

**THE NEXT
NOBEL PRIZE
WINNER**

**MICHAEL
LEVIN**



1
00:00:05,110 --> 00:00:02,950
today's guest is professor michael levin

2
00:00:07,510 --> 00:00:05,120
a developmental biologist and synthetic

3
00:00:09,589 --> 00:00:07,520
biologist at tufts university in my

4
00:00:11,430 --> 00:00:09,599
opinion his work is worthy of a nobel

5
00:00:13,910 --> 00:00:11,440
prize being the equivalent of

6
00:00:15,990 --> 00:00:13,920
discovering dna as the basis of genetic

7
00:00:17,990 --> 00:00:16,000
memory though instead of a biochemical

8
00:00:19,910 --> 00:00:18,000
code he found a bioelectric one and

9
00:00:22,150 --> 00:00:19,920
instead of genetic memory at the low

10
00:00:24,070 --> 00:00:22,160
level it's large-scale anatomical

11
00:00:25,670 --> 00:00:24,080
structures at the high level click on

12
00:00:27,670 --> 00:00:25,680
the time stamp in the description if

13
00:00:29,830 --> 00:00:27,680

you'd like to skip this intro michael

14

00:00:31,830 --> 00:00:29,840

evans work has direct implications for

15

00:00:34,310 --> 00:00:31,840

cancer research the regeneration of

16

00:00:36,630 --> 00:00:34,320

limbs the possible regeneration of

17

00:00:38,630 --> 00:00:36,640

tissue in general and thus may aid with

18

00:00:40,869 --> 00:00:38,640

alzheimer's research the creation of

19

00:00:42,790 --> 00:00:40,879

engineered life that can scour areas for

20

00:00:45,029 --> 00:00:42,800

toxins and remove them

21

00:00:47,270 --> 00:00:45,039

the creation of an entirely new drug

22

00:00:49,910 --> 00:00:47,280

market based on non-neural bioelectric

23

00:00:51,430 --> 00:00:49,920

manipulation and even recovering traits

24

00:00:53,990 --> 00:00:51,440

that have been in species that have went

25

00:00:55,910 --> 00:00:54,000

extinct millions of years ago that live

26
00:00:57,590 --> 00:00:55,920
in us via mechanisms we're only now

27
00:00:59,189 --> 00:00:57,600
beginning to understand because of

28
00:01:01,990 --> 00:00:59,199
michael and his teams and his

29
00:01:03,990 --> 00:01:02,000
collaborators teams work truly truly

30
00:01:05,990 --> 00:01:04,000
groundbreaking for those new to this

31
00:01:07,350 --> 00:01:06,000
channel my name is kurt jaimungle i'm a

32
00:01:09,510 --> 00:01:07,360
filmmaker with a background in

33
00:01:11,510 --> 00:01:09,520
mathematical physics dedicated to the

34
00:01:13,830 --> 00:01:11,520
explication of what are called theories

35
00:01:15,830 --> 00:01:13,840
of everything from a theoretical physics

36
00:01:17,590 --> 00:01:15,840
perspective but as well as delineating

37
00:01:19,670 --> 00:01:17,600
the possible connection consciousness

38
00:01:21,830 --> 00:01:19,680

has to the fundamental laws of nature

39

00:01:23,350 --> 00:01:21,840

provided these laws exist at all and are

40

00:01:25,749 --> 00:01:23,360

knowable to us

41

00:01:27,910 --> 00:01:25,759

if you enjoy witnessing and or engaging

42

00:01:30,710 --> 00:01:27,920

in real-time conversation with others on

43

00:01:33,830 --> 00:01:30,720

the topics of psychology neurobiology

44

00:01:36,230 --> 00:01:33,840

physics consciousness free will god and

45

00:01:38,149 --> 00:01:36,240

so on then do visit the discord and the

46

00:01:40,149 --> 00:01:38,159

subreddit the links for those are in the

47

00:01:42,149 --> 00:01:40,159

description there's also a link to the

48

00:01:43,990 --> 00:01:42,159

patreon in the description that is

49

00:01:46,230 --> 00:01:44,000

patreon.com

50

00:01:48,149 --> 00:01:46,240

kurt jaimungle as the patrons and the

51
00:01:49,990 --> 00:01:48,159
sponsors are the only reason i'm able to

52
00:01:51,830 --> 00:01:50,000
do this full time it would be near

53
00:01:53,910 --> 00:01:51,840
impossible for me to have conversations

54
00:01:54,789 --> 00:01:53,920
like this with any fidelity with any

55
00:01:56,389 --> 00:01:54,799
depth

56
00:01:58,789 --> 00:01:56,399
on topics like consciousness loop

57
00:02:00,789 --> 00:01:58,799
quantum gravity geometric unity that's

58
00:02:03,590 --> 00:02:00,799
coming up string theory non-neural

59
00:02:06,069 --> 00:02:03,600
bioelectric manipulation and so on if

60
00:02:07,670 --> 00:02:06,079
not for the patrons and the sponsors

61
00:02:10,869 --> 00:02:07,680
thank you and again that link is

62
00:02:13,430 --> 00:02:10,879
patreon.com kurchimongo speaking of

63
00:02:16,070 --> 00:02:13,440

sponsors there are two the first sponsor

64

00:02:18,630 --> 00:02:16,080

is algo algo is an end-to-end supply

65

00:02:20,309 --> 00:02:18,640

chain optimization software company with

66

00:02:22,550 --> 00:02:20,319

software that helps business users

67

00:02:24,790 --> 00:02:22,560

optimize sales and operations planning

68

00:02:26,790 --> 00:02:24,800

to avoid stockouts reduce returns and

69

00:02:29,030 --> 00:02:26,800

inventory write-downs while reducing

70

00:02:31,990 --> 00:02:29,040

inventory investment it's a supply chain

71

00:02:33,910 --> 00:02:32,000

ai that drives smart roi headed by amjad

72

00:02:36,229 --> 00:02:33,920

hussein who's been a huge supporter of

73

00:02:38,630 --> 00:02:36,239

this podcast since near its inception

74

00:02:39,830 --> 00:02:38,640

now omdat has a podcast on ai and

75

