



**NICK
LANE**

**LIFE IS
THE FLOW
OF ENERGY**

1
00:00:04,309 --> 00:00:02,310
nick lane is a biochemist a writer and a

2
00:00:06,869 --> 00:00:04,319
professor at university college london

3
00:00:08,870 --> 00:00:06,879
whose book transformer exposes on the

4
00:00:10,950 --> 00:00:08,880
origins of life not being so heavily

5
00:00:12,950 --> 00:00:10,960
contingent on rna as many think but

6
00:00:15,030 --> 00:00:12,960
instead in something called the krebs

7
00:00:16,710 --> 00:00:15,040
cycle poetically you can think of this

8
00:00:18,630 --> 00:00:16,720
as the difference between an information

9
00:00:20,630 --> 00:00:18,640
theory of life which is the current

10
00:00:23,830 --> 00:00:20,640
dominant view to one of the

11
00:00:25,910 --> 00:00:23,840
thermodynamic energy flow of life which

12
00:00:27,349 --> 00:00:25,920
is nick lane's view as usual click on

13
00:00:29,349 --> 00:00:27,359

the time stamp in the description to

14

00:00:31,669 --> 00:00:29,359

skip this intro my name is kurt jay

15

00:00:33,750 --> 00:00:31,679

mungle i'm a torontonian filmmaker with

16

00:00:35,270 --> 00:00:33,760

a background in mathematical physics and

17

00:00:37,590 --> 00:00:35,280

this channel is dedicated to the

18

00:00:40,310 --> 00:00:37,600

explication of the variegated terrain of

19

00:00:42,630 --> 00:00:40,320

theories of everything that is primarily

20

00:00:44,790 --> 00:00:42,640

from a theoretical physics perspective

21

00:00:46,470 --> 00:00:44,800

so for example grand unification and

22

00:00:48,150 --> 00:00:46,480

quantum gravity but as well as

23

00:00:50,389 --> 00:00:48,160

understanding the role consciousness has

24

00:00:52,150 --> 00:00:50,399

to play to the fundamental laws provided

25

00:00:54,310 --> 00:00:52,160

these laws exist at all in a form

26
00:00:55,990 --> 00:00:54,320
knowable to us two quick announcements

27
00:00:57,990 --> 00:00:56,000
firstly there's a physics and

28
00:00:58,950 --> 00:00:58,000
consciousness contest on this channel

29
00:01:00,470 --> 00:00:58,960
the link to which will be in the

30
00:01:02,310 --> 00:01:00,480
description as well as the thumbnail is

31
00:01:04,390 --> 00:01:02,320
over here essentially it's the physics

32
00:01:06,469 --> 00:01:04,400
version of the three blue one brown math

33
00:01:08,070 --> 00:01:06,479
contest except ours is for physics and

34
00:01:10,149 --> 00:01:08,080
consciousness as well if you have an

35
00:01:12,469 --> 00:01:10,159
idea for some explainer of an advanced

36
00:01:14,070 --> 00:01:12,479
physics or consciousness concept then

37
00:01:15,670 --> 00:01:14,080
think about creating a video for this

38
00:01:17,670 --> 00:01:15,680

and submitting as you have the chance to

39

00:01:19,429 --> 00:01:17,680

win one thousand dollars brilliant has

40

00:01:21,190 --> 00:01:19,439

come in to give five thousand among the

41

00:01:22,710 --> 00:01:21,200

top five so that's one thousand for each

42

00:01:26,070 --> 00:01:22,720

the second announcement is that there's

43

00:01:27,749 --> 00:01:26,080

a new theories of everything.org website

44

00:01:28,710 --> 00:01:27,759

this is a website where you can support

45

00:01:30,390 --> 00:01:28,720

toe

46

00:01:32,550 --> 00:01:30,400

curt which is me

47

00:01:34,870 --> 00:01:32,560

instead of on patreon because patreon

48

00:01:36,469 --> 00:01:34,880

takes a huge cut as well as paypal takes

49

00:01:38,310 --> 00:01:36,479

a cut there's many different places that

50

00:01:40,310 --> 00:01:38,320

take their share and as a creator you

51
00:01:41,910 --> 00:01:40,320
don't have control over your donations

52
00:01:44,230 --> 00:01:41,920
so for instance

53
00:01:45,990 --> 00:01:44,240
patreon may decide to shut you down for

54
00:01:47,590 --> 00:01:46,000
whatever reason they like there are also

55
00:01:49,510 --> 00:01:47,600
a variety of benefits that come with

56
00:01:50,950 --> 00:01:49,520
being a member on the toe website for

57
00:01:52,789 --> 00:01:50,960
instance you get an ad free version of

58
00:01:54,870 --> 00:01:52,799
the shows that are coming out an audio

59
00:01:56,870 --> 00:01:54,880
ad free version that is to say you get a

60
00:01:58,709 --> 00:01:56,880
private link to the rss feed to download

61
00:02:01,510 --> 00:01:58,719
the audio versions and they come out

62
00:02:03,190 --> 00:02:01,520
about 12 to 48 hours sometimes even one

63
00:02:04,950 --> 00:02:03,200

week prior to you seeing them here on

64

00:02:06,709 --> 00:02:04,960

youtube just so you know the way that it

65

00:02:08,389 --> 00:02:06,719

works is that i finished editing and

66

00:02:10,229 --> 00:02:08,399

then i have to do another run through

67

00:02:13,110 --> 00:02:10,239

and go through time stamps and catalog

68

00:02:15,350 --> 00:02:13,120

references and so on that takes time and

69

00:02:17,750 --> 00:02:15,360

what it means is that i put it out on

70

00:02:19,750 --> 00:02:17,760

youtube and then i have a lag so that i

71

00:02:21,350 --> 00:02:19,760

can build up some hype and some audience

72

00:02:22,790 --> 00:02:21,360

prior to the premiere but then that

73

00:02:25,430 --> 00:02:22,800

means that i've actually finished the

74

00:02:27,350 --> 00:02:25,440

episode a couple days before so what

75

00:02:29,350 --> 00:02:27,360

i'll do is i'll upload simultaneously

76
00:02:31,270 --> 00:02:29,360
for the members an audio version ads

77
00:02:32,229 --> 00:02:31,280
free and then later it premieres on

78
00:02:35,750 --> 00:02:32,239
youtube

79
00:02:37,750 --> 00:02:35,760
changes this is the way i've always done

80
00:02:40,070 --> 00:02:37,760
it it's just that i have here an audio

81
00:02:41,830 --> 00:02:40,080
version for a little while prior which

82
00:02:43,670 --> 00:02:41,840
i'm going to release to the tow members

83
00:02:45,270 --> 00:02:43,680
as a thank you and it's going to be ads

84
00:02:46,470 --> 00:02:45,280
free so that's one of the benefits from

85
00:02:48,869 --> 00:02:46,480
this point forward there may be

86
00:02:50,710 --> 00:02:48,879
mid-rolls that is ads in the middle of a

87
00:02:53,030 --> 00:02:50,720
podcast and that's just part and parcel

88
00:02:55,430 --> 00:02:53,040

of the toll members of the tow audience

89

00:02:57,190 --> 00:02:55,440

you are sponsoring toe and then the

90

00:02:59,110 --> 00:02:57,200

sponsors also sponsor toe so thank you

91

00:03:01,110 --> 00:02:59,120

for your support those won't be there in

92

00:03:03,270 --> 00:03:01,120

the audio ads free version for the tow

93

00:03:05,589 --> 00:03:03,280

members second benefit is that you get

94

00:03:07,670 --> 00:03:05,599

discounts to any live events when we do

95

00:03:10,630 --> 00:03:07,680

have them for instance i'd like to do

96

00:03:12,630 --> 00:03:10,640

carl fristen in london live in front of

97

00:03:14,550 --> 00:03:12,640

an audience same with ema gilchrist and

98

00:03:16,070 --> 00:03:14,560

john verveicky at some point another

99

00:03:18,149 --> 00:03:16,080

benefit is that there will be exclusive

100

00:03:19,830 --> 00:03:18,159

merch offered to the tow members another

101
00:03:21,430 --> 00:03:19,840
benefit is that there's a number to text

102
00:03:23,430 --> 00:03:21,440
me again if that's what you're into

103
00:03:25,110 --> 00:03:23,440
we're testing this out for about a month

104
00:03:27,110 --> 00:03:25,120
and yes this is something where i am

105
00:03:28,470 --> 00:03:27,120
texting you back to your phone

106
00:03:30,710 --> 00:03:28,480
throughout much of this you can see that

107
00:03:32,229 --> 00:03:30,720
the artwork here is exquisite on the

108
00:03:34,630 --> 00:03:32,239
website and that's because it's been

109
00:03:36,470 --> 00:03:34,640
done by boris martinez costello a link

110
00:03:38,309 --> 00:03:36,480
to his instagram is in the description

111
00:03:40,070 --> 00:03:38,319
as well thank you boris thank you so

112
00:03:42,550 --> 00:03:40,080
much as for today's sponsor it's

113
00:03:44,550 --> 00:03:42,560

brilliant brilliant.org now brilliant

114

00:03:46,229 --> 00:03:44,560

has been with toe since near the

115

00:03:48,550 --> 00:03:46,239

beginning i recommend you check out

116

00:03:50,630 --> 00:03:48,560

brilliant.org toe if you're interested

117

00:03:52,470 --> 00:03:50,640

in learning math and physics and science

118

00:03:53,830 --> 00:03:52,480

so brilliant is a place that you go to

119

00:03:55,270 --> 00:03:53,840

learn about stem subjects in an

120

00:03:58,229 --> 00:03:55,280

interactive manner they have these

121

00:04:00,070 --> 00:03:58,239

bite-sized courses it's extremely easy

122

00:04:02,470 --> 00:04:00,080

you may think that special relativity is

123

00:04:03,910 --> 00:04:02,480

beyond you no it's not it's something

124

00:04:05,670 --> 00:04:03,920

that someone can understand in

125

00:04:06,949 --> 00:04:05,680

elementary school the way that brilliant

126

00:04:09,030 --> 00:04:06,959

breaks down these

127

00:04:11,190 --> 00:04:09,040

extremely ordinarily extremely advanced

128

00:04:12,630 --> 00:04:11,200

concepts is elementary at some point

129

00:04:15,589 --> 00:04:12,640

i'll be doing an introduction to

130

00:04:17,590 --> 00:04:15,599

information theory in particular there's

131

00:04:19,430 --> 00:04:17,600

david deutsch and chiara marletta's

132

00:04:21,509 --> 00:04:19,440

constructor theory and because i'd like

133

00:04:22,950 --> 00:04:21,519

to learn that i decided let me brush up

134

00:04:25,110 --> 00:04:22,960

on the fundamentals of information

135

00:04:27,390 --> 00:04:25,120

theory and i took brilliance course just

136

00:04:31,110 --> 00:04:27,400

to do so over this winter break visit

137

00:04:33,030 --> 00:04:31,120

brilliant.org toe that's t-o-e to get 20

138

00:04:34,710 --> 00:04:33,040

off the annual subscription i recommend

139

00:04:36,950 --> 00:04:34,720

that you don't stop before four lessons

140

00:04:38,790 --> 00:04:36,960

just keep going until you hit four and

141

00:04:40,550 --> 00:04:38,800

you'll be greatly surprised at the ease

142

00:04:42,710 --> 00:04:40,560

at which you can now comprehend subjects

143

00:04:44,550 --> 00:04:42,720

you previously had a difficult time

144

00:04:46,629 --> 00:04:44,560

grokking okay thank you and enjoy

145

00:04:48,870 --> 00:04:46,639

today's episode professor thank you so

146

00:04:51,030 --> 00:04:48,880

much for joining me on

147

00:04:53,510 --> 00:04:51,040

on toe thank you so much it's my

148

00:04:55,749 --> 00:04:53,520

pleasure thank you

149

00:04:58,390 --> 00:04:55,759

why don't we go over your primary thesis

150

00:04:59,590 --> 00:04:58,400

about how the krebs cycle predates life

151

00:05:01,830 --> 00:04:59,600

and

152

00:05:03,830 --> 00:05:01,840

perhaps you can contrast that with a

153

00:05:06,790 --> 00:05:03,840

reverse predominant view which is that

154

00:05:08,070 --> 00:05:06,800

genes cause metabolism or genes create

155

00:05:10,150 --> 00:05:08,080

metabolism or the conditions for

156

00:05:14,150 --> 00:05:10,160

metabolism yeah i mean this is a this is

157

00:05:16,070 --> 00:05:14,160

an argument that goes back decades in in

158

00:05:18,950 --> 00:05:16,080

work on the origin of life and and you

159

00:05:21,029 --> 00:05:18,960

mentioned the krebs cycle already um

160

00:05:24,070 --> 00:05:21,039

those ideas also go back decades this is

161

00:05:25,990 --> 00:05:24,080

nothing particularly new uh from me um

162

00:05:28,550 --> 00:05:26,000

but

163

00:05:31,350 --> 00:05:28,560

what's changed is that there is now some

164

00:05:33,830 --> 00:05:31,360

experimental evidence um and that's been

165

00:05:35,749 --> 00:05:33,840

lacking so

166

00:05:37,029 --> 00:05:35,759

i guess the the whole field of biology

167

00:05:39,189 --> 00:05:37,039

has been obsessed with genes and

168

00:05:41,590 --> 00:05:39,199

information over

169

00:05:42,870 --> 00:05:41,600

since the 1960s since the code was

170

00:05:45,830 --> 00:05:42,880

cracked

171

00:05:48,070 --> 00:05:45,840

and and the idea that rna

172

00:05:51,110 --> 00:05:48,080

which is the kind of the template

173

00:05:53,189 --> 00:05:51,120

taken from dna it can it can catalyze

174

00:05:55,510 --> 00:05:53,199

things it can also

175

00:05:57,830 --> 00:05:55,520

supposedly copy itself it can act as a

176

00:05:59,909 --> 00:05:57,840

template for itself and so on so it's a

177

00:06:01,510 --> 00:05:59,919

beautiful idea it's called the rna world

178

00:06:02,469 --> 00:06:01,520

it's been around for quite a long time

179

00:06:04,790 --> 00:06:02,479

now

180

00:06:07,430 --> 00:06:04,800

uh and it kind of takes you further and

181

00:06:09,189 --> 00:06:07,440

further away from biology as we know it

182

00:06:11,990 --> 00:06:09,199

and i end up in a place where as a

183

00:06:13,909 --> 00:06:12,000

biochemist i'm i'm i i just don't

184

00:06:14,710 --> 00:06:13,919

recognize the landscape

185

00:06:17,830 --> 00:06:14,720

um

186

00:06:20,150 --> 00:06:17,840

so these ideas of metabolism first

187

00:06:22,150 --> 00:06:20,160

i suppose the problem there is that it

188

00:06:24,309 --> 00:06:22,160

asks a lot of the environment

189

00:06:27,110 --> 00:06:24,319

effectively it's asking

190

00:06:29,110 --> 00:06:27,120

one specific place one specific setting

191

00:06:31,749 --> 00:06:29,120

to start out with something like carbon

192

00:06:34,150 --> 00:06:31,759

dioxide and hydrogen and not much else

193

00:06:35,749 --> 00:06:34,160

and to make everything from it in the

194

00:06:38,309 --> 00:06:35,759

absence of genes in the absence of

195

00:06:41,909 --> 00:06:38,319

enzymes it's it's it's a big ask

196

00:06:44,909 --> 00:06:41,919

um and uh and people who've argued this

197

00:06:46,870 --> 00:06:44,919

harold morovitz one of the great um

198

00:06:48,629 --> 00:06:46,880

biophysicists who worked a lot on the

199

00:06:50,309 --> 00:06:48,639

origin of life he he linked it in with

200

00:06:52,070 --> 00:06:50,319

metabolism first and the krebs cycle

201
00:06:53,909 --> 00:06:52,080
very early

202
00:06:56,070 --> 00:06:53,919
and he was largely dismissed because

203
00:06:58,390 --> 00:06:56,080
there wasn't any any serious evidence

204
00:06:59,589 --> 00:06:58,400
that it could actually work

205
00:07:01,589 --> 00:06:59,599
and now what's happened over the last

206
00:07:03,029 --> 00:07:01,599
five or six years is is it's beginning

207
00:07:04,629 --> 00:07:03,039
to look as if it really does work and

208
00:07:06,469 --> 00:07:04,639
it's not just the krebs cycle not as a

209
00:07:07,990 --> 00:07:06,479
complete cycle but as a kind of a linear

210
00:07:09,270 --> 00:07:08,000
pathway with parts of it it's not the

211
00:07:12,469 --> 00:07:09,280
whole thing

212
00:07:14,309 --> 00:07:12,479
um but also other core biochemical

213
00:07:15,350 --> 00:07:14,319

pathways seem to just spontaneously

214

00:07:17,909 --> 00:07:15,360

happen

215

00:07:20,309 --> 00:07:17,919

and they make so much more sense

216

00:07:22,710 --> 00:07:20,319

of the whole structure of biochemistry

217

00:07:24,629 --> 00:07:22,720

and then also how it is that information

218

00:07:26,309 --> 00:07:24,639

comes into biology because it comes in

219

00:07:27,830 --> 00:07:26,319

it comes in

220

00:07:29,110 --> 00:07:27,840

in a context where it's already

221

00:07:30,710 --> 00:07:29,120

optimizing things that are happening

222

00:07:31,510 --> 00:07:30,720

anyway and so there's there's a kind of

223

00:07:38,870 --> 00:07:31,520

a

224

00:07:40,870 --> 00:07:38,880

solving

225

00:07:42,390 --> 00:07:40,880

metabolism as being a biochemistry

226

00:07:44,870 --> 00:07:42,400

question or physics question or a

227

00:07:45,749 --> 00:07:44,880

biology question

228

00:07:48,150 --> 00:07:45,759

yes

229

00:07:50,230 --> 00:07:48,160

are those distinctions important

230

00:07:52,070 --> 00:07:50,240

they are important from the point of

231

00:07:53,350 --> 00:07:52,080

view of people's backgrounds they're not

232

00:07:54,629 --> 00:07:53,360

important from the point of view of the

233

00:07:56,629 --> 00:07:54,639

question because the question is a

234

00:07:58,390 --> 00:07:56,639

question in science the question is it

235

00:08:00,469 --> 00:07:58,400

needs physics it needs chemistry it

236

00:08:01,990 --> 00:08:00,479

needs biology and geology and so on and

237

00:08:04,309 --> 00:08:02,000

this is part of the problem

238

00:08:07,029 --> 00:08:04,319

uh that it's been a kind of collision of

239

00:08:09,749 --> 00:08:07,039

disciplines each of which have

240

00:08:11,670 --> 00:08:09,759

you know 100 years or more of its own

241

00:08:12,950 --> 00:08:11,680

intellectual history and ways of seeing

242

00:08:14,629 --> 00:08:12,960

the question

243

00:08:16,230 --> 00:08:14,639

so i think

244

00:08:18,869 --> 00:08:16,240

the the dominant

245

00:08:20,629 --> 00:08:18,879

way of seeing the question over the last

246

00:08:23,189 --> 00:08:20,639

really since the military experiment in

247

00:08:25,270 --> 00:08:23,199

1953 has been through the lens of

248

00:08:27,110 --> 00:08:25,280

chemistry and what the chemists have

249

00:08:29,029 --> 00:08:27,120

tried to do is what synthetic chemists

250

00:08:30,950 --> 00:08:29,039

try to do which is to say

251
00:08:32,230 --> 00:08:30,960
you tell me i need to make a nucleotide

252
00:08:33,190 --> 00:08:32,240
so i'm going to make you a nucleotide

253
00:08:34,949 --> 00:08:33,200
i'm going to make you nothing but

254
00:08:37,589 --> 00:08:34,959
nucleotides it's going to have a high

255
00:08:39,990 --> 00:08:37,599
yield it's going to be pure i can make

256
00:08:42,949 --> 00:08:40,000
you 70 and i need to start with cyanide

257
00:08:44,870 --> 00:08:42,959
therefore this is how life starts

258
00:08:45,990 --> 00:08:44,880
and from a from a biologist's point of

259
00:08:47,269 --> 00:08:46,000
view

260
00:08:48,710 --> 00:08:47,279
um

261
00:08:51,030 --> 00:08:48,720
well you'd see it the other way around

262
00:08:53,190 --> 00:08:51,040
you'd say well natural selection

263
00:08:55,590 --> 00:08:53,200

optimizes things that

264

00:08:57,030 --> 00:08:55,600

um that you know were worse at the

265

00:08:59,269 --> 00:08:57,040

beginning and now they're better because

266

00:09:00,790 --> 00:08:59,279

selection optimized them uh and

267

00:09:02,710 --> 00:09:00,800

therefore what we're looking for is a

268

00:09:05,030 --> 00:09:02,720

process that kind of works a bit but is

269

00:09:07,670 --> 00:09:05,040

really very bad um that means i want a

270

00:09:10,310 --> 00:09:07,680

low yield it means i want low purity uh

271

00:09:12,230 --> 00:09:10,320

you know it it kind of turns a hot it

272

00:09:14,550 --> 00:09:12,240

would it would it would bring any any

273

00:09:17,509 --> 00:09:14,560

self-respecting synthetic chemist out in

274

00:09:19,590 --> 00:09:17,519

hives to try and do it that badly

275

00:09:21,190 --> 00:09:19,600

but that's really what a biologist wants

276

00:09:23,030 --> 00:09:21,200

to see what a geologist might want to

277

00:09:25,030 --> 00:09:23,040

see is well what kind of an environment

278

00:09:28,389 --> 00:09:25,040

is conducive to

279

00:09:30,230 --> 00:09:28,399

um any of these chemistries

280

00:09:31,190 --> 00:09:30,240

are there settings on the ancient earth

281

00:09:32,630 --> 00:09:31,200

that are

282

00:09:34,949 --> 00:09:32,640

conductive to

283

00:09:36,949 --> 00:09:34,959

cyanide for example or to co2 or

284

00:09:39,269 --> 00:09:36,959

whatever it may be so there's this this

285

00:09:42,230 --> 00:09:39,279

collision really between disciplines and

286

00:09:44,150 --> 00:09:42,240

ways of thinking about it and we can't

287

00:09:46,550 --> 00:09:44,160

all be right

288

00:09:48,230 --> 00:09:46,560

and people have spent decades of their

289

00:09:49,910 --> 00:09:48,240

lives

290

00:09:51,269 --> 00:09:49,920

um

291

00:09:52,949 --> 00:09:51,279

seeing seeing a question from a

292

00:09:55,030 --> 00:09:52,959

particular point of view

293

00:09:57,110 --> 00:09:55,040

and it's it's very difficult for any

294

00:09:58,790 --> 00:09:57,120

human being to kind of step back and and

295

00:10:00,070 --> 00:09:58,800

stand on a soapbox and say well i got it

296

00:10:02,070 --> 00:10:00,080

all wrong i've just wasted the last

297

00:10:04,310 --> 00:10:02,080

three decades of my life

298

00:10:05,910 --> 00:10:04,320

often the answer is somewhere between

299

00:10:07,990 --> 00:10:05,920

between different theories different

300

00:10:09,350 --> 00:10:08,000

hypotheses it's a bit of this and a bit

301

00:10:11,590 --> 00:10:09,360

of that but you can't test that you've

302

00:10:13,990 --> 00:10:11,600

got to be purist about what you test

303

00:10:16,550 --> 00:10:14,000

um and and you know most of us are going

304

00:10:18,870 --> 00:10:16,560

to be wrong about most of it and and

305

00:10:19,829 --> 00:10:18,880

that can mean that you end up

306

00:10:21,990 --> 00:10:19,839

with

307

00:10:24,310 --> 00:10:22,000

quite unpleasant personal animosities

308

00:10:25,910 --> 00:10:24,320

between the researchers in the field

309

00:10:27,590 --> 00:10:25,920

okay so the chemist or the synthetic

310

00:10:29,670 --> 00:10:27,600

chemists see that there are certain

311

00:10:31,829 --> 00:10:29,680

building blocks to life and they want to

312

00:10:33,590 --> 00:10:31,839

create those in the lab artificially or

313

00:10:35,590 --> 00:10:33,600

starting from simpler ingredients and

314

00:10:38,150 --> 00:10:35,600

then the biologists say no well look if

315

00:10:39,990 --> 00:10:38,160

we have these ingredients the way that

316

00:10:41,829 --> 00:10:40,000

evolutionary biology works that we start

317

00:10:44,150 --> 00:10:41,839

from something that's less pure and then

318

00:10:45,509 --> 00:10:44,160

we work upward

319

00:10:47,590 --> 00:10:45,519

yeah the real the real the real

320

00:10:51,190 --> 00:10:47,600

difference here i suppose is is that

321

00:10:52,630 --> 00:10:51,200

what the chemists have done is is

322

00:10:54,949 --> 00:10:52,640

it's as if you say

323

00:10:57,030 --> 00:10:54,959

right we need we need nucleotides the

324

00:10:59,670 --> 00:10:57,040

building blocks of rna and dna we need

325

00:11:01,269 --> 00:10:59,680

amino acids we need to have fatty acids

326

00:11:03,269 --> 00:11:01,279

the building blocks of membranes and so

327

00:11:05,190 --> 00:11:03,279

on um so

328

00:11:06,630 --> 00:11:05,200

so so go make them for me and the

329

00:11:08,870 --> 00:11:06,640

chemists go away and they make all of

330

00:11:10,470 --> 00:11:08,880

these things um and they've they've

331

00:11:13,190 --> 00:11:10,480

started with co₂ but it doesn't work

332

00:11:15,350 --> 00:11:13,200

very well the yields are low and so on

333

00:11:17,670 --> 00:11:15,360

so they put that aside as unworkable

334

00:11:19,829 --> 00:11:17,680

chemistry and they start with with

335

00:11:22,230 --> 00:11:19,839

cyanide or something which is very

336

00:11:23,750 --> 00:11:22,240

energetic but i mean large amounts of

337

00:11:25,910 --> 00:11:23,760

cyanide you're practically asking for an

338

00:11:27,190 --> 00:11:25,920

atmosphere which is just saturated with

339

00:11:27,990 --> 00:11:27,200

cyanide

340

00:11:32,870 --> 00:11:28,000

and

341

00:11:34,870 --> 00:11:32,880

building blocks of life but by with a

342

00:11:37,350 --> 00:11:34,880

starting point that no life ever uses

343

00:11:38,710 --> 00:11:37,360

via pathways that life never uses and so

344

00:11:42,470 --> 00:11:38,720

it kind of leaves you with the same

345

00:11:44,389 --> 00:11:42,480

question which is to say okay so if

346

00:11:45,750 --> 00:11:44,399

that's how it started then you end up

347

00:11:47,269 --> 00:11:45,760

with an environment that's got all these

348

00:11:49,430 --> 00:11:47,279

building blocks floating around you've

349

00:11:51,269 --> 00:11:49,440

got the perfect primordial suit but but

350

00:11:53,030 --> 00:11:51,279

then what happens and there isn't really

351

00:11:55,030 --> 00:11:53,040

an answer to that it has to i mean you

352

00:11:57,590 --> 00:11:55,040

may as well say then a miracle happens

353

00:11:59,509 --> 00:11:57,600

everything has to self-organize

354

00:12:01,269 --> 00:11:59,519

whereas

355

00:12:02,870 --> 00:12:01,279

why does it invent biochemistry as we

356

00:12:06,150 --> 00:12:02,880

know it if that's

357

00:12:07,110 --> 00:12:06,160

the worst possible way of doing it so

358

00:12:11,829 --> 00:12:07,120

what

359

00:12:13,430 --> 00:12:11,839

biochemist and a bunch of other people

360

00:12:15,590 --> 00:12:13,440

is

361

00:12:17,509 --> 00:12:15,600

do these pathways at the core of

362

00:12:19,269 --> 00:12:17,519

biochemistry happen spontaneously in the

363

00:12:21,030 --> 00:12:19,279

right environment not very well just a

364

00:12:23,430 --> 00:12:21,040

little bit but

365

00:12:25,590 --> 00:12:23,440

whole you know pathways with 10 15 20

366

00:12:27,269 --> 00:12:25,600

steps in them that you might say well

367

00:12:29,269 --> 00:12:27,279

that's asking a lot of the environment

368

00:12:30,389 --> 00:12:29,279

can it happen though and the answer is

369

00:12:31,670 --> 00:12:30,399

often yes

370

00:12:34,550 --> 00:12:31,680

um

371

00:12:36,550 --> 00:12:34,560

at levels that were undetectable 20 or

372

00:12:39,350 --> 00:12:36,560

30 years ago but you know we're in a lab

373

00:12:40,870 --> 00:12:39,360

we're we're doing we're we're looking at

374

00:12:42,310 --> 00:12:40,880

a very small subset of possible

375

00:12:43,750 --> 00:12:42,320

conditions we don't really know what the

376

00:12:46,870 --> 00:12:43,760

right conditions are so to make it

377

00:12:48,550 --> 00:12:46,880

happen at all is a big step forward

378

00:12:51,030 --> 00:12:48,560

the issues with the synthetic chemists

379

00:12:53,269 --> 00:12:51,040

is that they can produce the building

380

00:12:54,790 --> 00:12:53,279

blocks of life but then they don't show

381

00:12:56,870 --> 00:12:54,800

a way of how those building blocks

382

00:12:58,470 --> 00:12:56,880

interact in order to create life or that

383

00:13:01,350 --> 00:12:58,480

the conditions necessary to produce

384

00:13:03,509 --> 00:13:01,360

those building blocks are so unrealistic

385

00:13:04,949 --> 00:13:03,519

uh to my mind and the chemist of course

386

00:13:07,269 --> 00:13:04,959

would disagree

387

00:13:09,350 --> 00:13:07,279

and and you know we don't know so much

388

00:13:10,470 --> 00:13:09,360

about what the early earth was really

389

00:13:11,990 --> 00:13:10,480

like so

390

00:13:15,030 --> 00:13:12,000

they probably have a point

391

00:13:16,629 --> 00:13:15,040

um but to my mind the it's not

392

00:13:18,150 --> 00:13:16,639

consistent with what we do know about

393

00:13:20,550 --> 00:13:18,160

the early earth it was mostly a water

394

00:13:23,110 --> 00:13:20,560

world mostly an ocean there was there

395

00:13:25,430 --> 00:13:23,120

was probably one to ten bars of co2 in

396

00:13:29,110 --> 00:13:25,440

the atmosphere it's highly doubtful that

397

00:13:31,269 --> 00:13:29,120

there was very much cyanide if any um

398

00:13:32,870 --> 00:13:31,279

perhaps there were some and and the

399

00:13:34,790 --> 00:13:32,880

pathways that they've come up with look

400

00:13:36,470 --> 00:13:34,800

nothing like biochemistry as i know it

401
00:13:37,829 --> 00:13:36,480
as a biochemist and so even when you've

402
00:13:40,069 --> 00:13:37,839
answered the problem you've still got to

403
00:13:41,829 --> 00:13:40,079
say okay so so how did life start then

404
00:13:43,509 --> 00:13:41,839
you you've got all the building blocks

405
00:13:45,030 --> 00:13:43,519
but then what happens next

406
00:13:46,790 --> 00:13:45,040
whereas if what you're looking at is a

407
00:13:49,110 --> 00:13:46,800
is an environment which is kind of

408
00:13:50,949 --> 00:13:49,120
dynamic and continuously you've got a

409
00:13:52,629 --> 00:13:50,959
continuous flow in say a hydrothermal

410
00:13:55,190 --> 00:13:52,639
vent you've got a continuous reaction

411
00:13:56,150 --> 00:13:55,200
going on and remember that you know we

412
00:13:59,430 --> 00:13:56,160
are

413
00:14:00,870 --> 00:13:59,440

you put a plastic bag over your head and

414

00:14:02,629 --> 00:14:00,880

start breathing then your continuous

415

00:14:06,230 --> 00:14:02,639

chemical reaction stops

416

00:14:06,949 --> 00:14:06,240

uh and and life stops so

417

00:14:12,310 --> 00:14:06,959

we

418

00:14:13,990 --> 00:14:12,320

this sophisticated way of making sure

419

00:14:15,590 --> 00:14:14,000

this reaction is happening in each and

420

00:14:17,189 --> 00:14:15,600

every one of our cells

421

00:14:18,710 --> 00:14:17,199

so take all of that away and say well

422

00:14:19,910 --> 00:14:18,720

how can you have a continuous chemical

423

00:14:22,389 --> 00:14:19,920

reaction that's happening which is

424

00:14:23,990 --> 00:14:22,399

converting the environment into more of

425

00:14:26,550 --> 00:14:24,000

me you might say

426

00:14:28,150 --> 00:14:26,560

uh and the answer is well you need a you

427

00:14:29,509 --> 00:14:28,160

need a dynamic environment something

428

00:14:31,430 --> 00:14:29,519

like a hydrothermal vent where you've

429

00:14:34,790 --> 00:14:31,440

got a continuous flow of reactive things

430

00:14:38,470 --> 00:14:34,800

that are mixing and and reacting and

431

00:14:39,910 --> 00:14:38,480

producing structures right there

432

00:14:42,230 --> 00:14:39,920

when you use the word pathways or

433

00:14:44,790 --> 00:14:42,240

biologists use the word pathways is that

434

00:14:45,990 --> 00:14:44,800

referencing the step by the recipe that

435

00:14:47,990 --> 00:14:46,000

creates

436

00:14:50,629 --> 00:14:48,000

some end product

437

00:14:51,590 --> 00:14:50,639

what is the word pathways yes sorry

438

00:14:53,350 --> 00:14:51,600

this

439

00:14:55,829 --> 00:14:53,360

a lot of people have seen a metabolic

440

00:14:57,350 --> 00:14:55,839

map which kind of is like the the you

441

00:14:58,629 --> 00:14:57,360

know map of the london underground or

442

00:15:00,389 --> 00:14:58,639

something except

443

00:15:02,150 --> 00:15:00,399

a whole lot worse

444

00:15:04,150 --> 00:15:02,160

really detailed

445

00:15:06,790 --> 00:15:04,160

um

446

00:15:08,389 --> 00:15:06,800

lots of names of particular chemicals

447

00:15:10,389 --> 00:15:08,399

with arrows going from one to the next

448

00:15:13,189 --> 00:15:10,399

one and names of enzymes connecting up

449

00:15:14,949 --> 00:15:13,199

the arrows so a pathway would be you

450

00:15:16,949 --> 00:15:14,959

start with this compound you end up with

451
00:15:19,030 --> 00:15:16,959
that compound and there's 10 steps along

452
00:15:20,150 --> 00:15:19,040
that way and and you link them all up

453
00:15:22,389 --> 00:15:20,160
and that's the pathway that's a

454
00:15:24,629 --> 00:15:22,399
biochemical pathway which starts with

455
00:15:27,110 --> 00:15:24,639
this substrate and ends up with this

456
00:15:29,590 --> 00:15:27,120
product and it links them up in a way

457
00:15:31,110 --> 00:15:29,600
which all life does pretty much in this

458
00:15:32,949 --> 00:15:31,120
in the heart of biochemistry it's

459
00:15:35,509 --> 00:15:32,959
universally conserved not always the

460
00:15:37,269 --> 00:15:35,519
genes or the enzymes but the chemistry

461
00:15:40,710 --> 00:15:37,279
itself that underpins it is almost

462
00:15:41,829 --> 00:15:40,720
always the same across all of life ah ah

463
00:15:42,949 --> 00:15:41,839

so you're not just looking for the

464

00:15:45,110 --> 00:15:42,959

products you're also looking for a

465

00:15:47,189 --> 00:15:45,120

similar pathway exactly or a pathway

466

00:15:48,790 --> 00:15:47,199

that's similar enough that conceivably

467

00:15:50,870 --> 00:15:48,800

with variation it could have moved on to

468

00:15:51,910 --> 00:15:50,880

what exactly okay yes

469

00:15:54,389 --> 00:15:51,920

yes

470

00:15:56,550 --> 00:15:54,399

and this this all together is is is

471

00:15:58,230 --> 00:15:56,560

we're talking about scores of reactions

472

00:16:00,710 --> 00:15:58,240

maybe a couple of hundred types of

473

00:16:03,269 --> 00:16:00,720

reaction all linked up in very specific

474

00:16:05,590 --> 00:16:03,279

ways which we see in life which is now

475

00:16:06,790 --> 00:16:05,600

encoded by genes

476

00:16:08,389 --> 00:16:06,800

but the

477

00:16:10,790 --> 00:16:08,399

you know the question of how did those

478

00:16:12,629 --> 00:16:10,800

genes come to encode that metabolism is

479

00:16:14,310 --> 00:16:12,639

a really difficult question unless

480

00:16:16,230 --> 00:16:14,320

you're able to turn it on its head and

481

00:16:19,110 --> 00:16:16,240

say well the metabolism happens first

482

00:16:20,949 --> 00:16:19,120

all this well this network of reactions

483

00:16:23,189 --> 00:16:20,959

is spontaneous in the right environment

484

00:16:25,269 --> 00:16:23,199

and the genes kind of emerged afterwards

485

00:16:26,150 --> 00:16:25,279

and sped it up and optimized it and you

486

00:16:27,749 --> 00:16:26,160

know

487

00:16:30,150 --> 00:16:27,759

improved it

488

00:16:31,910 --> 00:16:30,160

okay and part of the reason why it's

489

00:16:34,069 --> 00:16:31,920

strange to think of genes first

490

00:16:35,670 --> 00:16:34,079

producing the metabolism is because the

491

00:16:37,910 --> 00:16:35,680

way that we think of genes is operating

492

00:16:39,749 --> 00:16:37,920

is sequentially incrementally and these

493

00:16:41,990 --> 00:16:39,759

pathways are so

494

00:16:43,829 --> 00:16:42,000

well it would it's difficult to think of

495

00:16:45,910 --> 00:16:43,839

half of a krebs cycle or half of one of

496

00:16:46,949 --> 00:16:45,920

these steps as working

497

00:16:50,470 --> 00:16:46,959

um

498

00:16:52,310 --> 00:16:50,480

yes and if you if you take it that way

499

00:16:54,069 --> 00:16:52,320

um

500

00:16:56,150 --> 00:16:54,079

i mean there are various ways of

501
00:16:57,829 --> 00:16:56,160
thinking about this but but how how does

502
00:17:00,150 --> 00:16:57,839
a pathway let's say you've got 10 steps

503
00:17:02,710 --> 00:17:00,160
in this in this biochemical pathway

504
00:17:03,590 --> 00:17:02,720
and let's say it's invented by genes

505
00:17:05,350 --> 00:17:03,600
how

506
00:17:06,150 --> 00:17:05,360
what what do those genes

507
00:17:08,150 --> 00:17:06,160
do

508
00:17:10,230 --> 00:17:08,160
so there's two main ideas one of them is

509
00:17:11,029 --> 00:17:10,240
well you've got plenty of the product in

510
00:17:16,390 --> 00:17:11,039
the

511
00:17:18,309 --> 00:17:16,400
beginning to eat that product in some

512
00:17:20,949 --> 00:17:18,319
way and so now there's less of it so if

513
00:17:23,590 --> 00:17:20,959

you if you can come up with a gene which

514

00:17:26,390 --> 00:17:23,600

takes the precursor to that product and

515

00:17:27,110 --> 00:17:26,400

converts it into the product then you've

516

00:17:28,549 --> 00:17:27,120

got

517

00:17:30,310 --> 00:17:28,559

an advantage

518

00:17:32,150 --> 00:17:30,320

so you kind of start at the end of the

519

00:17:34,150 --> 00:17:32,160

pathway and work your way back one step

520

00:17:36,150 --> 00:17:34,160

at a time or you can do it the other way

521

00:17:38,470 --> 00:17:36,160

around you can start with the precursor

522

00:17:41,029 --> 00:17:38,480

and work your way up one step at the

523

00:17:42,549 --> 00:17:41,039

time but both of those ideas basically

524

00:17:44,710 --> 00:17:42,559

assume that all of the intermediates

525

00:17:46,710 --> 00:17:44,720

along that pathway exist at high

526

00:17:48,870 --> 00:17:46,720

concentrations in the environment and

527

00:17:51,510 --> 00:17:48,880

that you can get at them and that they

528

00:17:53,029 --> 00:17:51,520

are useful in some way and

529

00:17:55,190 --> 00:17:53,039

you know all of these are very hand

530

00:17:56,710 --> 00:17:55,200

waving ideas and there's basically no

531

00:17:59,029 --> 00:17:56,720

truth to any of them

532

00:18:00,390 --> 00:17:59,039

whereas if what you're assuming is that

533

00:18:02,150 --> 00:18:00,400

actually

534

00:18:04,630 --> 00:18:02,160

going from one to another along this

535

00:18:06,230 --> 00:18:04,640

pathway at a low level

536

00:18:07,830 --> 00:18:06,240

it just happens you know these things

537

00:18:09,270 --> 00:18:07,840

just interconvert into each other

538

00:18:10,230 --> 00:18:09,280

there's not

539

00:18:12,070 --> 00:18:10,240

and so

540

00:18:15,029 --> 00:18:12,080

at that point a gene which which speeds

541

00:18:17,750 --> 00:18:15,039

up any step will tend to

542

00:18:19,270 --> 00:18:17,760

will tend to increase the whole pathway

543

00:18:20,950 --> 00:18:19,280

so it's much it's much easier as a

544

00:18:23,270 --> 00:18:20,960

question in evolutionary biology about

545

00:18:25,270 --> 00:18:23,280

how how do you then um

546

00:18:27,029 --> 00:18:25,280

kind of ramp up you because all you're

547

00:18:29,110 --> 00:18:27,039

doing is increasing the flux through a

548

00:18:30,789 --> 00:18:29,120

system that exists anyway

549

00:18:33,190 --> 00:18:30,799

and where does energy enter into this

550

00:18:35,350 --> 00:18:33,200

the way that i understand your the

551
00:18:37,430 --> 00:18:35,360
difference between you and how biology

552
00:18:39,750 --> 00:18:37,440
ordinarily thinks is with regard to

553
00:18:41,909 --> 00:18:39,760
information based is the biological way

554
00:18:43,669 --> 00:18:41,919
of thinking and then yours is energy

555
00:18:45,270 --> 00:18:43,679
based so i haven't heard energy come

556
00:18:46,630 --> 00:18:45,280
into this and i'd like to hear it yeah

557
00:18:47,990 --> 00:18:46,640
yeah

558
00:18:51,990 --> 00:18:48,000
so

559
00:18:52,870 --> 00:18:52,000
you look at the tree of life and this is

560
00:18:54,789 --> 00:18:52,880
another

561
00:18:57,270 --> 00:18:54,799
way in which biology has kind of

562
00:18:59,590 --> 00:18:57,280
intruded into the question of the origin

563
00:19:00,630 --> 00:18:59,600

of life over the last couple of decades

564

00:19:02,710 --> 00:19:00,640

um

565

00:19:05,510 --> 00:19:02,720

what does the tree of life say about the

566

00:19:07,909 --> 00:19:05,520

very base uh the the kind of bacteria

567

00:19:10,150 --> 00:19:07,919

that are the most ancient the the very

568

00:19:12,070 --> 00:19:10,160

first ones they're not the very first

569

00:19:13,750 --> 00:19:12,080

ones these are things with genes with

570

00:19:15,669 --> 00:19:13,760

enzymes they're pretty sophisticated

571

00:19:17,750 --> 00:19:15,679

cells this is the common ancestor of all

572

00:19:19,669 --> 00:19:17,760

of life as we know it

573

00:19:21,590 --> 00:19:19,679

and you could say well it's not got much

574

00:19:23,750 --> 00:19:21,600

to do with the origin of life or you

575

00:19:24,870 --> 00:19:23,760

could say well perhaps it points in that

576

00:19:26,870 --> 00:19:24,880

direction

577

00:19:28,470 --> 00:19:26,880

we can keep an open mind about that so

578

00:19:29,909 --> 00:19:28,480

what does it do what are the what do

579

00:19:31,750 --> 00:19:29,919

these deepest branches in the tree of

580

00:19:34,630 --> 00:19:31,760

life do well they're bacterial-like

581

00:19:36,549 --> 00:19:34,640

things archaea and bacteria

582

00:19:38,630 --> 00:19:36,559

and they're pretty much autotrophic

583

00:19:42,230 --> 00:19:38,640

which means that they are converting

584

00:19:44,390 --> 00:19:42,240

gases in the environment into organic

585

00:19:46,070 --> 00:19:44,400

molecules like photosynthesis except

586

00:19:48,549 --> 00:19:46,080

probably not photosynthesis

587

00:19:52,390 --> 00:19:48,559

um and they're almost universally

588

00:19:54,310 --> 00:19:52,400

starting with co2 and hydrogen

589

00:19:56,470 --> 00:19:54,320

and that's the very core of biochemistry

590

00:19:58,789 --> 00:19:56,480

you go you react co2 and hydrogen and

591

00:20:00,630 --> 00:19:58,799

you get krebs cycle intermediates that's

592

00:20:02,390 --> 00:20:00,640

that's the first things that you get and

593

00:20:04,549 --> 00:20:02,400

from there you get amino acids and from

594

00:20:06,710 --> 00:20:04,559

there you get nucleotides and so on

595

00:20:08,630 --> 00:20:06,720

the problem is that hydrogen and co2

596

00:20:10,710 --> 00:20:08,640

don't react very easily this is the

597

00:20:12,549 --> 00:20:10,720

problem that the chemists had for a long

598

00:20:15,430 --> 00:20:12,559

time you can heat them up you can add a

599

00:20:18,230 --> 00:20:15,440

catalyst it's you know it it does work

600

00:20:19,510 --> 00:20:18,240

but it's uh it's difficult it's only

601
00:20:21,590 --> 00:20:19,520
been in the last few years that people

602
00:20:22,789 --> 00:20:21,600
have succeeded in doing it now what life

603
00:20:24,549 --> 00:20:22,799
does

604
00:20:26,230 --> 00:20:24,559
is it uses effectively an electrical

605
00:20:28,149 --> 00:20:26,240
charge on the membrane around the cell

606
00:20:30,630 --> 00:20:28,159
to drive that reaction

607
00:20:32,390 --> 00:20:30,640
um the problem is it's it's

608
00:20:34,149 --> 00:20:32,400
thermodynamically favored which is to

609
00:20:36,149 --> 00:20:34,159
say if you've got a mixture of hydrogen

610
00:20:38,549 --> 00:20:36,159
and co2 and you mix them up at say 50

611
00:20:40,390 --> 00:20:38,559
degrees centigrade thermodynamically you

612
00:20:43,270 --> 00:20:40,400
should get cells it's actually more

613
00:20:46,470 --> 00:20:43,280

stable to have cells than it is to have

614

00:20:47,990 --> 00:20:46,480

a disequilibrium of hydrogen and co2

615

00:20:49,270 --> 00:20:48,000

they want to react so long as there's no

616

00:20:51,270 --> 00:20:49,280

oxygen around

617

00:20:52,630 --> 00:20:51,280

but kinetically there's a barrier and

618

00:20:55,029 --> 00:20:52,640

they don't react

619

00:20:57,350 --> 00:20:55,039

um and that kinetic barrier is broken

620

00:20:58,390 --> 00:20:57,360

down by by this electrical charge on the

621

00:20:59,909 --> 00:20:58,400

membrane

622

00:21:02,470 --> 00:20:59,919

sorry just to clarify when you say you

623

00:21:04,549 --> 00:21:02,480

get cells you don't mean cells as we

624

00:21:06,070 --> 00:21:04,559

know it as life you mean that there's a

625

00:21:07,830 --> 00:21:06,080

membrane and it's oily and then there's

626

00:21:10,070 --> 00:21:07,840

a separation or

627

00:21:12,070 --> 00:21:10,080

i i mean that um

628

00:21:13,669 --> 00:21:12,080

if you look at the thermodynamics

629

00:21:16,390 --> 00:21:13,679

theoretical thermodynamics that goes

630

00:21:18,310 --> 00:21:16,400

back to jan ammond and tom mccollum and

631

00:21:19,750 --> 00:21:18,320

they have considered under the kind of

632

00:21:21,510 --> 00:21:19,760

conditions that i'm thinking about this

633

00:21:22,950 --> 00:21:21,520

is 20 years ago now

634

00:21:24,710 --> 00:21:22,960

under the kind of conditions that i'm

635

00:21:26,789 --> 00:21:24,720

talking about in alkaline hydrothermal

636

00:21:28,830 --> 00:21:26,799

vents at 50 degrees centigrade in

637

00:21:31,830 --> 00:21:28,840

alkaline conditions

638

00:21:32,710 --> 00:21:31,840

um energy is released

639

00:21:35,909 --> 00:21:32,720

um

640

00:21:39,110 --> 00:21:35,919

to make amino acids and fatty acids

641

00:21:43,029 --> 00:21:39,120

and overall total cell biomass

642

00:21:45,990 --> 00:21:43,039

releases energy from hydrogen co2

643

00:21:47,350 --> 00:21:46,000

so yes it's favored it's it's actually

644

00:21:50,230 --> 00:21:47,360

energetically

645

00:21:52,710 --> 00:21:50,240

more favored to have literally cells

646

00:21:55,110 --> 00:21:52,720

than it is to have a mixture of gases

647

00:21:56,230 --> 00:21:55,120

that's what's driving life the problem

648

00:21:58,149 --> 00:21:56,240

is that there's a barrier to it

649

00:21:59,590 --> 00:21:58,159

happening and that barrier is broken

650

00:22:01,909 --> 00:21:59,600

down by this electrical charge on

651
00:22:02,950 --> 00:22:01,919
membrane so my kind of driving question

652
00:22:04,630 --> 00:22:02,960
is

653
00:22:06,310 --> 00:22:04,640
where did that come from

654
00:22:07,510 --> 00:22:06,320
how did it get going

655
00:22:09,750 --> 00:22:07,520
why do you think it is that there's so

656
00:22:11,750 --> 00:22:09,760
much disagreement about the definition

657
00:22:13,510 --> 00:22:11,760
of life so in mathematics you just

658
00:22:15,750 --> 00:22:13,520
simply state the definition there's no

659
00:22:17,110 --> 00:22:15,760
squabbling over that ah but have you

660
00:22:19,990 --> 00:22:17,120
come up with the definition of life in

661
00:22:21,669 --> 00:22:20,000
mathematics i mean the answer is no

662
00:22:24,230 --> 00:22:21,679
um

663
00:22:26,149 --> 00:22:24,240

it's basically it's not

664

00:22:27,430 --> 00:22:26,159

it's not easy to put it into an equation

665

00:22:30,230 --> 00:22:27,440

i think that's

666

00:22:31,750 --> 00:22:30,240

i i i personally think the is the wrong

667

00:22:34,549 --> 00:22:31,760

question because

668

00:22:36,390 --> 00:22:34,559

life is a process over time it's it's

669

00:22:37,350 --> 00:22:36,400

not a thing

670

00:22:39,510 --> 00:22:37,360

um

671

00:22:41,350 --> 00:22:39,520

and the origin of life is is not a

672

00:22:42,870 --> 00:22:41,360

moment it's not

673

00:22:44,789 --> 00:22:42,880

there isn't one moment where something

674

00:22:47,190 --> 00:22:44,799

becomes alive it's a continuum from

675

00:22:48,870 --> 00:22:47,200

prebiotic chemistry right the way up to

676
00:22:51,590 --> 00:22:48,880
you know quite sophisticated cells with

677
00:22:54,149 --> 00:22:51,600
genes and macromolecular machines motors

678
00:22:55,830 --> 00:22:54,159
and what have you um and every step

679
00:22:57,909 --> 00:22:55,840
along that way there isn't one moment

680
00:22:59,350 --> 00:22:57,919
where you would say it's now alive

681
00:23:00,230 --> 00:22:59,360
there's suddenly something goes like

682
00:23:01,830 --> 00:23:00,240
that

683
00:23:03,990 --> 00:23:01,840
and you know you can you could argue

684
00:23:05,350 --> 00:23:04,000
about is a virus alive or not i would

685
00:23:06,870 --> 00:23:05,360
say it is but it doesn't have a

686
00:23:08,789 --> 00:23:06,880
metabolism of its own and it wouldn't

687
00:23:11,190 --> 00:23:08,799
fall within most definitions of life

688
00:23:13,110 --> 00:23:11,200

what about jumping jeans retro elements

689

00:23:14,710 --> 00:23:13,120

these kind of things are they alive what

690

00:23:17,510 --> 00:23:14,720

about something which is dormant to

691

00:23:19,190 --> 00:23:17,520

spore in in deep space is it alive no

692

00:23:21,029 --> 00:23:19,200

it's not living now but it could come

693

00:23:23,590 --> 00:23:21,039

back to life so there's all these

694

00:23:25,750 --> 00:23:23,600

ambiguities about

695

00:23:27,350 --> 00:23:25,760

i i think what is living is a much

696

00:23:28,789 --> 00:23:27,360

better question

697

00:23:30,230 --> 00:23:28,799

and you know it's very easy to kind of

698

00:23:32,350 --> 00:23:30,240

wave your arms and say well it needs

699

00:23:34,230 --> 00:23:32,360

metabolism in these information in these

700

00:23:36,710 --> 00:23:34,240

compartmentalization those things are

701
00:23:38,630 --> 00:23:36,720
probably true um

702
00:23:42,230 --> 00:23:38,640
but

703
00:23:44,230 --> 00:23:42,240
definition that you come up with of life

704
00:23:45,990 --> 00:23:44,240
can usually be attacked the the classic

705
00:23:47,909 --> 00:23:46,000
one is uh from

706
00:23:49,270 --> 00:23:47,919
is is known as the the working

707
00:23:50,470 --> 00:23:49,280
definition of life

708
00:23:52,230 --> 00:23:50,480
from nasa

709
00:23:54,310 --> 00:23:52,240
and i probably can't get this quite

710
00:23:55,990 --> 00:23:54,320
right but it's roughly a

711
00:23:58,310 --> 00:23:56,000
self-sustaining

712
00:24:00,149 --> 00:23:58,320
system capable of making copies of

713
00:24:01,830 --> 00:24:00,159

itself or capable of evolving or

714

00:24:03,750 --> 00:24:01,840

something along those lines

715

00:24:05,190 --> 00:24:03,760

um and i have a real problem with the

716

00:24:06,789 --> 00:24:05,200

word self-sustaining because it's

717

00:24:09,110 --> 00:24:06,799

basically sustained by the environment

718

00:24:11,590 --> 00:24:09,120

by disequilibrium in them in the

719

00:24:13,269 --> 00:24:11,600

environment but you know people have

720

00:24:15,029 --> 00:24:13,279

poked fun at it by saying well by that

721

00:24:16,470 --> 00:24:15,039

definition a rabbit is not alive only a

722

00:24:19,430 --> 00:24:16,480

pair of rabbits would be alive because

723

00:24:20,950 --> 00:24:19,440

only a pair of rabbits could make a copy

724

00:24:22,950 --> 00:24:20,960

right right right

725

00:24:24,950 --> 00:24:22,960

okay so there's some arbitrariness to it

726

00:24:26,870 --> 00:24:24,960

because it's akin to saying when does a

727

00:24:29,430 --> 00:24:26,880

grain of sand become a heap by adding

728

00:24:30,950 --> 00:24:29,440

more and more greens okay yes so then it

729

00:24:34,710 --> 00:24:30,960

would be better to characterize it as a

730

00:24:39,350 --> 00:24:37,830

uh it's certainly not binary yes i mean

731

00:24:41,510 --> 00:24:39,360

you might even say that death looks

732

00:24:42,549 --> 00:24:41,520

binary doesn't it but it's even death is

733

00:24:44,789 --> 00:24:42,559

not because

734

00:24:47,909 --> 00:24:44,799

when we die some of our cells will stay

735

00:24:49,510 --> 00:24:47,919

alive for a while longer it feels binary

736

00:24:51,350 --> 00:24:49,520

and therefore the origin of life perhaps

737

00:24:53,510 --> 00:24:51,360

feels binary for exactly the opposite

738

00:24:55,830 --> 00:24:53,520

reasons you know you wonder about when

739

00:24:58,230 --> 00:24:55,840

when does it when when does a

740

00:25:00,230 --> 00:24:58,240

when does life begin in in humans

741

00:25:01,990 --> 00:25:00,240

there's terrible arguments about that

742

00:25:04,070 --> 00:25:02,000

kind of question and there isn't really

743

00:25:05,350 --> 00:25:04,080

a correct answer to it either

744

00:25:07,590 --> 00:25:05,360

you know if

745

00:25:09,350 --> 00:25:07,600

sperm are alive in some sense but but

746

00:25:11,830 --> 00:25:09,360

and a fertilized

747

00:25:13,590 --> 00:25:11,840

egg is is alive but it's not really

748

00:25:14,390 --> 00:25:13,600

aware of very much but you know where do

749

00:25:16,470 --> 00:25:14,400

you draw

750

00:25:18,070 --> 00:25:16,480

a line of where awareness comes in it's

751

00:25:19,590 --> 00:25:18,080

it's basically an impossible ask and

752

00:25:21,590 --> 00:25:19,600

it's it's a matter of for people to try

753

00:25:23,750 --> 00:25:21,600

and come to an agreement about but it's

754

00:25:25,830 --> 00:25:23,760

there isn't a definition

755

00:25:29,510 --> 00:25:25,840

so a better question may be

756

00:25:30,789 --> 00:25:29,520

when is living or what is living

757

00:25:32,870 --> 00:25:30,799

i remember you said living the word

758

00:25:35,510 --> 00:25:32,880

living versus yes yes i mean living is

759

00:25:37,750 --> 00:25:35,520

an active process over time and it's

760

00:25:39,029 --> 00:25:37,760

it's it's a continuous reaction that is

761

00:25:42,149 --> 00:25:39,039

converting

762

00:25:44,149 --> 00:25:42,159

um the environment into in one way or

763

00:25:46,390 --> 00:25:44,159

another more of itself whether that more

764

00:25:48,870 --> 00:25:46,400

of itself is just replace the broken

765

00:25:50,310 --> 00:25:48,880

bits or if it's a case of make a copy of

766

00:25:51,350 --> 00:25:50,320

the whole cell

767

00:25:53,750 --> 00:25:51,360

um

768

00:25:59,350 --> 00:25:53,760

or or

769

00:26:02,549 --> 00:25:59,360

through some complicated process of of

770

00:26:04,310 --> 00:26:02,559

sex and so on but in the end

771

00:26:07,190 --> 00:26:04,320

life is effectively parasitizing the

772

00:26:08,830 --> 00:26:07,200

environment to make copies of itself

773

00:26:11,190 --> 00:26:08,840

and it does that through

774

00:26:14,470 --> 00:26:11,200

metabolism okay so two thoughts occur to

775

00:26:16,230 --> 00:26:14,480

me so one is is there a way to put a

776

00:26:17,909 --> 00:26:16,240

number like i mentioned a real number

777

00:26:20,789 --> 00:26:17,919

but perhaps it's not as simple as that

778

00:26:22,470 --> 00:26:20,799

is there a way to place a number to how

779

00:26:24,549 --> 00:26:22,480

much something is characterized by

780

00:26:25,990 --> 00:26:24,559

living in the same way that you may say

781

00:26:27,590 --> 00:26:26,000

well consciousness is either you either

782

00:26:29,190 --> 00:26:27,600

have it or don't but then there's some

783

00:26:31,350 --> 00:26:29,200

theories like tononi's integrated

784

00:26:33,350 --> 00:26:31,360

information theory where you have phi

785

00:26:35,029 --> 00:26:33,360

which is like okay if you have a large

786

00:26:36,230 --> 00:26:35,039

number okay so that's the first thought

787

00:26:37,750 --> 00:26:36,240

and then i'll say the second one then

788

00:26:39,110 --> 00:26:37,760

i'll come back to them just so that i

789

00:26:41,029 --> 00:26:39,120

don't forget them then the second

790

00:26:43,430 --> 00:26:41,039

thought was how far can we generalize

791

00:26:45,190 --> 00:26:43,440

this is so-and-so living

792

00:26:47,110 --> 00:26:45,200

because in the self-development world

793

00:26:49,110 --> 00:26:47,120

when you read you walk by the sections

794

00:26:50,830 --> 00:26:49,120

in the library they'll say yeah you're

795

00:26:53,990 --> 00:26:50,840

alive but you're not

796

00:26:55,430 --> 00:26:54,000

living your purpose uh well that's

797

00:26:57,510 --> 00:26:55,440

that's kind of

798

00:26:59,269 --> 00:26:57,520

that's playing with semantics okay so

799

00:27:00,710 --> 00:26:59,279

that's taking it too far okay okay so

800

00:27:02,310 --> 00:27:00,720

let's focus on the first one is there a

801
00:27:04,070 --> 00:27:02,320
way i mean i'm using living in the in

802
00:27:04,950 --> 00:27:04,080
the in the in the broadest possible

803
00:27:10,390 --> 00:27:04,960
sense

804
00:27:11,990 --> 00:27:10,400
uh so so but you know

805
00:27:13,430 --> 00:27:12,000
consciousness you know if you look at

806
00:27:15,110 --> 00:27:13,440
the medical literature there's all kinds

807
00:27:16,710 --> 00:27:15,120
of gradations of conscious states

808
00:27:19,110 --> 00:27:16,720
whether you're fully anesthetized or

809
00:27:21,110 --> 00:27:19,120
fully unconscious or in some lower level

810
00:27:23,190 --> 00:27:21,120
of consciousness and so on and it's you

811
00:27:24,710 --> 00:27:23,200
know it it's it's worth looking at that

812
00:27:26,390 --> 00:27:24,720
medical literature every now and then to

813
00:27:28,390 --> 00:27:26,400

realize that it's not an on or off

814

00:27:29,830 --> 00:27:28,400

switch there either

815

00:27:31,430 --> 00:27:29,840

yeah i'm super interested in speaking

816

00:27:33,669 --> 00:27:31,440

with you about consciousness so we'll

817

00:27:35,430 --> 00:27:33,679

get to that toward the end just so you

818

00:27:38,070 --> 00:27:35,440

know i've been

819

00:27:40,710 --> 00:27:38,080

just absorbing your work for the past

820

00:27:41,750 --> 00:27:40,720

maybe two weeks or so every single day

821

00:27:43,990 --> 00:27:41,760

and

822

00:27:45,590 --> 00:27:44,000

i i have my own nick cycle so people

823

00:27:47,029 --> 00:27:45,600

have krebs cycle have a knick cycle in

824

00:27:49,350 --> 00:27:47,039

my brain

825

00:27:50,180 --> 00:27:49,360

that sounds

826

00:27:51,909 --> 00:27:50,190

sounds hard

827

00:27:53,510 --> 00:27:51,919

[Laughter]

