13:26,019
80 base pair or you can have like or

304
00:13:32,369 --> 00:13:28,989
sorry ribosome au base pair or a GC base

305
00:13:34,049 --> 00:13:32,379
pair and like there's like differences

306
00:13:35,689 --> 00:13:34,059
in that but like we look at the

307
00:13:37,829 --> 00:13:35,699
structure of it it looks the same

308
00:13:39,269 --> 00:13:37,839
approximately but like those sequences

309
00:13:41,699 --> 00:13:39,279
might be different and there's like some

310
00:13:45,539 --> 00:13:41,709
parts that like are unique to different

311
00:13:47,069 --> 00:13:45,549
species so and plus I just like the RNA

312
00:13:49,619 --> 00:13:47,079
without like the protein like the

313
00:13:53,449 --> 00:13:49,629

proteins are very different between a a

314
00:13:56,400 --> 00:13:53,459
lot of organisms some homology

315
00:13:58,650 --> 00:13:56,410
okay well uh have people don't gather a

316
00:14:01,460 --> 00:13:58,660
metric measurements of ribozymes like

317
00:14:05,579 --> 00:14:01,470
measuring heat capacities and volumes

318
00:14:07,289 --> 00:14:05,589
hmm yeah yeah of course I think some all

319
00:14:09,779 --> 00:14:07,299
right IDC experiments that everything

320
00:14:13,859 --> 00:14:09,789
like that cool thanks i'm done with nam