00:02:41,670 --> 00:02:39,840

consciousness and if you'd like to

76

00:02:43,030 --> 00:02:41,680

support this channel that is the toe

77

00:02:45,030 --> 00:02:43,040

channel then please visit the

78

00:02:47,430 --> 00:02:45,040

description and support his channel as

79

00:02:49,589 --> 00:02:47,440

doing so supports this indirectly the

80

00:02:51,910 --> 00:02:49,599

second sponsor is brilliant brilliance

81

00:02:53,670 --> 00:02:51,920

illuminates the soul of mathematics

82

00:02:55,270 --> 00:02:53,680

science and engineering through these

83

00:02:57,910 --> 00:02:55,280

bite-sized interactive learning

84

00:02:59,990 --> 00:02:57,920

experiences brilliance courses explore

85

00:03:01,750 --> 00:03:00,000

the laws that shape our world it

86

00:03:04,229 --> 00:03:01,760

elevates math and science from something

87

00:03:06,390 --> 00:03:04,239

to be feared to a delightful experience

88

00:03:07,990 --> 00:03:06,400

of guided discovery you can even learn

89

00:03:09,589 --> 00:03:08,000

group theory which is what's being

90

00:03:12,070 --> 00:03:09,599

referenced when you hear that the

91

00:03:14,869 --> 00:03:12,080

standard model is contingent on u1 cross

92

00:03:16,390 --> 00:03:14,879

su-2 cross su-3 those are technically

93

00:03:19,670 --> 00:03:16,400

called lead groups and those are local

94

00:03:21,990 --> 00:03:19,680

symmetries visit brilliant.org toe that

95

00:03:23,589 --> 00:03:22,000

is t-o-e and i think you'll be greatly

96

00:03:25,589 --> 00:03:23,599

surprised at the ease at which you can

97

00:03:27,910 --> 00:03:25,599

comprehend subjects you had previously

98

00:03:30,470 --> 00:03:27,920

had a difficult time grocking don't stop

99

00:03:32,630 --> 00:03:30,480

before four lessons thank you and enjoy

100

00:03:35,030 --> 00:03:32,640

this non-blessing and wondrously

101
00:03:36,550 --> 00:03:35,040
eye-opening conversation with professor

102
00:03:37,830 --> 00:03:36,560
michael levin

103
00:03:39,670 --> 00:03:37,840
i think what you're doing is nobel

104
00:03:41,910 --> 00:03:39,680
prize-winning work well thank you so

105
00:03:43,509 --> 00:03:41,920
much that's very kind thank you i'm

106
00:03:46,070 --> 00:03:43,519
extremely

107
00:03:48,229 --> 00:03:46,080
very much looking forward to this thank

108
00:03:49,910 --> 00:03:48,239
you when i was researching you about

109
00:03:50,869 --> 00:03:49,920
every 10 minutes or so you would say

110
00:03:53,589 --> 00:03:50,879
this

111
00:03:55,509 --> 00:03:53,599
some offhand comment that would

112
00:03:57,429 --> 00:03:55,519
floor me because of its consequences and

113
00:03:59,350 --> 00:03:57,439

then you'd move on and then you'd say

114

00:04:01,670 --> 00:03:59,360

what trumps what came before and this

115

00:04:03,670 --> 00:04:01,680

happened over and over

116

00:04:06,710 --> 00:04:03,680

so why don't you start with

117

00:04:09,110 --> 00:04:06,720

what non-neural bioelectric states are

118

00:04:10,390 --> 00:04:09,120

their relationship to anatomical results

119

00:04:12,149 --> 00:04:10,400

and then later we can compare and

120

00:04:13,750 --> 00:04:12,159

contrast to standard developmental

121

00:04:15,509 --> 00:04:13,760

biology for decades which is it's the

122

00:04:17,110 --> 00:04:15,519

genome that instructs constructs perhaps

123

00:04:18,870 --> 00:04:17,120

what's epigenetic so we'll start with

124

00:04:20,229 --> 00:04:18,880

what are bioelectric non-neural

125

00:04:22,950 --> 00:04:20,239

bioelectric states and their

126

00:04:25,510 --> 00:04:22,960

relationship to anatomical results

127

00:04:27,590 --> 00:04:25,520

sure uh okay well

128

00:04:30,710 --> 00:04:27,600

so so non-neural bioelectrical states

129

00:04:33,189 --> 00:04:30,720

are simply the fact that all cells in

130

00:04:34,870 --> 00:04:33,199

your body not just neurons have the same

131

00:04:37,270 --> 00:04:34,880

machinery that's normally associated

132

00:04:39,270 --> 00:04:37,280

with neural cells so ion channels

133

00:04:42,550 --> 00:04:39,280

electrical synapses neurotransmitter

134

00:04:45,590 --> 00:04:42,560

pathways all of these things are way

135

00:04:47,749 --> 00:04:45,600

older than nervous systems and all every

136

00:04:49,990 --> 00:04:47,759

cell in your body is creating an

137

00:04:51,909 --> 00:04:50,000

electrical potential across its membrane

138

00:04:53,830 --> 00:04:51,919

most cells in your body are

139

00:04:56,469 --> 00:04:53,840

communicating those states to their

140

00:04:57,270 --> 00:04:56,479

neighbors via these electrical synapses

141

00:05:02,790 --> 00:04:57,280

and

142

00:05:05,110 --> 00:05:02,800

if you ask yourself where did neurons

143

00:05:06,710 --> 00:05:05,120

and brains come from they didn't just

144

00:05:07,749 --> 00:05:06,720

spring up out of nowhere evolution

145

00:05:10,710 --> 00:05:07,759

basically

146

00:05:12,710 --> 00:05:10,720

uh speed optimized processes that were

147

00:05:14,710 --> 00:05:12,720

already here around the time of

148

00:05:15,990 --> 00:05:14,720

bacterial biofilms they're ancient these

149

00:05:17,510 --> 00:05:16,000

things are ancient

150

00:05:18,469 --> 00:05:17,520

and so

151

00:05:24,150 --> 00:05:18,479