828

00:27:56,070 --> 00:27:53,520

so i just you know my background isn't

829

00:27:58,950 --> 00:27:56,080

math and physics yeah yeah yeah and i

830

00:28:00,870 --> 00:27:58,960

don't like biology because there's so

831

00:28:03,430 --> 00:28:00,880

many terms too many times

832

00:28:05,510 --> 00:28:03,440

there's pyruvic acid which i assume so i

833

00:28:07,110 --> 00:28:05,520

can only apologize about my book i mean

834

00:28:08,870 --> 00:28:07,120

you know it's uh

835

00:28:11,269 --> 00:28:08,880

it's basically a problem with biology

836

00:28:12,710 --> 00:28:11,279

and physicists always have this problem

837

00:28:14,310 --> 00:28:12,720

with biology

838

00:28:15,590 --> 00:28:14,320

yeah and and you know it's

839

00:28:16,710 --> 00:28:15,600

understandable

840

00:28:17,990 --> 00:28:16,720

um

841

00:28:20,149 --> 00:28:18,000

and

842

00:28:21,750 --> 00:28:20,159

there are i think the the most

843

00:28:23,830 --> 00:28:21,760

interesting questions in biology now

844

00:28:25,750 --> 00:28:23,840

really of questions in physics

845

00:28:27,510 --> 00:28:25,760

um but because we've had this almost

846

00:28:29,269 --> 00:28:27,520

kind of phase

847

00:28:30,389 --> 00:28:29,279

separation between physicists and

848

00:28:32,310 --> 00:28:30,399

biologists

849

00:28:34,950 --> 00:28:32,320

there's not enough people who are

850

00:28:36,549 --> 00:28:34,960

biophysicists who are grappling with the

851

00:28:38,149 --> 00:28:36,559

biophysics of life

852

00:28:39,750 --> 00:28:38,159

and so biology has gone off in the

853

00:28:41,269 --> 00:28:39,760

direction of information but without

854

00:28:43,269 --> 00:28:41,279

really a very serious grounding in

855

00:28:45,750 --> 00:28:43,279

information theory as a physicist

856

00:28:47,190 --> 00:28:45,760

understand it uh it's really about you

857

00:28:48,549 --> 00:28:47,200

know just just

858

00:28:49,909 --> 00:28:48,559

let's sequence the hell out of

859

00:28:52,389 --> 00:28:49,919

everything and see if we can find a

860

00:28:54,470 --> 00:28:52,399

pattern um and that's kind of

861

00:28:56,710 --> 00:28:54,480

intellectually very shallow there are

862

00:28:57,990 --> 00:28:56,720

patterns there and we've learned

863

00:28:59,669 --> 00:28:58,000

you know almost everything about the

864

00:29:01,269 --> 00:28:59,679

world from doing that

865

00:29:02,950 --> 00:29:01,279

but it doesn't really tell us you know

866

00:29:04,549 --> 00:29:02,960

your question what is life and what is

867

00:29:07,110 --> 00:29:04,559

living and those things

868

00:29:09,430 --> 00:29:07,120

the answer is not to be found in in

869

00:29:11,190 --> 00:29:09,440

sequencing all the organisms you know

870

00:29:13,190 --> 00:29:11,200

you have to take a step back and think

871

00:29:15,190 --> 00:29:13,200

about well what is metabolism and what

872

00:29:16,870 --> 00:29:15,200

are genes and which came first and how

873

00:29:19,029 --> 00:29:16,880

do they relate to each other

874

00:29:20,789 --> 00:29:19,039

uh and what processes on the planet are

875

00:29:22,870 --> 00:29:20,799

driving this whole process and these are

876

00:29:25,269 --> 00:29:22,880

often questions in physics

877

00:29:26,789 --> 00:29:25,279

um but biology is so intrinsically

878

00:29:28,789 --> 00:29:26,799

complex

879

00:29:30,789 --> 00:29:28,799

that physicists very often

880

00:29:31,830 --> 00:29:30,799

get pissed off and back away and you

881

00:29:35,029 --> 00:29:31,840

know

882

00:29:37,190 --> 00:29:35,039

they can't deal with too much pyruvate

883

00:29:39,430 --> 00:29:37,200

yeah there's a flurry of unmitigated

884

00:29:41,350 --> 00:29:39,440

polysyllabic terminology that it's

885

00:29:43,029 --> 00:29:41,360

difficult to become acquainted with like

886

00:29:45,350 --> 00:29:43,039

it's a moral i the way that i imagine is

887

00:29:47,350 --> 00:29:45,360

that you become used to it over time and

888

00:29:49,750 --> 00:29:47,360

so if you first encounter it then it's

889

00:29:51,909 --> 00:29:49,760

overwhelming at least for me but you and

890

00:29:54,870 --> 00:29:51,919

michael evan are responsible for turn in

891

00:29:56,389 --> 00:29:54,880

toe in this channel toward more

892

00:29:59,110 --> 00:29:56,399

to interviewing more biology michael

893

00:30:01,430 --> 00:29:59,120

levin is doing amazing work and and

894

00:30:03,269 --> 00:30:01,440

you know all this

895

00:30:04,630 --> 00:30:03,279

electrical fields controlling

896

00:30:06,389 --> 00:30:04,640

development

897

00:30:11,190 --> 00:30:06,399

is

898

00:30:12,549 --> 00:30:11,200

that to them would probably freak out

899

00:30:15,269 --> 00:30:12,559

probably back i don't know what he said

900

00:30:18,310 --> 00:30:15,279

to you about this but um you know he he

901
00:30:19,750 --> 00:30:18,320
he's obviously right he's obviously

902
00:30:22,310 --> 00:30:19,760
found something which is really

903
00:30:24,950 --> 00:30:22,320
important um you know his nobel prize

904
00:30:26,630 --> 00:30:24,960
winning stuff he that he's doing in my

905
00:30:28,549 --> 00:30:26,640
opinion um

906
00:30:31,669 --> 00:30:28,559
and and it's profound and this is the

907
00:30:33,590 --> 00:30:31,679
direction of 21st century biology um and

908
00:30:35,590 --> 00:30:33,600
and you you know it's trying to

909
00:30:37,990 --> 00:30:35,600
understand what what actually is this

910
00:30:40,630 --> 00:30:38,000
language of fields in cells you know

911
00:30:44,149 --> 00:30:40,640
it's early days in terms of that but

912
00:30:45,590 --> 00:30:44,159
most biologists still now would would um

913
00:30:47,750 --> 00:30:45,600

back away from it

914

00:30:50,070 --> 00:30:47,760

and

915

00:30:50,870 --> 00:30:50,080

treat it in some way as pseudoscience or

916

00:30:52,950 --> 00:30:50,880

as

917

00:30:53,909 --> 00:30:52,960

you know just not real

918

00:30:55,669 --> 00:30:53,919

um

919

00:30:58,149 --> 00:30:55,679

and yet there's you know there's corners

920

00:31:00,310 --> 00:30:58,159

of zoology which deal with with you know

921

00:31:02,230 --> 00:31:00,320

electric eels and electric fields in

922

00:31:04,710 --> 00:31:02,240

fish or

923

00:31:06,549 --> 00:31:04,720

magnetic fields in in navigation systems

924

00:31:08,310 --> 00:31:06,559

in birds and insects and whatever else

925

00:31:10,549 --> 00:31:08,320

you know biologists have known about

926

00:31:12,549 --> 00:31:10,559

this stuff for a while not necessarily

927

00:31:15,669 --> 00:31:12,559

the development pathways but

928

00:31:18,470 --> 00:31:15,679

it's some marginalized small corner

929

00:31:21,029 --> 00:31:18,480

where of a field of information in terms

930

00:31:23,830 --> 00:31:21,039

of gene sequences is completely dominant

931

00:31:25,590 --> 00:31:23,840

and genes don't tell you anything about

932

00:31:27,510 --> 00:31:25,600

shape about structure you can look at

933

00:31:29,830 --> 00:31:27,520

any genome you want

934

00:31:31,669 --> 00:31:29,840

and nobody unless they already knew what

935

00:31:33,190 --> 00:31:31,679

the organism was that's coded for there

936

00:31:36,789 --> 00:31:33,200

would be able to tell you what shape it

937

00:31:38,230 --> 00:31:36,799

is what kind of an organism is it

938

00:31:40,470 --> 00:31:38,240

like i mentioned i have a nick cycle in

939

00:31:41,990 --> 00:31:40,480

my head so

940

00:31:43,990 --> 00:31:42,000

well i mean that in many ways because i

941

00:31:46,070 --> 00:31:44,000

started bicycling more just to get your

942

00:31:48,070 --> 00:31:46,080

audio back in the head so cycling is a

943

00:31:50,149 --> 00:31:48,080

great word certain words that you say

944

00:31:52,710 --> 00:31:50,159

strike me because your book is in my

945

00:31:55,269 --> 00:31:52,720

working memory currently and you said

946

00:31:57,430 --> 00:31:55,279

20th century biology is going to be the

947

00:31:59,590 --> 00:31:57,440

biology sorry 21st century biologically

948

00:32:02,149 --> 00:31:59,600

the biology of fields okay why don't we

949

00:32:03,029 --> 00:32:02,159

expand on that

950

00:32:04,789 --> 00:32:03,039

um

951
00:32:06,870 --> 00:32:04,799
so so that was right at the end of the

952
00:32:10,710 --> 00:32:06,880
book uh we're talking about

953
00:32:12,950 --> 00:32:10,720
consciousness really um but but also

954
00:32:15,830 --> 00:32:12,960
development and how

955
00:32:18,549 --> 00:32:15,840
how cells know when to stop nowhere to

956
00:32:20,470 --> 00:32:18,559
go no no no you know there's all kinds

957
00:32:21,430 --> 00:32:20,480
of questions that michael levin talks

958
00:32:23,590 --> 00:32:21,440
about

959
00:32:25,110 --> 00:32:23,600
from my own point of view

960
00:32:26,389 --> 00:32:25,120
um

961
00:32:28,630 --> 00:32:26,399
i've been

962
00:32:31,269 --> 00:32:28,640
thinking for a long time about

963
00:32:32,470 --> 00:32:31,279

bioenergetics that's my own kind of

964

00:32:34,310 --> 00:32:32,480

specialty

965

00:32:36,470 --> 00:32:34,320

and what cells are doing in the

966

00:32:38,950 --> 00:32:36,480

mitochondria is effectively pumping

967

00:32:40,789 --> 00:32:38,960

protons across a membrane and generating

968

00:32:42,789 --> 00:32:40,799

a charge on the membrane and that charge

969

00:32:43,750 --> 00:32:42,799

on the membrane is driving everything

970

00:32:47,110 --> 00:32:43,760

else

971

00:32:49,190 --> 00:32:47,120

um but i hadn't thought very much about

972

00:32:52,470 --> 00:32:49,200

fields as such

973

00:32:56,149 --> 00:32:52,480

um because to to generate coherent feels

974

00:32:58,389 --> 00:32:56,159

you you um would need to have quite

975

00:32:59,509 --> 00:32:58,399

quite specific morphology

976

00:33:01,190 --> 00:32:59,519

um

977

00:33:03,110 --> 00:33:01,200

and it's not something i really worried

978

00:33:05,430 --> 00:33:03,120

about very much but if you look at

979

00:33:07,830 --> 00:33:05,440

mitochondria under a microscope what

980

00:33:09,509 --> 00:33:07,840

you'll often see is is is these

981

00:33:11,669 --> 00:33:09,519

membranes which are parallel to each

982

00:33:13,509 --> 00:33:11,679

other which are offset by the same

983

00:33:15,430 --> 00:33:13,519

degree and you know there's there's a

984

00:33:17,669 --> 00:33:15,440

very detailed structure there and the

985

00:33:19,590 --> 00:33:17,679

more we know about these structures the

986

00:33:21,990 --> 00:33:19,600

more we realize that they play a really

987

00:33:24,310 --> 00:33:22,000

important role in how mitochondria and

988

00:33:26,710 --> 00:33:24,320

energy works it's not a trivial thing

989

00:33:29,029 --> 00:33:26,720

those membranes are arranged that way

990

00:33:31,269 --> 00:33:29,039

for a reason and and and

991

00:33:33,669 --> 00:33:31,279

and we realize now as well that the

992

00:33:36,070 --> 00:33:33,679

the the the motors the atp synthase

993

00:33:37,590 --> 00:33:36,080

they're dimers at the end of these

994

00:33:38,950 --> 00:33:37,600

christie and all the rest of the

995

00:33:40,870 --> 00:33:38,960

complexes are in the middle and so

996

00:33:42,149 --> 00:33:40,880

you've got a circuit going on you've

997

00:33:44,870 --> 00:33:42,159

basically got a

998

00:33:46,470 --> 00:33:44,880

um an oscillating charge

999

00:33:48,549 --> 00:33:46,480

um which is

1000

00:33:50,549 --> 00:33:48,559

going to produce a field and we've got

1001
00:33:51,750 --> 00:33:50,559
multiple parallel christian all lined up

1002
00:33:53,509 --> 00:33:51,760
next to each other and if they're

1003
00:33:55,269 --> 00:33:53,519
oscillating in phase then these fields

1004
00:33:56,470 --> 00:33:55,279
should be strengthened

1005
00:33:58,310 --> 00:33:56,480
um

1006
00:33:59,430 --> 00:33:58,320
you know now if talking in a language

1007
00:34:01,430 --> 00:33:59,440
where

1008
00:34:03,750 --> 00:34:01,440
you're much more comfortable than i am

1009
00:34:06,389 --> 00:34:03,760
but um

1010
00:34:07,990 --> 00:34:06,399
if you are able and you know things that

1011
00:34:10,069 --> 00:34:08,000
have happened in neurology relatively

1012
00:34:12,550 --> 00:34:10,079
recently if you if you cut

1013
00:34:15,750 --> 00:34:12,560

an axon for example and separate it by

1014

00:34:17,909 --> 00:34:15,760

up to about 40 micrometers uh an action

1015

00:34:19,030 --> 00:34:17,919

potential can still hop the gap

1016

00:34:20,710 --> 00:34:19,040

you know it's

1017

00:34:23,750 --> 00:34:20,720

we've known about the eeg for more than

1018

00:34:25,510 --> 00:34:23,760

a century um the electroencephalogram so

1019

00:34:27,829 --> 00:34:25,520

we know that the brain is basically

1020

00:34:29,190 --> 00:34:27,839

electrical but amazingly people don't

1021

00:34:30,790 --> 00:34:29,200

really know

1022

00:34:33,190 --> 00:34:30,800

where those charges coming from there's

1023

00:34:35,030 --> 00:34:33,200

an assumption which is that oh it's just

1024

00:34:36,230 --> 00:34:35,040

depolarizing neurons it's an action

1025

00:34:37,990 --> 00:34:36,240

potential going down this you know

1026
00:34:38,950 --> 00:34:38,000
there's a network of all these neurons

1027
00:34:40,950 --> 00:34:38,960
all

1028
00:34:43,109 --> 00:34:40,960
doing their thing hundreds of cells

1029
00:34:44,869 --> 00:34:43,119
maybe thousands of cells all firing

1030
00:34:46,550 --> 00:34:44,879
simultaneously or in a circuit order but

1031
00:34:48,629 --> 00:34:46,560
that's what we're picking up on

1032
00:34:50,790 --> 00:34:48,639
but do we actually know that i don't

1033
00:34:53,750 --> 00:34:50,800
think we do the the fields are quite

1034
00:34:55,109 --> 00:34:53,760
weak on the on the membrane itself but

1035
00:34:57,190 --> 00:34:55,119
inside the cells we've got all these

1036
00:34:59,109 --> 00:34:57,200
mitochondria with stacked christie

1037
00:35:01,430 --> 00:34:59,119
generating what ought to be quite

1038
00:35:03,430 --> 00:35:01,440

powerful fields um

1039

00:35:06,310 --> 00:35:03,440

which should interact with the fields on

1040

00:35:07,910 --> 00:35:06,320

the membranes as well directly and and

1041

00:35:11,109 --> 00:35:07,920

interfere with whether or not they're

1042

00:35:12,950 --> 00:35:11,119

sending a signal or not um and this is a

1043

00:35:14,550 --> 00:35:12,960

whole area of biology that you know the

1044

00:35:16,150 --> 00:35:14,560

moment is hand waving we don't know if

1045

00:35:17,510 --> 00:35:16,160

any of this is true and it makes a very

1046

00:35:19,510 --> 00:35:17,520

specific prediction about the

1047

00:35:21,030 --> 00:35:19,520

orientation of membranes if they're all

1048

00:35:22,230 --> 00:35:21,040

offset to each other then the fields

1049

00:35:24,069 --> 00:35:22,240

would interfere with each other and it

1050

00:35:26,230 --> 00:35:24,079

would never work so you know there's

1051
00:35:27,270 --> 00:35:26,240
quite specific requirements for this to

1052
00:35:30,630 --> 00:35:27,280
work

1053
00:35:33,589 --> 00:35:31,589
it's

1054
00:35:35,270 --> 00:35:33,599
it does seem to be oriented that way it

1055
00:35:36,470 --> 00:35:35,280
does seem to work that way and then then

1056
00:35:39,109 --> 00:35:36,480
you end up with really interesting

1057
00:35:40,069 --> 00:35:39,119
questions to me which is well

1058
00:35:46,150 --> 00:35:40,079
why

1059
00:35:48,310 --> 00:35:46,160
networks

1060
00:35:50,470 --> 00:35:48,320
and the reason for me there

1061
00:35:52,310 --> 00:35:50,480
goes goes back

1062
00:35:53,589 --> 00:35:52,320
actually i wrote a book 10 years ago 12

1063
00:35:54,630 --> 00:35:53,599

years ago called life ascending and

1064

00:35:56,710 --> 00:35:54,640

there's a chapter in there on

1065

00:35:58,230 --> 00:35:56,720

consciousness where i failed to answer

1066

00:36:00,630 --> 00:35:58,240

the question at all to my own

1067

00:36:02,390 --> 00:36:00,640

satisfaction at least well everyone does

1068

00:36:03,430 --> 00:36:02,400

you're uncomfortable comfortable uh well

1069

00:36:05,750 --> 00:36:03,440

i i

1070

00:36:07,589 --> 00:36:05,760

i was left with with two uncomfortable

1071

00:36:08,950 --> 00:36:07,599

conclusions one of them was that and

1072

00:36:11,510 --> 00:36:08,960

this i was really only reporting on what

1073

00:36:13,589 --> 00:36:11,520

other people said um one of them is that

1074

00:36:15,349 --> 00:36:13,599

it's property of physics it's a property

1075

00:36:17,589 --> 00:36:15,359

of matter it's an unknown

1076

00:36:18,950 --> 00:36:17,599

uh unknown property of matter and when

1077

00:36:20,390 --> 00:36:18,960

we know a bit more physics than we'll

1078

00:36:22,710 --> 00:36:20,400

understand what consciousness is and so

1079

00:36:25,349 --> 00:36:22,720

the sun is conscious in some

1080

00:36:27,190 --> 00:36:25,359

way or another it's pan psychism and

1081

00:36:29,750 --> 00:36:27,200

it's got a you know people like roger

1082

00:36:31,829 --> 00:36:29,760

penrose and and and hammer off and so on

1083

00:36:34,390 --> 00:36:31,839

have been arguing along these lines

1084

00:36:35,990 --> 00:36:34,400

uh for for for a long time

1085

00:36:37,349 --> 00:36:36,000

um

1086

00:36:38,870 --> 00:36:37,359

i find it

1087

00:36:41,030 --> 00:36:38,880

uncomfortable

1088

00:36:42,870 --> 00:36:41,040

um i don't really believe that the sun

1089

00:36:45,190 --> 00:36:42,880

or the moon is consciousness conscious

1090

00:36:47,270 --> 00:36:45,200

in a meaningful way i tend to think of

1091

00:36:49,270 --> 00:36:47,280

it as a well basically a property of a

1092

00:36:50,230 --> 00:36:49,280

nervous system

1093

00:36:51,750 --> 00:36:50,240

um

1094

00:36:53,589 --> 00:36:51,760

so but but if you think of it just as a

1095

00:36:55,829 --> 00:36:53,599

property of a nervous system

1096

00:36:57,829 --> 00:36:55,839

then then it comes down from from my

1097

00:37:00,069 --> 00:36:57,839

point of view as a biochemist you've got

1098

00:37:01,510 --> 00:37:00,079

a depolarizing neuron you've got you

1099

00:37:02,710 --> 00:37:01,520

you've got you've got sodium ions

1100

00:37:06,470 --> 00:37:02,720

rushing in

1101

00:37:09,510 --> 00:37:06,480

um potassium ions you know your ions are

1102

00:37:11,190 --> 00:37:09,520

changing around um and that gives rise

1103

00:37:13,349 --> 00:37:11,200

to a feeling

1104

00:37:15,670 --> 00:37:13,359

and if what's the feeling in physical

1105

00:37:17,750 --> 00:37:15,680

terms if it's not a property of matter

1106

00:37:19,030 --> 00:37:17,760

what actually is it more you know is it

1107

00:37:20,550 --> 00:37:19,040

simply

1108

00:37:22,950 --> 00:37:20,560

in that sense an illusion that's

1109

00:37:25,510 --> 00:37:22,960

concocted by a central nervous system

1110

00:37:26,950 --> 00:37:25,520

and i find that very unsatisfying as an

1111

00:37:29,829 --> 00:37:26,960

answer as well

1112

00:37:31,349 --> 00:37:29,839

and it also kind of says that

1113

00:37:33,990 --> 00:37:31,359

it's a property of central nervous

1114

00:37:35,510 --> 00:37:34,000

systems so what did selection act on and

1115

00:37:37,270 --> 00:37:35,520

this is where michael levin's ideas are

1116

00:37:39,589 --> 00:37:37,280

really important because he's saying

1117

00:37:42,069 --> 00:37:39,599

that no is much wider than that all

1118

00:37:44,550 --> 00:37:42,079

cells have these fields all cells are

1119

00:37:47,270 --> 00:37:44,560

communicating electrically it goes right

1120

00:37:49,829 --> 00:37:47,280

back to not just the earliest

1121

00:37:52,069 --> 00:37:49,839

animals but probably back to single

1122

00:37:54,550 --> 00:37:52,079

uh critters as well

1123

00:37:56,150 --> 00:37:54,560

and then when you start thinking about

1124

00:37:58,310 --> 00:37:56,160

well the charges in mitochondria are

1125

00:38:01,030 --> 00:37:58,320

inside cells well mitochondria were

1126
00:38:02,470 --> 00:38:01,040
bacteria once they were free living once

1127
00:38:04,870 --> 00:38:02,480
and so the charges that they have on

1128
00:38:07,030 --> 00:38:04,880
their membranes

1129
00:38:09,670 --> 00:38:07,040
is separating the inside of the

1130
00:38:11,990 --> 00:38:09,680
bacterial cell from the outside world

1131
00:38:13,510 --> 00:38:12,000
and so it has much more meaning you can

1132
00:38:15,510 --> 00:38:13,520
see you can understand why selection

1133
00:38:17,030 --> 00:38:15,520
would act on that it's effectively

1134
00:38:19,510 --> 00:38:17,040
telling you how am i doing in the world

1135
00:38:21,430 --> 00:38:19,520
right now am i am i about to die am i is

1136
00:38:23,030 --> 00:38:21,440
something gone wrong is you know it's a

1137
00:38:24,310 --> 00:38:23,040
real selective value that this is kind

1138
00:38:26,630 --> 00:38:24,320

of giving you an

1139

00:38:28,310 --> 00:38:26,640

integrated real-time feedback on your

1140

00:38:30,790 --> 00:38:28,320

state in the world as an electrical

1141

00:38:32,470 --> 00:38:30,800

field as integrates the whole cell

1142

00:38:33,589 --> 00:38:32,480

and when you start thinking in those

1143

00:38:36,310 --> 00:38:33,599

terms

1144

00:38:38,710 --> 00:38:36,320

and you start realizing that well

1145

00:38:40,710 --> 00:38:38,720

driving this reaction between co2 and

1146

00:38:42,150 --> 00:38:40,720

hydrogen at the origin of life requires

1147

00:38:47,270 --> 00:38:42,160

an electric

1148

00:38:48,790 --> 00:38:47,280

um and so electrically charged membranes

1149

00:38:51,030 --> 00:38:48,800

go right back to the beginning and it's

1150

00:38:53,109 --> 00:38:51,040

the only way really of integrating the

1151

00:38:54,710 --> 00:38:53,119

cell as an entity in relation to its

1152

00:38:56,790 --> 00:38:54,720

environment then there's a beautiful

1153

00:38:59,109 --> 00:38:56,800

idea there i'm not really saying that

1154

00:39:00,790 --> 00:38:59,119

bacteria are conscious in a meaningful

1155

00:39:02,069 --> 00:39:00,800

way it's just that

1156

00:39:04,470 --> 00:39:02,079

there are

1157

00:39:06,710 --> 00:39:04,480

kind of integrated states of their state

1158

00:39:08,550 --> 00:39:06,720

of being in the world either they're

1159

00:39:10,069 --> 00:39:08,560

doing well or they're stressed you know

1160

00:39:11,190 --> 00:39:10,079

that kind of level of

1161

00:39:13,430 --> 00:39:11,200

um

1162

00:39:15,829 --> 00:39:13,440

of feedback

1163

00:39:17,910 --> 00:39:15,839

it it's calibrated by a field and

1164

00:39:19,750 --> 00:39:17,920

those fields are used during development

1165

00:39:21,349 --> 00:39:19,760

to say okay now you've grown enough now

1166

00:39:23,109 --> 00:39:21,359

stop now you're in a high or whatever it

1167

00:39:25,270 --> 00:39:23,119

may be and this is a whole language of

1168

00:39:27,270 --> 00:39:25,280

how fields are communicating in biology

1169

00:39:29,910 --> 00:39:27,280

which we've barely

1170

00:39:32,069 --> 00:39:29,920

touched the tip of the iceberg

1171

00:39:34,069 --> 00:39:32,079

okay let me see if i got the stream

1172

00:39:35,750 --> 00:39:34,079

so earlier we you mentioned that there's

1173

00:39:37,750 --> 00:39:35,760

an axon you can cut it and then you can

1174

00:39:39,190 --> 00:39:37,760

separate it such that

1175

00:39:40,550 --> 00:39:39,200

chemicals shouldn't be able to be

1176

00:39:42,790 --> 00:39:40,560

interchanged between here like

1177

00:39:44,230 --> 00:39:42,800

neurotransmitters too slow for that yes

1178

00:39:45,270 --> 00:39:44,240

so it'll just hop over as if there was

1179

00:39:46,630 --> 00:39:45,280

no gap

1180

00:39:49,510 --> 00:39:46,640

however there's still a signal that

1181

00:39:50,310 --> 00:39:49,520

signals called an action potential yep

1182

00:39:52,790 --> 00:39:50,320

okay

1183

00:39:55,109 --> 00:39:52,800

and one of the reasons you think or

1184

00:39:57,030 --> 00:39:55,119

people think mitochondria are important

1185

00:39:59,829 --> 00:39:57,040

are because you use this word christy

1186

00:40:01,750 --> 00:39:59,839

which i believe refers to the these are

1187

00:40:03,349 --> 00:40:01,760

the membranes inside

1188

00:40:05,670 --> 00:40:03,359

yes exactly

1189

00:40:07,670 --> 00:40:05,680

okay and the reason why these folds are

1190

00:40:11,270 --> 00:40:07,680

important is because they have plenty of

1191

00:40:13,510 --> 00:40:11,280

surface area even though they're small

1192

00:40:15,190 --> 00:40:13,520

yes they they have a lot of surface area

1193

00:40:17,349 --> 00:40:15,200

but they also have a structure and an

1194

00:40:18,710 --> 00:40:17,359

orientation they're lined up in parallel

1195

00:40:20,630 --> 00:40:18,720

very often

1196

00:40:21,589 --> 00:40:20,640

and and they they have a very high

1197

00:40:23,190 --> 00:40:21,599

charge

1198

00:40:24,470 --> 00:40:23,200

and ironically

1199

00:40:25,430 --> 00:40:24,480

it's very difficult to measure that

1200

00:40:27,670 --> 00:40:25,440

charge

1201
00:40:29,510 --> 00:40:27,680
um why because

1202
00:40:31,030 --> 00:40:29,520
because if you're measuring the charge

1203
00:40:33,190 --> 00:40:31,040
in a neuron

1204
00:40:35,030 --> 00:40:33,200
you can you can insert a microelectrode

1205
00:40:37,670 --> 00:40:35,040
into a neuron and it was all originally

1206
00:40:40,150 --> 00:40:37,680
it was all done uh with giant neurons in

1207
00:40:41,910 --> 00:40:40,160
squids and things like that um

1208
00:40:43,510 --> 00:40:41,920
but but still you can insert an

1209
00:40:46,310 --> 00:40:43,520
electrode into a neuron but remember a

1210
00:40:48,790 --> 00:40:46,320
mitochondrion is a small part of a cell

1211
00:40:49,750 --> 00:40:48,800
so it's much smaller than a neuron

1212
00:40:50,870 --> 00:40:49,760
um

1213
00:40:53,990 --> 00:40:50,880

and

1214

00:40:55,430 --> 00:40:54,000

inserted microelectrodes into

1215

00:40:56,950 --> 00:40:55,440

mitochondria

1216

00:40:59,670 --> 00:40:56,960

and the irony is they've never really

1217

00:41:01,109 --> 00:40:59,680

measured much of a potential difference

1218

00:41:02,710 --> 00:41:01,119

and the reason for that is almost

1219

00:41:04,550 --> 00:41:02,720

certainly that what they they've just

1220

00:41:06,309 --> 00:41:04,560

inserted it into what's called a matrix

1221

00:41:08,069 --> 00:41:06,319

which is the main kind of bulk space

1222

00:41:09,349 --> 00:41:08,079

inside the mitochondrion and so they're

1223

00:41:10,710 --> 00:41:09,359

measuring a difference between that and

1224

00:41:12,550 --> 00:41:10,720

the rest of the cell

1225

00:41:14,470 --> 00:41:12,560

and it's not much but then you've got

1226

00:41:16,630 --> 00:41:14,480

these structures that christie which are

1227

00:41:19,109 --> 00:41:16,640

very tight membranes which is basically

1228

00:41:21,349 --> 00:41:19,119

impossible to poke a needle into

1229

00:41:22,950 --> 00:41:21,359

and that's where all the charges so to

1230

00:41:24,550 --> 00:41:22,960

try and measure that charge is a really

1231

00:41:26,950 --> 00:41:24,560

difficult thing to do

1232

00:41:29,030 --> 00:41:26,960

uh and people are getting closer to it

1233

00:41:30,950 --> 00:41:29,040

now there's some really clever ingenious

1234

00:41:33,670 --> 00:41:30,960

ways of trying to measure what exactly

1235

00:41:35,910 --> 00:41:33,680

is the charge in this closed space

1236

00:41:36,870 --> 00:41:35,920

really narrow closed space

1237

00:41:38,950 --> 00:41:36,880

um

1238

00:41:40,790 --> 00:41:38,960

but it you know it's it's it's a very

1239

00:41:42,470 --> 00:41:40,800

difficult technical problem you can cut

1240

00:41:43,990 --> 00:41:42,480

you can basically calculate it you can

1241

00:41:45,510 --> 00:41:44,000

show it with dyes but you never really

1242

00:41:47,430 --> 00:41:45,520

know what the dyes are interacting with

1243

00:41:49,829 --> 00:41:47,440

otherwise so it's it's intrinsically

1244

00:41:51,510 --> 00:41:49,839

difficult uh okay do you imagine that

1245

00:41:53,589 --> 00:41:51,520

this is a technological problem that

1246

00:41:55,349 --> 00:41:53,599

will be solved in the near future i hope

1247

00:41:56,710 --> 00:41:55,359

or there's some in principle reason why

1248

00:41:59,030 --> 00:41:56,720

it can't be done

1249

00:42:00,470 --> 00:41:59,040

uh no i think um i i mean it's just

1250

00:42:02,790 --> 00:42:00,480

difficult but i think we can do it i

1251
00:42:04,230 --> 00:42:02,800
mean i intend to give it my own best

1252
00:42:07,030 --> 00:42:04,240
shot but there's a few other people

1253
00:42:09,349 --> 00:42:07,040
thinking along these lines as well

1254
00:42:11,190 --> 00:42:09,359
now the fact that mitochondria may be

1255
00:42:13,589 --> 00:42:11,200
important for consciousness does that

1256
00:42:15,510 --> 00:42:13,599
imply that the bacteria which don't have

1257
00:42:17,510 --> 00:42:15,520
mitochondria are not conscious or at a

1258
00:42:19,030 --> 00:42:17,520
much lower level of consciousness than

1259
00:42:24,630 --> 00:42:19,040
protozoa

1260
00:42:26,390 --> 00:42:24,640
um and you know you can see videos of

1261
00:42:29,109 --> 00:42:26,400
the way that they behave and they're

1262
00:42:30,550 --> 00:42:29,119
astonishing i mean you know watch videos

1263
00:42:32,550 --> 00:42:30,560

of protozoa the way that they move

1264

00:42:34,230 --> 00:42:32,560

around and they they go fishing they do

1265

00:42:35,670 --> 00:42:34,240

all kinds

1266

00:42:37,829 --> 00:42:35,680

the control of their behavior is

1267

00:42:39,270 --> 00:42:37,839

exquisite um

1268

00:42:40,790 --> 00:42:39,280

it's the kind of thing that

1269

00:42:42,829 --> 00:42:40,800

you know should make people believe in

1270

00:42:44,790 --> 00:42:42,839

god it's just so beautiful

1271

00:42:46,710 --> 00:42:44,800

um so

1272

00:42:48,230 --> 00:42:46,720

it's not a matter of genes being

1273

00:42:49,670 --> 00:42:48,240

expressed there's something controlling

1274

00:42:51,109 --> 00:42:49,680

this system

1275

00:42:52,150 --> 00:42:51,119

uh which is

1276

00:42:54,470 --> 00:42:52,160

which is

1277

00:42:56,309 --> 00:42:54,480

happening in in nanoseconds is you know

1278

00:42:58,390 --> 00:42:56,319

it's happening extremely quickly and

1279

00:43:00,230 --> 00:42:58,400

it's it's the whole cell which is doing

1280

00:43:01,430 --> 00:43:00,240

this it's not just one bit of the cell

1281

00:43:03,270 --> 00:43:01,440

it's not you know

1282

00:43:04,630 --> 00:43:03,280

imagine you're a molecule

1283

00:43:05,990 --> 00:43:04,640

finish the book this way imagine that

1284

00:43:07,589 --> 00:43:06,000

you're a molly shrink yourself down to

1285

00:43:08,550 --> 00:43:07,599

the size of a molecule a cell is like a

1286

00:43:10,150 --> 00:43:08,560

city

1287

00:43:12,710 --> 00:43:10,160

um

1288

00:43:16,390 --> 00:43:12,720

where i am now i'm in london and

1289

00:43:17,829 --> 00:43:16,400

20 15 20 miles away uh through to canary

1290

00:43:19,589 --> 00:43:17,839

wharf or greenwich or somewhere like

1291

00:43:21,349 --> 00:43:19,599

that um

1292

00:43:23,270 --> 00:43:21,359

there would be other molecules you know

1293

00:43:25,190 --> 00:43:23,280

the people over there would be like me

1294

00:43:27,349 --> 00:43:25,200

as a molecule as a pyruvate molecule

1295

00:43:29,109 --> 00:43:27,359

inside a cell or something so what is it

1296

00:43:30,230 --> 00:43:29,119

that unites me

1297

00:43:31,190 --> 00:43:30,240

with this

1298

00:43:32,870 --> 00:43:31,200

person

1299

00:43:34,870 --> 00:43:32,880

20 miles away

1300

00:43:36,950 --> 00:43:34,880

in a cell and and the answer is well you

1301

00:43:39,190 --> 00:43:36,960

know

1302

00:43:40,950 --> 00:43:39,200

in the city not much some kind of shared

1303

00:43:42,630 --> 00:43:40,960

sense of identity as a londoner or

1304

00:43:43,829 --> 00:43:42,640

something but you know you know you you

1305

00:43:45,910 --> 00:43:43,839

know that you're living in a city but

1306

00:43:48,230 --> 00:43:45,920

that's conscious awareness but in a cell

1307

00:43:51,430 --> 00:43:48,240

while we're dealing with molecules

1308

00:43:52,829 --> 00:43:51,440

how does something happening over here

1309

00:43:54,309 --> 00:43:52,839

happen over there

1310

00:43:57,750 --> 00:43:54,319

simultaneously essentially

1311

00:44:00,150 --> 00:43:57,760

simultaneously effectively 20 miles away

1312

00:44:02,630 --> 00:44:00,160

so that we're integrated in in real time

1313

00:44:03,589 --> 00:44:02,640

and doing the same thing

1314

00:44:05,910 --> 00:44:03,599

now

1315

00:44:07,430 --> 00:44:05,920

fields can do that for sure so how would

1316

00:44:08,870 --> 00:44:07,440

you have a field that operates on the

1317

00:44:10,630 --> 00:44:08,880

whole cell if it's on the membrane that

1318

00:44:12,390 --> 00:44:10,640

surrounds the cell

1319

00:44:13,910 --> 00:44:12,400

and if what that membrane is reporting

1320

00:44:15,109 --> 00:44:13,920

on is how are you doing in relation to

1321

00:44:16,950 --> 00:44:15,119

the environment because if you you know

1322

00:44:19,430 --> 00:44:16,960

if you're if you're taking up food from

1323

00:44:21,030 --> 00:44:19,440

the environment and burning it and using

1324

00:44:22,150 --> 00:44:21,040

the energy to generate an electrical

1325

00:44:23,829 --> 00:44:22,160

charge on the membrane and there's

1326

00:44:25,190 --> 00:44:23,839

plenty of food you've got a nice charge

1327

00:44:26,150 --> 00:44:25,200

everything's good

1328

00:44:28,470 --> 00:44:26,160

um

1329

00:44:30,309 --> 00:44:28,480

so it's it's telling you that the the

1330

00:44:31,750 --> 00:44:30,319

whole cell has got a nice electrical

1331

00:44:33,750 --> 00:44:31,760

charge on the membrane there's a nice

1332

00:44:35,430 --> 00:44:33,760

field crossing the cell

1333

00:44:37,190 --> 00:44:35,440

oscillation so

1334

00:44:40,309 --> 00:44:37,200

water molecules within the cell are kind

1335

00:44:41,510 --> 00:44:40,319

of locking things in some kind of phase

1336

00:44:45,430 --> 00:44:41,520

and

1337

00:44:47,270 --> 00:44:45,440

that is telling you about your state if

1338

00:44:48,470 --> 00:44:47,280

you move into an area where there's

1339

00:44:50,230 --> 00:44:48,480

toxins

1340

00:44:51,670 --> 00:44:50,240

or where there's no food or whatever it

1341

00:44:53,270 --> 00:44:51,680

may be then

1342

00:44:54,710 --> 00:44:53,280

then you're you're you know they're

1343

00:44:57,190 --> 00:44:54,720

going to interfere

1344

00:44:59,990 --> 00:44:57,200

with how this charge works it's going to

1345

00:45:01,829 --> 00:45:00,000

change the field and and you're going to

1346

00:45:03,030 --> 00:45:01,839

shift you're going to change what you do

1347

00:45:05,510 --> 00:45:03,040

you're going to move over there you're

1348

00:45:08,630 --> 00:45:05,520

going to set your your

1349

00:45:10,150 --> 00:45:08,640

your flagellum whirring or something

1350

00:45:13,190 --> 00:45:10,160

you you'll change your behavior but you

1351
00:45:14,790 --> 00:45:13,200
do it at the level of a whole cell

1352
00:45:18,069 --> 00:45:14,800
and what's integrating at the level of

1353
00:45:19,670 --> 00:45:18,079
the cell in my view now is is the the

1354
00:45:21,670 --> 00:45:19,680
charge on the membrane generating a

1355
00:45:24,150 --> 00:45:21,680
field which is integrating all the

1356
00:45:24,950 --> 00:45:24,160
component molecules in the cell to act

1357
00:45:29,430 --> 00:45:24,960
as a

1358
00:45:31,430 --> 00:45:29,440
here's one question if we have one cell

1359
00:45:33,589 --> 00:45:31,440
and it's we imagine that it may have

1360
00:45:35,510 --> 00:45:33,599
some proto form of consciousness because

1361
00:45:36,630 --> 00:45:35,520
it's interacting with the outside okay

1362
00:45:39,109 --> 00:45:36,640
and then if we have two and they're

1363
00:45:42,230 --> 00:45:39,119

interacting with one another then we

1364

00:45:44,150 --> 00:45:42,240

have a consciousness that is of the two

1365

00:45:47,190 --> 00:45:44,160

as a whole

1366

00:45:49,430 --> 00:45:47,200

um not necessarily uh if they're in if

1367

00:45:51,589 --> 00:45:49,440

they're locked in phase in some way as

1368

00:45:54,309 --> 00:45:51,599

they may be if with two neurons locked

1369

00:45:56,230 --> 00:45:54,319

in phase in a multicellular organism

1370

00:45:58,950 --> 00:45:56,240

um then yes they could be but if they're

1371

00:46:00,950 --> 00:45:58,960

not in phase then then they

1372

00:46:02,550 --> 00:46:00,960

would interfere with each other in some

1373

00:46:04,150 --> 00:46:02,560

way there's actually lots of evidence

1374

00:46:06,790 --> 00:46:04,160

that for example

1375

00:46:09,270 --> 00:46:06,800

um pollinating insects when they arrive

1376

00:46:11,190 --> 00:46:09,280

on a flower can sense electrically

1377

00:46:12,390 --> 00:46:11,200

whether or not it's already

1378

00:46:14,710 --> 00:46:12,400

whether the nectar is already being

1379

00:46:16,470 --> 00:46:14,720

taken so they don't bother to go there

1380

00:46:18,069 --> 00:46:16,480

you know there's an interference that i

1381

00:46:19,829 --> 00:46:18,079

don't know very much about

1382

00:46:21,349 --> 00:46:19,839

um but

1383

00:46:23,750 --> 00:46:21,359

you know there's quite a lot of evidence

1384

00:46:25,270 --> 00:46:23,760

that the animals have fields that are

1385

00:46:27,030 --> 00:46:25,280

capable of interacting with each other

1386

00:46:29,030 --> 00:46:27,040

we just don't know a huge amount about

1387

00:46:31,349 --> 00:46:29,040

it and the idea that cells would do the

1388

00:46:32,630 --> 00:46:31,359

same thing i mean you can see it under

1389

00:46:34,550 --> 00:46:32,640

the microscope we don't know exactly

1390

00:46:35,670 --> 00:46:34,560

what's going on i don't think we've ever

1391

00:46:37,670 --> 00:46:35,680

measured it

1392

00:46:39,670 --> 00:46:37,680

but i'm fairly

1393

00:46:41,430 --> 00:46:39,680

fairly persuaded that fields would be

1394

00:46:43,430 --> 00:46:41,440

one of the most powerful ways of trying

1395

00:46:45,349 --> 00:46:43,440

to explain the interactions you see

1396

00:46:47,349 --> 00:46:45,359

between single cells yes

1397

00:46:48,710 --> 00:46:47,359

now this locked in phase quality i

1398

00:46:51,510 --> 00:46:48,720

imagine is also

1399

00:46:53,829 --> 00:46:51,520

a spectrum and not zero to not binary or

1400

00:46:55,589 --> 00:46:53,839

is it i know well

1401
00:46:57,190 --> 00:46:55,599
you tell me you're the physicist i mean

1402
00:46:59,190 --> 00:46:57,200
i i would imagine that there's something

1403
00:47:00,390 --> 00:46:59,200
of a spectrum but but there's some

1404
00:47:01,910 --> 00:47:00,400
element in which once you get

1405
00:47:04,870 --> 00:47:01,920
interference then you don't have you

1406
00:47:06,390 --> 00:47:04,880
would not have any locked in place

1407
00:47:08,470 --> 00:47:06,400
what i'm thinking is that

1408
00:47:09,829 --> 00:47:08,480
i'm imagining the brain akin to those

1409
00:47:11,349 --> 00:47:09,839
vertices of there's points there's

1410
00:47:13,589 --> 00:47:11,359
vertices and then there's edges between

1411
00:47:14,710 --> 00:47:13,599
them and then there's a slew of them and

1412
00:47:17,589 --> 00:47:14,720
then they're interacting with one

1413
00:47:19,910 --> 00:47:17,599

another and that any subset of these

1414

00:47:22,309 --> 00:47:19,920

not any subset but there will be

1415

00:47:24,309 --> 00:47:22,319

manifold subsets so plenty not manifold

1416

00:47:26,710 --> 00:47:24,319

in the math sense but man many many

1417

00:47:29,190 --> 00:47:26,720

subsets that will be in phase with one

1418

00:47:30,870 --> 00:47:29,200

another any given point in time and so

1419

00:47:32,710 --> 00:47:30,880

any individual

1420

00:47:34,950 --> 00:47:32,720

comprises

1421

00:47:36,470 --> 00:47:34,960

perhaps more conscious

1422

00:47:38,630 --> 00:47:36,480

subsets than there are atoms in the

1423

00:47:40,470 --> 00:47:38,640

universe if you do some analysis of how

1424

00:47:43,190 --> 00:47:40,480

many subsets and so on that is to say

1425

00:47:45,430 --> 00:47:43,200

that nick is not just one consciousness

1426

00:47:46,790 --> 00:47:45,440

it would be trillions if or 10 to the

1427

00:47:48,550 --> 00:47:46,800

trillions

1428

00:47:50,150 --> 00:47:48,560

well but i don't know so because i don't

1429

00:47:52,230 --> 00:47:50,160

know what counts as consciousness here

1430

00:47:53,910 --> 00:47:52,240

yeah i mean i'm not i'm not a

1431

00:47:55,910 --> 00:47:53,920

neurologist and i'm not working on

1432

00:47:57,030 --> 00:47:55,920

consciousness as we know it in human

1433

00:47:57,829 --> 00:47:57,040

brains

1434

00:47:59,510 --> 00:47:57,839

um

1435

00:48:00,950 --> 00:47:59,520

what bothered me

1436

00:48:02,630 --> 00:48:00,960

um

1437

00:48:06,390 --> 00:48:02,640

you know it's a question in philosophy

1438

00:48:08,630 --> 00:48:06,400

as well is is is is if you've got an and

1439

00:48:11,190 --> 00:48:08,640

it touches on ai and whatever else if

1440

00:48:12,950 --> 00:48:11,200

you've got an extremely sophisticated

1441

00:48:13,990 --> 00:48:12,960

processing system

1442

00:48:15,430 --> 00:48:14,000

um

1443

00:48:18,710 --> 00:48:15,440

and the brain is an extremely

1444

00:48:20,790 --> 00:48:18,720

sophisticated processing system uh

1445

00:48:23,030 --> 00:48:20,800

does it need to be conscious is there

1446

00:48:26,630 --> 00:48:23,040

some kind of emergence

1447

00:48:29,349 --> 00:48:26,640

and if so what governs that emergence

1448

00:48:30,150 --> 00:48:29,359

um and it may be that that is the case

1449

00:48:33,030 --> 00:48:30,160

but

1450

00:48:35,589 --> 00:48:33,040

i'm i i find emergence one of those

1451

00:48:37,349 --> 00:48:35,599

words which is overused it has a real

1452

00:48:38,790 --> 00:48:37,359

meaning but it's very easy to say oh

1453

00:48:40,710 --> 00:48:38,800

it's an emergent property and you know

1454

00:48:42,630 --> 00:48:40,720

it's basically it says i have no clue

1455

00:48:44,309 --> 00:48:42,640

what i'm talking about it's just a nice

1456

00:48:45,109 --> 00:48:44,319

word um

1457

00:48:48,950 --> 00:48:45,119

so

1458

00:48:51,349 --> 00:48:48,960

i i can imagine

1459

00:48:54,150 --> 00:48:51,359

the classical philosopher's zombie which

1460

00:48:56,950 --> 00:48:54,160

is capable of behaving in a perfectly

1461

00:48:58,790 --> 00:48:56,960

normal human way without experiencing

1462

00:49:01,990 --> 00:48:58,800

any emotions or any feelings or anything

1463

00:49:05,430 --> 00:49:02,000

else and i can imagine robots and an ai

1464

00:49:07,750 --> 00:49:05,440

uh being like that as well capable of

1465

00:49:09,829 --> 00:49:07,760

being enormously intelligent and and

1466

00:49:12,790 --> 00:49:09,839

having you know conversations that would

1467

00:49:16,390 --> 00:49:12,800

persuade us that they are human um but

1468

00:49:18,309 --> 00:49:16,400

without feeling anything um

1469

00:49:20,309 --> 00:49:18,319

and so i'm background to this question

1470

00:49:22,069 --> 00:49:20,319

of well what is a feeling is it real is

1471

00:49:23,990 --> 00:49:22,079

it a is it a concoction of a central

1472

00:49:25,430 --> 00:49:24,000

nervous system an emergent property what

1473

00:49:27,430 --> 00:49:25,440

actually is it

1474

00:49:29,510 --> 00:49:27,440

and to my mind

1475

00:49:31,430 --> 00:49:29,520

um

1476

00:49:33,349 --> 00:49:31,440

natural selection always works on

1477

00:49:36,069 --> 00:49:33,359

something else there are simpler systems

1478

00:49:39,030 --> 00:49:36,079

so you know it it

1479

00:49:40,710 --> 00:49:39,040

so i'm perfectly happy to believe that a

1480

00:49:42,549 --> 00:49:40,720

dog for example

1481

00:49:44,790 --> 00:49:42,559

is not necessarily

1482

00:49:46,870 --> 00:49:44,800

that intelligent i don't know but i i i

1483

00:49:49,430 --> 00:49:46,880

would think it's consciously aware

1484

00:49:52,390 --> 00:49:49,440

and and and capable of feelings capable

1485

00:49:54,950 --> 00:49:52,400

of emotions and the idea that a dog will

1486

00:49:56,549 --> 00:49:54,960

pine after its masters died or whatever

1487

00:49:58,390 --> 00:49:56,559

is you know it's very familiar to most

1488

00:49:59,829 --> 00:49:58,400

people and and it seems

1489

00:50:01,750 --> 00:49:59,839

obvious to me

1490

00:50:03,270 --> 00:50:01,760

um that that would be the case and from

1491

00:50:05,109 --> 00:50:03,280

a biologist point of view why would it

1492

00:50:06,710 --> 00:50:05,119

not be the case selection has to act on

1493

00:50:08,230 --> 00:50:06,720

something why would one central nervous

1494

00:50:10,870 --> 00:50:08,240

system be utterly different to another

1495

00:50:12,549 --> 00:50:10,880

one there's a matter of it's a continuum

1496

00:50:14,950 --> 00:50:12,559

again we have a really

1497

00:50:17,910 --> 00:50:14,960

high power processing system but our

1498

00:50:19,910 --> 00:50:17,920

feelings our emotions

1499

00:50:21,589 --> 00:50:19,920

you know i i think we probably share

1500

00:50:24,390 --> 00:50:21,599

them with a lot of other creatures and

1501
00:50:26,630 --> 00:50:24,400
it's very easy to imagine that the the

1502
00:50:29,109 --> 00:50:26,640
you know chimpanzee can be in love or

1503
00:50:30,470 --> 00:50:29,119
can feel pain or or any of these

1504
00:50:31,750 --> 00:50:30,480
feelings

1505
00:50:34,069 --> 00:50:31,760
they feel

1506
00:50:36,309 --> 00:50:34,079
animalistic to me

1507
00:50:39,109 --> 00:50:36,319
and we can nuance them with with all

1508
00:50:42,470 --> 00:50:40,870
intelligence and thoughts and language

1509
00:50:44,549 --> 00:50:42,480
and whatever else but the you know a

1510
00:50:46,630 --> 00:50:44,559
feeling of of malignant sadness

1511
00:50:49,349 --> 00:50:46,640
underneath everything else is it's it's

1512
00:50:52,549 --> 00:50:49,359
it's not something which is

1513
00:50:53,829 --> 00:50:52,559

you that you have much control over

1514

00:50:55,589 --> 00:50:53,839

or a feeling of just being

1515

00:50:57,589 --> 00:50:55,599

overwhelmingly in love with someone what

1516

00:50:59,270 --> 00:50:57,599

what what can you do you know we have no

1517

00:51:02,150 --> 00:50:59,280

control over these these feelings

1518

00:51:04,309 --> 00:51:02,160

they're they're very

1519

00:51:05,670 --> 00:51:04,319

separate almost from from a parallel

1520

00:51:08,390 --> 00:51:05,680

processing system they can be

1521

00:51:10,470 --> 00:51:08,400

overwhelming um and so

1522

00:51:12,069 --> 00:51:10,480

so what what what are they and this is

1523

00:51:14,309 --> 00:51:12,079

where i think this language of feels and

1524

00:51:17,190 --> 00:51:14,319

so on comes in and i'm not saying that a

1525

00:51:18,710 --> 00:51:17,200

bacterium is conscious in a way that any

1526
00:51:21,270 --> 00:51:18,720
of us would recognize i'm just saying

1527
00:51:22,710 --> 00:51:21,280
it's the germ of a kind of a

1528
00:51:25,109 --> 00:51:22,720
something which tells you about your

1529
00:51:26,870 --> 00:51:25,119
state and which is not just it's more

1530
00:51:28,630 --> 00:51:26,880
than the sum of all of these parts it's

1531
00:51:29,990 --> 00:51:28,640
something which gives you an integrated

1532
00:51:32,309 --> 00:51:30,000
feedback on

1533
00:51:35,030 --> 00:51:32,319
am i am i effectively sad or happy you

1534
00:51:37,030 --> 00:51:35,040
might say i'm am i content in this

1535
00:51:38,390 --> 00:51:37,040
environment or am i stressed in this

1536
00:51:43,910 --> 00:51:38,400
environment that's the nature of a

1537
00:51:49,190 --> 00:51:46,790
okay so to be clear you're not claiming

1538
00:51:50,549 --> 00:51:49,200

that this solves the heart problem of

1539

00:51:52,309 --> 00:51:50,559

consciousness but rather if

1540

00:51:54,470 --> 00:51:52,319

consciousness was to have some physical

1541

00:51:56,069 --> 00:51:54,480

explanation perhaps we should look at

1542

00:51:58,309 --> 00:51:56,079

the what's occurring at the cell

1543

00:52:00,630 --> 00:51:58,319

membrane electrically

1544

00:52:02,790 --> 00:52:00,640

uh well the the membranes inside in the

1545

00:52:04,549 --> 00:52:02,800

mitochondria and so on yes i think

1546

00:52:06,790 --> 00:52:04,559

that's the language i think that

1547

00:52:07,910 --> 00:52:06,800

provides a selective basis for how it

1548

00:52:09,990 --> 00:52:07,920

began

1549

00:52:12,150 --> 00:52:10,000

i think it's it you know this question

1550

00:52:14,150 --> 00:52:12,160

about what purpose is consciousness in

1551
00:52:15,670 --> 00:52:14,160
in in natural selection

1552
00:52:18,470 --> 00:52:15,680
if you think about it at the level of

1553
00:52:19,990 --> 00:52:18,480
single cells if you think that it's

1554
00:52:22,309 --> 00:52:20,000
giving you this real time integrated

1555
00:52:24,069 --> 00:52:22,319
feedback on your state in the world

1556
00:52:26,630 --> 00:52:24,079
and whether or not you make a decision

1557
00:52:29,190 --> 00:52:26,640
as a cell to go over there or to stay

1558
00:52:30,630 --> 00:52:29,200
here or to depolarize your membrane and

1559
00:52:32,549 --> 00:52:30,640
kill yourself immediately if you've been

1560
00:52:36,069 --> 00:52:32,559
infected by a virus or all of these kind

1561
00:52:38,870 --> 00:52:36,079
of decisions that you take as an entity

1562
00:52:40,790 --> 00:52:38,880
um this is providing you with a kind of

1563
00:52:42,790 --> 00:52:40,800

language for the entity

1564

00:52:44,470 --> 00:52:42,800

and it you immediately see what

1565

00:52:46,549 --> 00:52:44,480

selection is acting on and the hard

1566

00:52:48,790 --> 00:52:46,559

problem in consciousness is

1567

00:52:51,270 --> 00:52:48,800

to a large extent about what what our

1568

00:52:52,950 --> 00:52:51,280

feelings what our emotions in in in

1569

00:52:54,950 --> 00:52:52,960

physical terms

1570

00:52:56,309 --> 00:52:54,960

uh and and that's

1571

00:52:58,710 --> 00:52:56,319

you know people have been talking about

1572

00:53:00,470 --> 00:52:58,720

electrical fields for quite a long time

1573

00:53:02,790 --> 00:53:00,480

in that sense as well this is again

1574

00:53:04,309 --> 00:53:02,800

nothing particularly new but but why

1575

00:53:07,030 --> 00:53:04,319

that language

1576
00:53:09,109 --> 00:53:07,040
why why would electrical fields give you

1577
00:53:11,270 --> 00:53:09,119
some kind of feeling of being conscious

1578
00:53:13,990 --> 00:53:11,280
when you take it out of the environment

1579
00:53:16,309 --> 00:53:14,000
of a nervous system and put it into the

1580
00:53:18,069 --> 00:53:16,319
environment of single cells and this

1581
00:53:19,510 --> 00:53:18,079
real-time feedback

1582
00:53:21,589 --> 00:53:19,520
on their environment their state in

1583
00:53:23,109 --> 00:53:21,599
their environment then you you see it's

1584
00:53:24,630 --> 00:53:23,119
the only language which is going to

1585
00:53:25,510 --> 00:53:24,640
integrate you as a unit which is going

1586
00:53:27,750 --> 00:53:25,520
to tell

1587
00:53:30,870 --> 00:53:27,760
tell the other half of the cell 20 miles

1588
00:53:33,829 --> 00:53:30,880

away over there that that uh

1589

00:53:36,150 --> 00:53:33,839

is that it's an er you know your action

1590

00:53:38,390 --> 00:53:36,160

is for the whole cell

1591

00:53:40,470 --> 00:53:38,400

and so when you put two cells together

1592

00:53:42,630 --> 00:53:40,480

and and you build multicellular

1593

00:53:45,030 --> 00:53:42,640

organisms you're using these fields to

1594

00:53:47,510 --> 00:53:45,040

control the development of the organisms

1595

00:53:49,349 --> 00:53:47,520

as as michael levin says and then as you

1596

00:53:51,990 --> 00:53:49,359

end up with a central nervous system

1597

00:53:53,829 --> 00:53:52,000

it's channeling more of that energy into

1598

00:53:55,510 --> 00:53:53,839

circuits and you know

1599

00:53:57,270 --> 00:53:55,520

whatever the explanation is it has to

1600

00:53:58,870 --> 00:53:57,280

correspond to what we already know about

1601
00:54:00,870 --> 00:53:58,880
neurology about the way that neural

1602
00:54:02,309 --> 00:54:00,880
networks actually work and the problem i

1603
00:54:03,510 --> 00:54:02,319
have for example with

1604
00:54:05,670 --> 00:54:03,520
with um

1605
00:54:07,349 --> 00:54:05,680
with penrose and hammer off and the idea

1606
00:54:10,870 --> 00:54:07,359
that it's it's all

1607
00:54:12,950 --> 00:54:10,880
uh to do with um with microtubules for

1608
00:54:15,349 --> 00:54:12,960
example is that it's not

1609
00:54:17,750 --> 00:54:15,359
very obvious

1610
00:54:20,549 --> 00:54:17,760
how they correspond to at least it's not

1611
00:54:22,470 --> 00:54:20,559
to me how they correspond to what we

1612
00:54:23,910 --> 00:54:22,480
already know about neurology about

1613
00:54:25,670 --> 00:54:23,920

neural networks and so on whereas

1614

00:54:26,710 --> 00:54:25,680

mitochondria are completely integrated

1615

00:54:28,630 --> 00:54:26,720

into that

1616

00:54:29,750 --> 00:54:28,640

um they're part of the neurons they're

1617

00:54:32,549 --> 00:54:29,760

part of

1618

00:54:34,150 --> 00:54:32,559

uh the depolarization of neurons they

1619

00:54:36,710 --> 00:54:34,160

can interfere with this electric

1620

00:54:38,549 --> 00:54:36,720

electrically and so on so they're

1621

00:54:40,950 --> 00:54:38,559

they're they're linked in

1622

00:54:42,549 --> 00:54:40,960

with the structure i think of the

1623

00:54:43,829 --> 00:54:42,559

neurons in a different in a different

1624

00:54:46,630 --> 00:54:43,839

way

1625

00:54:49,190 --> 00:54:46,640

the reason though that i

1626
00:54:50,829 --> 00:54:49,200
came back to this and and started taking

1627
00:54:53,589 --> 00:54:50,839
it seriously

1628
00:54:54,950 --> 00:54:53,599
um and you know lots of people seem to

1629
00:54:56,390 --> 00:54:54,960
think that i'm barking up the wrong tree

1630
00:54:58,630 --> 00:54:56,400
altogether and should never talk about

1631
00:55:01,589 --> 00:54:58,640
neurology again or consciousness again

1632
00:55:03,430 --> 00:55:01,599
um but the the the reason is is is an

1633
00:55:05,109 --> 00:55:03,440
interaction with a biophysicist called

1634
00:55:06,870 --> 00:55:05,119
luca turin

1635
00:55:08,309 --> 00:55:06,880
and and he came to see me a few years

1636
00:55:10,630 --> 00:55:08,319
ago and

1637
00:55:12,710 --> 00:55:10,640
was talking about anesthetics general

1638
00:55:14,230 --> 00:55:12,720

anesthetics we don't really know how

1639

00:55:16,069 --> 00:55:14,240

they work

1640

00:55:19,109 --> 00:55:16,079

um and

1641

00:55:21,349 --> 00:55:19,119

and and he he was interested in xenon in

1642

00:55:22,390 --> 00:55:21,359

particular which is an inert gas

1643

00:55:23,910 --> 00:55:22,400

and

1644

00:55:25,910 --> 00:55:23,920

that it doesn't really have a shape it's

1645

00:55:27,510 --> 00:55:25,920

a sphere of electron density so it's not

1646

00:55:29,030 --> 00:55:27,520

obviously going to interact with any

1647

00:55:30,150 --> 00:55:29,040

type of receptor

1648

00:55:31,829 --> 00:55:30,160

and all the different general

1649

00:55:33,349 --> 00:55:31,839

anaesthetics they have different shapes

1650

00:55:34,790 --> 00:55:33,359

and different different chemical

1651
00:55:36,549 --> 00:55:34,800
properties and it's not obvious that

1652
00:55:38,710 --> 00:55:36,559
there's any kind of

1653
00:55:39,990 --> 00:55:38,720
type of receptor that would deal with

1654
00:55:41,750 --> 00:55:40,000
them all

1655
00:55:43,270 --> 00:55:41,760
and and it doesn't really have any

1656
00:55:48,069 --> 00:55:43,280
chemistry but it can

1657
00:55:49,349 --> 00:55:48,079
uh transfer electrons and so it can

1658
00:55:51,589 --> 00:55:49,359
interfere

1659
00:55:53,270 --> 00:55:51,599
with electron transfer and what luca

1660
00:55:55,990 --> 00:55:53,280
turin had shown which really made me

1661
00:55:57,910 --> 00:55:56,000
excited is is is that

1662
00:55:59,589 --> 00:55:57,920
they do interfere with the transfer of

1663
00:56:01,589 --> 00:55:59,599

electrons to oxygen

1664

00:56:04,309 --> 00:56:01,599

in respiration now that doesn't prove

1665

00:56:05,670 --> 00:56:04,319

it's causal that just shows that

1666

00:56:07,990 --> 00:56:05,680

anesthetics

1667

00:56:10,150 --> 00:56:08,000

interfere in some way with respiration

1668

00:56:11,589 --> 00:56:10,160

and maybe if they simply suppress what

1669

00:56:13,270 --> 00:56:11,599

the rest of the cell is doing that would

1670

00:56:14,390 --> 00:56:13,280

have a knock-on effect on respiration

1671

00:56:15,430 --> 00:56:14,400

you could you could say that that would

1672

00:56:17,510 --> 00:56:15,440

be the case

1673

00:56:18,230 --> 00:56:17,520

but they he didn't find anything else

1674

00:56:19,829 --> 00:56:18,240

that

1675

00:56:21,270 --> 00:56:19,839

a general anaesthetic was having an

1676

00:56:22,950 --> 00:56:21,280

effect on

1677

00:56:24,309 --> 00:56:22,960

and so if you put it together with what

1678

00:56:25,990 --> 00:56:24,319

i was saying about

1679

00:56:27,910 --> 00:56:26,000

the requirement for cells and the

1680

00:56:29,190 --> 00:56:27,920

electrical charge on the membranes to

1681

00:56:31,510 --> 00:56:29,200

integrate

1682

00:56:32,870 --> 00:56:31,520

their state in the environment

1683

00:56:35,670 --> 00:56:32,880

then suddenly

1684

00:56:36,470 --> 00:56:35,680

it it's a rather thrilling idea

1685

00:56:38,069 --> 00:56:36,480

um

1686

00:56:39,829 --> 00:56:38,079

doug wallace is another person who's

1687

00:56:42,789 --> 00:56:39,839

been working on these fields in

1688

00:56:45,109 --> 00:56:42,799

mitochondria for some time now uh and

1689

00:56:46,789 --> 00:56:45,119

and again is

1690

00:56:48,470 --> 00:56:46,799

he's out there on a limb as far as

1691

00:56:50,789 --> 00:56:48,480

biology is concerned he's he's one of

1692

00:56:52,630 --> 00:56:50,799

the few people who's willing to

1693

00:56:55,750 --> 00:56:52,640

to talk about parallel christie

1694

00:56:57,270 --> 00:56:55,760

generating strong electromagnetic fields

1695

00:56:58,870 --> 00:56:57,280

that are reinforcing each other and

1696

00:57:01,670 --> 00:56:58,880

communicating

1697

00:57:03,430 --> 00:57:01,680

across distances this is not

1698

00:57:06,069 --> 00:57:03,440

this is not the language that biology is

1699

00:57:09,109 --> 00:57:06,079

used to and and you know doug wallace is

1700

00:57:09,990 --> 00:57:09,119

is very distinguished and so people will

1701

00:57:12,150 --> 00:57:10,000

kind of

1702

00:57:14,710 --> 00:57:12,160

tolerate him uh towards the end of his

1703

00:57:17,430 --> 00:57:14,720

career talking about these things

1704

00:57:19,430 --> 00:57:17,440

luca turin is is uh

1705

00:57:22,390 --> 00:57:19,440

i won't say he's an outcast but he you

1706

00:57:24,309 --> 00:57:22,400

know he's he's on the edge of

1707

00:57:25,910 --> 00:57:24,319

scientific respectability and he's not

1708

00:57:28,309 --> 00:57:25,920

because he's not a good he's a brilliant

1709

00:57:30,309 --> 00:57:28,319

scientist it's just that he's saying

1710

00:57:31,910 --> 00:57:30,319

things that people in biology don't want

1711

00:57:33,589 --> 00:57:31,920

to hear

1712

00:57:36,390 --> 00:57:33,599

interesting

1713

00:57:38,710 --> 00:57:36,400

turin has found that xenon interrupts or

1714

00:57:40,150 --> 00:57:38,720

interferes with respiration and when you

1715

00:57:41,829 --> 00:57:40,160

say respiration you mean cellular

1716

00:57:43,990 --> 00:57:41,839

respiration with the transfer of

1717

00:57:46,390 --> 00:57:44,000

electrons yes which is to say this is

1718

00:57:48,470 --> 00:57:46,400

what's going on in mitochondria the the

1719

00:57:51,510 --> 00:57:48,480

so you basically have a the current of

1720

00:57:53,109 --> 00:57:51,520

electrons going from food to oxygen

1721

00:57:56,069 --> 00:57:53,119

um and

1722

00:57:59,270 --> 00:57:56,079

and gases like xenon interfere with that

1723

00:58:01,670 --> 00:57:59,280

uh that that uh current of electrons and

1724

00:58:03,430 --> 00:58:01,680

that means that it makes respiration

1725

00:58:05,190 --> 00:58:03,440

less likely to occur and by the way what

1726

00:58:07,510 --> 00:58:05,200

is cellular respiration i assume you've

1727

00:58:09,430 --> 00:58:07,520

taken oxygen but um i don't know if that

1728

00:58:11,430 --> 00:58:09,440

analogy between my respiration yeah yeah

1729

00:58:13,030 --> 00:58:11,440

i mean basically you're yes no it's

1730

00:58:15,430 --> 00:58:13,040

exactly right i mean you're we're

1731

00:58:17,030 --> 00:58:15,440

stripping electrons from food

1732

00:58:18,950 --> 00:58:17,040

by the krebs cycle that's what the krebs

1733

00:58:21,750 --> 00:58:18,960

cycle is doing is taking electrons from

1734

00:58:23,109 --> 00:58:21,760

food it's feeding them into the membrane

1735

00:58:24,950 --> 00:58:23,119

and then we have a current of electrons

1736

00:58:27,829 --> 00:58:24,960

in the membrane going to oxygen oxygen

1737

00:58:29,589 --> 00:58:27,839

picks up two electrons and two protons

1738

00:58:30,470 --> 00:58:29,599

um and and

1739

00:58:31,430 --> 00:58:30,480

and

1740

00:58:36,630 --> 00:58:31,440

it

1741

00:58:38,789 --> 00:58:36,640

and and that and so so basically we

1742

00:58:40,710 --> 00:58:38,799

we're reacting hydrogen

1743

00:58:42,630 --> 00:58:40,720

the electrons and the protons we're

1744

00:58:44,710 --> 00:58:42,640

taking we're taking hydrogen from food

1745

00:58:46,789 --> 00:58:44,720

we're reacting with oxygen but we're not

1746

00:58:47,990 --> 00:58:46,799

doing it in one step that's rocket fuel

1747

00:58:51,270 --> 00:58:48,000

you know that's what's that's what's

1748

00:58:52,789 --> 00:58:51,280

powering a rocket um

1749

00:58:54,789 --> 00:58:52,799

we've basically got a current from one

1750

00:58:56,230 --> 00:58:54,799

to the other and that that current is

1751

00:58:58,230 --> 00:58:56,240

powering

1752

00:58:59,750 --> 00:58:58,240

the extrusion of protons across the

1753

00:59:01,829 --> 00:58:59,760

membrane and that's what's putting the

1754

00:59:03,030 --> 00:59:01,839

electrical charge on the membrane so now

1755

00:59:04,789 --> 00:59:03,040

we have an electrical charge on the

1756

00:59:06,309 --> 00:59:04,799

membrane and the orientation of these

1757

00:59:07,829 --> 00:59:06,319

christie structures

1758

00:59:10,230 --> 00:59:07,839

it means that this is a current of

1759

00:59:11,910 --> 00:59:10,240

protons it's an oscillating current of

1760

00:59:13,910 --> 00:59:11,920

protons and that's what's generating the

1761

00:59:15,349 --> 00:59:13,920

field is there a radio wave associated

1762

00:59:17,990 --> 00:59:15,359

with this

1763

00:59:19,109 --> 00:59:18,000

with turin found that somehow

1764

00:59:21,109 --> 00:59:19,119

okay

1765

00:59:23,270 --> 00:59:21,119

there there is yes

1766

00:59:24,950 --> 00:59:23,280

um i don't i have to say i don't quite

1767

00:59:26,789 --> 00:59:24,960

understand that please explain the

1768

00:59:28,230 --> 00:59:26,799

significance of this

1769

00:59:30,390 --> 00:59:28,240

um

1770

00:59:33,589 --> 00:59:30,400

well there's a funny story that he tells

1771

00:59:34,870 --> 00:59:33,599

about that um because the guy who uh i

1772

00:59:37,510 --> 00:59:34,880

forget his name now the guy who

1773

00:59:39,349 --> 00:59:37,520

discovered the eeg in the first place

1774

00:59:41,430 --> 00:59:39,359

the electro encephalogram michael cohen

1775

00:59:43,349 --> 00:59:41,440

or no no that's different no no this

1776

00:59:45,030 --> 00:59:43,359

goes back much before this goes i just

1777

00:59:46,950 --> 00:59:45,040

have different snippets of this book in

1778

00:59:49,270 --> 00:59:46,960

my head i remember michael cohen said

1779

00:59:50,789 --> 00:59:49,280

something like no one understands but he

1780

00:59:53,190 --> 00:59:50,799

no we're going we're going back 100

1781

00:59:55,349 --> 00:59:53,200

years or more uh to the to the discovery

1782

00:59:56,470 --> 00:59:55,359

that the brain is generating electrical

1783

00:59:58,470 --> 00:59:56,480

signals it can be detected with

1784

01:00:00,549 --> 00:59:58,480

electrodes on the scalp he was actually

1785

01:00:02,390 --> 01:00:00,559

looking for radio waves

1786

01:00:05,589 --> 01:00:02,400

he was looking for long distance

1787

01:00:06,630 --> 01:00:05,599

communications between people i think he

1788

01:00:07,670 --> 01:00:06,640

had

1789

01:00:09,990 --> 01:00:07,680

um

1790

01:00:11,910 --> 01:00:10,000

he'd had some premonition that terrible

1791

01:00:14,549 --> 01:00:11,920

accident had befallen his sister or

1792

01:00:16,069 --> 01:00:14,559

something and i i it turned out you know

1793

01:00:17,829 --> 01:00:16,079

lots of people have these premonitions

1794

01:00:18,870 --> 01:00:17,839

that something terrible has happened to

1795

01:00:20,390 --> 01:00:18,880

a friend

1796

01:00:21,990 --> 01:00:20,400

i have them as well and every time i

1797

01:00:23,990 --> 01:00:22,000

have them it never turns out to be true

1798

01:00:24,870 --> 01:00:24,000

but you know for some people it's it's

1799

01:00:32,230 --> 01:00:24,880

true

1800

01:00:34,309 --> 01:00:32,240

never looked exactly

1801

01:00:36,069 --> 01:00:34,319

um but but

1802

01:00:38,150 --> 01:00:36,079

that's what he was interested in that's

1803

01:00:40,069 --> 01:00:38,160

what he was looking for communication by

1804

01:00:43,190 --> 01:00:40,079

radio waves between people at a distance

1805

01:00:45,430 --> 01:00:43,200

of maybe hundreds of miles um and he

1806

01:00:49,030 --> 01:00:45,440

discovered the eeg instead

1807

01:00:51,190 --> 01:00:49,040

um and and it's ironic because

1808

01:00:52,789 --> 01:00:51,200

the key

1809

01:00:55,190 --> 01:00:52,799

we're on your ground again here more

1810

01:00:57,430 --> 01:00:55,200

more than my ground but um there's

1811

01:00:59,030 --> 01:00:57,440

there's a there's a an israeli scientist

1812

01:01:01,270 --> 01:00:59,040

who's shown that

1813

01:01:03,990 --> 01:01:01,280

electrons spin

1814

01:01:08,390 --> 01:01:04,000

if it's passing through a chiral medium

1815

01:01:11,109 --> 01:01:08,400

um ends up in in in the same spin state

1816

01:01:13,109 --> 01:01:11,119

so it's been polarized um

1817

01:01:15,030 --> 01:01:13,119

and a chiral medium includes proteins

1818

01:01:17,910 --> 01:01:15,040

because proteins are made of amino acids

1819

01:01:19,670 --> 01:01:17,920

and amino acids are always in the in in

1820

01:01:20,710 --> 01:01:19,680

in the left-handed form

1821

01:01:24,470 --> 01:01:20,720

um

1822

01:01:26,470 --> 01:01:24,480

and and so all the the the the current

1823

01:01:28,549 --> 01:01:26,480

of electrons that flows from hydrogen to

1824

01:01:31,349 --> 01:01:28,559

oxygen goes through proteins in this

1825

01:01:32,950 --> 01:01:31,359

membrane and those proteins are chiral

1826

01:01:35,190 --> 01:01:32,960

and that means that the

1827

01:01:36,870 --> 01:01:35,200

um the the the electrons that are

1828

01:01:38,870 --> 01:01:36,880

transferred are actually locked in the

1829

01:01:41,990 --> 01:01:38,880

same spin state

1830

01:01:43,829 --> 01:01:42,000

and and when you lose that spin state

1831

01:01:46,870 --> 01:01:43,839

that emits a radio signal and that's

1832

01:01:48,230 --> 01:01:46,880

what luca turin has detected

1833

01:01:50,069 --> 01:01:48,240

you mentioned something interesting

1834

01:01:52,150 --> 01:01:50,079

which is that there's apparently a

1835

01:01:53,750 --> 01:01:52,160

psychic phenomenon unverified or maybe

1836

01:01:55,270 --> 01:01:53,760

it has been but we don't know as far as

1837

01:01:56,470 --> 01:01:55,280

i know it's unverified well people

1838

01:01:58,470 --> 01:01:56,480

believe they can communicate to one

1839

01:02:00,150 --> 01:01:58,480

another one of the reasons why on

1840

01:02:02,390 --> 01:02:00,160

theories of everything i don't mind

1841

01:02:03,670 --> 01:02:02,400

talking to some people who believe

1842

01:02:05,270 --> 01:02:03,680

they've done studies and they're

1843

01:02:07,030 --> 01:02:05,280

excluded from academia for whatever

1844

01:02:08,870 --> 01:02:07,040

reason i want to find out the validity

1845

01:02:11,109 --> 01:02:08,880

of those because i think that there may

1846

01:02:12,789 --> 01:02:11,119

be something to with certain

1847

01:02:15,190 --> 01:02:12,799

aspects of what people consider to be

1848

01:02:17,270 --> 01:02:15,200

paranormal that their explanation for

1849

01:02:19,190 --> 01:02:17,280

why it works may be incorrect there may

1850

01:02:21,270 --> 01:02:19,200

be some physical basis like it's that we

1851
01:02:23,270 --> 01:02:21,280
we're obviously communicating right now

1852
01:02:24,549 --> 01:02:23,280
we don't think that there's any psychic

1853
01:02:26,390 --> 01:02:24,559
abilities involved because we're just

1854
01:02:27,990 --> 01:02:26,400
going through the computer but perhaps

1855
01:02:29,589 --> 01:02:28,000
something similar where radio waves are

1856
01:02:31,910 --> 01:02:29,599
being transmitted and if it's of a

1857
01:02:34,470 --> 01:02:31,920
strong enough distress then perhaps the

1858
01:02:37,190 --> 01:02:34,480
person feels it i think that science is

1859
01:02:38,549 --> 01:02:37,200
intrinsically very conservative

1860
01:02:39,990 --> 01:02:38,559
and there was a lovely phrase from peter

1861
01:02:42,230 --> 01:02:40,000
meadow who said science is the art of

1862
01:02:44,470 --> 01:02:42,240
the soluble which is to say

1863
01:02:46,230 --> 01:02:44,480

problems that we can actually solve

1864

01:02:47,829 --> 01:02:46,240

so problems that we can't solve because

1865

01:02:49,829 --> 01:02:47,839

we don't know how to go about it we tend

1866

01:02:50,950 --> 01:02:49,839

to put to one side and reject is not

1867

01:02:51,829 --> 01:02:50,960

science

1868

01:03:01,030 --> 01:02:51,839

um

1869

01:03:02,390 --> 01:03:01,040

i i to my mind there's two questions

1870

01:03:04,470 --> 01:03:02,400

number one is is

1871

01:03:05,510 --> 01:03:04,480

it real and then number two is well can

1872

01:03:07,109 --> 01:03:05,520

we

1873

01:03:08,549 --> 01:03:07,119

then explain it

1874

01:03:10,710 --> 01:03:08,559

and

1875

01:03:13,430 --> 01:03:10,720

i don't think very many scientists get

1876

01:03:16,950 --> 01:03:13,440

involved in the question of is it real

1877

01:03:19,589 --> 01:03:16,960

um it's it's just not part of what

1878

01:03:21,990 --> 01:03:19,599

science asks because it's not

1879

01:03:22,710 --> 01:03:22,000

there isn't that we don't have a

1880

01:03:25,430 --> 01:03:22,720

a

1881

01:03:27,430 --> 01:03:25,440

um

1882

01:03:28,549 --> 01:03:27,440

really so we don't ask it

1883

01:03:30,789 --> 01:03:28,559

and now

1884

01:03:31,910 --> 01:03:30,799

so it may be real or may not be real i i

1885

01:03:33,910 --> 01:03:31,920

don't know

1886

01:03:36,150 --> 01:03:33,920

i think there's another

1887

01:03:38,630 --> 01:03:36,160

factor though which is that

1888

01:03:40,470 --> 01:03:38,640

occam's razor which underpins all of

1889

01:03:42,630 --> 01:03:40,480

science really which says don't don't

1890

01:03:45,430 --> 01:03:42,640

multiply causes try and find the

1891

01:03:48,230 --> 01:03:45,440

simplest the simplest explanation that

1892

01:03:51,270 --> 01:03:48,240

explains everything we need to know

1893

01:03:53,510 --> 01:03:51,280

it may or may not actually be true

1894

01:03:55,270 --> 01:03:53,520

but but it is what governs science which

1895

01:03:56,549 --> 01:03:55,280

is to say you first of all take the

1896

01:04:00,549 --> 01:03:56,559

simplest

1897

01:04:02,309 --> 01:04:00,559

and if it doesn't work then try the next

1898

01:04:05,109 --> 01:04:02,319

simplest one and work your way up until

1899

01:04:07,510 --> 01:04:05,119

you end up with something mad but um

1900

01:04:09,589 --> 01:04:07,520

but the problem with with with anything

1901

01:04:12,230 --> 01:04:09,599

like esp is it's almost certainly not

1902

01:04:14,390 --> 01:04:12,240

the simplest explanation for things now

1903

01:04:16,230 --> 01:04:14,400

if someone were to show that it's real

1904

01:04:18,150 --> 01:04:16,240

and that it really is happening and and

1905

01:04:19,270 --> 01:04:18,160

you know statistically in some kind of

1906

01:04:20,870 --> 01:04:19,280

trial

1907

01:04:22,230 --> 01:04:20,880

it would have to be with the power of a

1908

01:04:23,910 --> 01:04:22,240

clinical trial and then it's going to

1909

01:04:25,589 --> 01:04:23,920

cost a lot of money and it's going to

1910

01:04:26,789 --> 01:04:25,599

you know there were so many comebacks

1911

01:04:29,670 --> 01:04:26,799

from people who are determined to

1912

01:04:30,950 --> 01:04:29,680

demonstrate that it's not true

1913

01:04:32,950 --> 01:04:30,960

that it would be

1914

01:04:35,990 --> 01:04:32,960

a very very difficult thing to do

1915

01:04:39,349 --> 01:04:37,270

then it boils down to personal

1916

01:04:41,029 --> 01:04:39,359

experience i i've never really

1917

01:04:42,950 --> 01:04:41,039

you know i don't really believe in

1918

01:04:44,470 --> 01:04:42,960

ghosts because i've never seen one or i

1919

01:04:46,390 --> 01:04:44,480

don't see any reason why they would

1920

01:04:47,990 --> 01:04:46,400

exist and i've never had any experience

1921

01:04:49,670 --> 01:04:48,000

with them but perhaps if i did then i

1922

01:04:51,270 --> 01:04:49,680

would change my mind i don't really

1923

01:04:52,789 --> 01:04:51,280

believe in esp because i have these

1924

01:04:54,630 --> 01:04:52,799

feelings that other people have that

1925

01:04:56,390 --> 01:04:54,640

says something terrible has happened but

1926

01:04:57,990 --> 01:04:56,400

then that phone them up and nothing

1927

01:04:59,589 --> 01:04:58,000

nothing had happened it was just

1928

01:05:01,109 --> 01:04:59,599

my imagination terrible happened to you

1929

01:05:02,390 --> 01:05:01,119

yeah well you know

1930

01:05:04,150 --> 01:05:02,400

there's a simpler explanation which is

1931

01:05:05,910 --> 01:05:04,160

just that my brain is active

1932

01:05:07,349 --> 01:05:05,920

um right so

1933

01:05:08,390 --> 01:05:07,359

you know you're thinking about someone

1934

01:05:09,990 --> 01:05:08,400

so so

1935

01:05:12,309 --> 01:05:10,000

and probably for most people most of the

1936

01:05:13,109 --> 01:05:12,319

time that's the real answer so i you

1937

01:05:15,190 --> 01:05:13,119

know i

1938

01:05:16,069 --> 01:05:15,200

i'm skeptical of these things

1939

01:05:17,670 --> 01:05:16,079

um

1940

01:05:19,750 --> 01:05:17,680

but there's a whole lot more out there

1941

01:05:21,510 --> 01:05:19,760

than than we know now and i've been

1942

01:05:22,789 --> 01:05:21,520

talking about fields and consciousness

1943

01:05:24,710 --> 01:05:22,799

and so on

1944

01:05:27,270 --> 01:05:24,720

and that is already pushing the barrel

1945

01:05:29,109 --> 01:05:27,280

out for most biologists in terms of what

1946

01:05:30,789 --> 01:05:29,119

are we willing to accept now i think

1947

01:05:32,870 --> 01:05:30,799

there's very strong grounds there for

1948

01:05:35,109 --> 01:05:32,880

accepting those kind of things and we

1949

01:05:37,109 --> 01:05:35,119

can begin to push it into looking at

1950

01:05:38,069 --> 01:05:37,119

other languages and genes

1951

01:05:38,870 --> 01:05:38,079

um

1952

01:05:41,510 --> 01:05:38,880