uh

152

00:05:25,990 --> 00:05:24,160

the phylogeny of of nervous systems and

153

00:05:27,749 --> 00:05:26,000

neural cells you find out that all cells

154

00:05:29,749 --> 00:05:27,759

have these and in fact we've had

155

00:05:31,990 --> 00:05:29,759

discussions very lengthy discussions on

156

00:05:34,150 --> 00:05:32,000

some of these basal cognition meetings

157

00:05:35,590 --> 00:05:34,160

in terms of what is a neuron you know

158

00:05:37,270 --> 00:05:35,600

people people will say well here are

159

00:05:39,350 --> 00:05:37,280

neurons and i'll and i'll say by the way

160

00:05:41,110 --> 00:05:39,360

what's a neuron and so they'll write on

161

00:05:42,790 --> 00:05:41,120

the board four or five criteria for what

162

00:05:46,390 --> 00:05:42,800

they think is a neuron and then they say

163

00:05:47,749 --> 00:05:46,400

well every cell does this and so uh

164

00:05:49,909 --> 00:05:47,759

there are a couple of there are a couple

165

00:05:53,189 --> 00:05:49,919

of differences but but but most things

166

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

are fairly universal and so then the

167

00:05:58,469 --> 00:05:55,520

question becomes we'll find what are

168

00:06:00,150 --> 00:05:58,479

they used what is this used for so in

169

00:06:02,070 --> 00:06:00,160

the brain what you have is a system

170

00:06:04,629 --> 00:06:02,080

where an electrical network is

171

00:06:06,950 --> 00:06:04,639

processing information to

172

00:06:09,029 --> 00:06:06,960

direct muscles that move your body

173

00:06:10,550 --> 00:06:09,039

through three-dimensional space that's

174

00:06:12,070 --> 00:06:10,560

behavior nervous system control of

175

00:06:13,029 --> 00:06:12,080

behavior

176

00:06:14,950 --> 00:06:13,039

in

177

00:06:17,990 --> 00:06:14,960

prior to that what these systems were

178

00:06:21,029 --> 00:06:18,000

used for were to generate signals that

179

00:06:23,510 --> 00:06:21,039

control cell behavior to move your body

180

00:06:25,430 --> 00:06:23,520

configuration through anatomical space

181

00:06:27,990 --> 00:06:25,440

that is the space of possible anatomical

182

00:06:30,629 --> 00:06:28,000

configurations so i think um and i'm

183

00:06:32,710 --> 00:06:30,639

working on some more stuff on this now

184

00:06:34,469 --> 00:06:32,720

in terms of really broadening this this

185

00:06:36,710 --> 00:06:34,479

idea but but i think what evolution did

186

00:06:40,550 --> 00:06:36,720

was pivot some of the same tricks

187

00:06:44,550 --> 00:06:40,560

across different spaces so electrical

188

00:06:46,870 --> 00:06:44,560

uh electrical networks were used to

189

00:06:48,790 --> 00:06:46,880

control to traverse

190

00:06:51,350 --> 00:06:48,800

first in evolution probably first

191

00:06:53,270 --> 00:06:51,360

metabolic spaces and then physiological

192

00:06:55,430 --> 00:06:53,280

spaces and then transcriptional spaces

193

00:06:57,670 --> 00:06:55,440

and amorphous spaces and eventually

194

00:06:59,350 --> 00:06:57,680

three-dimensional space when mussels

195

00:07:01,029 --> 00:06:59,360

came on the scene and animals could run

196

00:07:03,430 --> 00:07:01,039

around and do things like that

197

00:07:05,350 --> 00:07:03,440

but uh that's that's what electrical

198

00:07:06,629 --> 00:07:05,360

networks used to think about before they

199

00:07:07,830 --> 00:07:06,639

thought about behavior in

200

00:07:09,670 --> 00:07:07,840

three-dimensional space they thought

201
00:07:11,189 --> 00:07:09,680
about navigating other types of space

202
00:07:13,589 --> 00:07:11,199
now how does this compare to the

203
00:07:16,790 --> 00:07:13,599
standard view which is just it's our dna

204
00:07:18,150 --> 00:07:16,800
that programs us the the the the

205
00:07:21,830 --> 00:07:18,160
standard view is correct in the

206
00:07:24,309 --> 00:07:21,840
following sense what the dna specifies

207
00:07:26,710 --> 00:07:24,319
is the structure of the micro hardware

208
00:07:28,070 --> 00:07:26,720
of your cells so the dna gives you the

209
00:07:30,469 --> 00:07:28,080
protein level

210
00:07:32,550 --> 00:07:30,479
uh sequence meaning the the structure of

211
00:07:35,189 --> 00:07:32,560
the proteins that every cell has that's

212
00:07:37,270 --> 00:07:35,199
the hardware so the dna the dna is what

213
00:07:39,110 --> 00:07:37,280

specifies the hardware of the cells now

214

00:07:40,870 --> 00:07:39,120

it turns out that that hardware is

215

00:07:42,710 --> 00:07:40,880

awesome it's it's amazing in the

216

00:07:46,469 --> 00:07:42,720

following way when you put that hardware

217

00:07:48,790 --> 00:07:46,479

together it not only has specific uh

218

00:07:51,270 --> 00:07:48,800

sort of default behaviors but it also

219

00:07:53,510 --> 00:07:51,280

has lo it has computational capacity and

220

00:07:55,110 --> 00:07:53,520

it's reprogrammable that that's that's

221

00:07:58,629 --> 00:07:55,120

so that's actually one of the most

222

00:08:01,670 --> 00:07:58,639

exciting parts about it but uh the the

223

00:08:03,510 --> 00:08:01,680

the the the standard view is that

224

00:08:06,469 --> 00:08:03,520

you should be able to

225

00:08:07,990 --> 00:08:06,479

uh very directly go from what's in the

226

00:08:11,270 --> 00:08:08,000

genome to

227

00:08:13,350 --> 00:08:11,280

the anatomical structures and i i think

228

00:08:15,189 --> 00:08:13,360

what that view is missing is a very

229

00:08:17,350 --> 00:08:15,199

important middle layer that sits between

230

00:08:19,110 --> 00:08:17,360

the hardware and then of the anatomy of

231

00:08:21,350 --> 00:08:19,120

the the hardware of the genome rather

232

00:08:23,589 --> 00:08:21,360

and the final outcome this the santa

233

00:08:25,430 --> 00:08:23,599

these this anatomical homeostasis that

234

00:08:27,430 --> 00:08:25,440

we see in regeneration and development

235

00:08:29,589 --> 00:08:27,440

and so on and that layer is the software

236

00:08:31,909 --> 00:08:29,599

it's the physiological software that

237

00:08:32,870 --> 00:08:31,919

that uh that links those two things

238

00:08:34,630 --> 00:08:32,880

together

239

00:08:36,070 --> 00:08:34,640

can you tell me some of the experiments

240

00:08:37,430 --> 00:08:36,080

that you've done take the audience

241

00:08:38,870 --> 00:08:37,440

through a couple of the experiments so

242

00:08:41,269 --> 00:08:38,880

one you amputate a frog's leg and then

243

00:08:43,829 --> 00:08:41,279

you're able to regenerate it so on and

244

00:08:45,750 --> 00:08:43,839

so on maybe outline three that you find

245

00:08:49,509 --> 00:08:45,760

most flabbergasting

246

00:08:50,550 --> 00:08:49,519

sure sure um okay uh let's see so so so

247

00:08:52,710 --> 00:08:50,560

here's one

248

00:08:54,550 --> 00:08:52,720

if you use a voltage-sensitive

249

00:08:57,190 --> 00:08:54,560

fluorescent dye which basically just

250

00:08:58,710 --> 00:08:57,200

reports you flood your your tissue with

251

00:09:00,710 --> 00:08:58,720

it and it just reports

252

00:09:02,150 --> 00:09:00,720

with with um different types of

253

00:09:04,310 --> 00:09:02,160

fluorescence it reports where the

254

00:09:06,070 --> 00:09:04,320

different voltage values are if you look

255

00:09:08,389 --> 00:09:06,080

at the early embryo as it's putting its

256

00:09:10,070 --> 00:09:08,399

face together for example you will see

257

00:09:11,829 --> 00:09:10,080

something we call the electric face and

258

00:09:14,150 --> 00:09:11,839

this was discovered in work with my

259

00:09:15,509 --> 00:09:14,160

colleague danny adams where

260

00:09:18,470 --> 00:09:15,519

we found this thing called the electric

261

00:09:20,070 --> 00:09:18,480

face which is basically that prior to

262

00:09:21,350 --> 00:09:20,080

all the genes being turned on that are

263

00:09:23,110 --> 00:09:21,360

required to make different face

264

00:09:25,990 --> 00:09:23,120

components and so on and certainly prior

265

00:09:28,389 --> 00:09:26,000

to the anatomy there is a an electrical

266

00:09:29,430 --> 00:09:28,399

pre pattern that you see in that region

267

00:09:31,670 --> 00:09:29,440

that

268

00:09:33,030 --> 00:09:31,680

basically looks like a face you can see

269

00:09:34,310 --> 00:09:33,040

where the eyes are going to be because

270

00:09:35,590 --> 00:09:34,320

that's where the voltage is different

271

00:09:37,030 --> 00:09:35,600

you can see where the mouth is going to

272

00:09:38,550 --> 00:09:37,040

be you can see where the placards on the

273

00:09:40,630 --> 00:09:38,560

side of the head are going to be and so

274

00:09:43,269 --> 00:09:40,640

you see this electrical face and it and

275

00:09:44,870 --> 00:09:43,279

it raised the obvious uh the obvious

276

00:09:46,790 --> 00:09:44,880

question which is that if that pattern

277

00:09:48,710 --> 00:09:46,800

is instructive then you ought to be able

278

00:09:51,269 --> 00:09:48,720

to do two things you ought to be able to

279

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

mess it up and thus disrupt that

280

00:09:55,110 --> 00:09:52,959

electrical pattern and thus get defects

281

00:09:57,030 --> 00:09:55,120

in craniofacial patterning and and

282

00:09:58,630 --> 00:09:57,040

certainly you can do that and in fact

283

00:10:00,790 --> 00:09:58,640

there are even human channelopathies

284

00:10:02,630 --> 00:10:00,800

where humans have mutations and ion

285

00:10:04,389 --> 00:10:02,640

channels that give them craniofacial

286

00:10:06,550 --> 00:10:04,399

birth defects and defects of limb and

287

00:10:08,710 --> 00:10:06,560

brain and other things so that

288

00:10:10,230 --> 00:10:08,720

that so that's that's true but the other

289

00:10:11,350 --> 00:10:10,240

thing the more exciting thing you might

290

00:10:12,630 --> 00:10:11,360

be able to do

291

00:10:14,710 --> 00:10:12,640

is to take some of those electrical

292

00:10:16,630 --> 00:10:14,720

patterns and move them somewhere else

293

00:10:18,470 --> 00:10:16,640

and you could say okay if if this is the

294

00:10:20,150 --> 00:10:18,480

type of pattern that says to the cells

295

00:10:22,389 --> 00:10:20,160

build an eye here

296

00:10:23,829 --> 00:10:22,399

could we move that electrical state to

297

00:10:25,670 --> 00:10:23,839

somewhere else not move the cells but

298

00:10:27,269 --> 00:10:25,680

move the electrical pattern

299