but

1953

01:05:43,270 --> 01:05:41,520

if i then start spouting on about esp or

1954

01:05:44,630 --> 01:05:43,280

something then then then you know i'll

1955

01:05:46,390 --> 01:05:44,640

be cold-shouldered by the entire

1956

01:05:49,270 --> 01:05:46,400

community and i have no desire to go

1957

01:05:50,710 --> 01:05:49,280

down that path because i have no strong

1958

01:05:53,190 --> 01:05:50,720

reason to think that there is that

1959

01:05:54,789 --> 01:05:53,200

exists anyway

1960

01:05:56,789 --> 01:05:54,799

okay i don't have a question but i have

1961

01:05:58,309 --> 01:05:56,799

a some thoughts so then i can just state

1962

01:06:00,150 --> 01:05:58,319

them and then hear what your response is

1963

01:06:02,069 --> 01:06:00,160

to them so number one when it comes to

1964

01:06:03,990 --> 01:06:02,079

occam's razor i always find that a bit

1965

01:06:05,670 --> 01:06:04,000

tricky unless someone's speaking about

1966

01:06:08,630 --> 01:06:05,680

something in physical law something

1967

01:06:10,710 --> 01:06:08,640

mathematical occam's razor it's unclear

1968

01:06:13,349 --> 01:06:10,720

to me what constitutes as an assumption

1969

01:06:14,630 --> 01:06:13,359

so for example in physics the way that

1970

01:06:16,870 --> 01:06:14,640

you say that

1971

01:06:19,349 --> 01:06:16,880

a certain model is simpler is that you

1972

01:06:21,109 --> 01:06:19,359

use less parameters to specify it so

1973

01:06:22,789 --> 01:06:21,119

it's actually quantifiable how simple a

1974

01:06:23,990 --> 01:06:22,799

model is and that's one of the reasons

1975

01:06:25,750 --> 01:06:24,000

why people say string theory is the most

1976

01:06:27,589 --> 01:06:25,760

beautiful because it can supposedly

1977

01:06:29,270 --> 01:06:27,599

reduce it all down to one parameter it's

1978

01:06:30,309 --> 01:06:29,280

still one parameter like there's no you

1979

01:06:33,589 --> 01:06:30,319

have there's still some freedom there

1980

01:06:36,069 --> 01:06:33,599

but it's one as opposed to 26 or so

1981

01:06:38,069 --> 01:06:36,079

and then so let's say the principle of

1982

01:06:40,069 --> 01:06:38,079

induction in science is that one

1983

01:06:41,510 --> 01:06:40,079

assumption or is that two assumptions or

1984

01:06:42,950 --> 01:06:41,520

three assumptions because it presumes

1985

01:06:44,549 --> 01:06:42,960

there exists a future in the past and

1986

01:06:46,549 --> 01:06:44,559

then i'm sure you've heard of the

1987

01:06:48,870 --> 01:06:46,559

problem of induction the point is

1988

01:06:51,589 --> 01:06:48,880

if it's not mathematically stated then

1989

01:06:53,270 --> 01:06:51,599

to me because my brain is so analytical

1990

01:06:54,870 --> 01:06:53,280

it's difficult to see well what's being

1991

01:06:56,710 --> 01:06:54,880

assumed and what's not like is god the

1992

01:06:58,390 --> 01:06:56,720

simplest assumption well then god has

1993

01:07:00,390 --> 01:06:58,400

the trouble of explaining like you can't

1994

01:07:02,309 --> 01:07:00,400

predict from that but god certainly is

1995

01:07:04,710 --> 01:07:02,319

the most simple well

1996

01:07:07,430 --> 01:07:04,720

yes i mean it depends what um but then

1997

01:07:08,630 --> 01:07:07,440

it's not simply simplicity is god five

1998

01:07:10,549 --> 01:07:08,640

assumptions

1999

01:07:12,950 --> 01:07:10,559

yeah well i mean

2000

01:07:16,069 --> 01:07:12,960

as soon as you start wondering

2001

01:07:17,750 --> 01:07:16,079

where god came from

2002

01:07:18,870 --> 01:07:17,760

you know what what gave rise to god in

2003

01:07:21,029 --> 01:07:18,880

the first place there's a lot of

2004

01:07:23,670 --> 01:07:21,039

assumptions behind that so something as

2005

01:07:26,150 --> 01:07:23,680

as profound and all encompassing as god

2006

01:07:28,230 --> 01:07:26,160

it requires in some way an awful lot of

2007

01:07:29,829 --> 01:07:28,240

assumptions behind it but then you know

2008

01:07:31,670 --> 01:07:29,839

we know a lot about the world as well we

2009

01:07:34,069 --> 01:07:31,680

don't understand it all

2010

01:07:36,630 --> 01:07:34,079

but you know it's it's definitely four

2011

01:07:38,390 --> 01:07:36,640

and a half billion years old there's

2012

01:07:39,910 --> 01:07:38,400

definitely signs of bacteria from four

2013

01:07:41,589 --> 01:07:39,920

billion years ago there was definitely

2014

01:07:43,750 --> 01:07:41,599

stasis for about two billion years there

2015

01:07:46,549 --> 01:07:43,760

was definitely oxygen appearing

2016

01:07:48,390 --> 01:07:46,559

around 2 billion years ago

2017

01:07:50,390 --> 01:07:48,400

there were definitely more complex cells

2018

01:07:51,829 --> 01:07:50,400

appearing after that we animals

2019

01:07:54,630 --> 01:07:51,839

certainly appeared around the time of

2020

01:07:56,549 --> 01:07:54,640

the cambrian explosion 540 50 million

2021

01:07:58,789 --> 01:07:56,559

years ago um

2022

01:08:01,270 --> 01:07:58,799

and and so you know any assumption that

2023

01:08:02,789 --> 01:08:01,280

god did it would require either a deist

2024

01:08:04,230 --> 01:08:02,799

god that set it in motion at the

2025

01:08:06,950 --> 01:08:04,240

beginning and then it follows its own

2026

01:08:08,789 --> 01:08:06,960

path or a god that's kind of involved

2027

01:08:10,390 --> 01:08:08,799

all the way along with every little bit

2028

01:08:12,230 --> 01:08:10,400

here and there and there's no

2029

01:08:15,270 --> 01:08:12,240

there's no need for that as voltaire

2030

01:08:16,390 --> 01:08:15,280

said there's no requirement to for for

2031

01:08:18,070 --> 01:08:16,400

god to

2032

01:08:20,149 --> 01:08:18,080

kind of get involved in this this

2033

01:08:21,510 --> 01:08:20,159

species of bacteria

2034

01:08:22,390 --> 01:08:21,520

differentiating from that speech you

2035

01:08:23,990 --> 01:08:22,400

know

2036

01:08:25,510 --> 01:08:24,000

that's the level of detail he would have

2037

01:08:27,189 --> 01:08:25,520

to be involved in

2038

01:08:28,550 --> 01:08:27,199

so so there's no need for that

2039

01:08:29,990 --> 01:08:28,560

hypothesis

2040

01:08:32,149 --> 01:08:30,000

deism

2041

01:08:34,630 --> 01:08:32,159

um i think will be very difficult to

2042

01:08:35,910 --> 01:08:34,640

reject for most scientists who had an

2043

01:08:38,309 --> 01:08:35,920

open mind

2044

01:08:40,470 --> 01:08:38,319

um but deism i don't think is something

2045

01:08:42,550 --> 01:08:40,480

that most people who are religious

2046

01:08:45,349 --> 01:08:42,560

would be terribly happy about because i

2047

01:08:47,590 --> 01:08:45,359

think for most people god is

2048

01:08:48,950 --> 01:08:47,600

communicating with them personally in in

2049

01:08:50,309 --> 01:08:48,960

one way or another so the idea that

2050

01:08:51,590 --> 01:08:50,319

there's an aloof god somewhere at the

2051

01:08:53,110 --> 01:08:51,600

other end of the universe that sets

2052

01:08:55,110 --> 01:08:53,120

everything sets the laws of physics in

2053

01:08:56,950 --> 01:08:55,120

motion and then steps back and is never

2054

01:08:59,510 --> 01:08:56,960

seen again is not much of a comforting

2055

01:09:00,789 --> 01:08:59,520

figure for for most people but but

2056

01:09:03,829 --> 01:09:00,799

frankly

2057

01:09:05,590 --> 01:09:03,839

what we know about the world

2058

01:09:07,510 --> 01:09:05,600

if it's consistent with any form of god

2059

01:09:09,590 --> 01:09:07,520

is is more consistent with the deist

2060

01:09:13,590 --> 01:09:09,600

form of god i would say than anything

2061

01:09:15,269 --> 01:09:13,600

else um so then there are assumptions

2062

01:09:16,709 --> 01:09:15,279

and science works on these assumptions

2063

01:09:18,070 --> 01:09:16,719

and they may or may not be the simplest

2064

01:09:21,990 --> 01:09:18,080

ones but they underpin everything and

2065

01:09:24,390 --> 01:09:22,000

one of them is that um it's naturalistic

2066

01:09:28,470 --> 01:09:24,400

that it's not miracles that's not

2067

01:09:29,430 --> 01:09:28,480

science that's an assumption we assume

2068

01:09:30,470 --> 01:09:29,440

that

2069

01:09:32,550 --> 01:09:30,480

um

2070

01:09:34,950 --> 01:09:32,560

the that life started

2071

01:09:36,870 --> 01:09:34,960

uh and and and that we can understand

2072

01:09:39,269 --> 01:09:36,880

the principles that govern the origin of

2073

01:09:40,149 --> 01:09:39,279

life and and the evolution of life and

2074

01:09:42,229 --> 01:09:40,159

so on

2075

01:09:43,749 --> 01:09:42,239

it may be that there were miracles it

2076
01:09:45,269 --> 01:09:43,759
may be that it was delivered from outer

2077
01:09:46,630 --> 01:09:45,279
space there's all kinds of things that

2078
01:09:48,709 --> 01:09:46,640
could have happened

2079
01:09:50,229 --> 01:09:48,719
but we make a simplifying assumption

2080
01:09:51,590 --> 01:09:50,239
that it happened here on earth and it

2081
01:09:53,669 --> 01:09:51,600
happened for naturalistic reasons and

2082
01:09:55,510 --> 01:09:53,679
therefore we don't call on a miracle and

2083
01:09:57,350 --> 01:09:55,520
that we can understand those

2084
01:09:59,189 --> 01:09:57,360
naturalistic reasons these are three

2085
01:10:01,030 --> 01:09:59,199
huge assumptions

2086
01:10:02,790 --> 01:10:01,040
that may not be true there's nothing

2087
01:10:05,910 --> 01:10:02,800
scientific about them but all of science

2088
01:10:08,470 --> 01:10:05,920

is built on those ideas and and

2089

01:10:11,270 --> 01:10:08,480

the reason that i believe it to be true

2090

01:10:13,510 --> 01:10:11,280

and and most scientists would is that

2091

01:10:15,669 --> 01:10:13,520

well everything we know about the world

2092

01:10:17,910 --> 01:10:15,679

is consistent with that idea so

2093

01:10:20,550 --> 01:10:17,920

everything i was saying earlier on about

2094

01:10:22,070 --> 01:10:20,560

um you start with carbon dioxide and

2095

01:10:23,590 --> 01:10:22,080

hydrogen and you get krebs cycle

2096

01:10:24,870 --> 01:10:23,600

intermediates and you have electrical

2097

01:10:27,350 --> 01:10:24,880

charges on barriers in these

2098

01:10:28,790 --> 01:10:27,360

hydrothermal vel all of this is

2099

01:10:31,990 --> 01:10:28,800

is consistent

2100

01:10:33,990 --> 01:10:32,000

with the naturalistic origin of life

2101
01:10:35,430 --> 01:10:34,000
it's a long long way from proving that

2102
01:10:37,669 --> 01:10:35,440
that's what happened

2103
01:10:39,510 --> 01:10:37,679
but everything i know about it is

2104
01:10:41,189 --> 01:10:39,520
consistent with it sufficiently that i

2105
01:10:43,270 --> 01:10:41,199
have some faith

2106
01:10:44,630 --> 01:10:43,280
and i'm using the word deliberately

2107
01:10:45,910 --> 01:10:44,640
faith that

2108
01:10:47,350 --> 01:10:45,920
the gaps

2109
01:10:49,750 --> 01:10:47,360
between the bits that i know a little

2110
01:10:51,750 --> 01:10:49,760
bit about and and this long spectrum of

2111
01:10:53,189 --> 01:10:51,760
things that i don't know much about can

2112
01:10:55,189 --> 01:10:53,199
be filled in

2113
01:10:58,310 --> 01:10:55,199

in due course if we keep on thinking

2114

01:10:59,990 --> 01:10:58,320

constructively in that way so i think

2115

01:11:02,070 --> 01:11:00,000

you know science is always based on

2116

01:11:04,149 --> 01:11:02,080

assumptions and it's always

2117

01:11:06,070 --> 01:11:04,159

based on some form of faith which most

2118

01:11:07,990 --> 01:11:06,080

scientists are very reluctant to use the

2119

01:11:09,510 --> 01:11:08,000

word faith because in a religious sense

2120

01:11:10,709 --> 01:11:09,520

faith very often means belief in

2121

01:11:13,189 --> 01:11:10,719

something which

2122

01:11:15,990 --> 01:11:13,199

which is uh

2123

01:11:19,189 --> 01:11:16,000

you know irrational in some way that

2124

01:11:22,630 --> 01:11:19,199

it goes against the evidence

2125

01:11:24,630 --> 01:11:22,640

whereas in science faith is perhaps more

2126
01:11:25,910 --> 01:11:24,640
about i have faith that there'll be more

2127
01:11:27,910 --> 01:11:25,920
of this kind of evidence that will

2128
01:11:29,750 --> 01:11:27,920
explain the way that the world is it's a

2129
01:11:31,270 --> 01:11:29,760
form of faith

2130
01:11:34,070 --> 01:11:31,280
it may or may not be true it may be

2131
01:11:36,070 --> 01:11:34,080
delusional but it's very powerful

2132
01:11:37,669 --> 01:11:36,080
because it's led to all these scientific

2133
01:11:41,270 --> 01:11:37,679
advances that we see in the world and

2134
01:11:43,030 --> 01:11:41,280
that leads people and most people to

2135
01:11:45,189 --> 01:11:43,040
to begin to believe that

2136
01:11:46,630 --> 01:11:45,199
science really can explain the world and

2137
01:11:49,510 --> 01:11:46,640
there really isn't

2138
01:11:51,270 --> 01:11:49,520

a need for a god to explain the world

2139

01:11:52,709 --> 01:11:51,280

unless it be a deist god that put these

2140

01:11:54,870 --> 01:11:52,719

principles

2141

01:11:56,709 --> 01:11:54,880

in place in the first place

2142

01:11:58,149 --> 01:11:56,719

and that you know

2143

01:12:00,229 --> 01:11:58,159

that's the way i would see it but i have

2144

01:12:02,310 --> 01:12:00,239

a lot of sympathy with people who prefer

2145

01:12:04,550 --> 01:12:02,320

a religious view of the world there are

2146

01:12:06,950 --> 01:12:04,560

and i and and i certainly couldn't argue

2147

01:12:09,030 --> 01:12:06,960

against the deist's position

2148

01:12:11,030 --> 01:12:09,040

i wouldn't say that it's a minority the

2149

01:12:13,110 --> 01:12:11,040

deus position well when i say minority i

2150

01:12:15,110 --> 01:12:13,120

mean it's a sizable minority if it

2151
01:12:17,910 --> 01:12:15,120
exists because when i was looking at the

2152
01:12:19,990 --> 01:12:17,920
pew research data on belief i believe

2153
01:12:22,390 --> 01:12:20,000
something like 10 to 20 to 30 let's say

2154
01:12:24,390 --> 01:12:22,400
10 to 30 percent of people believe in a

2155
01:12:26,550 --> 01:12:24,400
deist god of those who say that they

2156
01:12:28,790 --> 01:12:26,560
believe in god that's sizeable because i

2157
01:12:31,830 --> 01:12:28,800
thought it would be 0.02

2158
01:12:33,430 --> 01:12:31,840
like the gnostics or something yes

2159
01:12:35,189 --> 01:12:33,440
i would expect it to be smaller as well

2160
01:12:36,870 --> 01:12:35,199
yeah it's an extreme amount and then

2161
01:12:38,550 --> 01:12:36,880
secondly that

2162
01:12:39,669 --> 01:12:38,560
there's a sizable portion of people who

2163
01:12:42,149 --> 01:12:39,679

believe that

2164

01:12:44,550 --> 01:12:42,159

the definition of god is reality so by

2165

01:12:46,630 --> 01:12:44,560

doing science one is studying god and

2166

01:12:49,669 --> 01:12:46,640

it's not so i used to be the son and i i

2167

01:12:51,990 --> 01:12:49,679

i love that as an idea i have to say i

2168

01:12:54,630 --> 01:12:52,000

don't i don't personally believe in god

2169

01:12:57,189 --> 01:12:54,640

but but but the idea

2170

01:12:59,990 --> 01:12:57,199

that you know people who have tried to

2171

01:13:01,510 --> 01:13:00,000

understand the world in the past as as

2172

01:13:03,669 --> 01:13:01,520

the world

2173

01:13:06,149 --> 01:13:03,679

that god put there

2174

01:13:07,830 --> 01:13:06,159

i have a huge fellow feeling with them

2175

01:13:09,430 --> 01:13:07,840

that you know they they were trying to

2176

01:13:11,590 --> 01:13:09,440

understand the world they were trying in

2177

01:13:13,990 --> 01:13:11,600

some way to understand the mind of god

2178

01:13:17,030 --> 01:13:14,000

um it's

2179

01:13:18,550 --> 01:13:17,040

what is nobler in this world and trying

2180

01:13:20,709 --> 01:13:18,560

to understand

2181

01:13:22,390 --> 01:13:20,719

these things and whether or not you put

2182

01:13:23,510 --> 01:13:22,400

the word god at the end of it

2183

01:13:26,229 --> 01:13:23,520

it seems to me almost a trivial

2184

01:13:31,830 --> 01:13:28,550

i remember my grandma saying to me

2185

01:13:33,669 --> 01:13:31,840

years and years ago that uh to her god

2186

01:13:35,110 --> 01:13:33,679

was the voice in her head that told her

2187

01:13:37,189 --> 01:13:35,120

what was right or what was wrong it was

2188

01:13:38,790 --> 01:13:37,199

basically her conscience and i remember

2189

01:13:39,990 --> 01:13:38,800

saying to her well i have a voice in my

2190

01:13:41,350 --> 01:13:40,000

head that tells me what's right and

2191

01:13:42,950 --> 01:13:41,360

what's wrong and i don't think that it's

2192

01:13:43,990 --> 01:13:42,960

god and she was shocked and horrified

2193

01:13:47,830 --> 01:13:44,000

that

2194

01:13:48,950 --> 01:13:47,840

believe in god and and it hurt her

2195

01:13:51,270 --> 01:13:48,960

deeply

2196

01:13:54,149 --> 01:13:51,280

and and i've never quite forgiven myself

2197

01:13:56,630 --> 01:13:54,159

and and you know i'm very careful

2198

01:13:58,229 --> 01:13:56,640

to try not to offend people because to

2199

01:14:01,430 --> 01:13:58,239

me it's

2200

01:14:03,510 --> 01:14:01,440

it's not very far away it's uh it's just

2201
01:14:04,630 --> 01:14:03,520
ways of phrasing things ways of seeing

2202
01:14:06,790 --> 01:14:04,640
things and there's no need to be

2203
01:14:09,189 --> 01:14:06,800
deliberately offensive to people when

2204
01:14:12,070 --> 01:14:09,199
actually we we may both see the glory of

2205
01:14:13,669 --> 01:14:12,080
the world and want to understand it

2206
01:14:14,870 --> 01:14:13,679
okay let me get philosophical here for a

2207
01:14:16,229 --> 01:14:14,880
moment

2208
01:14:17,510 --> 01:14:16,239
i think that was about as philosophical

2209
01:14:18,950 --> 01:14:17,520
as i can get

2210
01:14:20,390 --> 01:14:18,960
i may not stick when it comes to this so

2211
01:14:22,070 --> 01:14:20,400
i'm not coming at this from a religious

2212
01:14:24,709 --> 01:14:22,080
perspective just so you know so you can

2213
01:14:26,630 --> 01:14:24,719

feel safe to to surmise in any direction

2214

01:14:28,149 --> 01:14:26,640

what basis so your mother sorry your

2215

01:14:28,870 --> 01:14:28,159

grandmother had a basis to believe in

2216

01:14:31,669 --> 01:14:28,880

the

2217

01:14:33,430 --> 01:14:31,679

to follow her conscience if you don't

2218

01:14:36,149 --> 01:14:33,440

believe that comes from some higher

2219

01:14:37,830 --> 01:14:36,159

place what does hire mean who knows

2220

01:14:39,990 --> 01:14:37,840

for the sake of this let's just put that

2221

01:14:41,669 --> 01:14:40,000

aside and assume that we can intuit that

2222

01:14:43,669 --> 01:14:41,679

then why should you follow your

2223

01:14:47,990 --> 01:14:43,679

conscience

2224

01:14:50,550 --> 01:14:48,000

the context of society of human

2225

01:14:51,590 --> 01:14:50,560

societies of groups of human groups

2226

01:14:53,750 --> 01:14:51,600

um

2227

01:14:54,830 --> 01:14:53,760

to my mind at least you know there's all

2228

01:14:57,510 --> 01:14:54,840

this

2229

01:14:58,790 --> 01:14:57,520

um interesting questions about human

2230

01:15:01,910 --> 01:14:58,800

evolution

2231

01:15:03,350 --> 01:15:01,920

when and why did we

2232

01:15:04,790 --> 01:15:03,360

develop in the way that we did when did

2233

01:15:08,229 --> 01:15:04,800

the human mind

2234

01:15:10,950 --> 01:15:08,239

take on the ability to be creative to do

2235

01:15:11,669 --> 01:15:10,960

art to believe in gods and and what have

2236

01:15:14,950 --> 01:15:11,679

you

2237

01:15:15,910 --> 01:15:14,960

the things that we think of as human

2238

01:15:18,709 --> 01:15:15,920

um

2239

01:15:20,709 --> 01:15:18,719

and it's not obviously to do with tool

2240

01:15:24,149 --> 01:15:20,719

use for example they often you know the

2241

01:15:26,310 --> 01:15:24,159

use of of uh flints and things and

2242

01:15:27,430 --> 01:15:26,320

spearheads goes back

2243

01:15:29,110 --> 01:15:27,440

um

2244

01:15:31,510 --> 01:15:29,120

you know hundreds of thousands of years

2245

01:15:33,350 --> 01:15:31,520

if not more than that um

2246

01:15:36,149 --> 01:15:33,360

and didn't change very much over a long

2247

01:15:37,910 --> 01:15:36,159

time and and things like fire it's a

2248

01:15:39,830 --> 01:15:37,920

little difficult to know exactly when

2249

01:15:41,430 --> 01:15:39,840

was fire invented and language is

2250

01:15:43,430 --> 01:15:41,440

another thing that we tend to as soon as

2251

01:15:45,669 --> 01:15:43,440

we've got language then then we develop

2252

01:15:47,590 --> 01:15:45,679

our minds in some way the one thing that

2253

01:15:49,030 --> 01:15:47,600

it seems to correlate with most

2254

01:15:51,030 --> 01:15:49,040

interestingly

2255

01:15:53,750 --> 01:15:51,040

is population density

2256

01:15:56,470 --> 01:15:53,760

this is work uh that that i i know of

2257

01:15:57,669 --> 01:15:56,480

from mark thomas um who's a colleague at

2258

01:15:59,669 --> 01:15:57,679

ucl

2259

01:16:05,030 --> 01:15:59,679

um

2260

01:16:06,470 --> 01:16:05,040

it corresponds to climate change all

2261

01:16:09,430 --> 01:16:06,480

kinds of things that we're

2262

01:16:11,110 --> 01:16:09,440

very familiar with now but if you have

2263

01:16:12,630 --> 01:16:11,120

multiple groups of people that are

2264

01:16:14,550 --> 01:16:12,640

interacting with each other regularly

2265

01:16:17,030 --> 01:16:14,560

whether it be through warfare or whether

2266

01:16:18,830 --> 01:16:17,040

it be you know much more

2267

01:16:20,470 --> 01:16:18,840

congenial interactions

2268

01:16:22,790 --> 01:16:20,480

um

2269

01:16:25,830 --> 01:16:22,800

those interactions are forcing

2270

01:16:28,310 --> 01:16:25,840

creativity and ingenuity and you know

2271

01:16:29,830 --> 01:16:28,320

sense of loyalty or tribalism or

2272

01:16:32,310 --> 01:16:29,840

whatever it may be

2273

01:16:35,030 --> 01:16:32,320

and right and wrong it can hardly help

2274

01:16:37,669 --> 01:16:35,040

but you know it has to emerge in that

2275

01:16:40,149 --> 01:16:37,679

kind of an environment

2276

01:16:41,110 --> 01:16:40,159

and it has to be very conflicted

2277

01:16:42,790 --> 01:16:41,120

you know

2278

01:16:44,070 --> 01:16:42,800

surely anybody knows that the people in

2279

01:16:45,830 --> 01:16:44,080

the tribe over there that you've been

2280

01:16:47,910 --> 01:16:45,840

brought up to hate are human beings too

2281

01:16:49,189 --> 01:16:47,920

and have you know have everything that

2282

01:16:52,070 --> 01:16:49,199

you have

2283

01:16:54,390 --> 01:16:52,080

why do you hate them because your

2284

01:16:55,270 --> 01:16:54,400

tribe brought you up in some way

2285

01:17:00,550 --> 01:16:55,280

you know

2286

01:17:05,030 --> 01:17:02,709

our sense of right and wrong

2287

01:17:07,350 --> 01:17:05,040

comes from this kind of conflicted

2288

01:17:09,110 --> 01:17:07,360

feeling of fellow humans and loyalty to

2289

01:17:11,270 --> 01:17:09,120

groups and whatever else and no wonder

2290

01:17:13,750 --> 01:17:11,280

we can't agree about it it's uh you know

2291

01:17:16,149 --> 01:17:13,760

it's it's grounded very deeply in

2292

01:17:18,149 --> 01:17:16,159

in our emotions as individuals in the

2293

01:17:19,830 --> 01:17:18,159

social context

2294

01:17:22,550 --> 01:17:19,840

let me stay on this philosophical course

2295

01:17:24,550 --> 01:17:22,560

for just a few moments longer so firstly

2296

01:17:26,149 --> 01:17:24,560

this assumption which i believe is a

2297

01:17:27,990 --> 01:17:26,159

great assumption but it's i do believe

2298

01:17:29,590 --> 01:17:28,000

it to be an assumption that we're all

2299

01:17:31,270 --> 01:17:29,600

human the reason why i say that is that

2300

01:17:32,870 --> 01:17:31,280

while human biologically yes but human

2301

01:17:34,310 --> 01:17:32,880

also has a connotation of you being

2302

01:17:36,229 --> 01:17:34,320

worth a certain amount and having

2303

01:17:38,149 --> 01:17:36,239

dignity afford it to you and your rights

2304

01:17:40,630 --> 01:17:38,159

the same as mine that's fairly fairly

2305

01:17:42,950 --> 01:17:40,640

new genghis khan for example well many

2306

01:17:46,149 --> 01:17:42,960

if you just go back 1 000 years or 2 000

2307

01:17:47,910 --> 01:17:46,159

or 3000 years human is my tribe you're

2308

01:17:49,189 --> 01:17:47,920

not human you're inhuman you're

2309

01:17:51,350 --> 01:17:49,199

sub-human

2310

01:17:52,630 --> 01:17:51,360

yeah yeah i mean i don't know enough

2311

01:17:55,350 --> 01:17:52,640

history

2312

01:17:57,430 --> 01:17:55,360

to comment on that um

2313

01:17:58,950 --> 01:17:57,440

i i i mean i find it hard to believe

2314

01:18:01,590 --> 01:17:58,960

that

2315

01:18:03,590 --> 01:18:01,600

way

2316

01:18:06,070 --> 01:18:03,600

um it seems

2317

01:18:07,510 --> 01:18:06,080

i mean you know culture and society will

2318

01:18:09,830 --> 01:18:07,520

tell us that there are differences

2319

01:18:11,110 --> 01:18:09,840

between people and racism and everything

2320

01:18:14,630 --> 01:18:11,120

else

2321

01:18:19,750 --> 01:18:17,910

sustained human history but but but it's

2322

01:18:22,149 --> 01:18:19,760

it's kind of obvious and we know now you

2323

01:18:23,590 --> 01:18:22,159

know genetically and scientifically that

2324

01:18:26,550 --> 01:18:23,600

there are essentially we're amazingly

2325

01:18:27,990 --> 01:18:26,560

similar to each other as humans um we we

2326

01:18:29,990 --> 01:18:28,000

we we're

2327

01:18:32,149 --> 01:18:30,000

evolutionarily very closely related to

2328

01:18:34,470 --> 01:18:32,159

each other we've diverged very recently

2329

01:18:35,270 --> 01:18:34,480

and we have all of these systems

2330

01:18:37,990 --> 01:18:35,280

for

2331

01:18:39,590 --> 01:18:38,000

you know categorizing people and i'm

2332

01:18:41,990 --> 01:18:39,600

part of it in the sense that i work in

2333

01:18:43,110 --> 01:18:42,000

the university and i you know mark exams

2334

01:18:45,590 --> 01:18:43,120

and things like that and i'm very

2335

01:18:47,350 --> 01:18:45,600

conflicted over exams because they they

2336

01:18:48,550 --> 01:18:47,360

they they mark a certain type of

2337

01:18:51,110 --> 01:18:48,560

intelligence

2338

01:18:52,550 --> 01:18:51,120

and they give credit to and you know

2339

01:18:55,430 --> 01:18:52,560

there's so many different types of

2340

01:18:57,270 --> 01:18:55,440

intelligence that we're not adept at

2341

01:18:59,590 --> 01:18:57,280

categorizing

2342

01:19:00,310 --> 01:18:59,600

and very often to my mind the people who

2343

01:19:02,149 --> 01:19:00,320

are

2344

01:19:03,510 --> 01:19:02,159

the best researchers

2345

01:19:06,470 --> 01:19:03,520

they're not necessarily the people who

2346

01:19:08,550 --> 01:19:06,480

do best in exams they're the people who

2347

01:19:10,870 --> 01:19:08,560

who think about things in their own way

2348

01:19:12,550 --> 01:19:10,880

and who are obsessive about the question

2349

01:19:14,950 --> 01:19:12,560

and who who who

2350

01:19:16,630 --> 01:19:14,960

keep on pondering it and don't give up

2351

01:19:17,910 --> 01:19:16,640

very often and there are you know there

2352

01:19:19,430 --> 01:19:17,920

are some effortlessly brilliant people

2353

01:19:21,270 --> 01:19:19,440

but there are also you know darwin

2354

01:19:23,590 --> 01:19:21,280

himself was probably

2355

01:19:26,149 --> 01:19:23,600

not necessarily the sharpest cookie in

2356

01:19:28,149 --> 01:19:26,159

the basket but he he he asked and kept

2357

01:19:30,390 --> 01:19:28,159

on asking these questions and

2358

01:19:31,669 --> 01:19:30,400

and and and and ended up coming up with

2359

01:19:33,669 --> 01:19:31,679

answers that were more important than

2360

01:19:35,590 --> 01:19:33,679

anybody else's is different forms of

2361

01:19:37,030 --> 01:19:35,600

intelligence and you know

2362

01:19:42,950 --> 01:19:37,040

western

2363

01:19:45,510 --> 01:19:42,960

over over over centuries to

2364

01:19:46,950 --> 01:19:45,520

to categorize and to have a hierarchy

2365

01:19:48,630 --> 01:19:46,960

and to put the white man at the top of

2366

01:19:52,310 --> 01:19:48,640

the hierarchy and it's so patently not

2367

01:19:55,110 --> 01:19:52,320

true um the the it's shocking that it

2368

01:19:59,270 --> 01:19:57,430

okay so then here's some more thoughts

2369

01:20:00,550 --> 01:19:59,280

again a few questions but just thoughts

2370

01:20:02,470 --> 01:20:00,560

and then we'll get back to some well

2371

01:20:04,390 --> 01:20:02,480

these are biological questions so we're

2372

01:20:06,229 --> 01:20:04,400

saying that hey humans are so related to

2373

01:20:07,910 --> 01:20:06,239

one another and so it's difficult for

2374

01:20:09,350 --> 01:20:07,920

you to imagine that other people would

2375

01:20:11,189 --> 01:20:09,360

think of other people's not being human

2376

01:20:12,630 --> 01:20:11,199

but then to me i was like okay well we

2377

01:20:14,470 --> 01:20:12,640

have another spectrum issue there

2378

01:20:16,390 --> 01:20:14,480

because it's arbitrary where we define

2379

01:20:18,229 --> 01:20:16,400

the line as being sufficiently different

2380

01:20:20,630 --> 01:20:18,239

enough to not call human and then

2381

01:20:23,350 --> 01:20:20,640

secondly it's unclear as to what makes

2382

01:20:24,790 --> 01:20:23,360

you you is it purely your dna but or is

2383

01:20:25,669 --> 01:20:24,800

it also the culture and the ideas that

2384

01:20:26,709 --> 01:20:25,679

you

2385

01:20:29,270 --> 01:20:26,719

of course it's that culture and the

2386

01:20:31,270 --> 01:20:29,280

ideas and then if so well then what we

2387

01:20:32,630 --> 01:20:31,280

can say is this tribe has a right to say

2388

01:20:35,430 --> 01:20:32,640

that you are sufficiently different than

2389

01:20:37,510 --> 01:20:35,440

me unless you convert to me

2390

01:20:39,910 --> 01:20:37,520

uh i mean this is the nature of human

2391

01:20:41,510 --> 01:20:39,920

history isn't it it is tribalism and it

2392

01:20:43,590 --> 01:20:41,520

is it is

2393

01:20:45,350 --> 01:20:43,600

generating a sense of difference

2394

01:20:47,590 --> 01:20:45,360

um i mean you could almost say that

2395

01:20:50,149 --> 01:20:47,600

culture has has gone out of its way to

2396

01:20:51,110 --> 01:20:50,159

erect differences where they don't exist

2397

01:20:53,830 --> 01:20:51,120

um

2398

01:20:55,830 --> 01:20:53,840

you know i think individuals will always

2399

01:20:57,510 --> 01:20:55,840

if if two people from any culture

2400

01:20:59,110 --> 01:20:57,520

anywhere in the world are left as the

2401

01:21:00,390 --> 01:20:59,120

only two people left on the world and

2402

01:21:01,750 --> 01:21:00,400

are forced to talk to each other they

2403

01:21:03,189 --> 01:21:01,760

will realize they have everything in

2404

01:21:05,510 --> 01:21:03,199

common with each other and you know it's

2405

01:21:06,550 --> 01:21:05,520

it was true for practically anybody on

2406

01:21:09,430 --> 01:21:06,560

earth now

2407

01:21:11,830 --> 01:21:09,440

um and always has been but this you know

2408

01:21:12,470 --> 01:21:11,840

this idea of human or non-human or you

2409

01:21:14,630 --> 01:21:12,480

know

2410

01:21:17,750 --> 01:21:14,640

biology is so full of continua

2411

01:21:18,709 --> 01:21:17,760

um was the neanderthal of human

2412

01:21:20,149 --> 01:21:18,719

being

2413

01:21:22,229 --> 01:21:20,159

you know there was plenty in common i'm

2414

01:21:25,910 --> 01:21:22,239

sure there are gradations everywhere and

2415

01:21:28,229 --> 01:21:25,920

there isn't a there isn't a cutoff point

2416

01:21:30,950 --> 01:21:28,239

okay so then the last and i'll stop this

2417

01:21:34,310 --> 01:21:30,960

digression the last point is that if we

2418

01:21:35,990 --> 01:21:34,320

agree that tribalism is natural and is

2419

01:21:38,630 --> 01:21:36,000

almost a universal

2420

01:21:40,390 --> 01:21:38,640

then what if one's conscience

2421

01:21:42,630 --> 01:21:40,400

led them in the direction of saying hey

2422

01:21:44,790 --> 01:21:42,640

in order for my genes to survive it's

2423

01:21:46,709 --> 01:21:44,800

better than my group compete with your

2424

01:21:47,910 --> 01:21:46,719

group and my conscience is telling me so

2425

01:21:49,590 --> 01:21:47,920

so this gets back to the question

2426
01:21:51,110 --> 01:21:49,600
because i was asking yes well why follow

2427
01:21:53,189 --> 01:21:51,120
your conscience and you're saying well

2428
01:21:55,750 --> 01:21:53,199
because it developed evolutionarily well

2429
01:21:57,669 --> 01:21:55,760
what i'm saying is i can imagine it

2430
01:21:59,990 --> 01:21:57,679
yes yes in other words you're saying

2431
01:22:01,270 --> 01:22:00,000
it's wrong it grew up in the context of

2432
01:22:04,229 --> 01:22:01,280
tribalism

2433
01:22:06,709 --> 01:22:04,239
uh and antagonism between different

2434
01:22:08,229 --> 01:22:06,719
groups of people therefore and i said

2435
01:22:10,950 --> 01:22:08,239
you know the sense of right and wrong is

2436
01:22:12,629 --> 01:22:10,960
deeply conflicted and i'm probably not a

2437
01:22:14,470 --> 01:22:12,639
good guide to things

2438
01:22:15,990 --> 01:22:14,480

one of the i think one of the great

2439

01:22:19,750 --> 01:22:16,000

things about

2440

01:22:25,189 --> 01:22:22,629

as i i suppose

2441

01:22:27,910 --> 01:22:25,199

the the history

2442

01:22:32,790 --> 01:22:30,149

the uh from from the renaissance onwards

2443

01:22:35,030 --> 01:22:32,800

is is attempt to break down

2444

01:22:39,270 --> 01:22:35,040

some of these barriers

2445

01:22:41,189 --> 01:22:39,280

um to to to think in broad terms about

2446

01:22:42,390 --> 01:22:41,199

what human rights are and what what

2447

01:22:44,229 --> 01:22:42,400

what's

2448

01:22:46,470 --> 01:22:44,239

what are humans you know it's been a

2449

01:22:48,229 --> 01:22:46,480

very

2450

01:22:49,510 --> 01:22:48,239

you know it omitted women for a long

2451
01:22:51,430 --> 01:22:49,520
time and i've missed different groups

2452
01:22:52,390 --> 01:22:51,440
for a long time but but it was an

2453
01:22:53,270 --> 01:22:52,400
attempt

2454
01:22:57,910 --> 01:22:53,280
to

2455
01:22:59,430 --> 01:22:57,920
people as

2456
01:23:01,430 --> 01:22:59,440
as equal

2457
01:23:03,510 --> 01:23:01,440
and this idea that we're equal is

2458
01:23:05,189 --> 01:23:03,520
obviously again

2459
01:23:06,870 --> 01:23:05,199
we're not equal we're not equal

2460
01:23:09,270 --> 01:23:06,880
genetically we're all different

2461
01:23:10,390 --> 01:23:09,280
genetically we're all an equal almost by

2462
01:23:11,830 --> 01:23:10,400
definition that doesn't mean to say

2463
01:23:12,790 --> 01:23:11,840

someone's better than someone else is

2464

01:23:15,750 --> 01:23:12,800

different

2465

01:23:18,310 --> 01:23:15,760

now and we come from societal cultural

2466

01:23:19,910 --> 01:23:18,320

contexts which are different

2467

01:23:21,750 --> 01:23:19,920

and which condition you to think

2468

01:23:25,110 --> 01:23:21,760

differently about things and those are

2469

01:23:27,189 --> 01:23:25,120

breaking down and and thank god for that

2470

01:23:30,470 --> 01:23:27,199

we lose we lose things when they break

2471

01:23:32,709 --> 01:23:30,480

down you know we we we lose our

2472

01:23:34,709 --> 01:23:32,719

our our culture our tradition is that

2473

01:23:37,669 --> 01:23:34,719

you know people lose groups lose

2474

01:23:42,310 --> 01:23:39,350

there's a loss to

2475

01:23:44,070 --> 01:23:42,320

seeing humanity as a single

2476

01:23:45,669 --> 01:23:44,080

unit a global

2477

01:23:50,790 --> 01:23:45,679

family if you like

2478

01:23:53,590 --> 01:23:50,800

there's there's all the all the cultural

2479

01:23:55,910 --> 01:23:53,600

histories that groups have which are

2480

01:23:57,910 --> 01:23:55,920

wonderful and often you know different

2481

01:23:59,110 --> 01:23:57,920

but but similar

2482

01:24:01,189 --> 01:23:59,120

um

2483

01:24:04,149 --> 01:24:01,199

they can be engulfed and they can be

2484

01:24:06,950 --> 01:24:04,159

lost and and it's in a way it's tragic

2485

01:24:08,870 --> 01:24:06,960

but at the same time if if what we do is

2486

01:24:11,430 --> 01:24:08,880

cling to the

2487

01:24:13,830 --> 01:24:11,440

the differences and the cultural things

2488

01:24:16,870 --> 01:24:13,840

that set you apart from everybody else

2489

01:24:18,470 --> 01:24:16,880

and and then look down on other groups i

2490

01:24:20,950 --> 01:24:18,480

don't think there's anything in the in

2491

01:24:22,149 --> 01:24:20,960

in biology that that says that that's

2492

01:24:24,070 --> 01:24:22,159

the case

2493

01:24:26,709 --> 01:24:24,080

um

2494

01:24:29,590 --> 01:24:26,719

so you know what we need is somewhere

2495

01:24:31,350 --> 01:24:29,600

in the middle where we where we we we

2496

01:24:35,590 --> 01:24:31,360

we're proud of our cultures we're proud

2497

01:24:37,669 --> 01:24:35,600

of our traditions but we somehow um

2498

01:24:39,030 --> 01:24:37,679

understand other groups as equally human

2499

01:24:41,430 --> 01:24:39,040

with equally

2500

01:24:43,030 --> 01:24:41,440

valid and important traditions that we

2501

01:24:44,470 --> 01:24:43,040

live side by side together one of the

2502

01:24:46,229 --> 01:24:44,480

lovely things about living in a place

2503

01:24:48,229 --> 01:24:46,239

like london is it's often called a

2504

01:24:50,950 --> 01:24:48,239

melting pot but you know different

2505

01:24:52,550 --> 01:24:50,960

cultures live side by side

2506

01:24:53,669 --> 01:24:52,560

i won't say happily but reasonably

2507

01:24:55,830 --> 01:24:53,679

happily

2508

01:24:57,669 --> 01:24:55,840

people from countries that are at war

2509

01:24:58,950 --> 01:24:57,679

elsewhere in the world will we'll rub

2510

01:25:01,110 --> 01:24:58,960

shoulders together in a place like

2511

01:25:03,430 --> 01:25:01,120

london and get along together okay and

2512

01:25:05,830 --> 01:25:03,440

and and maintain something of their

2513

01:25:07,510 --> 01:25:05,840

culture and their own sense of identity

2514

01:25:12,629 --> 01:25:07,520

and self-worth

2515

01:25:14,310 --> 01:25:12,639

without without hating everybody else

2516

01:25:16,390 --> 01:25:14,320

okay let's get back to the book this is

2517

01:25:17,590 --> 01:25:16,400

a great transition because you mentioned

2518

01:25:19,030 --> 01:25:17,600

we should it would be great if we

2519

01:25:20,950 --> 01:25:19,040

thought of ourselves as a part of a

2520

01:25:23,110 --> 01:25:20,960

larger whole in the beginning of the

2521

01:25:25,590 --> 01:25:23,120

book i recall there was an analogy made

2522

01:25:27,830 --> 01:25:25,600

between a city and a cell and saying

2523

01:25:29,430 --> 01:25:27,840

okay let's zoom out at a helicopter view

2524

01:25:30,470 --> 01:25:29,440

and look at a city and it looks akin to

2525

01:25:34,629 --> 01:25:30,480

a cell

2526

01:25:36,550 --> 01:25:34,639

well i don't know if that's true but it

2527

01:25:39,030 --> 01:25:36,560

doesn't look much like a cell but yes i

2528

01:25:39,990 --> 01:25:39,040

mean i was i was i was uh comparing it

2529

01:25:41,590 --> 01:25:40,000

because there's plainly there's

2530

01:25:42,870 --> 01:25:41,600

metabolism there's movement there's

2531

01:25:45,030 --> 01:25:42,880

there's all kinds of things happening in

2532

01:25:47,910 --> 01:25:45,040

the city yes and then there was a line

2533

01:25:49,510 --> 01:25:47,920

that said the cell is living potentially

2534

01:25:51,430 --> 01:25:49,520

the cell is living but

2535

01:25:52,950 --> 01:25:51,440

it's but obviously the city is not

2536

01:25:54,550 --> 01:25:52,960

something like that obviously i was

2537

01:25:56,149 --> 01:25:54,560

thinking is it is it obviously that the

2538

01:25:58,149 --> 01:25:56,159

city's not like what makes something

2539

01:26:00,149 --> 01:25:58,159

living is it just is it something that

2540

01:26:02,229 --> 01:26:00,159

this is obvious that the city is not its

2541

01:26:04,070 --> 01:26:02,239

own conscious being if if one of our

2542

01:26:05,430 --> 01:26:04,080

neurons has some proto-consciousness but

2543

01:26:07,350 --> 01:26:05,440

then the collection of them also have a

2544

01:26:09,030 --> 01:26:07,360

larger consciousness are we a part of a

2545

01:26:11,189 --> 01:26:09,040

larger consciousness or is it slow

2546

01:26:13,350 --> 01:26:11,199

transmission speed yeah what you're back

2547

01:26:14,870 --> 01:26:13,360

to there really is is consciousness an

2548

01:26:16,950 --> 01:26:14,880

emergent property of a sufficiently

2549

01:26:19,270 --> 01:26:16,960

complex system

2550

01:26:20,390 --> 01:26:19,280

uh and what i was arguing earlier on is

2551

01:26:23,189 --> 01:26:20,400

that it's not

2552

01:26:25,990 --> 01:26:23,199

um that it's it is a property of an

2553

01:26:28,550 --> 01:26:26,000

extremely complex central nervous system

2554

01:26:30,390 --> 01:26:28,560

but but what it wasn't an emergent

2555

01:26:32,629 --> 01:26:30,400

property from it it was it was something

2556

01:26:35,110 --> 01:26:32,639

which was an integral part of that

2557

01:26:36,149 --> 01:26:35,120

complex system from the very beginning

2558

01:26:37,910 --> 01:26:36,159

i was talking about the language of

2559

01:26:39,910 --> 01:26:37,920

electrical fields and cells and so on

2560

01:26:41,590 --> 01:26:39,920

and this is what has been has been

2561

01:26:43,030 --> 01:26:41,600

ramped up and so

2562

01:26:44,229 --> 01:26:43,040

the the very

2563

01:26:46,629 --> 01:26:44,239

um

2564

01:26:49,110 --> 01:26:46,639

complex feelings and so on that we have

2565

01:26:50,390 --> 01:26:49,120

now are effectively

2566

01:26:52,550 --> 01:26:50,400

they've been through a process of

2567

01:26:54,229 --> 01:26:52,560

natural selection they have real meaning

2568

01:26:56,550 --> 01:26:54,239

for us because they've really been

2569

01:26:58,709 --> 01:26:56,560

selected we really

2570

01:27:01,590 --> 01:26:58,719

do it really does matter

2571

01:27:03,110 --> 01:27:01,600

um if you're starving or if you're if

2572

01:27:07,669 --> 01:27:03,120

you're

2573

01:27:08,709 --> 01:27:07,679

dying of thirst or if you

2574

01:27:10,550 --> 01:27:08,719

are

2575

01:27:12,790 --> 01:27:10,560

you know in in love or whatever it may

2576

01:27:14,629 --> 01:27:12,800

be these feelings are real because

2577

01:27:17,189 --> 01:27:14,639

they've been through

2578

01:27:20,229 --> 01:27:17,199

essentially

2579

01:27:23,030 --> 01:27:20,239

uncountable generations where

2580

01:27:25,189 --> 01:27:23,040

they bore some resemblance to

2581

01:27:28,390 --> 01:27:25,199

what happened to you what

2582

01:27:30,870 --> 01:27:28,400

to people to animals to organisms

2583

01:27:33,510 --> 01:27:30,880

in their lives that if you

2584

01:27:35,270 --> 01:27:33,520

if you have this overwhelming

2585

01:27:38,149 --> 01:27:35,280

fear of something and you run away you

2586

01:27:39,750 --> 01:27:38,159

will do better if this overwhelming

2587

01:27:42,390 --> 01:27:39,760

sense of something

2588

01:27:44,229 --> 01:27:42,400

um has a selective value

2589

01:27:45,910 --> 01:27:44,239

and at the level of single cells it has

2590

01:27:47,590 --> 01:27:45,920

a selective value just in terms of

2591

01:27:49,350 --> 01:27:47,600

integrating the cell as a unit as

2592

01:27:50,950 --> 01:27:49,360

something which can physically go over

2593

01:27:52,310 --> 01:27:50,960

there rather than have this flagellum

2594

01:27:54,070 --> 01:27:52,320

firing that way and this one going and

2595

01:27:55,189 --> 01:27:54,080

under what you know what what integrates

2596

01:27:56,070 --> 01:27:55,199

this system

2597

01:27:58,629 --> 01:27:56,080

um

2598

01:28:01,910 --> 01:27:58,639

so so so you have a you have a system

2599

01:28:05,669 --> 01:28:01,920

which is capable of of a purpose if you

2600

01:28:06,629 --> 01:28:05,679

like to read too big a word into it um

2601
01:28:08,709 --> 01:28:06,639
and that

2602
01:28:10,149 --> 01:28:08,719
has been honed by selection and ends up

2603
01:28:11,590 --> 01:28:10,159
in a central nervous system but it's not

2604
01:28:13,270 --> 01:28:11,600
an emergent property it's something

2605
01:28:16,070 --> 01:28:13,280
which was built in from the very

2606
01:28:18,629 --> 01:28:16,080
beginning and has just been kind of

2607
01:28:20,629 --> 01:28:18,639
raised as part of the edifice

2608
01:28:22,390 --> 01:28:20,639
now from the from that point of view a

2609
01:28:23,910 --> 01:28:22,400
city

2610
01:28:25,990 --> 01:28:23,920
you know it hasn't it hasn't been

2611
01:28:28,390 --> 01:28:26,000
through generations it hasn't given rise

2612
01:28:30,310 --> 01:28:28,400
directly to an offspring city it hasn't

2613
01:28:32,790 --> 01:28:30,320

competed it hasn't died you know

2614

01:28:35,189 --> 01:28:32,800

it doesn't it doesn't have any of these

2615

01:28:37,590 --> 01:28:35,199

biological mechanisms of selection so i

2616

01:28:39,189 --> 01:28:37,600

think any biologist and maybe we're very

2617

01:28:41,030 --> 01:28:39,199

limited here but any biologist would

2618

01:28:43,669 --> 01:28:41,040

immediately say a city's not alive as i

2619

01:28:45,430 --> 01:28:43,679

did any physicist would probably say

2620

01:28:46,790 --> 01:28:45,440

well hang on a minute do you are you

2621

01:28:48,470 --> 01:28:46,800

really so confident that you know what

2622

01:28:50,070 --> 01:28:48,480

life is that you can say that the city

2623

01:28:51,110 --> 01:28:50,080

is definitely not alive

2624

01:28:52,709 --> 01:28:51,120

um

2625

01:28:55,110 --> 01:28:52,719

and

2626

01:28:56,790 --> 01:28:55,120

that boils down you know i had a

2627

01:28:58,310 --> 01:28:56,800

subtitle of an earlier book was why is

2628

01:29:00,229 --> 01:28:58,320

life the way it is and

2629

01:29:03,030 --> 01:29:00,239

and the question to me is actually a

2630

01:29:04,950 --> 01:29:03,040

really serious question which is does it

2631

01:29:06,470 --> 01:29:04,960

have to be this way

2632

01:29:09,110 --> 01:29:06,480

is it or could it have been a different

2633

01:29:12,709 --> 01:29:09,120

way could we have fred hoyle's black

2634

01:29:13,590 --> 01:29:12,719

cloud could we could a city be alive can

2635

01:29:16,470 --> 01:29:13,600

uh

2636

01:29:17,270 --> 01:29:16,480

can can ai become alive

2637

01:29:19,350 --> 01:29:17,280

um

2638

01:29:21,189 --> 01:29:19,360

you know they're very interesting

2639

01:29:22,629 --> 01:29:21,199

difficult questions

2640

01:29:25,669 --> 01:29:22,639

um

2641

01:29:26,950 --> 01:29:25,679

and unless we understand

2642

01:29:28,629 --> 01:29:26,960

i think there's two ways of going about

2643

01:29:30,310 --> 01:29:28,639

it one would be to say oh you've got a

2644

01:29:32,149 --> 01:29:30,320

closed mind and you're you're you're

2645

01:29:33,510 --> 01:29:32,159

you're you're a biologist and you're

2646

01:29:35,430 --> 01:29:33,520

thinking about carbon and you're

2647

01:29:36,950 --> 01:29:35,440

thinking about cells and you know open

2648

01:29:37,669 --> 01:29:36,960

your mind and be

2649

01:29:39,270 --> 01:29:37,679

be

2650

01:29:41,830 --> 01:29:39,280

you know

2651

01:29:43,910 --> 01:29:41,840

open to other possibilities

2652

01:29:45,669 --> 01:29:43,920

yeah and and the other way of seeing it

2653

01:29:47,669 --> 01:29:45,679

is to say well i don't know does life

2654

01:29:49,590 --> 01:29:47,679

have to be these things we know the only

2655

01:29:51,270 --> 01:29:49,600

example of life we know is life here on

2656

01:29:53,270 --> 01:29:51,280

earth and we know that it's carbon-based

2657

01:29:56,629 --> 01:29:53,280

we know that it's cellular we know it

2658

01:29:58,629 --> 01:29:56,639

thrives in water um so did it have to be

2659

01:30:00,310 --> 01:29:58,639

that way or could it have taken a

2660

01:30:02,310 --> 01:30:00,320

different turn or could we you know if

2661

01:30:03,990 --> 01:30:02,320

we understand why life is carbon-based

2662

01:30:05,590 --> 01:30:04,000

then we can begin to say well life has

2663

01:30:08,550 --> 01:30:05,600

to be carbon-based or no it doesn't have

2664

01:30:11,189 --> 01:30:08,560

to be carbon-based or or some spectrum

2665

01:30:12,550 --> 01:30:11,199

in between um

2666

01:30:15,590 --> 01:30:12,560

and

2667

01:30:21,669 --> 01:30:17,510

physicists will very often

2668

01:30:23,590 --> 01:30:21,679

by temperament and by training split off

2669

01:30:24,870 --> 01:30:23,600

from biologists because physicists will

2670

01:30:26,390 --> 01:30:24,880

want to see

2671

01:30:27,830 --> 01:30:26,400

the universe

2672

01:30:30,550 --> 01:30:27,840

as

2673

01:30:33,590 --> 01:30:30,560

almost infinite possibilities with a

2674

01:30:36,070 --> 01:30:33,600

very small number of laws governing it

2675

01:30:37,669 --> 01:30:36,080

and a biologist will want to see

2676
01:30:38,629 --> 01:30:37,679
study the example that we have in front

2677
01:30:40,709 --> 01:30:38,639
of us

2678
01:30:42,629 --> 01:30:40,719
realize there are no laws but there are

2679
01:30:45,669 --> 01:30:42,639
some principles that guide us that you

2680
01:30:48,470 --> 01:30:45,679
know there are no laws in biology um and

2681
01:30:50,149 --> 01:30:48,480
so it's fuzzy and it's it's uh it's

2682
01:30:51,590 --> 01:30:50,159
immediately irritating for any

2683
01:30:53,270 --> 01:30:51,600
self-respecting physicist but that

2684
01:30:55,189 --> 01:30:53,280
doesn't mean to say that there isn't

2685
01:30:56,870 --> 01:30:55,199
something to understand from life on

2686
01:30:59,750 --> 01:30:56,880
earth as we know it and there's you know

2687
01:31:00,550 --> 01:30:59,760
the the origin of life field

2688
01:31:04,229 --> 01:31:00,560

has

2689

01:31:06,070 --> 01:31:04,239

in a strange way almost try to ignore

2690

01:31:08,310 --> 01:31:06,080

what life actually is

2691

01:31:09,750 --> 01:31:08,320

that we know about and and and and to my

2692

01:31:11,110 --> 01:31:09,760

mind

2693

01:31:13,350 --> 01:31:11,120

it it

2694

01:31:14,830 --> 01:31:13,360

if we were to find life on a thousand

2695

01:31:17,590 --> 01:31:14,840

different

2696

01:31:18,470 --> 01:31:17,600

planets throughout the

2697

01:31:23,430 --> 01:31:18,480

through

2698

01:31:26,149 --> 01:31:23,440

the milky way or something um

2699

01:31:27,750 --> 01:31:26,159

then just because carbon is so good at

2700

01:31:29,830 --> 01:31:27,760

the chemistry that it does because it's

2701

01:31:31,510 --> 01:31:29,840

so abundant it's one of the most

2702

01:31:33,669 --> 01:31:31,520

abundant

2703

01:31:36,229 --> 01:31:33,679

elements in the in the universe it it

2704

01:31:38,310 --> 01:31:36,239

it's really good at producing molecules

2705

01:31:40,629 --> 01:31:38,320

that are quite large water is also

2706

01:31:42,149 --> 01:31:40,639

extremely abundant and it does very

2707

01:31:44,390 --> 01:31:42,159

interesting things with organic

2708

01:31:45,669 --> 01:31:44,400

molecules you can have membranes that

2709

01:31:47,590 --> 01:31:45,679

are not soluble and you can have

2710

01:31:50,629 --> 01:31:47,600

proteins that are soluble you know

2711

01:31:52,790 --> 01:31:50,639

there's a wealth of possibilities there

2712

01:31:54,790 --> 01:31:52,800

so you you take into consideration the

2713

01:31:56,149 --> 01:31:54,800

abundance and how good it is at doing

2714

01:31:57,669 --> 01:31:56,159

this chemistry and then you think well

2715

01:31:59,510 --> 01:31:57,679

you know is there an important

2716

01:32:02,390 --> 01:31:59,520

distinction between an outside and an

2717

01:32:03,830 --> 01:32:02,400

inside do you need a compartment

2718

01:32:05,910 --> 01:32:03,840

and if if you're going to keep your

2719

01:32:07,990 --> 01:32:05,920

inside different to your outside

2720

01:32:10,790 --> 01:32:08,000

stuff has to come and go does that give

2721

01:32:12,709 --> 01:32:10,800

of size are there constraints on how

2722

01:32:14,470 --> 01:32:12,719

large something can be and how active it

2723

01:32:16,629 --> 01:32:14,480

can obviously there are you don't need

2724

01:32:18,709 --> 01:32:16,639

to really understand exactly what

2725

01:32:19,990 --> 01:32:18,719

governs those constraints but

2726

01:32:21,590 --> 01:32:20,000

plainly there's a difference between an

2727

01:32:23,830 --> 01:32:21,600

inside and outside and before you know

2728

01:32:25,350 --> 01:32:23,840

it you've argued that life is likely to

2729

01:32:27,669 --> 01:32:25,360

be carbon-based and likely to be

2730

01:32:30,470 --> 01:32:27,679

cellular and likely to be on a planet

2731

01:32:33,110 --> 01:32:30,480

with water and so on and maybe there are

2732

01:32:34,709 --> 01:32:33,120

other ways of doing it but 995 times out

2733

01:32:35,990 --> 01:32:34,719

of a thousand is going to be a bit like

2734

01:32:37,510 --> 01:32:36,000

this

2735

01:32:39,830 --> 01:32:37,520

so let's talk about life on other

2736

01:32:42,070 --> 01:32:39,840

planets potential life an interesting

2737

01:32:43,669 --> 01:32:42,080

phrase that people say when they speak

2738

01:32:45,350 --> 01:32:43,679

about life is life as we know it i

2739

01:32:46,629 --> 01:32:45,360

always found it to be interesting life

2740

01:32:48,709 --> 01:32:46,639

as we know it

2741

01:32:50,470 --> 01:32:48,719

because again like coming from math you

2742

01:32:52,070 --> 01:32:50,480

just have the definitions you just say

2743

01:32:54,310 --> 01:32:52,080

here are the necessary and sufficient

2744

01:32:57,350 --> 01:32:54,320

conditions and then that's it to say

2745

01:32:58,950 --> 01:32:57,360

some so and so as we know it

2746

01:33:00,870 --> 01:32:58,960

implies that there could be something

2747

01:33:02,550 --> 01:33:00,880

else why by what

2748

01:33:03,910 --> 01:33:02,560

we have to call that life it's as if we

2749

01:33:05,590 --> 01:33:03,920

have an intuitive feeling as to what

2750

01:33:06,870 --> 01:33:05,600

life is and we point to certain examples

2751

01:33:09,430 --> 01:33:06,880

and say this is living this is not

2752

01:33:11,510 --> 01:33:09,440

living we haven't quite captured it with

2753

01:33:13,189 --> 01:33:11,520

our explicit language but it's there

2754

01:33:15,270 --> 01:33:13,199

implicitly that's the only way that i

2755

01:33:16,470 --> 01:33:15,280

can make sense of life as we know it but

2756

01:33:18,790 --> 01:33:16,480

i mean i think that i think there's an

2757

01:33:20,149 --> 01:33:18,800

emotional charge to that phrase life as

2758

01:33:21,990 --> 01:33:20,159

we know it says

2759

01:33:23,669 --> 01:33:22,000

out there there is life as we don't know

2760

01:33:25,990 --> 01:33:23,679

it or there may be life as we don't know

2761

01:33:28,790 --> 01:33:26,000

it and and our little limited experience

2762

01:33:30,790 --> 01:33:28,800

is really just a tiny kind of bit of the

2763

01:33:33,350 --> 01:33:30,800

possible universal possibilities i i

2764

01:33:34,629 --> 01:33:33,360

think we we all as human beings thrill

2765

01:33:35,590 --> 01:33:34,639

to the idea that there could be

2766

01:33:38,310 --> 01:33:35,600

something

2767

01:33:40,070 --> 01:33:38,320

majestic out there life as we don't know

2768

01:33:41,910 --> 01:33:40,080

it something much bigger than the human

2769

01:33:44,709 --> 01:33:41,920

mind to consider and you know god would

2770

01:33:46,229 --> 01:33:44,719

probably fall into that category but

2771

01:33:47,910 --> 01:33:46,239

um

2772

01:33:49,350 --> 01:33:47,920

but that's kind of make-believe in some

2773

01:33:51,270 --> 01:33:49,360

sense

2774

01:33:53,110 --> 01:33:51,280

because it it it doesn't ask the

2775

01:33:53,990 --> 01:33:53,120

question so so

2776

01:33:57,510 --> 01:33:54,000

what

2777

01:33:59,830 --> 01:33:57,520

are the principles that govern life as

2778

01:34:01,830 --> 01:33:59,840

we know it and and are they binding

2779

01:34:04,310 --> 01:34:01,840

principles or are they

2780

01:34:07,110 --> 01:34:04,320

uh loose and could it be many other

2781

01:34:08,229 --> 01:34:07,120

different kinds of ways and you know

2782

01:34:10,229 --> 01:34:08,239

it's

2783

01:34:12,629 --> 01:34:10,239

i think one of the most powerful ideas

2784

01:34:15,189 --> 01:34:12,639

in biology is is natural selection and

2785

01:34:16,550 --> 01:34:15,199

and again a lot of physicists have a

2786

01:34:18,950 --> 01:34:16,560

problem with natural selection because

2787

01:34:21,030 --> 01:34:18,960

it's just so damn simple and easy and

2788

01:34:23,430 --> 01:34:21,040

it's hard to believe that

2789

01:34:25,270 --> 01:34:23,440

that something as trivial as that can be

2790

01:34:26,709 --> 01:34:25,280

as profound as that

2791

01:34:29,270 --> 01:34:26,719

um

2792

01:34:30,830 --> 01:34:29,280

but but it's it's becomes amazingly

2793

01:34:34,070 --> 01:34:30,840

complex it

2794

01:34:36,629 --> 01:34:34,080

becomes the stuff that

2795

01:34:39,669 --> 01:34:36,639

that can be explained by by

2796

01:34:41,110 --> 01:34:39,679

by how selection works is genuinely

2797

01:34:43,430 --> 01:34:41,120

astonishing

2798

01:34:44,870 --> 01:34:43,440

it's so rich as an idea you know i mean

2799

01:34:46,709 --> 01:34:44,880

you're talking about ideas in physics

2800

01:34:48,470 --> 01:34:46,719

that the the fewer parameters you can

2801
01:34:51,110 --> 01:34:48,480
boil it down to i mean natural selection

2802
01:34:54,070 --> 01:34:51,120
gets it down to very few parameters uh

2803
01:34:55,189 --> 01:34:54,080
with enormous possibilities and reach

2804
01:34:55,990 --> 01:34:55,199
um

2805
01:34:57,910 --> 01:34:56,000
and

2806
01:34:59,910 --> 01:34:57,920
biology as a discipline has spent you

2807
01:35:01,750 --> 01:34:59,920
know 100 years or more thinking about

2808
01:35:03,430 --> 01:35:01,760
well how does selection actually work

2809
01:35:05,990 --> 01:35:03,440
what are the units of selection is

2810
01:35:07,669 --> 01:35:06,000
acting on genes on cells on organisms on

2811
01:35:10,629 --> 01:35:07,679
groups and so on

2812
01:35:14,709 --> 01:35:10,639
and i would say we we have a fairly

2813
01:35:18,629 --> 01:35:14,719

decent understanding of a lot of it um

2814

01:35:23,189 --> 01:35:18,639

and it's it's um you know

2815

01:35:28,229 --> 01:35:25,430

it's capable of amazing feats but the

2816

01:35:30,790 --> 01:35:28,239

actual processes underlying it are are

2817

01:35:32,310 --> 01:35:30,800

quite simple and rely in in the end on

2818

01:35:33,590 --> 01:35:32,320

forms of copying

2819

01:35:35,990 --> 01:35:33,600

and richard dawkins has talked about

2820

01:35:38,229 --> 01:35:36,000

memes and so on and and yes they they

2821

01:35:40,709 --> 01:35:38,239

can copy and cultural cultural evolution

2822

01:35:43,189 --> 01:35:40,719

can happen but it requires the units of

2823

01:35:44,709 --> 01:35:43,199

living people underneath it with a

2824

01:35:46,390 --> 01:35:44,719

central nervous system which is capable

2825

01:35:48,310 --> 01:35:46,400

of propagating a meme and so on or a

2826

01:35:49,830 --> 01:35:48,320

computer which is capable of

2827

01:35:52,629 --> 01:35:49,840

in the end making copies of itself so

2828

01:35:54,149 --> 01:35:52,639

you know ai can come alive i have no

2829

01:35:56,470 --> 01:35:54,159

no real

2830

01:35:57,830 --> 01:35:56,480

doubt about that but i don't think that

2831

01:36:00,950 --> 01:35:57,840

a planet

2832

01:36:02,950 --> 01:36:00,960

can bootstrap itself up from nothing

2833

01:36:05,350 --> 01:36:02,960

to give ai kind of without without the

2834

01:36:08,629 --> 01:36:05,360

intermediary of humans along the way

2835

01:36:09,510 --> 01:36:08,639

or or at least complex animals capable

2836

01:36:12,629 --> 01:36:09,520

of

2837

01:36:15,270 --> 01:36:12,639

because i don't think that silicon

2838

01:36:16,229 --> 01:36:15,280

as a tool is ever going to get beyond

2839

01:36:18,790 --> 01:36:16,239

sand

2840

01:36:20,149 --> 01:36:18,800

uh on a planetary scale carbon is so

2841

01:36:21,990 --> 01:36:20,159

much better at what it does it may be

2842

01:36:23,830 --> 01:36:22,000

limited compared to silicon in the end

2843

01:36:25,990 --> 01:36:23,840

in terms of processing power but but in

2844

01:36:27,990 --> 01:36:26,000

terms of how do you start you know what

2845

01:36:29,830 --> 01:36:28,000

you have with with carbon is a lego

2846

01:36:31,030 --> 01:36:29,840

brick you have co2 it sits there in the

2847

01:36:32,790 --> 01:36:31,040

atmosphere you pluck it out of the

2848

01:36:34,629 --> 01:36:32,800

atmosphere and you build your amazing

2849

01:36:37,910 --> 01:36:34,639

lego kits which is life

2850

01:36:39,430 --> 01:36:37,920

um and and with silicon or something

2851

01:36:41,590 --> 01:36:39,440

you're dealing with a pile of sand it

2852

01:36:43,830 --> 01:36:41,600

just it doesn't work at the same level

2853

01:36:45,750 --> 01:36:43,840

we can fashion it so that it works his

2854

01:36:47,830 --> 01:36:45,760

life but it's never going to come alive

2855

01:36:49,350 --> 01:36:47,840

by itself

2856

01:36:51,109 --> 01:36:49,360

when i was younger and i was watching

2857

01:36:53,109 --> 01:36:51,119

the discovery channel

2858

01:36:54,790 --> 01:36:53,119

there was i remember hearing this phrase

2859

01:36:56,629 --> 01:36:54,800

that hey if life exists on other planets

2860

01:36:58,310 --> 01:36:56,639

maybe it's silicon based because silicon

2861

01:37:00,470 --> 01:36:58,320

serves the same purpose as carbon i

2862

01:37:01,910 --> 01:37:00,480

don't know i was too young to understand

2863

01:37:03,430 --> 01:37:01,920

what that meant and i haven't followed

2864

01:37:05,270 --> 01:37:03,440

up on that since you just reminded me of

2865

01:37:07,910 --> 01:37:05,280

it right now so is that indeed true or

2866

01:37:09,430 --> 01:37:07,920

not that silicon is just as versatile no

2867

01:37:11,270 --> 01:37:09,440

it's not nearly as versatile and that's

2868

01:37:12,790 --> 01:37:11,280

the problem i mean carbon forms much

2869

01:37:15,030 --> 01:37:12,800

stronger bonds

2870

01:37:16,870 --> 01:37:15,040

than silicon does it's capable of

2871

01:37:18,550 --> 01:37:16,880

forming much more interesting molecules

2872

01:37:20,470 --> 01:37:18,560

than silicon ever can

2873

01:37:22,310 --> 01:37:20,480

uh and silicon for the most part forms

2874

01:37:23,189 --> 01:37:22,320

silicon oxides which are

2875

01:37:25,590 --> 01:37:23,199

sand

2876

01:37:28,310 --> 01:37:25,600

um and and they're basically giant macro

2877

01:37:30,149 --> 01:37:28,320

molecules that a single grain of sand is

2878

01:37:31,750 --> 01:37:30,159

an enormous number of atoms in it and

2879

01:37:34,470 --> 01:37:31,760

it's just a repeating pattern of those

2880

01:37:37,109 --> 01:37:34,480

atoms it's a it's a giant crystal it's

2881

01:37:38,709 --> 01:37:37,119

not a building block a single co2 is a

2882

01:37:41,669 --> 01:37:38,719

building block you you know it's it's

2883

01:37:42,870 --> 01:37:41,679

like a brick um it's your lego brick

2884

01:37:43,750 --> 01:37:42,880

whereas

2885

01:37:45,189 --> 01:37:43,760

uh

2886

01:37:47,189 --> 01:37:45,199

you know i suppose trying to build from

2887

01:37:49,830 --> 01:37:47,199

silicon would be like trying to build

2888

01:37:51,750 --> 01:37:49,840

from enormous piles of lego and try to

2889

01:37:54,470 --> 01:37:51,760

put two piles together and fashion it

2890

01:37:55,990 --> 01:37:54,480

into some kind of unit

2891

01:37:58,629 --> 01:37:56,000

i recall you saying that the fact that

2892

01:38:00,709 --> 01:37:58,639

bacteria are limited in size on earth at

2893

01:38:02,629 --> 01:38:00,719

least has some implication for life in

2894

01:38:04,870 --> 01:38:02,639

the universe i don't remember the line

2895

01:38:07,189 --> 01:38:04,880

of reasoning so please if you know what

2896

01:38:10,149 --> 01:38:07,199

i'm referring to can you expound on that

2897

01:38:12,709 --> 01:38:10,159

yes i mean it's really an observation

2898

01:38:14,229 --> 01:38:12,719

on earth that bacteria are they're not

2899

01:38:15,750 --> 01:38:14,239

always tiny

2900

01:38:17,669 --> 01:38:15,760

but they're mostly to a first

2901

01:38:20,070 --> 01:38:17,679

approximation they're small they're

2902

01:38:22,070 --> 01:38:20,080

they're a couple of micrometers long and

2903

01:38:23,990 --> 01:38:22,080

and that that's that's that's it

2904

01:38:25,750 --> 01:38:24,000

um and when you look at them under a

2905

01:38:27,270 --> 01:38:25,760

conventional microscope you don't see

2906

01:38:28,070 --> 01:38:27,280

very much going on

2907

01:38:29,910 --> 01:38:28,080

um

2908

01:38:31,750 --> 01:38:29,920

now in terms of their biochemistry in

2909

01:38:33,109 --> 01:38:31,760

terms of the molecular machines and all

2910

01:38:36,229 --> 01:38:33,119

of these things they're enormously

2911

01:38:37,910 --> 01:38:36,239

sophisticated in terms of their

2912

01:38:40,390 --> 01:38:37,920

genomes they've got a different

2913

01:38:42,070 --> 01:38:40,400

structure to their genome so a single e

2914

01:38:44,629 --> 01:38:42,080

coli cell

2915

01:38:46,470 --> 01:38:44,639

might have about 4 000 genes and we have

2916

01:38:48,950 --> 01:38:46,480

about 20 000 genes

2917

01:38:51,430 --> 01:38:48,960

but an e coli has what's called a

2918

01:38:53,189 --> 01:38:51,440

metagenome which is to say other e coli

2919

01:38:54,950 --> 01:38:53,199

have different genomes and they swap

2920

01:38:57,109 --> 01:38:54,960

genes among themselves so an e coli

2921

01:38:59,030 --> 01:38:57,119

might have a kind of access to a genome

2922

01:39:02,390 --> 01:38:59,040

with 30 000 genes

2923

01:39:04,790 --> 01:39:02,400

which gives it a lot more scope for

2924

01:39:05,750 --> 01:39:04,800

changing for evolving for for switching

2925

01:39:06,709 --> 01:39:05,760

about

2926

01:39:08,950 --> 01:39:06,719

um

2927

01:39:10,709 --> 01:39:08,960

but it means that no two e coli are

2928

01:39:13,189 --> 01:39:10,719

exactly identical to each other and they

2929

01:39:14,870 --> 01:39:13,199

all have a small genome and and that

2930

01:39:16,629 --> 01:39:14,880

tends to mean that if you try and build

2931

01:39:18,310 --> 01:39:16,639

a multicellular organism from cells

2932

01:39:19,109 --> 01:39:18,320

which are genetically different to each

2933

01:39:20,870 --> 01:39:19,119

other

2934

01:39:23,590 --> 01:39:20,880

then what you end up with is a you know

2935

01:39:25,430 --> 01:39:23,600

a fight basically that would put fights

2936

01:39:27,510 --> 01:39:25,440

between different human groups were

2937

01:39:28,629 --> 01:39:27,520

basically genetically close to identical

2938

01:39:30,390 --> 01:39:28,639

to each other

2939

01:39:32,629 --> 01:39:30,400

um in the shade you know what we're

2940

01:39:34,070 --> 01:39:32,639

dealing with cells that are you know

2941

01:39:35,910 --> 01:39:34,080

utterly different to each other more

2942

01:39:38,390 --> 01:39:35,920

difference between two e coli cells and

2943

01:39:41,669 --> 01:39:38,400

the entire vertebrate kingdom

2944

01:39:43,189 --> 01:39:41,679

um interesting it's yeah it's it's huge

2945

01:39:43,910 --> 01:39:43,199

differences you you put them together

2946

01:39:45,590 --> 01:39:43,920

and

2947

01:39:47,669 --> 01:39:45,600

you're never going to make

2948

01:39:49,510 --> 01:39:47,679

anything as complex as a flea out of

2949

01:39:51,430 --> 01:39:49,520

bacterial cells because they don't have

2950

01:39:53,590 --> 01:39:51,440

a large enough genome what we do is we

2951
01:39:54,870 --> 01:39:53,600
have a large genome and we switch these

2952
01:39:56,550 --> 01:39:54,880
genes on in the brain and we switch

2953
01:39:58,790 --> 01:39:56,560
those genes on in the kidneys and these

2954
01:40:00,470 --> 01:39:58,800
genes in the in in the heart and so on

2955
01:40:02,550 --> 01:40:00,480
we're all genetically identical but we

2956
01:40:05,430 --> 01:40:02,560
switch off different genes in different

2957
01:40:07,189 --> 01:40:05,440
that now to get a genome that's that big

2958
01:40:09,590 --> 01:40:07,199
requires i think

2959
01:40:11,030 --> 01:40:09,600
the kind of radical restructuring of

2960
01:40:13,189 --> 01:40:11,040
genomes

2961
01:40:16,070 --> 01:40:13,199
and the reason for that is that

2962
01:40:17,990 --> 01:40:16,080
any giant bacteria that we see and there

2963
01:40:19,430 --> 01:40:18,000

are a few around they always have

2964

01:40:21,750 --> 01:40:19,440

thousands of copies of their complete

2965

01:40:22,950 --> 01:40:21,760

genome dotted right next to the membrane

2966

01:40:24,229 --> 01:40:22,960

and it seems that they're there because

2967

01:40:27,030 --> 01:40:24,239

they they need to control this

2968

01:40:28,070 --> 01:40:27,040

electrical charge on the membrane

2969

01:40:31,669 --> 01:40:28,080

which is

2970

01:40:33,430 --> 01:40:31,679

is is responsible for consciousness but

2971

01:40:35,590 --> 01:40:33,440

it's responsible for driving co2

2972

01:40:38,470 --> 01:40:35,600

fixation and for making energy the

2973

01:40:40,790 --> 01:40:38,480

currency the the atp currency of life

2974

01:40:42,870 --> 01:40:40,800

and so on it's it's used for

2975

01:40:45,030 --> 01:40:42,880

pretty much everything and it's a charge

2976

01:40:46,629 --> 01:40:45,040

which is enormously strong so if you

2977

01:40:48,790 --> 01:40:46,639

shrink yourself down to a size of a

2978

01:40:50,709 --> 01:40:48,800

molecule again and

2979

01:40:52,070 --> 01:40:50,719

the electrical field strength that you

2980

01:40:54,629 --> 01:40:52,080

would experience if you're sitting next

2981

01:40:56,709 --> 01:40:54,639

to that membrane is 30 million volts per

2982

01:40:57,910 --> 01:40:56,719

meter which is equivalent to a bolt of

2983

01:40:59,669 --> 01:40:57,920

lightning

2984

01:41:01,990 --> 01:40:59,679

so we're dealing with a membrane which

2985

01:41:04,709 --> 01:41:02,000

is five millionths of a meter thick five

2986

01:41:06,790 --> 01:41:04,719

nanometers thick um

2987

01:41:07,669 --> 01:41:06,800

five millionths of a millimeter sorry

2988

01:41:11,430 --> 01:41:07,679

thick

2989

01:41:12,870 --> 01:41:11,440

um so 10 to the minus nine of a meter um

2990

01:41:18,229 --> 01:41:12,880

so

2991

01:41:19,669 --> 01:41:18,239

across it is about 100 millivolts or 150

2992

01:41:21,590 --> 01:41:19,679

millivolts or something like that and

2993

01:41:23,270 --> 01:41:21,600

any but it but as a field strength

2994

01:41:25,750 --> 01:41:23,280

that's very high

2995

01:41:27,510 --> 01:41:25,760

you need genes to control that they need

2996

01:41:29,350 --> 01:41:27,520

to be next to it and the problem with

2997

01:41:31,189 --> 01:41:29,360

bacteria is if they try and just expand

2998

01:41:33,030 --> 01:41:31,199

up you end up with this enormous cost of

2999

01:41:35,990 --> 01:41:33,040

having all of these genomes sitting next

3000

01:41:37,669 --> 01:41:36,000

to that now what we have with

3001
01:41:38,629 --> 01:41:37,679
mitochondria

3002
01:41:39,990 --> 01:41:38,639
we have

3003
01:41:41,830 --> 01:41:40,000
the same what's called extreme

3004
01:41:43,350 --> 01:41:41,840
polyploidy we've got thousands of copies

3005
01:41:45,830 --> 01:41:43,360
of the mitochondrial genome but they've

3006
01:41:46,950 --> 01:41:45,840
been whittled down to almost nothing

3007
01:41:49,910 --> 01:41:46,960
there's only

3008
01:41:50,790 --> 01:41:49,920
um i mean there's that there's

3009
01:41:51,830 --> 01:41:50,800
i think

3010
01:41:55,030 --> 01:41:51,840
uh

3011
01:41:57,109 --> 01:41:55,040
38 genes in in the mitochondria

3012
01:41:59,669 --> 01:41:57,119
left in in humans

3013
01:42:01,350 --> 01:41:59,679

and they only are encoding the machinery

3014

01:42:03,030 --> 01:42:01,360

and the proteins that are doing

3015

01:42:05,590 --> 01:42:03,040

respiration that's it so they're

3016

01:42:08,310 --> 01:42:05,600

basically you could think of them as

3017

01:42:10,629 --> 01:42:08,320

the same power as a bacterium to to to

3018

01:42:12,390 --> 01:42:10,639

to generate energy but without all the

3019

01:42:14,070 --> 01:42:12,400

overhead costs that a normal bacterium

3020

01:42:17,189 --> 01:42:14,080

would have so we've got multi-bacterial

3021

01:42:19,350 --> 01:42:17,199

power like multi-horsepower or something

3022

01:42:22,229 --> 01:42:19,360

and what that allows us is to have a

3023

01:42:24,470 --> 01:42:22,239

swollen nuclear genome with with 20 000

3024

01:42:26,950 --> 01:42:24,480

genes and lots of regulatory capacity

3025

01:42:28,950 --> 01:42:26,960

and lots of energy for expressing those

3026

01:42:30,310 --> 01:42:28,960

genes so that we we can make tens of

3027

01:42:31,750 --> 01:42:30,320

thousands of copies of the protein

3028

01:42:34,709 --> 01:42:31,760

rather than just a thousand copies or

3029

01:42:36,470 --> 01:42:34,719

something so we we we we can scale up in

3030

01:42:39,669 --> 01:42:36,480

a way that is is basically impossible

3031

01:42:41,590 --> 01:42:39,679

for bacteria and and that came about as

3032

01:42:43,350 --> 01:42:41,600

a result of an endosymbiosis which is to

3033

01:42:45,189 --> 01:42:43,360

say one cell gets inside another cell

3034

01:42:47,510 --> 01:42:45,199

which is pretty rare in itself and it

3035

01:42:49,030 --> 01:42:47,520

has to survive there and you know

3036

01:42:50,149 --> 01:42:49,040

they have to get along

3037

01:42:51,350 --> 01:42:50,159

so the whole

3038

01:42:55,830 --> 01:42:51,360

history

3039

01:42:57,830 --> 01:42:55,840

of um

3040

01:43:00,149 --> 01:42:57,840

antagonism and cooperation and

3041

01:43:02,629 --> 01:43:00,159

eventually overcoming the obstacles and

3042

01:43:05,030 --> 01:43:02,639

the hurdles and and becoming integrated

3043

01:43:06,629 --> 01:43:05,040

as a as a functional unit

3044

01:43:09,189 --> 01:43:06,639

i didn't realize that there were only 38

3045

01:43:10,790 --> 01:43:09,199

genes in the mitochondria that sounds so

3046

01:43:12,709 --> 01:43:10,800

tiny

3047

01:43:14,950 --> 01:43:12,719

it's very few and for that reason

3048

01:43:15,910 --> 01:43:14,960

they're they're mostly ignored

3049

01:43:20,950 --> 01:43:15,920

so

3050

01:43:23,030 --> 01:43:20,960

genomes 20 000 genes want to sequence

3051
01:43:24,790 --> 01:43:23,040
the genome look to see which genes are

3052
01:43:26,550 --> 01:43:24,800
responsible for diseases

3053
01:43:28,070 --> 01:43:26,560
people do what are called g-wise studies

3054
01:43:30,550 --> 01:43:28,080
which is a genome

3055
01:43:31,270 --> 01:43:30,560
wide association studies so you you look

3056
01:43:33,750 --> 01:43:31,280
for

3057
01:43:35,350 --> 01:43:33,760
this this single letter change here or

3058
01:43:37,109 --> 01:43:35,360
that one there is associated with

3059
01:43:39,030 --> 01:43:37,119
epilepsy or alzheimer's disease or

3060
01:43:40,709 --> 01:43:39,040
whatever it may be and maybe there's

3061
01:43:42,149 --> 01:43:40,719
maybe there's a few hundred of these or

3062
01:43:43,030 --> 01:43:42,159
maybe there's thousands or millions of

3063
01:43:45,109 --> 01:43:43,040

them but

3064

01:43:47,030 --> 01:43:45,119

a few hundred may may kind of crop up

3065

01:43:48,950 --> 01:43:47,040

and say ah people who've got that letter