00:10:29,350 --> 00:10:27,279

reintroduce that electrical pattern

300

00:10:31,190 --> 00:10:29,360

somewhere else and and get it to build

301

00:10:32,550 --> 00:10:31,200

an ion so this is actually we we did

302

00:10:36,389 --> 00:10:32,560

this this is some of our some of our

303

00:10:39,269 --> 00:10:36,399

earlier work um you know around uh 2007

304

00:10:41,430 --> 00:10:39,279

or so we we discovered this uh basically

305

00:10:43,269 --> 00:10:41,440

you take one ion channel that's able to

306

00:10:46,150 --> 00:10:43,279

induce a particular electrical pattern

307

00:10:49,110 --> 00:10:46,160

in in the in a region of cells and you

308

00:10:50,389 --> 00:10:49,120

inject rna encoding that ion channel in

309

00:10:51,990 --> 00:10:50,399

some other part of the embryo that's

310

00:10:53,430 --> 00:10:52,000

going to be gut let's say okay it's

311

00:10:54,550 --> 00:10:53,440

going to make endoderms to make gut

312

00:10:57,750 --> 00:10:54,560

cells

313

00:10:58,949 --> 00:10:57,760

and sure enough uh and so and so three

314

00:11:01,030 --> 00:10:58,959

things are significant about what

315

00:11:02,310 --> 00:11:01,040

happens the first is that you get an i

316

00:11:04,310 --> 00:11:02,320

then you get an i in the middle of the

317

00:11:07,590 --> 00:11:04,320

gut you get an eye constructed from

318

00:11:10,230 --> 00:11:07,600

cells that were going to be gut

319

00:11:12,710 --> 00:11:10,240

so this is remarkable because if you

320

00:11:14,710 --> 00:11:12,720

look at the um

321

00:11:16,389 --> 00:11:14,720

developmental biology textbooks what you

322

00:11:18,389 --> 00:11:16,399

will see is that they say that cells

323

00:11:20,550 --> 00:11:18,399

outside of the anterior neuroderm are

324

00:11:21,990 --> 00:11:20,560

not competent to become eyes they're not

325

00:11:23,590 --> 00:11:22,000

supposed to be able to make eyes and

326

00:11:26,550 --> 00:11:23,600

that's true if you use the the

327

00:11:28,630 --> 00:11:26,560

biochemical master eye gene pac-6 if you

328

00:11:30,230 --> 00:11:28,640

if you try to re-induce eyes with pac-6

329

00:11:31,829 --> 00:11:30,240

that's true it doesn't form and it you

330

00:11:33,829 --> 00:11:31,839

can't get ectopic eyes anywhere outside

331

00:11:36,069 --> 00:11:33,839

the head but by introducing this

332

00:11:37,269 --> 00:11:36,079

bioelectric pattern you can and so

333

00:11:39,030 --> 00:11:37,279

that's so that's the first thing that

334

00:11:42,069 --> 00:11:39,040

you you can you can

335

00:11:44,150 --> 00:11:42,079

go beyond the known uh competency limits

336

00:11:45,829 --> 00:11:44,160

by using this very upstream sort of

337

00:11:47,350 --> 00:11:45,839

master regulator this this electrical

338

00:11:49,350 --> 00:11:47,360

pattern the second thing that's

339

00:11:51,829 --> 00:11:49,360

interesting about it is that

340

00:11:53,829 --> 00:11:51,839

the information content that we provide

341

00:11:56,230 --> 00:11:53,839

by putting in this channel is extremely

342

00:11:58,069 --> 00:11:56,240

low we don't micro specify the details

343

00:11:59,829 --> 00:11:58,079

of how to make an eye you know i has a

344

00:12:01,750 --> 00:11:59,839

dozen cell types all arranged in a

345

00:12:03,829 --> 00:12:01,760

particular way we don't know how to do

346

00:12:06,310 --> 00:12:03,839

that we couldn't possibly do you know we

347

00:12:08,629 --> 00:12:06,320

couldn't possibly do that in fact

348

00:12:10,389 --> 00:12:08,639

what what we do instead is provide a

349

00:12:12,870 --> 00:12:10,399

very simple signal

350

00:12:15,269 --> 00:12:12,880

that to a programmer basically looks

351

00:12:17,269 --> 00:12:15,279

like a subroutine call right it's a

352

00:12:18,949 --> 00:12:17,279

trigger it's a trigger for a cascade

353

00:12:20,629 --> 00:12:18,959

that the animal already knows how to do

354

00:12:22,069 --> 00:12:20,639

it already knows how to make eyes we're

355

00:12:23,190 --> 00:12:22,079

not saying how to make an eye what we're

356

00:12:24,949 --> 00:12:23,200

saying is

357

00:12:27,110 --> 00:12:24,959

make an eye here

358

00:12:28,629 --> 00:12:27,120

but by triggering that that eye building

359

00:12:29,670 --> 00:12:28,639

module which includes all the gene

360

00:12:31,910 --> 00:12:29,680

expression everything else that's

361

00:12:34,949 --> 00:12:31,920

downstream so that modularity that that

362

00:12:37,030 --> 00:12:34,959

that incredible um engineering trick

363

00:12:38,389 --> 00:12:37,040

that uh that that says that you can call

364

00:12:40,069 --> 00:12:38,399

up once you know how to do something you

365

00:12:41,350 --> 00:12:40,079

can reuse it

366

00:12:44,389 --> 00:12:41,360

in other places the fact that these

367

00:12:46,790 --> 00:12:44,399

bioelectrical states are triggers of

368

00:12:47,910 --> 00:12:46,800

developmental subroutines okay so that's

369

00:12:49,750 --> 00:12:47,920

that's kind of the second cool thing

370

00:12:53,269 --> 00:12:49,760

about it the third cool thing about it

371

00:12:56,150 --> 00:12:53,279

is that if you label the cells that you

372

00:12:58,230 --> 00:12:56,160

are injecting the channel rna into with