3066

01:43:50,229 --> 01:43:48,960

changed their slightly higher risk of

3067

01:43:52,550 --> 01:43:50,239

alzheimer's disease and if they've got

3068

01:43:54,550 --> 01:43:52,560

this one as well it's a little bit more

3069

01:43:55,990 --> 01:43:54,560

and people ignore the mitochondria but

3070

01:43:58,070 --> 01:43:56,000

the mitochondria

3071

01:44:00,550 --> 01:43:58,080

what makes us alive this is the

3072

01:44:02,629 --> 01:44:00,560

difference between just information

3073

01:44:05,510 --> 01:44:02,639

and a living system

3074

01:44:06,470 --> 01:44:05,520

where it's growing where it's capable of

3075

01:44:08,709 --> 01:44:06,480

of

3076

01:44:10,149 --> 01:44:08,719

powering all the work that cells need to

3077

01:44:11,750 --> 01:44:10,159

do you get anything wrong with those

3078

01:44:13,350 --> 01:44:11,760

genes or they don't work properly with a

3079

01:44:16,070 --> 01:44:13,360

nuclear background and you've

3080

01:44:18,390 --> 01:44:16,080

compromised the entire living system

3081

01:44:20,470 --> 01:44:18,400

so they they are there's not many of

3082

01:44:21,510 --> 01:44:20,480

them but they are the most important

3083

01:44:22,790 --> 01:44:21,520

genes

3084

01:44:25,109 --> 01:44:22,800

for

3085

01:44:27,990 --> 01:44:25,119

making us who we are you may say

3086

01:44:30,310 --> 01:44:28,000

for making us alive for for being

3087

01:44:32,070 --> 01:44:30,320

for being here at all and mitochondria

3088

01:44:33,669 --> 01:44:32,080

they have dna or rna

3089

01:44:34,550 --> 01:44:33,679

they have dna

3090

01:44:37,030 --> 01:44:34,560

yeah

3091

01:44:40,790 --> 01:44:37,040

they have rna as well but they they the

3092

01:44:43,830 --> 01:44:42,070

the blob of

3093

01:44:45,669 --> 01:44:43,840

of dna in the nucleus is that called

3094

01:44:46,550 --> 01:44:45,679

nuclear dna

3095

01:44:48,229 --> 01:44:46,560

yes

3096

01:44:50,310 --> 01:44:48,239

okay so there's mitochondrial dna

3097

01:44:52,470 --> 01:44:50,320

there's nucleus and dna yes all right

3098

01:44:54,070 --> 01:44:52,480

all right and they better work together

3099

01:44:55,910 --> 01:44:54,080

right right right i read that there was

3100

01:44:57,590 --> 01:44:55,920

some i in your book that there's some

3101

01:45:00,550 --> 01:44:57,600

compatibility condition between the

3102

01:45:01,750 --> 01:45:00,560

mitochondrial dna and the nuclear dna

3103

01:45:03,669 --> 01:45:01,760

and i think doug wallace was

3104

01:45:06,229 --> 01:45:03,679

investigating this and he took my dna

3105

01:45:07,669 --> 01:45:06,239

and then put into hamster yeah yeah that

3106

01:45:09,750 --> 01:45:07,679

was that was quite a long time ago lots

3107

01:45:12,709 --> 01:45:09,760

of people have done i've done similar

3108

01:45:14,229 --> 01:45:12,719

work since then but even within you know

3109

01:45:16,470 --> 01:45:14,239

so so some of my own work is on

3110

01:45:17,750 --> 01:45:16,480

drosophila uh different groups of

3111

01:45:20,310 --> 01:45:17,760

drosophila

3112

01:45:21,830 --> 01:45:20,320

um we're all within the same species but

3113

01:45:24,390 --> 01:45:21,840

if you kind of mismatch their

3114

01:45:25,669 --> 01:45:24,400

mitochondrial dna to to the nuclear

3115

01:45:26,550 --> 01:45:25,679

background

3116

01:45:28,070 --> 01:45:26,560

then

3117

01:45:29,990 --> 01:45:28,080

it increases

3118

01:45:31,590 --> 01:45:30,000

the risk of all kind i mean basically

3119

01:45:33,350 --> 01:45:31,600

the rate at which some flies age

3120

01:45:34,229 --> 01:45:33,360

compared to others or how fertile they

3121

01:45:36,550 --> 01:45:34,239

are there's

3122

01:45:38,070 --> 01:45:36,560

various kind of phenotypes and exactly

3123

01:45:40,390 --> 01:45:38,080

the same principles should apply to

3124

01:45:42,709 --> 01:45:40,400

humans as well

3125

01:45:44,149 --> 01:45:42,719

and somehow this is a driving force or

3126

01:45:46,149 --> 01:45:44,159

at least is proposed to be a driving

3127

01:45:48,070 --> 01:45:46,159

force behind speciation and i don't

3128

01:45:49,590 --> 01:45:48,080

recall how that line of

3129

01:45:51,830 --> 01:45:49,600

reasoning went

3130

01:45:54,950 --> 01:45:51,840

do you know what i'm referring to yes so

3131

01:45:56,870 --> 01:45:54,960

so so the idea and this is uh this is

3132

01:45:59,189 --> 01:45:56,880

i won't say it's a speculative idea but

3133

01:46:01,590 --> 01:45:59,199

there's there's not very much evidence

3134

01:46:03,350 --> 01:46:01,600

that it's really true but it's a it's a

3135

01:46:04,550 --> 01:46:03,360

very interesting idea

3136

01:46:05,510 --> 01:46:04,560

um

3137

01:46:08,070 --> 01:46:05,520

so

3138

01:46:09,669 --> 01:46:08,080

in effect if because mitochondrial genes

3139

01:46:11,669 --> 01:46:09,679

evolve much faster

3140

01:46:13,830 --> 01:46:11,679

than genes in the nucleus about 10 times

3141

01:46:15,910 --> 01:46:13,840

faster on average maybe more maybe 50

3142

01:46:16,709 --> 01:46:15,920

times faster we don't actually really

3143

01:46:17,669 --> 01:46:16,719

know

3144

01:46:19,270 --> 01:46:17,679

um

3145

01:46:21,669 --> 01:46:19,280

but they're they're changing very

3146

01:46:24,149 --> 01:46:21,679

quickly now this this selection

3147

01:46:27,109 --> 01:46:24,159

happening in the female germ line so

3148

01:46:29,830 --> 01:46:27,119

whenever um whenever

3149

01:46:33,270 --> 01:46:29,840

new oocytes egg cells are being made

3150

01:46:35,669 --> 01:46:33,280

there's a process of of um

3151
01:46:37,910 --> 01:46:35,679
effectively winnowing out the bad

3152
01:46:39,990 --> 01:46:37,920
mitochondria and and and

3153
01:46:42,629 --> 01:46:40,000
bringing the the better mitochondria

3154
01:46:44,390 --> 01:46:42,639
together and an egg cell has as many as

3155
01:46:47,910 --> 01:46:44,400
half a million mitochondria and copies

3156
01:46:50,310 --> 01:46:47,920
of mitochondrial dna in that egg cell

3157
01:46:52,229 --> 01:46:50,320
and they're all as close to a clone as

3158
01:46:53,669 --> 01:46:52,239
it's possible to make them without

3159
01:46:54,870 --> 01:46:53,679
without kind of killing yourself in the

3160
01:46:56,709 --> 01:46:54,880
process

3161
01:46:58,390 --> 01:46:56,719
um

3162
01:46:59,350 --> 01:46:58,400
and these genes are evolving very

3163
01:47:00,310 --> 01:46:59,360

quickly

3164

01:47:01,750 --> 01:47:00,320

and

3165

01:47:03,510 --> 01:47:01,760

can

3166

01:47:04,470 --> 01:47:03,520

effectively fail to interact properly

3167

01:47:06,310 --> 01:47:04,480

with the

3168

01:47:09,750 --> 01:47:06,320

genes in the nucleus so if you imagine

3169

01:47:11,750 --> 01:47:09,760

two populations that are diverging and

3170

01:47:13,510 --> 01:47:11,760

you know standard idea of speciation

3171

01:47:15,430 --> 01:47:13,520

there's two there's two populations are

3172

01:47:16,149 --> 01:47:15,440

on different sides of a mountain and

3173

01:47:20,830 --> 01:47:16,159

they

3174

01:47:22,950 --> 01:47:20,840

know thousands of generations or

3175

01:47:24,790 --> 01:47:22,960

something and then and then they come

3176

01:47:26,950 --> 01:47:24,800

back together again and they mix

3177

01:47:28,870 --> 01:47:26,960

and so which genes are going to be

3178

01:47:30,390 --> 01:47:28,880

involved so sometimes they'll intermix

3179

01:47:32,470 --> 01:47:30,400

perfectly well and other times there

3180

01:47:34,709 --> 01:47:32,480

will be um some kind of it's called

3181

01:47:36,629 --> 01:47:34,719

hybrid breakdown basically the the

3182

01:47:39,270 --> 01:47:36,639

offspring which is the the standard

3183

01:47:41,510 --> 01:47:39,280

biological definition of a species is if

3184

01:47:45,270 --> 01:47:41,520

you can't produce viable offspring

3185

01:47:46,870 --> 01:47:45,280

if the offspring of sterile or or

3186

01:47:49,270 --> 01:47:46,880

don't develop properly

3187

01:47:51,669 --> 01:47:49,280

then you've you've got two different

3188

01:47:53,510 --> 01:47:51,679

species very often different species can

3189

01:47:55,189 --> 01:47:53,520

interbreed perfectly well this is a very

3190

01:47:57,830 --> 01:47:55,199

bad definition of a species it's another

3191

01:48:00,950 --> 01:47:57,840

example in biology where where

3192

01:48:03,750 --> 01:48:00,960

there isn't a firm definition

3193

01:48:05,109 --> 01:48:03,760

there's just separate now the genes that

3194

01:48:06,790 --> 01:48:05,119

are evolving the fastest and changing

3195

01:48:08,709 --> 01:48:06,800

the fastest the mitochondrial genes are

3196

01:48:11,910 --> 01:48:08,719

the ones that are most likely

3197

01:48:13,990 --> 01:48:11,920

to cause trouble in those circumstances

3198

01:48:15,350 --> 01:48:14,000

they're the ones most likely to

3199

01:48:17,270 --> 01:48:15,360

not work well with the nuclear

3200

01:48:19,189 --> 01:48:17,280

background of the other population from

3201

01:48:20,870 --> 01:48:19,199

the other side of the mountain

3202

01:48:22,950 --> 01:48:20,880

this is the idea

3203

01:48:25,030 --> 01:48:22,960

um and and so

3204

01:48:26,870 --> 01:48:25,040

incipient speciation may be driven by

3205

01:48:28,950 --> 01:48:26,880

the rate of change of the mitochondria

3206

01:48:30,390 --> 01:48:28,960

which may you know if these guys live in

3207

01:48:32,070 --> 01:48:30,400

a hot climate and these guys live in a

3208

01:48:34,390 --> 01:48:32,080

cold climate then maybe the mitochondria

3209

01:48:36,229 --> 01:48:34,400

are specialized to different tasks and

3210

01:48:38,550 --> 01:48:36,239

that can drive these differences what

3211

01:48:40,310 --> 01:48:38,560

we've found with uh with with fly is

3212

01:48:42,149 --> 01:48:40,320

interestingly enough is

3213

01:48:45,189 --> 01:48:42,159

um

3214

01:48:47,430 --> 01:48:45,199

that the you can end up with 50 or 60

3215

01:48:49,910 --> 01:48:47,440

different letter changes

3216

01:48:50,790 --> 01:48:49,920

in in mitochondrial dna which is quite a

3217

01:48:52,629 --> 01:48:50,800

lot

3218

01:48:55,030 --> 01:48:52,639

um and

3219

01:48:56,390 --> 01:48:55,040

whether or not you have

3220

01:48:57,830 --> 01:48:56,400

observable

3221

01:49:00,070 --> 01:48:57,840

problems

3222

01:49:02,390 --> 01:49:00,080

for example not developing properly or

3223

01:49:03,990 --> 01:49:02,400

aging very quickly or not doesn't depend

3224

01:49:05,669 --> 01:49:04,000

on the number of the differences you

3225

01:49:07,270 --> 01:49:05,679

might expect to be a correlation if

3226

01:49:09,270 --> 01:49:07,280

you've got 50

3227

01:49:10,870 --> 01:49:09,280

50 letters different then then it's more

3228

01:49:13,270 --> 01:49:10,880

likely to go wrong than if you've only

3229

01:49:15,030 --> 01:49:13,280

got five letters different

3230

01:49:17,189 --> 01:49:15,040

and that's not the case what we actually

3231

01:49:18,870 --> 01:49:17,199

find is it's an absolute flat line that

3232

01:49:20,310 --> 01:49:18,880

if you've got five letters or one letter

3233

01:49:22,229 --> 01:49:20,320

difference it can cause some

3234

01:49:23,189 --> 01:49:22,239

catastrophic problems if they're bad

3235

01:49:27,270 --> 01:49:23,199

letters

3236

01:49:29,750 --> 01:49:27,280

um then then

3237

01:49:31,350 --> 01:49:29,760

uh it is it you know it can it can be

3238

01:49:32,950 --> 01:49:31,360

catastrophically bad or it can be fine

3239

01:49:34,629 --> 01:49:32,960

there is not necessarily any worse and

3240

01:49:36,790 --> 01:49:34,639

this these are the levels of differences

3241

01:49:37,750 --> 01:49:36,800

that we see across humans as well there

3242

01:49:39,910 --> 01:49:37,760

is no

3243

01:49:41,430 --> 01:49:39,920

you know there is a possibility

3244

01:49:43,350 --> 01:49:41,440

that different

3245

01:49:46,229 --> 01:49:43,360

human races could interbreed and then

3246

01:49:47,990 --> 01:49:46,239

produce produce offspring that were not

3247

01:49:49,750 --> 01:49:48,000

functional no one's ever seen it but

3248

01:49:52,229 --> 01:49:49,760

it's it's a theoretical possibility that

3249

01:49:53,350 --> 01:49:52,239

this work seems to say no way that's not

3250

01:49:55,750 --> 01:49:53,360

going to happen

3251
01:49:57,669 --> 01:49:55,760
because we can see individuals who have

3252
01:49:59,910 --> 01:49:57,679
a problem because there's an unfortunate

3253
01:50:00,950 --> 01:49:59,920
mismatch and incompatibility

3254
01:50:02,629 --> 01:50:00,960
that

3255
01:50:04,790 --> 01:50:02,639
we've always known about these things

3256
01:50:06,790 --> 01:50:04,800
two people just don't work together for

3257
01:50:08,709 --> 01:50:06,800
whatever reason um

3258
01:50:11,109 --> 01:50:08,719
but it's nothing to do with

3259
01:50:13,350 --> 01:50:11,119
with races or with speciation

3260
01:50:14,950 --> 01:50:13,360
once you've got really deep divergence

3261
01:50:16,470 --> 01:50:14,960
say between a mouse and a rat or

3262
01:50:18,950 --> 01:50:16,480
something between a chimpanzee and a

3263
01:50:20,229 --> 01:50:18,960

human being then you would see

3264

01:50:22,310 --> 01:50:20,239

then you would see certain now we're

3265

01:50:24,470 --> 01:50:22,320

dealing with thousands of thousands of

3266

01:50:26,229 --> 01:50:24,480

letter changes difference and and then

3267

01:50:28,709 --> 01:50:26,239

you'll begin to see that there really is

3268

01:50:30,070 --> 01:50:28,719

some kind of breakdown but within within

3269

01:50:32,709 --> 01:50:30,080

populations that are basically

3270

01:50:34,790 --> 01:50:32,719

homogeneous as the human populations are

3271

01:50:37,910 --> 01:50:34,800

we don't see those changes how many

3272

01:50:39,830 --> 01:50:37,920

letters make up the mitochondrial dna do

3273

01:50:40,709 --> 01:50:39,840

you know approximately

3274

01:50:43,590 --> 01:50:40,719

um

3275

01:50:45,109 --> 01:50:43,600

it's about eighteen thousand

3276

01:50:46,629 --> 01:50:45,119

eighteen to ten oh wow great great great

3277

01:50:48,709 --> 01:50:46,639

great memory okay and then dna is

3278

01:50:49,750 --> 01:50:48,719

drastically more sorry nuclear dna is

3279

01:50:50,870 --> 01:50:49,760

far more

3280

01:50:53,350 --> 01:50:50,880

oh we're dealing with about three

3281

01:50:54,310 --> 01:50:53,360

billion then okay why is it so strange

3282

01:50:56,149 --> 01:50:54,320

that

3283

01:50:58,629 --> 01:50:56,159

certain mutations so certain letter

3284

01:50:59,830 --> 01:50:58,639

changes in the mitochondrial dna

3285

01:51:01,590 --> 01:50:59,840

produce

3286

01:51:03,189 --> 01:51:01,600

horrible effects but then certain other

3287

01:51:05,109 --> 01:51:03,199

changes don't because that sounds the

3288

01:51:06,950 --> 01:51:05,119

same as nuclear dna and you were saying

3289

01:51:09,189 --> 01:51:06,960

like oh it's so strange one or two

3290

01:51:10,709 --> 01:51:09,199

letters off here but 50 letters well

3291

01:51:13,189 --> 01:51:10,719

that troubled me a lot and i didn't

3292

01:51:15,030 --> 01:51:13,199

understand it it's not what i expected

3293

01:51:16,470 --> 01:51:15,040

um and i actually find it quite welcome

3294

01:51:18,470 --> 01:51:16,480

in a strange way but it took me a long

3295

01:51:20,709 --> 01:51:18,480

time to understand

3296

01:51:22,149 --> 01:51:20,719

why what's going on there

3297

01:51:24,070 --> 01:51:22,159

and and

3298

01:51:25,189 --> 01:51:24,080

i think the reason is that there has to

3299

01:51:27,030 --> 01:51:25,199

be

3300

01:51:28,950 --> 01:51:27,040

quite a lot of tolerance

3301
01:51:30,870 --> 01:51:28,960
for different types of mitochondrial

3302
01:51:31,669 --> 01:51:30,880
function

3303
01:51:33,350 --> 01:51:31,679
so

3304
01:51:35,350 --> 01:51:33,360
women and men are different

3305
01:51:39,430 --> 01:51:35,360
in in in

3306
01:51:41,830 --> 01:51:39,440
in in dietary needs in in outputs of one

3307
01:51:43,750 --> 01:51:41,840
sort or another in metabolic rate

3308
01:51:46,709 --> 01:51:43,760
on average men have about 20 percent

3309
01:51:47,990 --> 01:51:46,719
higher metabolic rate than women do

3310
01:51:49,270 --> 01:51:48,000
so there are all these there are all

3311
01:51:51,030 --> 01:51:49,280
these differences and and the

3312
01:51:52,629 --> 01:51:51,040
mitochondria we inherit them from our

3313
01:51:56,149 --> 01:51:52,639

mothers only

3314

01:51:57,830 --> 01:51:56,159

um and that means in principle that they

3315

01:52:00,470 --> 01:51:57,840

adapt to being

3316

01:52:01,669 --> 01:52:00,480

in in in the female line

3317

01:52:03,270 --> 01:52:01,679

and

3318

01:52:04,709 --> 01:52:03,280

you know your mitochondria my

3319

01:52:06,149 --> 01:52:04,719

mitochondria they're going nowhere if

3320

01:52:07,510 --> 01:52:06,159

you have kids then then they're not

3321

01:52:09,350 --> 01:52:07,520

going to get your mitochondria your

3322

01:52:11,350 --> 01:52:09,360

mitochondria you're going in the bin

3323

01:52:14,310 --> 01:52:11,360

um and that means that

3324

01:52:15,430 --> 01:52:14,320

they can never really be fashioned to

3325

01:52:18,229 --> 01:52:15,440

work

3326

01:52:21,109 --> 01:52:18,239

to be adapted to being in men

3327

01:52:22,149 --> 01:52:21,119

um now the nuclear background can kind

3328

01:52:24,310 --> 01:52:22,159

of

3329

01:52:26,629 --> 01:52:24,320

fashion them to work in men

3330

01:52:28,709 --> 01:52:26,639

and the y chromosome for example can you

3331

01:52:30,790 --> 01:52:28,719

know can control genes that up regulates

3332

01:52:32,709 --> 01:52:30,800

those that make female mitochondria

3333

01:52:33,750 --> 01:52:32,719

effectively work better in men

3334

01:52:35,510 --> 01:52:33,760

um

3335

01:52:38,390 --> 01:52:35,520

so there's there are biological ways

3336

01:52:39,430 --> 01:52:38,400

around this but the bottom line is

3337

01:52:41,510 --> 01:52:39,440

um

3338

01:52:43,990 --> 01:52:41,520

there are different requirements on the

3339

01:52:46,229 --> 01:52:44,000

system in men and women but there are

3340

01:52:47,109 --> 01:52:46,239

different requirements as well depending

3341

01:52:49,510 --> 01:52:47,119

on

3342

01:52:51,030 --> 01:52:49,520

is it in the brain where

3343

01:52:53,109 --> 01:52:51,040

the genes that are expressed in the

3344

01:52:54,629 --> 01:52:53,119

nucleus is a completely different set of

3345

01:52:56,310 --> 01:52:54,639

genes compared to those in the kidney

3346

01:52:57,589 --> 01:52:56,320

where the mitochondria have a different

3347

01:52:58,709 --> 01:52:57,599

task and the same genes in the

3348

01:53:00,070 --> 01:52:58,719

mitochondria have to work with a

3349

01:53:02,790 --> 01:53:00,080

different set of nuclear genes with

3350

01:53:04,629 --> 01:53:02,800

different requirements so they basically

3351

01:53:06,550 --> 01:53:04,639

they've got to be generalists they've

3352

01:53:08,790 --> 01:53:06,560

got to have a lot of

3353

01:53:11,350 --> 01:53:08,800

slack that they can

3354

01:53:13,030 --> 01:53:11,360

operate well enough in completely

3355

01:53:14,229 --> 01:53:13,040

different tissues completely different

3356

01:53:15,589 --> 01:53:14,239

diets

3357

01:53:17,510 --> 01:53:15,599

you know different human groups have

3358

01:53:19,830 --> 01:53:17,520

very different diets and and and

3359

01:53:21,669 --> 01:53:19,840

different different um

3360

01:53:24,070 --> 01:53:21,679

you know

3361

01:53:25,669 --> 01:53:24,080

fat intake or or calorie intake or

3362

01:53:28,070 --> 01:53:25,679

whatever it may be that puts pressures

3363

01:53:30,790 --> 01:53:28,080

on on mitochondrial functions which can

3364

01:53:33,669 --> 01:53:30,800

be very different different temperatures

3365

01:53:35,669 --> 01:53:33,679

um that you're operating at um

3366

01:53:37,189 --> 01:53:35,679

and especially that's even even worse

3367

01:53:38,310 --> 01:53:37,199

with things like flies that are cold

3368

01:53:39,830 --> 01:53:38,320

blooded and if you change the

3369

01:53:41,589 --> 01:53:39,840

temperature then their whole body

3370

01:53:43,350 --> 01:53:41,599

temperature changes

3371

01:53:45,109 --> 01:53:43,360

so so they're basically they have to be

3372

01:53:47,750 --> 01:53:45,119

generalist and that means that they they

3373

01:53:49,910 --> 01:53:47,760

can tolerate a fair amount of of change

3374

01:53:51,830 --> 01:53:49,920

and most of the changes that happen

3375

01:53:55,830 --> 01:53:51,840

um are tolerated

3376

01:53:57,510 --> 01:53:55,840

but some of them are not um and and if

3377

01:54:00,550 --> 01:53:57,520

if you are unlucky enough to have a

3378

01:54:02,870 --> 01:54:00,560

change that is not tolerated then it it

3379

01:54:04,629 --> 01:54:02,880

affects all of the organs it affects

3380

01:54:05,669 --> 01:54:04,639

both the sexes it affects absolutely

3381

01:54:09,430 --> 01:54:05,679

everything

3382

01:54:10,870 --> 01:54:09,440

um and so so then you then you've got a

3383

01:54:12,550 --> 01:54:10,880

problem

3384

01:54:13,990 --> 01:54:12,560

because it's so fundamental just to the

3385

01:54:15,589 --> 01:54:14,000

process of living

3386

01:54:18,709 --> 01:54:15,599

i believe there's a concept called

3387

01:54:20,229 --> 01:54:18,719

mother's curse which is about okay so

3388

01:54:22,550 --> 01:54:20,239

firstly if you don't mind saying what

3389

01:54:24,550 --> 01:54:22,560

that is and then also why can't we

3390

01:54:26,229 --> 01:54:24,560

follow the same logic of mother's curse

3391

01:54:28,550 --> 01:54:26,239

and say that men should have drastically

3392

01:54:30,870 --> 01:54:28,560

shorter lifespans or be

3393

01:54:32,870 --> 01:54:30,880

far worse off i mean maybe this what may

3394

01:54:35,109 --> 01:54:32,880

be a why question well men do how men do

3395

01:54:37,109 --> 01:54:35,119

have shorter life spans

3396

01:54:39,830 --> 01:54:37,119

um by about five or six years i think on

3397

01:54:41,830 --> 01:54:39,840

average something of that order um so

3398

01:54:44,229 --> 01:54:41,840

mother's curse i i've actually kind of

3399

01:54:46,390 --> 01:54:44,239

already described this in a way

3400

01:54:49,270 --> 01:54:46,400

it's it's basically because

3401
01:54:51,669 --> 01:54:49,280
the mitochondria pass down the female

3402
01:54:53,430 --> 01:54:51,679
line so they're inherited from mother to

3403
01:54:56,229 --> 01:54:53,440
daughter to daughter to daughter and so

3404
01:54:57,830 --> 01:54:56,239
on um

3405
01:54:59,830 --> 01:54:57,840
they become

3406
01:55:00,790 --> 01:54:59,840
any any mutation

3407
01:55:01,910 --> 01:55:00,800
which is

3408
01:55:02,790 --> 01:55:01,920
bad

3409
01:55:05,109 --> 01:55:02,800
for

3410
01:55:06,070 --> 01:55:05,119
the daughter

3411
01:55:09,669 --> 01:55:06,080
would

3412
01:55:12,870 --> 01:55:09,679
um be selected against

3413
01:55:16,149 --> 01:55:12,880

whereas any mutation that is is is fine

3414

01:55:17,830 --> 01:55:16,159

for the daughter but bad for the sun

3415

01:55:19,350 --> 01:55:17,840

is not necessarily going to be selected

3416

01:55:20,870 --> 01:55:19,360

against because the sun's mitochondria

3417

01:55:21,830 --> 01:55:20,880

are not going anywhere they're a dead

3418

01:55:23,669 --> 01:55:21,840

end

3419

01:55:25,350 --> 01:55:23,679

so there's no direct selection there can

3420

01:55:28,070 --> 01:55:25,360

be indirect selection they can be you

3421

01:55:30,149 --> 01:55:28,080

know if all your sons die then they can

3422

01:55:32,310 --> 01:55:30,159

be you know indirect forms of selection

3423

01:55:34,310 --> 01:55:32,320

but there's no direct selection on them

3424

01:55:36,310 --> 01:55:34,320

and so mutations that are effectively if

3425

01:55:38,070 --> 01:55:36,320

there are differences between females

3426

01:55:39,350 --> 01:55:38,080

and males in metabolic requirements and

3427

01:55:41,910 --> 01:55:39,360

there are

3428

01:55:44,790 --> 01:55:41,920

and and the the mitochondria passed down

3429

01:55:47,750 --> 01:55:44,800

the female line only which they do

3430

01:55:50,629 --> 01:55:47,760

and some mutations may be harmless or

3431

01:55:51,910 --> 01:55:50,639

even beneficial to women but detrimental

3432

01:55:53,750 --> 01:55:51,920

to men

3433

01:55:55,189 --> 01:55:53,760

then selection will select for the ones

3434

01:55:57,990 --> 01:55:55,199

which are harmless or detrimental in

3435

01:55:59,270 --> 01:55:58,000

women and the the harmful ones to men

3436

01:56:01,270 --> 01:55:59,280

will tend to accumulate there's no

3437

01:56:02,950 --> 01:56:01,280

mechanism of selecting against no direct

3438

01:56:05,109 --> 01:56:02,960

mechanism of selecting against them so

3439

01:56:06,149 --> 01:56:05,119

that's mother's curse

3440

01:56:07,910 --> 01:56:06,159

and

3441

01:56:09,910 --> 01:56:07,920

you know a lot of mitochondrial diseases

3442

01:56:12,390 --> 01:56:09,920

for example and you know two or three

3443

01:56:13,510 --> 01:56:12,400

times more common in men than in women

3444

01:56:15,910 --> 01:56:13,520

a lot of diseases that have a

3445

01:56:18,310 --> 01:56:15,920

mitochondrial aspect to them like

3446

01:56:20,870 --> 01:56:18,320

parkinson's disease are twice as common

3447

01:56:23,910 --> 01:56:20,880

in in men than in women

3448

01:56:25,589 --> 01:56:23,920

and men age more quickly and and die

3449

01:56:28,070 --> 01:56:25,599

earlier than women and all of these

3450

01:56:29,589 --> 01:56:28,080

things have a mitochondrial component

3451

01:56:32,229 --> 01:56:29,599

and may be linked in some way to

3452

01:56:34,709 --> 01:56:32,239

mother's curse so it's it's real

3453

01:56:37,430 --> 01:56:34,719

but the i i use the word direct

3454

01:56:39,589 --> 01:56:37,440

selection on several occasions

3455

01:56:41,430 --> 01:56:39,599

the the genes in the nucleus can

3456

01:56:44,470 --> 01:56:41,440

compensate

3457

01:56:46,149 --> 01:56:44,480

and so for the most part

3458

01:56:48,470 --> 01:56:46,159

um most most men don't have

3459

01:56:51,589 --> 01:56:48,480

mitochondrial diseases and and men live

3460

01:56:52,790 --> 01:56:51,599

almost as long as women and and so on so

3461

01:56:54,470 --> 01:56:52,800

mostly

3462

01:56:56,870 --> 01:56:54,480

the the fact that we inherit

3463

01:56:59,109 --> 01:56:56,880

mitochondria that could be riddled with

3464

01:57:00,950 --> 01:56:59,119

mutations that are not good for men

3465

01:57:04,310 --> 01:57:00,960

are compensated for by genes in the

3466

01:57:06,950 --> 01:57:04,320

nucleus that are specifically male which

3467

01:57:08,709 --> 01:57:06,960

effectively offset those disadvantages

3468

01:57:10,790 --> 01:57:08,719

and this is where the problem if you if

3469

01:57:12,950 --> 01:57:10,800

you then um

3470

01:57:14,310 --> 01:57:12,960

if you if you then go and

3471

01:57:16,390 --> 01:57:14,320

breed with a completely different

3472

01:57:18,470 --> 01:57:16,400

population that doesn't have those

3473

01:57:20,390 --> 01:57:18,480

compensating genes in the nucleus that's

3474

01:57:22,310 --> 01:57:20,400

where this speciation effect can

3475

01:57:24,470 --> 01:57:22,320

potentially come in

3476

01:57:25,669 --> 01:57:24,480

and these compensating genes in the

3477

01:57:27,750 --> 01:57:25,679

nucleus

3478

01:57:29,510 --> 01:57:27,760

they don't detrimentally affect women

3479

01:57:33,669 --> 01:57:29,520

are they relegated to the y chromosome

3480

01:57:35,510 --> 01:57:33,679

for example um yes i mean there are

3481

01:57:37,510 --> 01:57:35,520

so so there are you know there

3482

01:57:39,270 --> 01:57:37,520

there are differences in what's called

3483

01:57:40,470 --> 01:57:39,280

gene expression between men and women

3484

01:57:43,109 --> 01:57:40,480

which is to say

3485

01:57:44,950 --> 01:57:43,119

um the y chromosome controls it but

3486

01:57:47,430 --> 01:57:44,960

there's only a handful of genes on the y

3487

01:57:49,430 --> 01:57:47,440

chromosome but those genes

3488

01:57:54,790 --> 01:57:49,440

say you you you

3489

01:57:59,350 --> 01:57:57,910

shut down um and so you know it biology

3490

01:58:01,109 --> 01:57:59,360

is not about which genes you have so

3491

01:58:03,189 --> 01:58:01,119

much as which genes are active now and

3492

01:58:04,149 --> 01:58:03,199

on a specific stage of development and

3493

01:58:06,790 --> 01:58:04,159

so on

3494

01:58:08,310 --> 01:58:06,800

um and and so

3495

01:58:09,589 --> 01:58:08,320

there are

3496

01:58:12,550 --> 01:58:09,599

you know that

3497

01:58:13,990 --> 01:58:12,560

in men the the genes which are expressed

3498

01:58:15,270 --> 01:58:14,000

at a certain time

3499

01:58:16,950 --> 01:58:15,280

uh can be

3500

01:58:19,109 --> 01:58:16,960

very different

3501

01:58:20,149 --> 01:58:19,119

yeah geez it's it's staggering

3502

01:58:21,669 --> 01:58:20,159

staggering

3503

01:58:23,430 --> 01:58:21,679

the complexity does your head in there's

3504

01:58:24,870 --> 01:58:23,440

no question yeah

3505

01:58:26,550 --> 01:58:24,880

so okay now let's talk about what's not

3506

01:58:28,310 --> 01:58:26,560

complex well maybe it's complex but i

3507

01:58:30,310 --> 01:58:28,320

haven't made an analogy between the cell

3508

01:58:32,550 --> 01:58:30,320

and the planet because one is charged on

3509

01:58:33,990 --> 01:58:32,560

the inside and okay can you talk about

3510

01:58:35,750 --> 01:58:34,000

that that's interesting and then i

3511

01:58:37,910 --> 01:58:35,760

wondered how far does that analogy go

3512

01:58:39,589 --> 01:58:37,920

does it go to the galaxy i mean

3513

01:58:42,070 --> 01:58:39,599

yes i mean no i don't think it would go

3514

01:58:43,510 --> 01:58:42,080

to the galaxy level but it um and it is

3515

01:58:46,950 --> 01:58:43,520

an analogy

3516

01:58:50,790 --> 01:58:49,030

i mean i i i i think you will be

3517

01:58:52,550 --> 01:58:50,800

unwise to take it too far but it's a

3518

01:58:54,629 --> 01:58:52,560

kind of a beautiful analogy and there's

3519

01:58:55,990 --> 01:58:54,639

definitely some truth in it i mean a

3520

01:58:57,669 --> 01:58:56,000

cell

3521

01:58:59,430 --> 01:58:57,679

is in effect

3522

01:59:02,229 --> 01:58:59,440

this electrical charge on the membrane

3523

01:59:03,109 --> 01:59:02,239

that i keep talking about on the inside

3524

01:59:05,189 --> 01:59:03,119

um

3525

01:59:07,669 --> 01:59:05,199

it's basically saturated in electrons

3526

01:59:10,070 --> 01:59:07,679

we've got organic molecules have taken

3527

01:59:11,830 --> 01:59:10,080

co2 and they've added hydrogen on and

3528

01:59:14,310 --> 01:59:11,840

hydrogen is an electron and a proton

3529

01:59:17,030 --> 01:59:14,320

basically um and so

3530

01:59:18,870 --> 01:59:17,040

and so in in making organic molecules

3531

01:59:20,390 --> 01:59:18,880

we've taken electrons from the outside

3532

01:59:22,629 --> 01:59:20,400

and put them inside

3533

01:59:24,470 --> 01:59:22,639

and so it's it's reduced it's more

3534

01:59:26,629 --> 01:59:24,480

reduced inside than it is outside that's

3535

01:59:27,990 --> 01:59:26,639

the technical term and reduced is one of

3536

01:59:29,030 --> 01:59:28,000

those terms that

3537

01:59:30,790 --> 01:59:29,040

you know

3538

01:59:32,709 --> 01:59:30,800

anybody who's not a chemist backs away

3539

01:59:34,070 --> 01:59:32,719

from him immediately just tries to

3540

01:59:37,430 --> 01:59:34,080

escape from the room

3541

01:59:39,189 --> 01:59:37,440

um so oxidized and reduced but

3542

01:59:41,669 --> 01:59:39,199

in effect there's more electrons inside

3543

01:59:42,790 --> 01:59:41,679

than outside okay and and there's more

3544

01:59:45,510 --> 01:59:42,800

protons

3545

01:59:46,709 --> 01:59:45,520

there's more negative insight yes yeah

3546

01:59:49,189 --> 01:59:46,719

um

3547

01:59:50,149 --> 01:59:49,199

and so is relatively positive outside

3548

01:59:52,470 --> 01:59:50,159

and

3549

01:59:53,910 --> 01:59:52,480

there are protons outside that's partly

3550

01:59:57,030 --> 01:59:53,920

what makes it

3551
01:59:58,709 --> 01:59:57,040
more positive outside and we've got this

3552
02:00:00,310 --> 01:59:58,719
we've got this charge on the membrane

3553
02:00:01,990 --> 02:00:00,320
which is basically the is relatively

3554
02:00:03,910 --> 02:00:02,000
positive outside relatively negative

3555
02:00:05,189 --> 02:00:03,920
inside and the membrane itself is

3556
02:00:07,270 --> 02:00:05,199
extremely thin

3557
02:00:09,510 --> 02:00:07,280
uh and so we have a charge on it now the

3558
02:00:10,310 --> 02:00:09,520
planet is basically the same

3559
02:00:14,070 --> 02:00:10,320
um

3560
02:00:16,310 --> 02:00:14,080
iron raw iron is is is electron dense

3561
02:00:18,790 --> 02:00:16,320
you might say most iron that people are

3562
02:00:21,270 --> 02:00:18,800
from when rus when iron rusts it's

3563
02:00:23,189 --> 02:00:21,280

effectively losing electrons to oxygen

3564

02:00:25,510 --> 02:00:23,199

oxygen stripping those electrons from it

3565

02:00:28,149 --> 02:00:25,520

and you end up with with three positive

3566

02:00:29,910 --> 02:00:28,159

charges on the ion the ion atom itself

3567

02:00:31,830 --> 02:00:29,920

ends up with three positive charges and

3568

02:00:33,830 --> 02:00:31,840

the oxygen gets the electrons and that

3569

02:00:35,830 --> 02:00:33,840

has a negative charge and you know you

3570

02:00:37,510 --> 02:00:35,840

have iron hydroxides and oxides and so

3571

02:00:38,310 --> 02:00:37,520

on and that's what rust is

3572

02:00:39,109 --> 02:00:38,320

um

3573

02:00:40,950 --> 02:00:39,119

now

3574

02:00:42,470 --> 02:00:40,960

the core of the planet is not rusty at

3575

02:00:44,390 --> 02:00:42,480

all there's no oxygen down there it's

3576

02:00:46,870 --> 02:00:44,400

got all these electrons sitting on the

3577

02:00:49,030 --> 02:00:46,880

iron um

3578

02:00:52,229 --> 02:00:49,040

and so it's relatively negative inside

3579

02:00:54,950 --> 02:00:52,239

and the outside the the atmosphere and

3580

02:00:57,189 --> 02:00:54,960

the oceans and so on um

3581

02:00:59,350 --> 02:00:57,199

because the gases that are coming from

3582

02:01:01,189 --> 02:00:59,360

volcanoes and so on are such a high

3583

02:01:03,270 --> 02:01:01,199

temperature they tend to have lost their

3584

02:01:05,430 --> 02:01:03,280

electrons and think you can get you get

3585

02:01:07,189 --> 02:01:05,440

gases like carbon dioxide

3586

02:01:09,750 --> 02:01:07,199

uh coming coming out

3587

02:01:11,830 --> 02:01:09,760

and the sun will also tend to oxidize

3588

02:01:13,910 --> 02:01:11,840

the surface the planet will would tend

3589

02:01:15,589 --> 02:01:13,920

to for example you can the sun would

3590

02:01:18,149 --> 02:01:15,599

split water

3591

02:01:20,390 --> 02:01:18,159

water is h₂o and it can be split in

3592

02:01:22,070 --> 02:01:20,400

effect into hydrogen and oxygen

3593

02:01:23,030 --> 02:01:22,080

and the hydrogen is light enough to

3594

02:01:24,629 --> 02:01:23,040

escape

3595

02:01:26,950 --> 02:01:24,639

uh into space

3596

02:01:29,430 --> 02:01:26,960

and the oxygen will react with rocks

3597

02:01:30,870 --> 02:01:29,440

like iron and and you get rusty rocks

3598

02:01:32,790 --> 02:01:30,880

and this is more or less what happened

3599

02:01:34,629 --> 02:01:32,800

on mars that's why it's the red planet

3600

02:01:36,310 --> 02:01:34,639

the oxygen that was formed from spitting

3601

02:01:38,070 --> 02:01:36,320

water reacted with iron in the rocks

3602

02:01:40,470 --> 02:01:38,080

turning the rusty red color and the

3603

02:01:43,830 --> 02:01:40,480

hydrogen escape to space a lot of the

3604

02:01:44,709 --> 02:01:43,840

oceans were were lost that way on mars

3605

02:01:46,870 --> 02:01:44,719

um

3606

02:01:48,709 --> 02:01:46,880

and so you end up with an with a kind of

3607

02:01:50,790 --> 02:01:48,719

a relatively positive charge in the

3608

02:01:52,870 --> 02:01:50,800

atmosphere and this relatively negative

3609

02:01:55,510 --> 02:01:52,880

charge inside which is basically the

3610

02:01:59,350 --> 02:01:55,520

same structure as a cell

3611

02:02:01,270 --> 02:01:59,360

and just as a cell membrane has

3612

02:02:02,709 --> 02:02:01,280

proteins that sit in it where you have

3613

02:02:04,470 --> 02:02:02,719

movement between the inside and the

3614

02:02:06,629 --> 02:02:04,480

outside hydrothermal vents are the

3615

02:02:08,390 --> 02:02:06,639

equivalent kind of

3616

02:02:09,430 --> 02:02:08,400

conductance between

3617

02:02:11,589 --> 02:02:09,440

between the

3618

02:02:13,910 --> 02:02:11,599

the the negative charge of the interior

3619

02:02:16,149 --> 02:02:13,920

and the positive charge of the exterior

3620

02:02:17,270 --> 02:02:16,159

uh it's you have movement going through

3621

02:02:18,790 --> 02:02:17,280

through vents

3622

02:02:21,510 --> 02:02:18,800

connecting it up

3623

02:02:23,189 --> 02:02:21,520

and within these vents the pores inside

3624

02:02:24,870 --> 02:02:23,199

the vents have got the same structure as

3625

02:02:26,550 --> 02:02:24,880

well they're effectively inside they're

3626

02:02:28,550 --> 02:02:26,560

filled with the material that came from

3627

02:02:30,310 --> 02:02:28,560

inside the earth and the outside they're

3628

02:02:33,270 --> 02:02:30,320

surrounded by the material that came

3629

02:02:35,030 --> 02:02:33,280

from the from the oceans and so again we

3630

02:02:37,350 --> 02:02:35,040

have a negative charge inside positive

3631

02:02:39,430 --> 02:02:37,360

charge outside relative to each other

3632

02:02:41,350 --> 02:02:39,440

it's not that there's an actual charge

3633

02:02:43,270 --> 02:02:41,360

it's just that there's a

3634

02:02:44,470 --> 02:02:43,280

the electrons want to move from here to

3635

02:02:45,589 --> 02:02:44,480

there

3636

02:02:47,750 --> 02:02:45,599

now do you believe this to be a

3637

02:02:50,470 --> 02:02:47,760

coincidence or that life is somehow

3638

02:02:52,070 --> 02:02:50,480

mimicking cellular life is somehow no i

3639

02:02:53,830 --> 02:02:52,080

i don't think it's a coincidence at all

3640

02:02:54,790 --> 02:02:53,840

i think this is exactly how cells work

3641

02:02:55,510 --> 02:02:54,800

and

3642

02:02:57,510 --> 02:02:55,520

that

3643

02:02:59,189 --> 02:02:57,520

what this is doing is there's

3644

02:03:00,790 --> 02:02:59,199

effectively there's an electrical charge

3645

02:03:02,470 --> 02:03:00,800

on the earth between the inside and the

3646

02:03:04,070 --> 02:03:02,480

outside there's an electrical charge and

3647

02:03:05,109 --> 02:03:04,080

the pores in these hydrothermal vents

3648

02:03:06,550 --> 02:03:05,119

between the inside and the outside

3649

02:03:08,310 --> 02:03:06,560

there's electrical charge on cells

3650

02:03:09,669 --> 02:03:08,320

between the inside and the outside

3651
02:03:12,470 --> 02:03:09,679
they're all

3652
02:03:14,870 --> 02:03:12,480
equivalent topology

3653
02:03:16,790 --> 02:03:14,880
because they've all been formed

3654
02:03:18,870 --> 02:03:16,800
from the same process as you might say

3655
02:03:20,390 --> 02:03:18,880
because the hydrothermal vents is where

3656
02:03:22,390 --> 02:03:20,400
there is the mixing zone between the

3657
02:03:24,790 --> 02:03:22,400
inside and the outside so it naturally

3658
02:03:27,669 --> 02:03:24,800
forms pores where we have this the same

3659
02:03:29,510 --> 02:03:27,679
charges forming and those charges

3660
02:03:31,109 --> 02:03:29,520
are more or less necessary to drive the

3661
02:03:32,950 --> 02:03:31,119
reaction between hydrogen and carbon

3662
02:03:35,270 --> 02:03:32,960
dioxide to make the organic molecules

3663
02:03:37,350 --> 02:03:35,280

that make up life at all

3664

02:03:39,030 --> 02:03:37,360

um so

3665

02:03:40,790 --> 02:03:39,040

i find it a beautiful conception it

3666

02:03:43,030 --> 02:03:40,800

doesn't mean it's true but i find it

3667

02:03:43,990 --> 02:03:43,040

beautiful that the the planet has the

3668

02:03:46,709 --> 02:03:44,000

same

3669

02:03:50,070 --> 02:03:46,719

basic topological structure as a cell

3670

02:03:52,070 --> 02:03:50,080

cells emerged from the the the the the

3671

02:03:55,109 --> 02:03:52,080

mixing zone between the inside and the

3672

02:03:58,149 --> 02:03:55,119

outside effectively part of the circuit

3673

02:04:00,390 --> 02:03:58,159

um and and are driving copies of

3674

02:04:02,070 --> 02:04:00,400

themselves by making more miniature

3675

02:04:02,950 --> 02:04:02,080

earths if you like

3676

02:04:03,750 --> 02:04:02,960

um

3677

02:04:06,149 --> 02:04:03,760

by

3678

02:04:08,229 --> 02:04:06,159

reacting the hydrogen from the inside

3679

02:04:09,750 --> 02:04:08,239

with the co2 from the outside to make

3680

02:04:11,430 --> 02:04:09,760

organic molecules it's a it's a

3681

02:04:12,550 --> 02:04:11,440

planetary scale and it's a beautiful

3682

02:04:14,629 --> 02:04:12,560

conception

3683

02:04:17,669 --> 02:04:14,639

something i love about you is firstly

3684

02:04:19,589 --> 02:04:17,679

you write beautifully and secondly you

3685

02:04:21,109 --> 02:04:19,599

are not afraid to ask why and you

3686

02:04:23,189 --> 02:04:21,119

mentioned this that you're the most

3687

02:04:25,109 --> 02:04:23,199

biologists don't like to ask the why

3688

02:04:26,870 --> 02:04:25,119

question perhaps because it teeters too

3689

02:04:28,550 --> 02:04:26,880

much on the religious side and they

3690

02:04:30,709 --> 02:04:28,560

would like to stay away or for whatever

3691

02:04:32,629 --> 02:04:30,719

reason physicists don't like to as well

3692

02:04:35,270 --> 02:04:32,639

there's a famous or an infamous video of

3693

02:04:36,950 --> 02:04:35,280

feynman who is castigating a fairly at

3694

02:04:39,109 --> 02:04:36,960

least in my opinion well-intentioned

3695

02:04:40,629 --> 02:04:39,119

interviewer for asking a why question

3696

02:04:42,629 --> 02:04:40,639

you recall that

3697

02:04:44,470 --> 02:04:42,639

i don't remember that one no i mean i

3698

02:04:46,149 --> 02:04:44,480

love listening to feinman but yes he

3699

02:04:47,750 --> 02:04:46,159

could castigate people

3700

02:04:49,830 --> 02:04:47,760

i thought it was a perfectly reasonable

3701

02:04:52,629 --> 02:04:49,840

question and feynman said yeah but you

3702

02:04:54,070 --> 02:04:52,639

shouldn't ask why because so and so so

3703

02:04:56,310 --> 02:04:54,080

why is it that you

3704

02:04:57,990 --> 02:04:56,320

don't mind asking why and why and and

3705

02:05:00,629 --> 02:04:58,000

simultaneously why do others not like

3706

02:05:06,950 --> 02:05:01,430

i

3707

02:05:08,149 --> 02:05:06,960

and why

3708

02:05:09,830 --> 02:05:08,159

um

3709

02:05:12,709 --> 02:05:09,840

and i think most biochemists are happy

3710

02:05:15,109 --> 02:05:12,719

asking how how does this system work

3711

02:05:16,390 --> 02:05:15,119

um and i can't quite distinguish that

3712

02:05:19,589 --> 02:05:16,400

from

3713

02:05:22,950 --> 02:05:19,599

rather than a different way that's kind

3714

02:05:24,070 --> 02:05:22,960

of almost another way of saying how

3715

02:05:26,070 --> 02:05:24,080

and

3716

02:05:29,189 --> 02:05:26,080

i think

3717

02:05:31,750 --> 02:05:29,199

why is one of the most human questions

3718

02:05:34,629 --> 02:05:31,760

and it's a childlike question

3719

02:05:36,390 --> 02:05:34,639

children always want to know why and and

3720

02:05:38,070 --> 02:05:36,400

i think it's the motivation for many

3721

02:05:40,310 --> 02:05:38,080

people to go into science and one of the

3722

02:05:42,550 --> 02:05:40,320

things about science is it tries to stop

3723

02:05:44,790 --> 02:05:42,560

you from being too naive and tries to

3724

02:05:48,149 --> 02:05:44,800

impose a method on you to

3725

02:05:49,189 --> 02:05:48,159

to be objective and to not ask questions

3726

02:05:51,830 --> 02:05:49,199

that are

3727

02:05:53,510 --> 02:05:51,840

unanswerable in some way to stick to the

3728

02:05:54,470 --> 02:05:53,520

as i mentioned the art of the soluble

3729

02:05:56,629 --> 02:05:54,480

before

3730

02:05:58,390 --> 02:05:56,639

we'll never know why but but we can't

3731

02:05:59,750 --> 02:05:58,400

help asking why and as i say i can't

3732

02:06:03,109 --> 02:05:59,760

tell the difference between why and how

3733

02:06:04,149 --> 02:06:03,119

anyway so um it's very exciting asking

3734

02:06:06,709 --> 02:06:04,159

why

3735

02:06:08,390 --> 02:06:06,719

and um

3736

02:06:11,669 --> 02:06:08,400

and perhaps it's more forgiven in books

3737

02:06:14,070 --> 02:06:11,679

than it is in in in papers and and you

3738

02:06:16,550 --> 02:06:14,080

know the more scientific literature

3739

02:06:17,510 --> 02:06:16,560

books i think are a good place to ask

3740

02:06:18,870 --> 02:06:17,520

why

3741

02:06:20,790 --> 02:06:18,880

um

3742

02:06:22,709 --> 02:06:20,800

and uh and maybe that's why i write

3743

02:06:24,550 --> 02:06:22,719

books in part because it gives me this

3744

02:06:26,229 --> 02:06:24,560

outlet to wonder about things to wonder

3745

02:06:28,070 --> 02:06:26,239

about the world and in the end that is

3746

02:06:31,189 --> 02:06:28,080

what science is it's about

3747

02:06:33,350 --> 02:06:31,199

how do we explain the world which is to

3748

02:06:35,030 --> 02:06:33,360

say why is the world this way when it

3749

02:06:37,189 --> 02:06:35,040

could have been so many other ways i

3750

02:06:38,550 --> 02:06:37,199

think why is it is in fact you know it's

3751

02:06:40,629 --> 02:06:38,560

a question in physics why are the

3752

02:06:42,229 --> 02:06:40,639

cosmological constants that way rather

3753

02:06:44,950 --> 02:06:42,239

than some other way that's the theory of

3754

02:06:46,550 --> 02:06:44,960

everything supposed to explain that um

3755

02:06:47,430 --> 02:06:46,560

it's a why question

3756

02:06:49,030 --> 02:06:47,440

to me

3757

02:06:51,109 --> 02:06:49,040

you could say how did it come to be that

3758

02:06:53,270 --> 02:06:51,119

way

3759

02:06:55,109 --> 02:06:53,280

i see the strengths of science as being

3760

02:06:57,270 --> 02:06:55,119

what you mentioned the focusing on

3761

02:06:58,550 --> 02:06:57,280

what's soluble and then the weakness is

3762

02:06:59,990 --> 02:06:58,560

also that too

3763

02:07:02,149 --> 02:07:00,000

the reason why i say that but i don't

3764

02:07:03,669 --> 02:07:02,159

know how to solve this so i'm just gonna

3765

02:07:06,470 --> 02:07:03,679

pose this as a question

3766

02:07:08,550 --> 02:07:06,480

if one was to go into a phd program but

3767

02:07:10,550 --> 02:07:08,560

produced no papers in four years or

3768

02:07:13,589 --> 02:07:10,560

produced papers with all negative

3769

02:07:17,030 --> 02:07:13,599

results then you would likely not be

3770

02:07:18,709 --> 02:07:17,040

hired and so yes when you're

3771

02:07:19,669 --> 02:07:18,719

a young person when you're at your most

3772

02:07:21,830 --> 02:07:19,679

creative

3773

02:07:23,589 --> 02:07:21,840

you're disincentivized for pursuing wild

3774

02:07:24,950 --> 02:07:23,599

ideas that because most likely they

3775

02:07:26,629 --> 02:07:24,960

won't work but they may also lead to

3776

02:07:28,229 --> 02:07:26,639

breakthroughs

3777

02:07:30,470 --> 02:07:28,239

now there's a bit of a tragedy about

3778

02:07:32,390 --> 02:07:30,480

that it means that we we prioritize

3779

02:07:33,830 --> 02:07:32,400

certain incremental progress yes versus

3780

02:07:37,270 --> 02:07:33,840

these substantial things absolutely

3781

02:07:39,669 --> 02:07:37,280

agree and now you know i i my lab mostly

3782

02:07:41,270 --> 02:07:39,679

works on the origin of life and and uh

3783

02:07:43,270 --> 02:07:41,280

you know i have phd students and

3784

02:07:44,950 --> 02:07:43,280

post-docs and so on and i face this

3785

02:07:46,470 --> 02:07:44,960

problem every day

3786

02:07:49,109 --> 02:07:46,480

um that

3787

02:07:49,990 --> 02:07:49,119

most of the results we get are negative

3788

02:07:51,669 --> 02:07:50,000

um

3789

02:07:53,669 --> 02:07:51,679

what are we going to do

3790

02:07:55,189 --> 02:07:53,679

uh how do i

3791

02:07:57,750 --> 02:07:55,199

you know i don't want my

3792

02:07:59,750 --> 02:07:57,760

students to all fail to publish any

3793

02:08:01,589 --> 02:07:59,760

papers fail to get any positive results

3794

02:08:03,350 --> 02:08:01,599

and finish their careers that's the last

3795

02:08:04,310 --> 02:08:03,360

thing i i want for them

3796

02:08:05,430 --> 02:08:04,320

um

3797

02:08:09,510 --> 02:08:05,440

so

3798

02:08:11,669 --> 02:08:09,520

you've got to you've got to aim for the

3799

02:08:13,430 --> 02:08:11,679

lowest hanging fruit you've got to keep

3800

02:08:16,149 --> 02:08:13,440

the big picture at the back of your mind

3801
02:08:18,310 --> 02:08:16,159
and try to think of experiments that

3802
02:08:19,430 --> 02:08:18,320
that will

3803
02:08:20,830 --> 02:08:19,440
um

3804
02:08:23,030 --> 02:08:20,840
work in one way or

3805
02:08:25,189 --> 02:08:23,040
another um

3806
02:08:27,030 --> 02:08:25,199
and and you've got to not forget about

3807
02:08:28,950 --> 02:08:27,040
the the bigger questions behind it and

3808
02:08:30,790 --> 02:08:28,960
keep on trying them so i think you have

3809
02:08:34,149 --> 02:08:30,800
to move people around

3810
02:08:36,149 --> 02:08:34,159
so that if something starts working

3811
02:08:37,669 --> 02:08:36,159
and one students had two years of

3812
02:08:38,629 --> 02:08:37,679
getting nothing then you've got to give

3813
02:08:39,990 --> 02:08:38,639

them something where they're going to

3814

02:08:42,229 --> 02:08:40,000

get something now

3815

02:08:45,109 --> 02:08:42,239

um that you know

3816

02:08:47,589 --> 02:08:45,119

it's it's difficult and it's difficult

3817

02:08:49,669 --> 02:08:47,599

not because of the scientific question

3818

02:08:51,109 --> 02:08:49,679

so much because the human aspect of

3819

02:08:53,270 --> 02:08:51,119

people's careers that they need to be

3820

02:08:54,870 --> 02:08:53,280

able to come out of it with

3821

02:08:56,470 --> 02:08:54,880

with um

3822

02:08:58,069 --> 02:08:56,480

you know a career ahead of them

3823

02:09:00,709 --> 02:08:58,079

something to look forward to why do you

3824

02:09:03,270 --> 02:09:00,719

think it is that negative results aren't

3825

02:09:05,510 --> 02:09:03,280

seen as worthy as or as worthy as

3826

02:09:07,830 --> 02:09:05,520

positive results because to me just as

3827

02:09:08,950 --> 02:09:07,840

an outsider i see this as data even if

3828

02:09:10,790 --> 02:09:08,960

you were to say so and so it doesn't

3829

02:09:12,870 --> 02:09:10,800

work great now i know so-and-so doesn't

3830

02:09:14,950 --> 02:09:12,880

work there's the replication crisis in

3831

02:09:16,310 --> 02:09:14,960

psychology yes particularly because

3832

02:09:17,990 --> 02:09:16,320

people are incentivized to find

3833

02:09:21,030 --> 02:09:18,000

affirming or new results rather than

3834

02:09:24,550 --> 02:09:22,629

i think it's um

3835

02:09:28,069 --> 02:09:24,560

i mean we've got a

3836

02:09:29,510 --> 02:09:28,079

a paper coming up um

3837

02:09:31,270 --> 02:09:29,520

it's probably going to be under embargo

3838

02:09:33,270 --> 02:09:31,280

but it's actually is out there as a

3839

02:09:36,790 --> 02:09:33,280

pre-print anyway so i'll tell you about

3840

02:09:39,669 --> 02:09:36,800

it anyway exclusive to toe

3841

02:09:42,550 --> 02:09:39,679

uh this is this is about how how atp

3842

02:09:44,950 --> 02:09:42,560

is uh formed now we've found this is

3843

02:09:46,709 --> 02:09:44,960

silvana pinner who did her phd with me

3844

02:09:47,910 --> 02:09:46,719

and she finished a while ago and and

3845

02:09:49,030 --> 02:09:47,920

this is her

3846

02:09:51,430 --> 02:09:49,040

big paper

3847

02:09:52,709 --> 02:09:51,440

from this and what she found was

3848

02:09:54,629 --> 02:09:52,719

actually what she did was was

3849

02:09:56,390 --> 02:09:54,639

effectively repeat some earlier work

3850

02:09:59,510 --> 02:09:56,400

from a japanese group

3851
02:10:00,950 --> 02:09:59,520
um from 20 years ago and they had found

3852
02:10:01,830 --> 02:10:00,960
by chance

3853
02:10:04,950 --> 02:10:01,840
that

3854
02:10:08,629 --> 02:10:04,960
um a corroding iron electrode

3855
02:10:10,550 --> 02:10:08,639
uh when they got adp in solution

3856
02:10:12,149 --> 02:10:10,560
around that electrode i actually formed

3857
02:10:13,910 --> 02:10:12,159
some atp

3858
02:10:15,750 --> 02:10:13,920
and they they looked into it and it

3859
02:10:17,990 --> 02:10:15,760
turned out that ferric iron which is say

3860
02:10:18,790 --> 02:10:18,000
iron with three positive charges on it

3861
02:10:20,470 --> 02:10:18,800
um

3862
02:10:22,870 --> 02:10:20,480
will catalyze

3863
02:10:24,390 --> 02:10:22,880

um the formation this had to be in the

3864

02:10:26,149 --> 02:10:24,400

presence of something called acetyl

3865

02:10:27,270 --> 02:10:26,159

phosphate which is just a two carbon

3866

02:10:29,350 --> 02:10:27,280

compound

3867

02:10:31,750 --> 02:10:29,360

would catalyze the the phosphorylation

3868

02:10:34,390 --> 02:10:31,760

of adp to atp which is what our

3869

02:10:36,149 --> 02:10:34,400

mitochondria are doing all the time

3870

02:10:37,990 --> 02:10:36,159

but instead of having all this molecular

3871

02:10:40,390 --> 02:10:38,000

machinery like the atp synthase it's

3872

02:10:42,310 --> 02:10:40,400

just happening in water with ferric iron

3873

02:10:44,390 --> 02:10:42,320

as the only catalyst so that's pretty

3874

02:10:47,189 --> 02:10:44,400

amazing

3875

02:10:48,950 --> 02:10:47,199

so she repeated this it took a while to

3876

02:10:50,550 --> 02:10:48,960

figure out exactly how they'd done it

3877

02:10:52,629 --> 02:10:50,560

and this is very often the case and for

3878

02:10:54,390 --> 02:10:52,639

a period i remember we were concerned

3879

02:10:57,430 --> 02:10:54,400

that it would not be

3880

02:11:00,310 --> 02:10:57,440

possible to replicate it

3881

02:11:01,189 --> 02:11:00,320

and then she succeeded in replicating it

3882

02:11:03,830 --> 02:11:01,199

um

3883

02:11:04,950 --> 02:11:03,840

and that's i i find that increasingly

3884

02:11:06,870 --> 02:11:04,960

pleasing

3885

02:11:08,629 --> 02:11:06,880

just simply to replicate other people's

3886

02:11:10,629 --> 02:11:08,639

work because of this problem that

3887

02:11:11,589 --> 02:11:10,639

sometimes you know it's sometimes it's

3888

02:11:13,430 --> 02:11:11,599

made up

3889

02:11:17,589 --> 02:11:13,440

sometimes

3890

02:11:19,750 --> 02:11:17,599

but it's for whatever reason there was

3891

02:11:21,030 --> 02:11:19,760

some aspect of chance that allowed it to

3892

02:11:23,030 --> 02:11:21,040

you know

3893

02:11:25,189 --> 02:11:23,040

to be able to replicate science i think

3894

02:11:27,350 --> 02:11:25,199

is the perhaps the single most important

3895

02:11:29,830 --> 02:11:27,360

thing in science and and so it's very

3896

02:11:32,069 --> 02:11:29,840

pleasing when you succeed in doing it

3897

02:11:35,189 --> 02:11:32,079

now she is the probably the single most

3898

02:11:38,229 --> 02:11:35,199

careful uh scientist that i've ever met

3899

02:11:39,750 --> 02:11:38,239

she she really uh is is amazingly

3900

02:11:40,870 --> 02:11:39,760

precise you could never see her error

3901

02:11:41,830 --> 02:11:40,880

bars

3902

02:11:43,990 --> 02:11:41,840

because

3903

02:11:46,870 --> 02:11:44,000

the repeats were so so similar to each

3904

02:11:48,870 --> 02:11:46,880

other this really wasn't one um

3905

02:11:51,270 --> 02:11:48,880

but all her all the rest of her data was

3906

02:11:53,189 --> 02:11:51,280

negative

3907

02:11:54,790 --> 02:11:53,199

which was very interesting she so so he

3908

02:11:57,350 --> 02:11:54,800

worked with ferric iron but she tried

3909

02:11:59,910 --> 02:11:57,360

with about 10 other different metal ions

3910

02:12:01,910 --> 02:11:59,920

and none of the other metal ions worked

3911

02:12:03,589 --> 02:12:01,920

and she tried with about seven or eight

3912

02:12:05,270 --> 02:12:03,599

different phosphorylating agents instead

3913

02:12:07,589 --> 02:12:05,280

of acetyl phosphate and none of those

3914

02:12:09,910 --> 02:12:07,599

worked and she tried with the other

3915

02:12:13,030 --> 02:12:09,920

bases so instead of adp she tried with

3916

02:12:15,589 --> 02:12:13,040

gdp and cdps or the other letters in in

3917

02:12:16,870 --> 02:12:15,599

rna and udp and so on none of those

3918

02:12:18,790 --> 02:12:16,880

worked either

3919

02:12:20,950 --> 02:12:18,800

so this is a paper made up entirely of

3920

02:12:22,470 --> 02:12:20,960

negative data apart from one result

3921

02:12:24,870 --> 02:12:22,480

which had actually been done by someone

3922

02:12:26,790 --> 02:12:24,880

else 20 years earlier and replicated by

3923

02:12:28,550 --> 02:12:26,800

still manner and the

3924

02:12:29,990 --> 02:12:28,560

now this is where negative data really

3925

02:12:30,950 --> 02:12:30,000

comes into its own

3926

02:12:33,510 --> 02:12:30,960

because

3927

02:12:34,629 --> 02:12:33,520

it it basically says there is something

3928

02:12:37,350 --> 02:12:34,639

avored

3929

02:12:39,109 --> 02:12:37,360

about adp compared to the other bases

3930

02:12:40,709 --> 02:12:39,119

and about acetal phosphate compared to

3931

02:12:42,149 --> 02:12:40,719

the other phosphorylating ages and about

3932

02:12:45,189 --> 02:12:42,159

this metal iron compared to those other

3933

02:12:46,950 --> 02:12:45,199

metal ions this is favored chemistry why

3934

02:12:49,030 --> 02:12:46,960

is it favored we could come up with a

3935

02:12:50,629 --> 02:12:49,040

mechanism for it and so on

3936

02:12:52,310 --> 02:12:50,639

but there the negative data is

3937

02:12:54,629 --> 02:12:52,320

effectively saying there's a limited

3938

02:12:55,510 --> 02:12:54,639

number of ways that this will happen

3939

02:12:57,669 --> 02:12:55,520

um

3940

02:12:59,510 --> 02:12:57,679

and and here's one way where it does

3941

02:13:01,350 --> 02:12:59,520

maybe there are other ways that does as

3942

02:13:03,030 --> 02:13:01,360

well and we just look at those some

3943

02:13:05,830 --> 02:13:03,040

other metal iron that was not in our

3944

02:13:08,229 --> 02:13:05,840

panel um you know you can have huge

3945

02:13:09,750 --> 02:13:08,239

combinatorial panels but we looked at

3946

02:13:11,510 --> 02:13:09,760

all the metal ions that seem to have any

3947

02:13:13,669 --> 02:13:11,520

relevance to life or any relevance to

3948

02:13:16,390 --> 02:13:13,679

geochemistry and this ferric ion was the

3949

02:13:17,589 --> 02:13:16,400

only one that worked

3950

02:13:19,510 --> 02:13:17,599

now

3951

02:13:23,350 --> 02:13:19,520

the problem

3952

02:13:25,350 --> 02:13:23,360

is that imagine that ferric iron didn't

3953

02:13:27,669 --> 02:13:25,360

work either then you would have a paper

3954

02:13:29,030 --> 02:13:27,679

where everything was negative

3955

02:13:30,709 --> 02:13:29,040

let's just say that she didn't know

3956

02:13:32,470 --> 02:13:30,719

about that paper and that she never

3957

02:13:33,990 --> 02:13:32,480

tried ferric iron and that she tried all

3958

02:13:35,589 --> 02:13:34,000

the others what she would have had would

3959

02:13:36,550 --> 02:13:35,599

have been a completely negative set of

3960

02:13:37,669 --> 02:13:36,560

data

3961

02:13:40,629 --> 02:13:37,679

which

3962

02:13:43,589 --> 02:13:40,639

would be unpublishable because

3963

02:13:46,149 --> 02:13:43,599

um nothing worked now

3964

02:13:47,510 --> 02:13:46,159

maybe if she tried some other ions

3965

02:13:50,390 --> 02:13:47,520

then it would have worked like ferric

3966

02:13:52,149 --> 02:13:50,400

ion did but if you don't happen to

3967

02:13:54,310 --> 02:13:52,159

choose that one then you'll never know

3968

02:13:56,149 --> 02:13:54,320

and so you can never rule something out

3969

02:13:58,229 --> 02:13:56,159

you can never you know if all your data

3970

02:13:59,589 --> 02:13:58,239

is negative it doesn't mean it can't

3971

02:14:01,830 --> 02:13:59,599

work it just means that everything we

3972

02:14:03,990 --> 02:14:01,840

tried under the conditions that we tried

3973

02:14:05,990 --> 02:14:04,000

it it never did work

3974

02:14:07,750 --> 02:14:06,000

and at that point we decided to pull the

3975

02:14:09,030 --> 02:14:07,760

project because this poor phd student's

3976

02:14:10,629 --> 02:14:09,040

never going to get a paper out of it

3977

02:14:11,990 --> 02:14:10,639

that we we explored it as well as we

3978

02:14:14,550 --> 02:14:12,000

could but the reality is we've got to

3979

02:14:16,310 --> 02:14:14,560

move on and so you've never disproved it

3980

02:14:18,069 --> 02:14:16,320

but you've kind of just given up trying

3981

02:14:19,589 --> 02:14:18,079

to prove it now

3982

02:14:21,589 --> 02:14:19,599

whereas the fact that someone had done

3983

02:14:23,109 --> 02:14:21,599

it before meant that that was the one

3984

02:14:25,030 --> 02:14:23,119

that she tried first which meant that

3985

02:14:26,390 --> 02:14:25,040

when we when the paper comes now we have

3986

02:14:28,149 --> 02:14:26,400

something which is really exciting which

3987

02:14:30,550 --> 02:14:28,159

is to say the reason that atp is the

3988

02:14:32,629 --> 02:14:30,560

universal energy currency is precisely

3989

02:14:34,629 --> 02:14:32,639

that it works as prebiotic chemistry in

3990

02:14:36,149 --> 02:14:34,639

water or by itself just with one metal

3991

02:14:37,510 --> 02:14:36,159

ion as a catalyst and that works and

3992

02:14:40,149 --> 02:14:37,520

nothing else does work and that's why

3993

02:14:41,910 --> 02:14:40,159

it's this way so suddenly you've got a

3994

02:14:44,229 --> 02:14:41,920

very sexy message

3995

02:14:45,750 --> 02:14:44,239

um which in the end is based on the fact

3996

02:14:46,790 --> 02:14:45,760

that someone else had

3997

02:14:48,709 --> 02:14:46,800

found

3998

02:14:50,629 --> 02:14:48,719

out something 20 years ago that was

3999

02:14:52,149 --> 02:14:50,639

really a serendipitous discovery that

4000

02:14:53,910 --> 02:14:52,159

they were not applying to the origin of

4001
02:14:55,430 --> 02:14:53,920
life or anything else it's just you know

4002
02:14:57,750 --> 02:14:55,440
and and science is built this way

4003
02:14:59,990 --> 02:14:57,760
science is built on it's kind of network

4004
02:15:01,669 --> 02:15:00,000
of the efforts of different people doing

4005
02:15:04,149 --> 02:15:01,679
different things for different reasons

4006
02:15:06,470 --> 02:15:04,159
and you try and put it together and

4007
02:15:07,910 --> 02:15:06,480
you've got to you know juggle what works

4008
02:15:09,669 --> 02:15:07,920
what doesn't work when do you give up

4009
02:15:11,430 --> 02:15:09,679
and and very rarely can you ever

4010
02:15:13,830 --> 02:15:11,440
disprove anything formally in a way that

4011
02:15:15,030 --> 02:15:13,840
a physicist would understand disprove

4012
02:15:16,069 --> 02:15:15,040
just you know

4013
02:15:17,669 --> 02:15:16,079

it's

4014

02:15:19,830 --> 02:15:17,679

that's why the positive results are

4015

02:15:21,189 --> 02:15:19,840

important because

4016

02:15:23,270 --> 02:15:21,199

they are

4017

02:15:24,950 --> 02:15:23,280

they give you something to say

4018

02:15:26,390 --> 02:15:24,960

whereas the negative results don't give

4019

02:15:28,229 --> 02:15:26,400

you anything to say they just say

4020

02:15:29,510 --> 02:15:28,239

everything we tried didn't work it's

4021

02:15:30,390 --> 02:15:29,520

possible that something else would have

4022

02:15:31,910 --> 02:15:30,400

worked

4023

02:15:34,229 --> 02:15:31,920

but we don't know because we didn't do

4024

02:15:36,470 --> 02:15:34,239

that so that's not it's not going to

4025

02:15:38,310 --> 02:15:36,480

sell any papers

4026

02:15:39,669 --> 02:15:38,320

i'm not entirely sure about that well

4027

02:15:41,030 --> 02:15:39,679

you would know in your domain but in

4028

02:15:43,510 --> 02:15:41,040

physics there's something called no go

4029

02:15:45,030 --> 02:15:43,520

theorems so for example there's the no

4030

02:15:47,830 --> 02:15:45,040

go theorem which says that you can't

4031

02:15:49,669 --> 02:15:47,840

have a graviton in 4d quantum field

4032

02:15:51,430 --> 02:15:49,679

theory and then that then you're like

4033

02:15:52,629 --> 02:15:51,440

well what's the hope for gravity and

4034

02:15:55,189 --> 02:15:52,639

then that's one of the reasons why

4035

02:15:57,270 --> 02:15:55,199

people think that there's ads cft

4036

02:15:59,270 --> 02:15:57,280

correspondence the holographic principle

4037

02:16:01,350 --> 02:15:59,280

because okay there there was a hidden

4038

02:16:03,189 --> 02:16:01,360

assumption that wasn't stated by whitten

4039

02:16:05,270 --> 02:16:03,199

actually and he's a careful person which

4040

02:16:07,750 --> 02:16:05,280

is that you can't have a graviton in

4041

02:16:09,589 --> 02:16:07,760

your same three plus one quantum field

4042

02:16:11,189 --> 02:16:09,599

theory but you can in a different

4043

02:16:12,550 --> 02:16:11,199

quantum field theory so you can have

4044

02:16:14,390 --> 02:16:12,560

that's why you have this universe within

4045

02:16:15,990 --> 02:16:14,400

another border okay but anyway so a

4046

02:16:17,189 --> 02:16:16,000

negative result can still lead to

4047

02:16:19,750 --> 02:16:17,199

breakthroughs like it leads to hope

4048

02:16:21,750 --> 02:16:19,760

there's ads cft is like almost a whole

4049

02:16:24,149 --> 02:16:21,760

field in and of itself the way that when

4050

02:16:26,629 --> 02:16:24,159

i hear this what i'm wondering is hmm

4051
02:16:28,390 --> 02:16:26,639
why is it not the case that studies in

4052
02:16:30,229 --> 02:16:28,400
different fields

4053
02:16:31,589 --> 02:16:30,239
pre-register i don't know if this is

4054
02:16:32,870 --> 02:16:31,599
forgive me if i'm speaking out well i

4055
02:16:34,870 --> 02:16:32,880
think a lot of clinical trials

4056
02:16:36,549 --> 02:16:34,880
pre-register in that sense so a clinical

4057
02:16:38,709 --> 02:16:36,559
trial that is negative

4058
02:16:40,469 --> 02:16:38,719
and there you're you know there it's

4059
02:16:42,469 --> 02:16:40,479
often funded by a pharmaceutical company

4060
02:16:45,190 --> 02:16:42,479
or something you have some interest in

4061
02:16:47,669 --> 02:16:45,200
not publishing negative data but the the

4062
02:16:48,870 --> 02:16:47,679
regulators or the other you know it's in

4063
02:16:50,709 --> 02:16:48,880

it's in the public interest that it

4064

02:16:52,150 --> 02:16:50,719

should be published and and so this idea

4065

02:16:54,230 --> 02:16:52,160

of pre-registering

4066

02:16:56,309 --> 02:16:54,240

is uh is a good one but the there's a

4067

02:16:58,830 --> 02:16:56,319

there's a kind of a big difference

4068

02:17:01,509 --> 02:16:58,840

the big clinical trials

4069

02:17:03,429 --> 02:17:01,519

um are are

4070

02:17:05,270 --> 02:17:03,439

they're very expensive to set up they're

4071

02:17:07,270 --> 02:17:05,280

very constrained in the way in which

4072

02:17:09,830 --> 02:17:07,280

they're set up they're only

4073

02:17:13,190 --> 02:17:09,840

there there's kind of statistically

4074

02:17:16,309 --> 02:17:14,870

they've been set up so statistically

4075

02:17:18,070 --> 02:17:16,319

they can demonstrate a difference

4076

02:17:19,669 --> 02:17:18,080

between a treatment or a different

4077

02:17:20,629 --> 02:17:19,679

treatment or no treatment or whatever it

4078

02:17:22,870 --> 02:17:20,639

may be

4079

02:17:25,030 --> 02:17:22,880

um so

4080

02:17:26,549 --> 02:17:25,040

so

4081

02:17:28,629 --> 02:17:26,559

they come up with you know they they

4082

02:17:29,910 --> 02:17:28,639

come up with an outcome and and the

4083

02:17:31,990 --> 02:17:29,920

chances are

4084

02:17:33,910 --> 02:17:32,000

it's going to be about as reliable a

4085

02:17:36,389 --> 02:17:33,920

statement as you can make

4086

02:17:38,230 --> 02:17:36,399

um but it's very unwieldy it might take

4087

02:17:41,030 --> 02:17:38,240

five years to do it it might cost 20

4088

02:17:44,309 --> 02:17:41,040

million pounds or something it's where's

4089

02:17:46,389 --> 02:17:44,319

a lot of a lot of smaller scale science

4090

02:17:48,230 --> 02:17:46,399

is much more maneuverable

4091

02:17:51,589 --> 02:17:48,240

you can you know if

4092

02:17:53,110 --> 02:17:51,599

no phd student would ever

4093

02:17:55,030 --> 02:17:53,120

no and i mean there's also this

4094

02:17:56,389 --> 02:17:55,040

competitive side in science as well

4095

02:17:57,750 --> 02:17:56,399

whereas if you told everybody what you

4096

02:17:59,030 --> 02:17:57,760

were doing then they would do it quicker

4097

02:18:01,589 --> 02:17:59,040

than you could so there's the you know

4098

02:18:03,429 --> 02:18:01,599

there's there's some element in which

4099

02:18:05,110 --> 02:18:03,439

uh people don't want to say what they're

4100

02:18:06,629 --> 02:18:05,120

doing necessarily i'm not sure that

4101

02:18:08,309 --> 02:18:06,639

that's a good thing but it is the

4102

02:18:10,309 --> 02:18:08,319

reality

4103

02:18:11,830 --> 02:18:10,319

basically what i was saying what i was

4104

02:18:14,070 --> 02:18:11,840

thinking is that hey the negative

4105

02:18:15,990 --> 02:18:14,080

results themselves maybe there were 30

4106

02:18:18,309 --> 02:18:16,000

other people across

4107

02:18:20,870 --> 02:18:18,319

the history of biology that have tried

4108

02:18:22,790 --> 02:18:20,880

to formulate atp

4109

02:18:24,870 --> 02:18:22,800

using those metals that didn't work but

4110

02:18:26,629 --> 02:18:24,880

sylvana your assistant couldn't sorry

4111

02:18:29,669 --> 02:18:26,639

you're a phd student correct

4112

02:18:31,110 --> 02:18:29,679

yes yes your phd student couldn't

4113

02:18:32,549 --> 02:18:31,120

didn't see the literature because

4114

02:18:34,469 --> 02:18:32,559

everyone else said no and so then she

4115

02:18:35,990 --> 02:18:34,479

wasted her time too and those 29 other

4116

02:18:37,910 --> 02:18:36,000

people wasted their time and i was

4117

02:18:39,669 --> 02:18:37,920

thinking well then if you publish

4118

02:18:41,669 --> 02:18:39,679

negative results does that just bloat

4119

02:18:43,429 --> 02:18:41,679

all the journals or like is there

4120

02:18:45,830 --> 02:18:43,439

another reason to not well i mean the

4121

02:18:48,150 --> 02:18:45,840

journal the journals are already bloated

4122

02:18:49,030 --> 02:18:48,160

i i actually think that

4123

02:18:51,830 --> 02:18:49,040

um

4124

02:18:53,270 --> 02:18:51,840

reading too much of the journals is not

4125

02:18:55,910 --> 02:18:53,280

good for you

4126

02:18:58,070 --> 02:18:55,920

um which is to say

4127

02:18:59,589 --> 02:18:58,080

when when i have new students starting

4128

02:19:02,389 --> 02:18:59,599

very often they're encouraged to do a

4129

02:19:03,830 --> 02:19:02,399

literature review and they'll often get

4130

02:19:05,669 --> 02:19:03,840

bogged down because literature is

4131

02:19:08,230 --> 02:19:05,679

overwhelming there's so much of it out

4132

02:19:09,349 --> 02:19:08,240

there and and it's written in such a way

4133

02:19:11,270 --> 02:19:09,359

as to

4134

02:19:14,469 --> 02:19:11,280

imply that the results that they did

4135

02:19:15,750 --> 02:19:14,479

were decisive in some way um and you'll

4136

02:19:17,110 --> 02:19:15,760

come out with the feeling that

4137

02:19:19,830 --> 02:19:17,120

everything's been done and there's

4138

02:19:21,990 --> 02:19:19,840

really nothing left to do here and

4139

02:19:22,950 --> 02:19:22,000

well i you might as well despair at that

4140

02:19:25,190 --> 02:19:22,960

point

4141

02:19:27,910 --> 02:19:25,200

um so it's actually much more productive

4142

02:19:29,669 --> 02:19:27,920

not to know about any of that to to be

4143

02:19:33,110 --> 02:19:29,679

deliberately ignorant

4144

02:19:34,629 --> 02:19:33,120

and to just blunder around for a while

4145

02:19:36,709 --> 02:19:34,639

until you begin to see something and

4146

02:19:39,030 --> 02:19:36,719

then at that point is the time to access

4147

02:19:41,030 --> 02:19:39,040

the literature so has have other people

4148

02:19:43,429 --> 02:19:41,040

done this before and the answer is often

4149

02:19:44,790 --> 02:19:43,439

yes they have but we did this bit

4150

02:19:46,469 --> 02:19:44,800

different and we did that bit different

4151
02:19:49,670 --> 02:19:46,479
and they did this but we did that and so

4152
02:19:51,030 --> 02:19:49,680
on and so on and so um

4153
02:19:54,230 --> 02:19:51,040
you often end up getting different

4154
02:19:56,950 --> 02:19:54,240
results to what they got and you realize

4155
02:19:58,870 --> 02:19:56,960
that well if we'd just taken for granted

4156
02:20:00,630 --> 02:19:58,880
what they said and didn't do anything we

4157
02:20:01,510 --> 02:20:00,640
would never have found that

4158
02:20:03,670 --> 02:20:01,520
so

4159
02:20:05,750 --> 02:20:03,680
and and and if you find exactly the same

4160
02:20:07,190 --> 02:20:05,760
as them then that's kind of nice to know

4161
02:20:08,630 --> 02:20:07,200
as well and you'll probably try and drop

4162
02:20:10,630 --> 02:20:08,640
it into a paper somewhere just to make

4163
02:20:12,469 --> 02:20:10,640

it clear that this you have successfully

4164

02:20:14,230 --> 02:20:12,479

replicated someone else's work it's

4165

02:20:17,030 --> 02:20:14,240

worth saying that you've done that

4166

02:20:19,110 --> 02:20:17,040

but but very often you know a paper may

4167

02:20:20,389 --> 02:20:19,120

close down an area by saying this is not

4168

02:20:21,830 --> 02:20:20,399

possible and in fact they were wrong

4169

02:20:23,590 --> 02:20:21,840

because they did the wrong experiment

4170

02:20:25,670 --> 02:20:23,600

and there's so many possible experiments

4171

02:20:28,710 --> 02:20:25,680

you can do that so long as you don't

4172

02:20:31,110 --> 02:20:28,720

close yourself down by believing them

4173

02:20:32,550 --> 02:20:31,120

then you'll go on and find something new

4174

02:20:35,030 --> 02:20:32,560

so i

4175

02:20:36,630 --> 02:20:35,040

i would sing the praises of uh of

4176

02:20:38,070 --> 02:20:36,640

blundering around in ignorance in the

4177

02:20:40,469 --> 02:20:38,080

scientific undergrowth because it's the

4178

02:20:41,670 --> 02:20:40,479

way to make progress

4179

02:20:43,510 --> 02:20:41,680

let's wrap i just got to use the

4180

02:20:45,270 --> 02:20:43,520

washroom once more and i would be remiss

4181

02:20:47,670 --> 02:20:45,280

if i didn't ask you carl fristan's

4182

02:20:48,389 --> 02:20:47,680

questions he sent me some to ask you

4183

02:20:49,670 --> 02:20:48,399

uh

4184

02:20:55,190 --> 02:20:49,680

right yeah

4185

02:20:59,190 --> 02:20:56,710

now this question comes from carl

4186

02:21:01,270 --> 02:20:59,200

fristen number one is the increase in

4187

02:21:03,990 --> 02:21:01,280

diversity and complexity of phenotypic

4188

02:21:05,830 --> 02:21:04,000

forms a universal feature of evolution

4189

02:21:08,150 --> 02:21:05,840

and if so

4190

02:21:09,110 --> 02:21:08,160

is there any principled explanation for

4191

02:21:11,030 --> 02:21:09,120

this

4192

02:21:13,590 --> 02:21:11,040

um

4193