373

00:13:00,550 --> 00:12:58,240

some with us with a color so you can so

374

00:13:01,269 --> 00:13:00,560

you can tell which cells actually got

375

00:13:05,509 --> 00:13:01,279

the

376

00:13:07,430 --> 00:13:05,519

you look at that eye that you've created

377

00:13:09,269 --> 00:13:07,440

what you will see is that often for

378

00:13:12,150 --> 00:13:09,279

example half the eye

379

00:13:13,910 --> 00:13:12,160

will have the channel you put in the

380

00:13:15,590 --> 00:13:13,920

other half the eye doesn't have it that

381

00:13:16,790 --> 00:13:15,600

means that what the cells that you

382

00:13:19,030 --> 00:13:16,800

affected what they did was they

383

00:13:21,030 --> 00:13:19,040

recruited their normal neighbors

384

00:13:22,949 --> 00:13:21,040

right which by themselves were never

385

00:13:24,790 --> 00:13:22,959

modified by you they were completely

386

00:13:26,389 --> 00:13:24,800

wild-type and

387

00:13:28,150 --> 00:13:26,399

and yet they got recruited by their

388

00:13:29,829 --> 00:13:28,160

neighbors to be part of this thing so

389

00:13:32,069 --> 00:13:29,839

there's two levels of instruction here

390

00:13:34,470 --> 00:13:32,079

there's instruction by us saying to a

391

00:13:36,389 --> 00:13:34,480

region you make an eye and then there's

392

00:13:37,590 --> 00:13:36,399

a secondary instruction by those cells

393

00:13:39,030 --> 00:13:37,600

that say oh and by the way i'm going to

394

00:13:40,710 --> 00:13:39,040

need more cells hey you guys over here

395

00:13:42,310 --> 00:13:40,720

you're going to be part of this lens and

396

00:13:44,230 --> 00:13:42,320

they all come and they even the ones

397

00:13:46,949 --> 00:13:44,240

that we never directly affected and so

398

00:13:49,750 --> 00:13:46,959

this third part is cool because

399

00:13:51,990 --> 00:13:49,760

well the the the second part is cool the

400

00:13:53,670 --> 00:13:52,000

the fact that it's it's modular and a

401
00:13:54,629 --> 00:13:53,680
trigger is cool because that means that

402
00:13:57,509 --> 00:13:54,639
you can

403
00:13:59,670 --> 00:13:57,519
achieve regenerative medicine outcomes

404
00:14:02,230 --> 00:13:59,680
things that are way too complex for us

405
00:14:03,670 --> 00:14:02,240
to micromanage by using triggers if we

406
00:14:05,430 --> 00:14:03,680
can identify

407
00:14:07,350 --> 00:14:05,440
the triggers of the subroutines that we

408
00:14:08,230 --> 00:14:07,360
want make an eye make a layer make a

409
00:14:09,829 --> 00:14:08,240
liver

410
00:14:11,350 --> 00:14:09,839
then we can trigger those things long

411
00:14:13,509 --> 00:14:11,360
before we actually know all the details

412
00:14:15,750 --> 00:14:13,519
about how to micromanage it right so

413
00:14:17,110 --> 00:14:15,760

part of part of reverse engineering and

414

00:14:19,030 --> 00:14:17,120

i very much see this as a reverse

415

00:14:21,110 --> 00:14:19,040

engineering task part of reverse

416

00:14:23,110 --> 00:14:21,120

engineering is finding out all the cool

417

00:14:24,790 --> 00:14:23,120

hooks in the system that are already

418

00:14:26,790 --> 00:14:24,800

there for you not that you have to put

419

00:14:28,310 --> 00:14:26,800

them together from scratch but they're

420

00:14:29,990 --> 00:14:28,320

already there for you what is the

421

00:14:31,670 --> 00:14:30,000

trigger that that's the build and i sub

422

00:14:33,590 --> 00:14:31,680

routine what other subroutines are there

423

00:14:35,430 --> 00:14:33,600

right that's that's that's part of our

424

00:14:36,949 --> 00:14:35,440

job the other the thing that's cool

425

00:14:39,269 --> 00:14:36,959

about that third part is that it's

426

00:14:41,350 --> 00:14:39,279

non-cell autonomous meaning

427

00:14:43,189 --> 00:14:41,360

you can exert effects on cells without

428

00:14:44,790 --> 00:14:43,199

touching them directly because cells

429

00:14:45,910 --> 00:14:44,800

communicate to each other so by

430

00:14:47,269 --> 00:14:45,920

convincing

431

00:14:50,470 --> 00:14:47,279

a bunch of cells over here that they

432

00:14:51,990 --> 00:14:50,480

should make an eye you in effect uh

433

00:14:53,910 --> 00:14:52,000

affect a bunch of other cells and cause

434

00:14:55,829 --> 00:14:53,920

them to be part of that eye without

435

00:14:56,949 --> 00:14:55,839

having to touch them directly and that

436

00:14:57,910 --> 00:14:56,959

comes up

437

00:14:59,990 --> 00:14:57,920

sorry that's what you meant when you

438

00:15:02,150 --> 00:15:00,000

were talking about recruiting earlier

439

00:15:03,509 --> 00:15:02,160

exactly exactly right exactly right yeah

440

00:15:05,829 --> 00:15:03,519

so that's so that's kind of the first

441

00:15:07,750 --> 00:15:05,839

that's the first example um that that i

442

00:15:09,990 --> 00:15:07,760

would i would talk about the second

443

00:15:12,230 --> 00:15:10,000

example i would talk about uh has to do

444

00:15:14,069 --> 00:15:12,240

with has to do with cancer and so

445

00:15:16,550 --> 00:15:14,079

michael is it okay if we hold on that

446

00:15:19,110 --> 00:15:16,560

cancer result because what you said was

447

00:15:21,110 --> 00:15:19,120

so profound and i want to unpack it okay