02:21:14,630 --> 02:21:13,600

i mean this the simple answer is

4194

02:21:16,630 --> 02:21:14,640

yes

4195

02:21:19,510 --> 02:21:16,640

uh and

4196

02:21:22,309 --> 02:21:19,520

i suppose the reason is simply mutations

4197

02:21:24,309 --> 02:21:22,319

um which leads to diversity

4198

02:21:26,150 --> 02:21:24,319

so

4199

02:21:28,550 --> 02:21:26,160

mutations are almost impossible to i

4200

02:21:30,710 --> 02:21:28,560

mean all of all of evolution is based on

4201
02:21:32,469 --> 02:21:30,720
mutations and they have

4202
02:21:33,349 --> 02:21:32,479
an enormous power

4203
02:21:35,429 --> 02:21:33,359
um

4204
02:21:37,910 --> 02:21:35,439
this the standard

4205
02:21:39,670 --> 02:21:37,920
the standard way of seeing

4206
02:21:41,110 --> 02:21:39,680
natural selection from a population

4207
02:21:42,630 --> 02:21:41,120
genetics point of view so i'm not a

4208
02:21:45,590 --> 02:21:42,640
population geneticist but i'm in the

4209
02:21:47,190 --> 02:21:45,600
department of genetics and uh

4210
02:21:48,790 --> 02:21:47,200
and i work with some population

4211
02:21:51,910 --> 02:21:48,800
geneticists who

4212
02:21:53,590 --> 02:21:51,920
uh you know worked with some of the

4213
02:21:55,910 --> 02:21:53,600

the the founding fathers of the field

4214

02:21:58,469 --> 02:21:55,920

people like jbs haldane and john maynard

4215

02:21:59,990 --> 02:21:58,479

smith and so on um

4216

02:22:03,990 --> 02:22:00,000

and that

4217

02:22:06,070 --> 02:22:04,000

field kind of only lets itself see

4218

02:22:07,670 --> 02:22:06,080

detrimental mutations which is to say

4219

02:22:09,510 --> 02:22:07,680

mutations that are bad for you in one

4220

02:22:10,389 --> 02:22:09,520

way or another now we know that there

4221

02:22:15,030 --> 02:22:10,399

are

4222

02:22:16,230 --> 02:22:15,040

neutral don't make really much of a

4223

02:22:18,070 --> 02:22:16,240

difference

4224

02:22:19,910 --> 02:22:18,080

and there are a few beneficial mutations

4225

02:22:22,469 --> 02:22:19,920

but the ones that are

4226

02:22:24,790 --> 02:22:22,479

effectively bad detrimental

4227

02:22:27,590 --> 02:22:24,800

are are the ones that the field of

4228

02:22:29,670 --> 02:22:27,600

population genetics has historically

4229

02:22:31,990 --> 02:22:29,680

really focused on because they are the

4230

02:22:33,590 --> 02:22:32,000

ones that are most likely to be selected

4231

02:22:35,030 --> 02:22:33,600

against

4232

02:22:37,110 --> 02:22:35,040

so neutral ones will be ignored by

4233

02:22:39,590 --> 02:22:37,120

selection or almost ignored beneficial

4234

02:22:41,910 --> 02:22:39,600

ones are very rare in comparison and and

4235

02:22:44,790 --> 02:22:41,920

detrimental mutations are very common

4236

02:22:46,710 --> 02:22:44,800

um and i find this uh i find this quite

4237

02:22:48,950 --> 02:22:46,720

difficult to get used to because i want

4238

02:22:51,190 --> 02:22:48,960

to think positively about

4239

02:22:51,910 --> 02:22:51,200

about beneficial mutations

4240

02:22:53,590 --> 02:22:51,920

but

4241

02:22:55,429 --> 02:22:53,600

i've become used to thinking in this

4242

02:22:57,750 --> 02:22:55,439

framework and i'm shocked at how much

4243

02:22:59,510 --> 02:22:57,760

power it has so we have a paper out just

4244

02:23:01,750 --> 02:22:59,520

recently with another phd student of

4245

02:23:04,389 --> 02:23:01,760

mine who's a physicist by training uh

4246

02:23:06,630 --> 02:23:04,399

marco colnagi

4247

02:23:08,389 --> 02:23:06,640

and this is asking

4248

02:23:11,110 --> 02:23:08,399

about

4249

02:23:14,070 --> 02:23:11,120

bacteria i mentioned earlier on bacteria

4250

02:23:16,309 --> 02:23:14,080

have this metagenome where they an e

4251
02:23:19,510 --> 02:23:16,319
coli might have 4 000 genes but access

4252
02:23:20,389 --> 02:23:19,520
to 30 000 genes from out there somewhere

4253
02:23:22,150 --> 02:23:20,399
um

4254
02:23:24,150 --> 02:23:22,160
and and they do what's called lateral or

4255
02:23:26,070 --> 02:23:24,160
horizontal gene transfer which is they

4256
02:23:28,150 --> 02:23:26,080
pick up bits of dna from the environment

4257
02:23:30,469 --> 02:23:28,160
and they bind it into themselves

4258
02:23:31,429 --> 02:23:30,479
uh and various people have shown that

4259
02:23:33,429 --> 02:23:31,439
this

4260
02:23:36,230 --> 02:23:33,439
is a little bit equivalent to sex which

4261
02:23:38,790 --> 02:23:36,240
is to say it's doing recombination it's

4262
02:23:41,590 --> 02:23:38,800
changing the gene set that you've got

4263
02:23:43,750 --> 02:23:41,600

and even if on average you pick up genes

4264

02:23:45,349 --> 02:23:43,760

that are worse than the ones you've got

4265

02:23:47,030 --> 02:23:45,359

on average you'll benefit from it

4266

02:23:49,349 --> 02:23:47,040

because you're generating variation that

4267

02:23:52,070 --> 02:23:49,359

selection can act on and if selection

4268

02:23:53,270 --> 02:23:52,080

sees differences between individuals

4269

02:23:54,469 --> 02:23:53,280

then it will

4270

02:23:55,830 --> 02:23:54,479

it will

4271

02:23:57,750 --> 02:23:55,840

select against the ones with the

4272

02:23:58,870 --> 02:23:57,760

detrimental mutations and the ones don't

4273

02:24:00,710 --> 02:23:58,880

have them will

4274

02:24:03,110 --> 02:24:00,720

will flourish and so on

4275

02:24:05,270 --> 02:24:03,120

so basically selection is all about the

4276

02:24:07,270 --> 02:24:05,280

differences between individuals and

4277

02:24:09,110 --> 02:24:07,280

mutations generate differences between

4278

02:24:11,510 --> 02:24:09,120

individuals but moving genes around

4279

02:24:12,870 --> 02:24:11,520

bilateral gene transfer amplifies those

4280

02:24:15,750 --> 02:24:12,880

differences

4281

02:24:17,270 --> 02:24:15,760

and sex is an extraordinary machine for

4282

02:24:18,950 --> 02:24:17,280

generating differences between

4283

02:24:20,389 --> 02:24:18,960

individuals

4284

02:24:22,870 --> 02:24:20,399

and it uses the same machinery that

4285

02:24:24,309 --> 02:24:22,880

bacteria use but it organizes it

4286

02:24:26,070 --> 02:24:24,319

completely different and so there's this

4287

02:24:28,469 --> 02:24:26,080

question why

4288

02:24:31,750 --> 02:24:28,479

and the answer i i think we've we've

4289

02:24:33,590 --> 02:24:31,760

found part of the answer at least um

4290

02:24:35,429 --> 02:24:33,600

i mentioned mitochondria before that

4291

02:24:37,429 --> 02:24:35,439

mitochondria allow you to have a much

4292

02:24:39,270 --> 02:24:37,439

larger genome

4293

02:24:40,870 --> 02:24:39,280

and and having a very large genome gives

4294

02:24:43,510 --> 02:24:40,880

you a problem with preventing it from

4295

02:24:45,670 --> 02:24:43,520

being degraded by mutations

4296

02:24:47,429 --> 02:24:45,680

and the way that bacteria prevent the

4297

02:24:49,349 --> 02:24:47,439

genomes being degraded by mutations is

4298

02:24:52,070 --> 02:24:49,359

picking up bits of dna from around

4299

02:24:53,910 --> 02:24:52,080

around the place and patching it in

4300

02:24:56,150 --> 02:24:53,920

and it works for a bacterial sized

4301
02:24:59,830 --> 02:24:56,160
genome but if you have a much larger

4302
02:25:01,750 --> 02:24:59,840
genome and let's say five times larger

4303
02:25:03,910 --> 02:25:01,760
and you pick up a random bit of dna from

4304
02:25:05,990 --> 02:25:03,920
the environment in effect the chances of

4305
02:25:07,349 --> 02:25:06,000
you getting the right bit is is much

4306
02:25:09,349 --> 02:25:07,359
lower

4307
02:25:11,190 --> 02:25:09,359
and really the only way around it is to

4308
02:25:13,510 --> 02:25:11,200
pick up large chunks

4309
02:25:15,830 --> 02:25:13,520
of dna from the environment and then

4310
02:25:17,590 --> 02:25:15,840
there's a problem that you if if you've

4311
02:25:18,389 --> 02:25:17,600
got any

4312
02:25:20,309 --> 02:25:18,399
any

4313
02:25:21,830 --> 02:25:20,319

sequences that match somewhere else in

4314

02:25:23,429 --> 02:25:21,840

your genome and this is more like the

4315

02:25:25,750 --> 02:25:23,439

larger your genome the more likely to

4316

02:25:27,670 --> 02:25:25,760

have repeat sequence as you are the more

4317

02:25:29,750 --> 02:25:27,680

likely to delete information you are

4318

02:25:31,030 --> 02:25:29,760

when you bring this bit in and throw

4319

02:25:32,230 --> 02:25:31,040

away your bit

4320

02:25:33,910 --> 02:25:32,240

so you end up

4321

02:25:36,389 --> 02:25:33,920

with a system which is

4322

02:25:39,349 --> 02:25:36,399

only set up to

4323

02:25:41,110 --> 02:25:39,359

eliminate detrimental mutations

4324

02:25:43,510 --> 02:25:41,120

can account for

4325

02:25:45,830 --> 02:25:43,520

the transition from bacterial lateral

4326

02:25:47,590 --> 02:25:45,840

gene transfer to what's called meiosis

4327

02:25:49,030 --> 02:25:47,600

and and sex where you like where you

4328

02:25:50,790 --> 02:25:49,040

bring two cells together they fuse

4329

02:25:52,870 --> 02:25:50,800

together they line up the chromosomes

4330

02:25:55,030 --> 02:25:52,880

and so on um

4331

02:25:57,190 --> 02:25:55,040

so the whole the whole thing

4332

02:25:58,950 --> 02:25:57,200

is based on generating differences

4333

02:26:00,950 --> 02:25:58,960

between individuals so that selection

4334

02:26:03,670 --> 02:26:00,960

can act so to come back around in a

4335

02:26:06,389 --> 02:26:03,680

large circle to carl fristan's question

4336

02:26:08,150 --> 02:26:06,399

about divergence between things is

4337

02:26:09,750 --> 02:26:08,160

driven by mutations and it's basically

4338

02:26:12,150 --> 02:26:09,760

inevitable and it will be a property of

4339

02:26:14,389 --> 02:26:12,160

any biological system that's got

4340

02:26:16,389 --> 02:26:14,399

information at the base of it

4341

02:26:18,630 --> 02:26:16,399

all right he has a second question it's

4342

02:26:20,870 --> 02:26:18,640

right carl fristen says what is the role

4343

02:26:23,270 --> 02:26:20,880

of sequestration and isolation in

4344

02:26:25,590 --> 02:26:23,280

evolution at the molecular or cellular

4345

02:26:27,670 --> 02:26:25,600

scale

4346

02:26:30,550 --> 02:26:27,680

sequestration

4347

02:26:32,790 --> 02:26:30,560

um

4348

02:26:35,510 --> 02:26:32,800

so i'm not quite sure what he

4349

02:26:37,110 --> 02:26:35,520

specifically had in mind there

4350

02:26:38,870 --> 02:26:37,120

um

4351
02:26:42,469 --> 02:26:38,880
i just sent him a message once more over

4352
02:26:46,070 --> 02:26:43,670
yeah

4353
02:26:51,429 --> 02:26:48,070
yes i mean what i immediately think of

4354
02:26:54,070 --> 02:26:51,439
uh when when when i read sequestration

4355
02:26:56,550 --> 02:26:54,080
is sequestration within cells which is

4356
02:26:58,150 --> 02:26:56,560
to say you have compartments you

4357
02:27:00,469 --> 02:26:58,160
sequester

4358
02:27:03,190 --> 02:27:00,479
the machinery for respiration within the

4359
02:27:04,309 --> 02:27:03,200
compartment of mitochondria for example

4360
02:27:05,750 --> 02:27:04,319
now i don't know if that's actually what

4361
02:27:08,070 --> 02:27:05,760
he had in mind

4362
02:27:10,550 --> 02:27:08,080
but there's a lovely point about

4363
02:27:12,389 --> 02:27:10,560

bacteria which is that they are

4364

02:27:17,270 --> 02:27:12,399

essentially indivisible

4365

02:27:18,389 --> 02:27:17,280

they don't have any sequestrated bits so

4366

02:27:20,870 --> 02:27:18,399

there isn't

4367

02:27:22,790 --> 02:27:20,880

a compartment which is responsible for

4368

02:27:25,110 --> 02:27:22,800

respiration there isn't a compartment

4369

02:27:27,190 --> 02:27:25,120

which is responsible for you know

4370

02:27:30,389 --> 02:27:27,200

putting the genes in and for protecting

4371

02:27:32,550 --> 02:27:30,399

genes and so on it's a single open

4372

02:27:33,750 --> 02:27:32,560

system with a mem noise well it's not a

4373

02:27:35,030 --> 02:27:33,760

super it's actually got quite a lot of

4374

02:27:37,270 --> 02:27:35,040

structure

4375

02:27:39,590 --> 02:27:37,280

um there's a lot of interest these days

4376

02:27:41,830 --> 02:27:39,600

in phase separations between

4377

02:27:43,830 --> 02:27:41,840

effectively uh liquid liquid phase

4378

02:27:45,830 --> 02:27:43,840

separations and and you know the the

4379

02:27:48,309 --> 02:27:45,840

genes in in a bacterial cell are phase

4380

02:27:50,150 --> 02:27:48,319

separated from the cytosol

4381

02:27:52,550 --> 02:27:50,160

and there's no membrane between the two

4382

02:27:54,550 --> 02:27:52,560

of them so the compartment is

4383

02:27:56,550 --> 02:27:54,560

not a complete compartment in the same

4384

02:27:58,950 --> 02:27:56,560

way whereas the mitochondria have got a

4385

02:28:01,030 --> 02:27:58,960

membrane around them and it sequesters

4386

02:28:04,550 --> 02:28:01,040

the inside of the mitochondria from the

4387

02:28:07,030 --> 02:28:04,560

rest of the cell and that allows you to

4388

02:28:07,830 --> 02:28:07,040

have enormously more power it allows you

4389

02:28:10,070 --> 02:28:07,840

to

4390

02:28:11,750 --> 02:28:10,080

charge up those membranes from the

4391

02:28:14,389 --> 02:28:11,760

inside let me just give one example to

4392

02:28:17,349 --> 02:28:14,399

do with with um

4393

02:28:19,349 --> 02:28:17,359

with sequestration and mitochondria

4394

02:28:21,750 --> 02:28:19,359

um

4395

02:28:24,469 --> 02:28:21,760

when when anybody thinks

4396

02:28:26,710 --> 02:28:24,479

of a mitochondria they'll tend to think

4397

02:28:28,630 --> 02:28:26,720

of a kind of sausage-shaped thing with

4398

02:28:31,270 --> 02:28:28,640

membranes inside the cell and there are

4399

02:28:33,510 --> 02:28:31,280

all these sausage-shaped things in there

4400

02:28:34,230 --> 02:28:33,520

and that's not really how they are at

4401

02:28:37,750 --> 02:28:34,240

all

4402

02:28:39,429 --> 02:28:37,760

they're very dynamic they're moving

4403

02:28:41,429 --> 02:28:39,439

around they fuse together they fission

4404

02:28:43,349 --> 02:28:41,439

apart they separate out but a lot of the

4405

02:28:44,550 --> 02:28:43,359

time they're fused together into a giant

4406

02:28:46,469 --> 02:28:44,560

network

4407

02:28:47,910 --> 02:28:46,479

uh which which kind of fills up the

4408

02:28:51,110 --> 02:28:47,920

volume of the cell

4409

02:28:52,309 --> 02:28:51,120

as a kind of branching network in there

4410

02:28:54,469 --> 02:28:52,319

um

4411

02:28:56,150 --> 02:28:54,479

and you can think of it as power cables

4412

02:28:58,230 --> 02:28:56,160

this is a much more efficient way of

4413

02:28:59,990 --> 02:28:58,240

generating energy because the charge is

4414

02:29:03,030 --> 02:29:00,000

distributed across the entire surface of

4415

02:29:04,710 --> 02:29:03,040

this network um and is much better for

4416

02:29:06,870 --> 02:29:04,720

distributing oxygen

4417

02:29:08,710 --> 02:29:06,880

around because it dissolves better in in

4418

02:29:10,550 --> 02:29:08,720

the fatty membranes than it does

4419

02:29:12,150 --> 02:29:10,560

in in aqueous solution

4420

02:29:14,230 --> 02:29:12,160

um and and so

4421

02:29:15,190 --> 02:29:14,240

it's it's probably the more efficient

4422

02:29:17,190 --> 02:29:15,200

way

4423

02:29:20,550 --> 02:29:17,200

of structuring your network to generate

4424

02:29:22,469 --> 02:29:20,560

power you can give it a power grid

4425

02:29:23,750 --> 02:29:22,479

but if you prevent it from splintering

4426

02:29:24,630 --> 02:29:23,760

up again

4427

02:29:27,990 --> 02:29:24,640

then

4428

02:29:29,670 --> 02:29:28,000

uh the cell would degenerate and die

4429

02:29:31,590 --> 02:29:29,680

it seems that it's important for

4430

02:29:33,990 --> 02:29:31,600

mitochondria to go back to being little

4431

02:29:35,670 --> 02:29:34,000

independent sausage-shaped things and if

4432

02:29:37,670 --> 02:29:35,680

you stop them from doing that then the

4433

02:29:38,550 --> 02:29:37,680

system doesn't work so why

4434

02:29:40,550 --> 02:29:38,560

well

4435

02:29:43,190 --> 02:29:40,560

because with this independent

4436

02:29:45,510 --> 02:29:43,200

sausage-shaped thing you can sequester a

4437

02:29:47,270 --> 02:29:45,520

copy of the mitochondrial dna

4438

02:29:48,870 --> 02:29:47,280

so now what we have

4439

02:29:51,349 --> 02:29:48,880

is a little sausage

4440

02:29:53,910 --> 02:29:51,359

with a genome of its own

4441

02:29:55,990 --> 02:29:53,920

and that genome is responsible for

4442

02:29:58,950 --> 02:29:56,000

making sure respiration works in that

4443

02:30:00,710 --> 02:29:58,960

mitochondrion so it's it it generates an

4444

02:30:02,790 --> 02:30:00,720

electrical charge on the membrane in its

4445

02:30:04,550 --> 02:30:02,800

own little sausage thing

4446

02:30:07,349 --> 02:30:04,560

so now we have a relationship between a

4447

02:30:09,110 --> 02:30:07,359

genotype and a phenotype the genotype is

4448

02:30:10,790 --> 02:30:09,120

that mitochondrial genome the phenotype

4449

02:30:13,110 --> 02:30:10,800

is the membrane potential the electrical

4450

02:30:15,349 --> 02:30:13,120

charge on this membrane and if if this

4451

02:30:17,270 --> 02:30:15,359

mitochondrial dna is damaged it's

4452

02:30:19,750 --> 02:30:17,280

mutated and it can't generate membrane

4453

02:30:22,550 --> 02:30:19,760

potential then the the cell machinery

4454

02:30:25,270 --> 02:30:22,560

can see that and kill it at that point

4455

02:30:26,070 --> 02:30:25,280

so it's a quality control mechanism

4456

02:30:28,309 --> 02:30:26,080

um

4457

02:30:30,710 --> 02:30:28,319

and if you if what you have is an open

4458

02:30:33,110 --> 02:30:30,720

network with let's say you know 500

4459

02:30:35,270 --> 02:30:33,120

copies of mitochondrial dna in there and

4460

02:30:36,469 --> 02:30:35,280

one of them's got mutations selection

4461

02:30:37,590 --> 02:30:36,479

can never see it because it's

4462

02:30:41,429 --> 02:30:37,600

effectively

4463

02:30:43,030 --> 02:30:41,439

its effect is is hidden by the 499 other

4464

02:30:44,630 --> 02:30:43,040

ones that are all contributing to the

4465

02:30:46,230 --> 02:30:44,640

shared common phenotype of the

4466

02:30:48,389 --> 02:30:46,240

electrical charge across this entire

4467

02:30:50,469 --> 02:30:48,399

network so you'll never notice it so you

4468

02:30:51,750 --> 02:30:50,479

can't get rid of it so more mutations

4469

02:30:54,070 --> 02:30:51,760

can happen

4470

02:30:55,830 --> 02:30:54,080

so so the very fact that we all have

4471

02:30:58,070 --> 02:30:55,840

mitochondria which are still functional

4472

02:30:59,349 --> 02:30:58,080

after two billion years of evolution

4473

02:31:01,349 --> 02:30:59,359

is because the selection on the

4474

02:31:03,030 --> 02:31:01,359

mitochondrial dna which is because of

4475

02:31:05,590 --> 02:31:03,040

sequestration

4476

02:31:07,590 --> 02:31:05,600
of the mitochondria within

4477

02:31:09,030 --> 02:31:07,600
the eukaryotic cell and that is the

4478

02:31:10,950 --> 02:31:09,040
difference between

4479

02:31:13,270 --> 02:31:10,960
lots of e coli between a planet full of

4480

02:31:15,910 --> 02:31:13,280
bacteria that basically can never

4481

02:31:18,070 --> 02:31:15,920
get beyond bacteria and the planet full

4482

02:31:19,510 --> 02:31:18,080
of eukaryotic life plants and animals

4483

02:31:22,070 --> 02:31:19,520
and everything else

4484

02:31:25,030 --> 02:31:22,080
that's the result of sequestration of

4485

02:31:26,710 --> 02:31:25,040
bacteria inside other cells with their

4486

02:31:28,389 --> 02:31:26,720
own dna now i don't know if that's what

4487

02:31:30,630 --> 02:31:28,399
he had in mind but that's what comes to

4488

02:31:31,750 --> 02:31:30,640

my mind when when when you asked me

4489

02:31:34,150 --> 02:31:31,760

about that

4490

02:31:37,190 --> 02:31:34,160

sure and now a near final question comes

4491

02:31:39,030 --> 02:31:37,200

from user rh0d3z

4492

02:31:41,190 --> 02:31:39,040

which says this is much more of a

4493

02:31:43,750 --> 02:31:41,200

technical question what are proflain's

4494

02:31:46,710 --> 02:31:43,760

views on mitochondrial resperosomes

4495

02:31:49,030 --> 02:31:46,720

slash supercomplexes in disease this may

4496

02:31:51,510 --> 02:31:49,040

be particularly important seeing that

4497

02:31:53,510 --> 02:31:51,520

they can omit complex ii and bypass

4498

02:31:56,950 --> 02:31:53,520

krebs cycle pathways

4499

02:31:59,590 --> 02:31:56,960

yes um very interesting question there

4500

02:32:00,950 --> 02:31:59,600

are actually some recently there's uh

4501
02:32:03,030 --> 02:32:00,960
there's one super complex has been

4502
02:32:05,510 --> 02:32:03,040
discovered with uh with complex two in

4503
02:32:06,630 --> 02:32:05,520
it uh but mostly

4504
02:32:08,870 --> 02:32:06,640
whoever asked the question is quite

4505
02:32:11,110 --> 02:32:08,880
right complex two is not normally part

4506
02:32:13,349 --> 02:32:11,120
of it um

4507
02:32:16,230 --> 02:32:13,359
so for people who don't know

4508
02:32:17,910 --> 02:32:16,240
um the the super complexes

4509
02:32:20,070 --> 02:32:17,920
normally what you have or normally how

4510
02:32:22,710 --> 02:32:20,080
we're taught and what we imagine is that

4511
02:32:24,950 --> 02:32:22,720
we have four or five complexes from

4512
02:32:26,950 --> 02:32:24,960
complex one complex two complex three

4513
02:32:28,389 --> 02:32:26,960

complex four and the electrons pass from

4514

02:32:30,870 --> 02:32:28,399

one to the next one to the next one and

4515

02:32:33,349 --> 02:32:30,880

so on um complex two is always a little

4516

02:32:35,429 --> 02:32:33,359

bit on the side in that sense

4517

02:32:37,030 --> 02:32:35,439

uh they go from complex one to complex

4518

02:32:38,550 --> 02:32:37,040

three and then to complex four then

4519

02:32:39,590 --> 02:32:38,560

dental oxygen

4520

02:32:41,349 --> 02:32:39,600

um

4521

02:32:43,590 --> 02:32:41,359

now

4522

02:32:44,950 --> 02:32:43,600

the respirosome or the super complexes

4523

02:32:46,389 --> 02:32:44,960

are where these complexes are brought

4524

02:32:48,870 --> 02:32:46,399

together very often with a specific

4525

02:32:51,750 --> 02:32:48,880

stoichiometry so you might have uh two

4526

02:32:53,429 --> 02:32:51,760

complex ones and and one complex three

4527

02:32:54,950 --> 02:32:53,439

and one complex four or various other

4528

02:32:56,790 --> 02:32:54,960

stoichiometries of these things where

4529

02:32:59,429 --> 02:32:56,800

you have fixed numbers of these things

4530

02:33:00,309 --> 02:32:59,439

they fit together in snug ways

4531

02:33:02,710 --> 02:33:00,319

and

4532

02:33:05,349 --> 02:33:02,720

until about ten years ago

4533

02:33:07,349 --> 02:33:05,359

um it was their existence was kind of

4534

02:33:08,870 --> 02:33:07,359

denied almost it was it's quite

4535

02:33:10,950 --> 02:33:08,880

difficult to demonstrate that they

4536

02:33:12,469 --> 02:33:10,960

really do exist that they're really real

4537

02:33:14,710 --> 02:33:12,479

now it's generally established that they

4538

02:33:17,429 --> 02:33:14,720

are and there's a lot of cryo-electron

4539

02:33:18,389 --> 02:33:17,439

microscopy shows that these things are

4540

02:33:19,750 --> 02:33:18,399

real

4541

02:33:21,910 --> 02:33:19,760

um but there's a lot that's still not

4542

02:33:23,750 --> 02:33:21,920

known about them do they really speed up

4543

02:33:25,190 --> 02:33:23,760

respiration for example

4544

02:33:27,670 --> 02:33:25,200

seems that they do

4545

02:33:30,389 --> 02:33:27,680

um but there's you know it's early days

4546

02:33:32,309 --> 02:33:30,399

in in this field now the specific bit

4547

02:33:34,309 --> 02:33:32,319

about complex ii

4548

02:33:36,230 --> 02:33:34,319

as part of the krebs cycle it's the only

4549

02:33:38,790 --> 02:33:36,240

enzyme in the krebs cycle which is

4550

02:33:40,469 --> 02:33:38,800

anchored into the membrane itself

4551
02:33:42,790 --> 02:33:40,479
and which is

4552
02:33:43,990 --> 02:33:42,800
effectively passing electrons directly

4553
02:33:46,830 --> 02:33:44,000
but it's excluded from these

4554
02:33:49,429 --> 02:33:46,840
supercomplexes

4555
02:33:50,790 --> 02:33:49,439
um how that works i

4556
02:33:53,910 --> 02:33:50,800
don't know

4557
02:33:58,550 --> 02:33:57,030
there's a i i think it's

4558
02:34:02,389 --> 02:33:58,560
that i mean there's some very strange

4559
02:34:05,590 --> 02:34:02,399
factors here so so so complex one is the

4560
02:34:07,349 --> 02:34:05,600
only one that that oxidizes nadh and i

4561
02:34:08,710 --> 02:34:07,359
don't want to get too technical here but

4562
02:34:10,389 --> 02:34:08,720
it's the only one which is really

4563
02:34:11,429 --> 02:34:10,399

capable of spinning the whole krebs

4564

02:34:13,590 --> 02:34:11,439

cycle

4565

02:34:15,670 --> 02:34:13,600

so if complex one is is deficient or

4566

02:34:16,710 --> 02:34:15,680

broken then the krebs cycle can't work

4567

02:34:18,309 --> 02:34:16,720

properly

4568

02:34:20,070 --> 02:34:18,319

um

4569

02:34:22,309 --> 02:34:20,080

if it's part of a respirosome it's

4570

02:34:24,230 --> 02:34:22,319

likely to be operating at a faster rate

4571

02:34:25,830 --> 02:34:24,240

and it's likely to spin the krebs cycle

4572

02:34:28,150 --> 02:34:25,840

faster than it would otherwise be able

4573

02:34:29,830 --> 02:34:28,160

to spin but it also depends on the

4574

02:34:31,590 --> 02:34:29,840

structure of the christie and all kinds

4575

02:34:33,910 --> 02:34:31,600

of other factors so there's a kind of

4576
02:34:35,670 --> 02:34:33,920
macromolecular scale of organization of

4577
02:34:37,190 --> 02:34:35,680
mitochondria that we don't know a lot

4578
02:34:39,590 --> 02:34:37,200
about yet

4579
02:34:41,349 --> 02:34:39,600
uh and it's definitely important i

4580
02:34:43,270 --> 02:34:41,359
mentioned fission and fusion of

4581
02:34:45,670 --> 02:34:43,280
mitochondrial networks and you know all

4582
02:34:46,710 --> 02:34:45,680
of this is is linked it's a very dynamic

4583
02:34:48,710 --> 02:34:46,720
system

4584
02:34:51,270 --> 02:34:48,720
uh so

4585
02:34:53,910 --> 02:34:51,280
the interesting thing about complex two

4586
02:34:55,990 --> 02:34:53,920
is it pumps fewer protons

4587
02:34:59,349 --> 02:34:56,000
than complex if you if you if you put

4588
02:35:00,710 --> 02:34:59,359

electrons into complex two

4589

02:35:02,630 --> 02:35:00,720

and then they go into three and then

4590

02:35:04,309 --> 02:35:02,640

four you can pump a total of six protons

4591

02:35:06,070 --> 02:35:04,319

whereas if you put them into complex one

4592

02:35:07,990 --> 02:35:06,080

they can pump a total of ten

4593

02:35:09,110 --> 02:35:08,000

protons so you may think then that

4594

02:35:11,429 --> 02:35:09,120

there's more

4595

02:35:14,070 --> 02:35:11,439

power if you like but it's actually it's

4596

02:35:15,830 --> 02:35:14,080

not power so much as gearing

4597

02:35:18,230 --> 02:35:15,840

so it's like being if you're using

4598

02:35:21,030 --> 02:35:18,240

complex one it's like being in in a high

4599

02:35:22,790 --> 02:35:21,040

gear on a bike you can be in tenth gear

4600

02:35:25,670 --> 02:35:22,800

or something and you you can coast very

4601

02:35:27,190 --> 02:35:25,680

easily along along a flat road but if

4602

02:35:29,349 --> 02:35:27,200

you get onto a hill then you want to go

4603

02:35:31,270 --> 02:35:29,359

down to a lower gear

4604

02:35:32,389 --> 02:35:31,280

and a lower gear in the mitochondria if

4605

02:35:34,469 --> 02:35:32,399

you're putting if you're putting

4606

02:35:36,710 --> 02:35:34,479

electrons into complex two

4607

02:35:38,630 --> 02:35:36,720

effectively uh you've got almost the

4608

02:35:40,950 --> 02:35:38,640

same amount of power which is to say the

4609

02:35:42,230 --> 02:35:40,960

the the the

4610

02:35:43,830 --> 02:35:42,240

energy that's released when the

4611

02:35:45,830 --> 02:35:43,840

electrons that go into complex two get

4612

02:35:47,429 --> 02:35:45,840

through to oxygen is not quite as much

4613

02:35:48,710 --> 02:35:47,439

as when it's coming from nadh but it's

4614

02:35:51,030 --> 02:35:48,720

nearly the same

4615

02:35:52,870 --> 02:35:51,040

but that total energy amount is only

4616

02:35:54,870 --> 02:35:52,880

pumping six protons rather than ten

4617

02:35:56,870 --> 02:35:54,880

protons so you've got nearly the same

4618

02:35:59,190 --> 02:35:56,880

energy pumping fewer protons and that

4619

02:36:00,389 --> 02:35:59,200

means you can pump them against a higher

4620

02:36:02,389 --> 02:36:00,399

potential

4621

02:36:04,550 --> 02:36:02,399

it's you can go uphill now

4622

02:36:05,429 --> 02:36:04,560

you can effectively

4623

02:36:07,590 --> 02:36:05,439

um

4624

02:36:10,550 --> 02:36:07,600

switch down to you know second or third

4625

02:36:12,710 --> 02:36:10,560

gear or something and and keep on going

4626

02:36:14,389 --> 02:36:12,720

now how all of this works itself out in

4627

02:36:16,070 --> 02:36:14,399

terms of super complexes and christy

4628

02:36:18,309 --> 02:36:16,080

structure and everything else i don't

4629

02:36:19,990 --> 02:36:18,319

really know it will have a feedback

4630

02:36:22,070 --> 02:36:20,000

effect on the krebs cycle because the

4631

02:36:23,830 --> 02:36:22,080

krebs cycle needs to go through this

4632

02:36:25,830 --> 02:36:23,840

step if it's not going to

4633

02:36:27,830 --> 02:36:25,840

increase succinate levels which leak out

4634

02:36:31,110 --> 02:36:27,840

and that's an epigenetic switch which

4635

02:36:35,670 --> 02:36:32,150

this is

4636

02:36:37,349 --> 02:36:35,680

it's hardly been

4637

02:36:38,950 --> 02:36:37,359

explored

4638

02:36:40,550 --> 02:36:38,960

i mean this is a fantastic thing about

4639

02:36:41,910 --> 02:36:40,560

science we in some ways we seem to know

4640

02:36:44,150 --> 02:36:41,920

so much and in other ways there's this

4641

02:36:45,990 --> 02:36:44,160

kind of jungle of of dynamic

4642

02:36:47,670 --> 02:36:46,000

mitochondria that are changing shape

4643

02:36:49,349 --> 02:36:47,680

that are forming christie's that have

4644

02:36:51,110 --> 02:36:49,359

got an organization they're probably

4645

02:36:53,670 --> 02:36:51,120

generating electric magnetic fields that

4646

02:36:55,429 --> 02:36:53,680

are forming super complexes that are

4647

02:36:56,630 --> 02:36:55,439

have they you know if you've got a

4648

02:36:58,469 --> 02:36:56,640

closed christie structure and you're

4649

02:37:01,270 --> 02:36:58,479

pumping protons into it

4650

02:37:02,309 --> 02:37:01,280

there's a you know the limits that

4651
02:37:05,590 --> 02:37:02,319
you can

4652
02:37:08,070 --> 02:37:05,600
membrane potential if you put succinate

4653
02:37:11,190 --> 02:37:08,080
in a complex two than if you put an adh

4654
02:37:11,990 --> 02:37:11,200
unit complex one so you have this

4655
02:37:17,590 --> 02:37:12,000
th

4656
02:37:19,270 --> 02:37:17,600
only

4657
02:37:20,790 --> 02:37:19,280
hardly been touched on

4658
02:37:22,550 --> 02:37:20,800
um between one christian and other

4659
02:37:24,469 --> 02:37:22,560
christians if you've got a super complex

4660
02:37:26,469 --> 02:37:24,479
or you don't have super complex as if

4661
02:37:29,030 --> 02:37:26,479
complex two is part of it or not part of

4662
02:37:31,429 --> 02:37:29,040
it you know there's a world out there

4663
02:37:33,670 --> 02:37:31,439

that we've barely discovered and it's a

4664

02:37:34,870 --> 02:37:33,680

world frankly of physics

4665

02:37:38,950 --> 02:37:34,880

this is

4666

02:37:40,389 --> 02:37:38,960

pushing against charge and this the

4667

02:37:41,750 --> 02:37:40,399

power and it's the energetics of the

4668

02:37:43,910 --> 02:37:41,760

whole thing so it's it's not

4669

02:37:47,830 --> 02:37:43,920

conventional biology but this is

4670

02:37:48,710 --> 02:37:47,840

to my mind where biology needs to go

4671

02:37:50,630 --> 02:37:48,720

thank you

4672

02:37:52,710 --> 02:37:50,640

professor and we didn't get to talk

4673

02:37:54,710 --> 02:37:52,720

maybe next time we can talk about if we

4674

02:37:56,389 --> 02:37:54,720

if i'm so blessed just to be with you

4675

02:37:59,349 --> 02:37:56,399

again thank you to talk about the

4676

02:37:59,670 --> 02:37:59,359

reverse krebs cycle and

4677

02:38:00,790 --> 02:37:59,680

it aging

4678

02:38:03,030 --> 02:38:00,800

be a pleasure to come back that was a

4679

02:38:05,349 --> 02:38:03,040

lot of fun thank you yeah do you mind

4680

02:38:07,110 --> 02:38:05,359

ending by reading the poem from the last

4681

02:38:09,590 --> 02:38:07,120

chapter or the last bit of your book i

4682

02:38:11,190 --> 02:38:09,600

believe it's a short poem

4683

02:38:12,870 --> 02:38:11,200

i'm happy to do that do i have a copy of

4684

02:38:15,349 --> 02:38:12,880

the book anywhere near

4685

02:38:16,550 --> 02:38:15,359

um i have to go and get one just give me

4686

02:38:17,910 --> 02:38:16,560

a moment

4687

02:38:19,830 --> 02:38:17,920

i don't know that this will make sense

4688

02:38:21,670 --> 02:38:19,840

to anybody who hasn't read the book but

4689

02:38:22,870 --> 02:38:21,680

it's a it's a it's a beautiful poem

4690

02:38:23,910 --> 02:38:22,880

anyway

4691

02:38:25,670 --> 02:38:23,920

uh

4692

02:38:27,349 --> 02:38:25,680

i don't know how much sense it would

4693

02:38:30,150 --> 02:38:27,359

make

4694

02:38:32,870 --> 02:38:30,160

even without the context of the book yes

4695

02:38:35,349 --> 02:38:32,880

so this is like most revelations by

4696

02:38:38,469 --> 02:38:35,359

richard howard

4697

02:38:41,670 --> 02:38:38,479

it is the movement that incites the form

4698

02:38:43,830 --> 02:38:41,680

discovered as a downward rapture yes it

4699

02:38:46,309 --> 02:38:43,840

is the movement that delights the form

4700

02:38:48,790 --> 02:38:46,319

sustained by its own velocity

4701
02:38:51,349 --> 02:38:48,800
and yet it is the movement that delays

4702
02:38:53,830 --> 02:38:51,359
the form while darkness slows and

4703
02:38:56,630 --> 02:38:53,840
encumbers in fact it is the movement

4704
02:38:59,750 --> 02:38:56,640
that betrays the form baffled in such

4705
02:39:02,150 --> 02:38:59,760
toils of ease until it is the movement

4706
02:39:04,469 --> 02:39:02,160
that deceives the form beguiling our

4707
02:39:07,349 --> 02:39:04,479
attention we suppose it is the movement

4708
02:39:09,030 --> 02:39:07,359
that achieves the form were we mistaken

4709
02:39:11,110 --> 02:39:09,040
what does it matter if it is the

4710
02:39:13,990 --> 02:39:11,120
movement that negates the form

4711
02:39:16,630 --> 02:39:14,000
even though we give give up ourselves to

4712
02:39:21,670 --> 02:39:16,640
this mortal process of continuing

4713
02:39:25,030 --> 02:39:23,670

oh

4714

02:39:27,030 --> 02:39:25,040

well thank you

4715

02:39:28,710 --> 02:39:27,040

thank you professor for being with me

4716

02:39:29,990 --> 02:39:28,720

with the tow audience for

4717

02:39:31,429 --> 02:39:30,000

for so long

4718

02:39:32,630 --> 02:39:31,439

thank you for having me on it's been a

4719

02:39:34,469 --> 02:39:32,640

pleasure

4720

02:39:36,550 --> 02:39:34,479

okay all right thank you thank you for

4721

02:39:38,950 --> 02:39:36,560

sticking around for two and a half hours

4722

02:39:40,950 --> 02:39:38,960

maybe maybe longer i appreciate that i

4723

02:39:43,750 --> 02:39:40,960

hope that it was enjoyable to you again

4724

02:39:45,030 --> 02:39:43,760

there's the website theoriesofthing.org

4725

02:39:47,110 --> 02:39:45,040

that's a place that you can go to

4726
02:39:48,309 --> 02:39:47,120
support toe if you're interested in that

4727
02:39:50,309 --> 02:39:48,319
like i mentioned in the intro there are

4728
02:39:52,630 --> 02:39:50,319
several benefits you get an ads free

4729
02:39:55,590 --> 02:39:52,640
audio version you get that

4730
02:39:57,670 --> 02:39:55,600
sometimes 12 to 48 hours to a few days

4731
02:39:59,190 --> 02:39:57,680
prior to premiering on youtube you get

4732
02:40:01,030 --> 02:39:59,200
discounts to the live events when we

4733
02:40:03,270 --> 02:40:01,040
finally do have them sometimes those

4734
02:40:05,190 --> 02:40:03,280
tickets may even be free so for instance

4735
02:40:07,030 --> 02:40:05,200
i'm looking into doing something with

4736
02:40:09,030 --> 02:40:07,040
john verveiki and ian mcgillcrist in

4737
02:40:10,870 --> 02:40:09,040
person this is all extremely tentative

4738
02:40:13,270 --> 02:40:10,880

right now but this is a plan to do in

4739

02:40:14,790 --> 02:40:13,280

the future carl fristen in london live

4740

02:40:16,630 --> 02:40:14,800

in front of an audience is another

4741

02:40:18,550 --> 02:40:16,640

example there will be exclusive merch

4742

02:40:20,070 --> 02:40:18,560

and so on there's quite a few benefits

4743

02:40:21,590 --> 02:40:20,080

you can text me if you like there's a

4744

02:40:23,990 --> 02:40:21,600

number at least we're testing that for

4745

02:40:25,830 --> 02:40:24,000

about one week or one month or so again

4746

02:40:27,670 --> 02:40:25,840

that's theoriesofthing.org

4747

02:40:29,510 --> 02:40:27,680

thank you all for watching it's great to

4748

02:40:31,670 --> 02:40:29,520

see you in the live chat i appreciate

4749

02:40:34,950 --> 02:40:31,680

all of the love thank you thank you so

4750

02:40:38,630 --> 02:40:36,870

the podcast is now finished if you'd

4751

02:40:39,910 --> 02:40:38,640

like to support conversations like this

4752

02:40:41,510 --> 02:40:39,920

then do consider going to

4753

02:40:43,270 --> 02:40:41,520

theoriesofeverything.org

4754

02:40:44,870 --> 02:40:43,280

it's support from the patrons and from

4755

02:40:46,469 --> 02:40:44,880

the sponsors that allow me to do this