448

00:15:22,470 --> 00:15:21,120

sure sure yeah we'll hold on tell me if

449

00:15:24,829 --> 00:15:22,480

this is broadly correct let's imagine

450

00:15:27,590 --> 00:15:24,839

i'm a frog where the frog is

451
00:15:29,430 --> 00:15:27,600
developing before an eye or a stomach or

452
00:15:31,269 --> 00:15:29,440
a throat or whatever it is is made you

453
00:15:33,189 --> 00:15:31,279
see some ad abrasion some atomization

454
00:15:34,790 --> 00:15:33,199
some electrical atomization like a hint

455
00:15:36,629 --> 00:15:34,800
of it and then what you could do is you

456
00:15:38,230 --> 00:15:36,639
can say well there's some pattern let's

457
00:15:40,310 --> 00:15:38,240
imagine it's a circle to be simplistic

458
00:15:42,949 --> 00:15:40,320
there's some circular voltage gradient

459
00:15:44,629 --> 00:15:42,959
and that means i so what if i induce

460
00:15:46,310 --> 00:15:44,639
that what if i induce a voltage gradient

461
00:15:48,389 --> 00:15:46,320
over here near the heart i know you said

462
00:15:49,829 --> 00:15:48,399
something but whatever over here

463
00:15:51,590 --> 00:15:49,839

then what will happen

464

00:15:53,350 --> 00:15:51,600

is instead ordinarily we would think

465

00:15:55,189 --> 00:15:53,360

well you need to micro tune that eye

466

00:15:56,230 --> 00:15:55,199

each molecule it's extremely difficult

467

00:15:57,990 --> 00:15:56,240

to make an eye we don't actually know

468

00:16:00,310 --> 00:15:58,000

how to from the bottom up molecularly

469

00:16:01,749 --> 00:16:00,320

make an eye but we see this pattern what

470

00:16:04,389 --> 00:16:01,759

if we put that pattern on the heart or

471

00:16:07,030 --> 00:16:04,399

the stomach oh lo and behold some time

472

00:16:09,269 --> 00:16:07,040

amount later then an eye is born is that

473

00:16:11,110 --> 00:16:09,279

correct yeah that's that that's that's

474

00:16:13,189 --> 00:16:11,120

correct and the only thing i would add

475

00:16:15,030 --> 00:16:13,199

to that first of all is that the reason

476

00:16:17,110 --> 00:16:15,040

i was i was telling you about that

477

00:16:18,949 --> 00:16:17,120

electric face pattern is because it's

478

00:16:20,870 --> 00:16:18,959

kind of the most obvious one in the

479

00:16:22,790 --> 00:16:20,880

sense that the electric face pattern

480

00:16:24,389 --> 00:16:22,800

actually looks like a face you can't

481

00:16:26,310 --> 00:16:24,399

miss it it just it just looks like a

482

00:16:28,710 --> 00:16:26,320

face but not all of them are that simple

483

00:16:31,350 --> 00:16:28,720

some of them are really um

484

00:16:33,590 --> 00:16:31,360

kind of uh um

485

00:16:35,350 --> 00:16:33,600

they're encoded more deeply such that by

486

00:16:37,749 --> 00:16:35,360

by staring at it you can't tell what

487

00:16:39,110 --> 00:16:37,759

it's going to be right so so for example

488

00:16:41,590 --> 00:16:39,120

there are there are other patterns that

489

00:16:43,990 --> 00:16:41,600

we've seen where the only way we know

490

00:16:45,670 --> 00:16:44,000

what they are is is by watching what

491

00:16:47,749 --> 00:16:45,680

they make we you couldn't have guessed

492

00:16:49,509 --> 00:16:47,759

you know so some some of them are very

493

00:16:51,590 --> 00:16:49,519

direct almost a paint by numbers you can

494

00:16:53,269 --> 00:16:51,600

sort of see what's going to happen and

495

00:16:54,069 --> 00:16:53,279

others are really complicated and you

496

00:16:56,389 --> 00:16:54,079

need

497

00:16:57,990 --> 00:16:56,399

computational tools to deconvolve what

498

00:16:59,990 --> 00:16:58,000

you're looking at to figure out what

499

00:17:01,990 --> 00:17:00,000

it's going to be so so not all of them

500

00:17:04,150 --> 00:17:02,000

are as obvious as as the electric face

501
00:17:05,669 --> 00:17:04,160
pattern right yeah one of the questions

502
00:17:07,750 --> 00:17:05,679
i had was why hasn't this been found out

503
00:17:09,750 --> 00:17:07,760
before was there a technological limit

504
00:17:11,590 --> 00:17:09,760
or did they just not look at cells with

505
00:17:13,350 --> 00:17:11,600
the dye that give an indication of

506
00:17:15,189 --> 00:17:13,360
voltage gradients or optogenetic

507
00:17:15,990 --> 00:17:15,199
technologies and so on yeah so so that

508
00:17:19,590 --> 00:17:16,000
so

509
00:17:21,829 --> 00:17:19,600
why why not before i mean on the one

510
00:17:23,350 --> 00:17:21,839
hand everything has to have a beginning

511
00:17:24,870 --> 00:17:23,360
at some point right so so whenever it

512
00:17:26,390 --> 00:17:24,880
was it would have you know you could

513
00:17:27,990 --> 00:17:26,400

have asked well like why not before

514

00:17:29,430 --> 00:17:28,000

right but hindsight is always obvious

515

00:17:31,029 --> 00:17:29,440

you can always you can always say but

516

00:17:33,750 --> 00:17:31,039

but let's but let's kind of dig into

517

00:17:36,070 --> 00:17:33,760

that um on the one hand there was a

518

00:17:38,549 --> 00:17:36,080

conceptual uh

519

00:17:40,310 --> 00:17:38,559

leap that kept this pretty much under i

520

00:17:42,390 --> 00:17:40,320

mean let's be clear i am not the first

521

00:17:44,310 --> 00:17:42,400

person to talk about the importance of

522

00:17:46,870 --> 00:17:44,320

bioelectric signals people have been

523

00:17:50,310 --> 00:17:46,880

studying endogenous by electricity since

524

00:17:52,150 --> 00:17:50,320

before 1900 so so it certainly has

525

00:17:53,510 --> 00:17:52,160

occurred to people that maybe electrical

526

00:17:54,870 --> 00:17:53,520

signals are important in development

527

00:17:57,350 --> 00:17:54,880

regeneration

528

00:17:59,190 --> 00:17:57,360

all of my work i was i was incredibly

529

00:18:00,870 --> 00:17:59,200

heavily inspired

530

00:18:03,110 --> 00:18:00,880

by by work that was done in this in the

531

00:18:04,789 --> 00:18:03,120

60s 70s and 80s by a bunch of people

532

00:18:07,110 --> 00:18:04,799

that worked really hard on this stuff

533

00:18:10,230 --> 00:18:07,120

the reason that it hadn't gone far

534

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

enough was to two reasons number one

535

00:18:13,510 --> 00:18:12,080

the tools weren't there so these dyes

536

00:18:15,270 --> 00:18:13,520

didn't exist all they had was

537

00:18:17,029 --> 00:18:15,280

traditional electrophysiology in

538

00:18:18,950 --> 00:18:17,039

traditional electrophysiology you have

539

00:18:20,549 --> 00:18:18,960

one electrode and you're poking it into

540

00:18:21,830 --> 00:18:20,559

cells and if you want to have a picture

541

00:18:23,830 --> 00:18:21,840

of what's going on you got to poke all

542

00:18:25,830 --> 00:18:23,840

the cells and that's just completely

543

00:18:28,870 --> 00:18:25,840

impractical right these dyes didn't

544

00:18:31,590 --> 00:18:28,880

exist the conceptual thing was that

545

00:18:34,150 --> 00:18:31,600

um around the time that this stuff was

546

00:18:36,390 --> 00:18:34,160

was taking off using using electrodes

547

00:18:38,789 --> 00:18:36,400

and things like that uh biochemistry and

548

00:18:40,870 --> 00:18:38,799

molecular biology took off and the thing

549

00:18:42,870 --> 00:18:40,880

that the reason molecular biology drew

550

00:18:45,270 --> 00:18:42,880

all the attention is because you could

551
00:18:47,110 --> 00:18:45,280
do molecular biology and biochemistry in

552
00:18:49,110 --> 00:18:47,120
dead fixed tissue

553
00:18:51,190 --> 00:18:49,120
so you can you can kill and fix your

554
00:18:52,870 --> 00:18:51,200
cells and you can sequence the dna you

555
00:18:55,750 --> 00:18:52,880
can sequence the rna you can get a

556
00:18:57,190 --> 00:18:55,760
proteome you can get a uh you know all

557
00:18:58,230 --> 00:18:57,200
of these all of these kinds of things

558
00:18:59,430 --> 00:18:58,240
you can do

559
00:19:01,430 --> 00:18:59,440
none of that is possible with

560
00:19:03,350 --> 00:19:01,440
bioelectrics so the minute your cell is

561
00:19:05,270 --> 00:19:03,360
dead all of it goes away

562
00:19:07,590 --> 00:19:05,280
so none of the typical omics approaches

563
00:19:09,909 --> 00:19:07,600

work so it's it's it's uh it's it's that

564

00:19:11,590 --> 00:19:09,919

much harder and so it really lagged

565

00:19:13,669 --> 00:19:11,600

behind because all the interest went

566

00:19:16,230 --> 00:19:13,679

into the molecular uh you know kind of

567

00:19:18,630 --> 00:19:16,240

molecular biochemistry and uh and it had

568

00:19:20,789 --> 00:19:18,640

to wait for some of these tools to to

569

00:19:22,310 --> 00:19:20,799

come up the third thing the third thing

570

00:19:23,350 --> 00:19:22,320

is is that

571

00:19:24,549 --> 00:19:23,360

i think

572

00:19:29,190 --> 00:19:24,559

while

573

00:19:31,029 --> 00:19:29,200

think about uh the importance of these

574

00:19:33,510 --> 00:19:31,039

bioelectric gradients

575

00:19:35,590 --> 00:19:33,520

nobody to my knowledge uh

576

00:19:36,470 --> 00:19:35,600

before we did it really thought about it

577

00:19:39,430 --> 00:19:36,480

as

578

00:19:41,590 --> 00:19:39,440

the beginnings of the nervous system and

579

00:19:43,590 --> 00:19:41,600

to really put that computational spin on

580

00:19:45,669 --> 00:19:43,600

it the fact that this thing really is

581

00:19:48,070 --> 00:19:45,679

liking neural network doing computations

582

00:19:51,270 --> 00:19:48,080

about development i i think that's new i

583

00:19:54,549 --> 00:19:51,280

i will say um harold burr who was this

584

00:19:57,750 --> 00:19:54,559

guy was working in the 30s 1930s 40s and

585

00:19:59,669 --> 00:19:57,760

50s okay he had one of the first good

586

00:20:02,390 --> 00:19:59,679

volt meters around and he went around

587

00:20:04,789 --> 00:20:02,400

measuring things you know elm trees and

588

00:20:07,270 --> 00:20:04,799

rabbits and tumors and embryos and all

589

00:20:09,990 --> 00:20:07,280

kinds of stuff on the basis of this he

590

00:20:13,029 --> 00:20:10,000

wrote an amazing book um

591

00:20:14,470 --> 00:20:13,039

that basically said most of the things

592

00:20:16,230 --> 00:20:14,480

that we're discovering now the guy had a

593

00:20:18,070 --> 00:20:16,240

crystal ball it's incredible it's

594

00:20:19,830 --> 00:20:18,080

absolutely incredible so he he could

595

00:20:21,270 --> 00:20:19,840

clearly see a lot of this stuff the

596

00:20:22,870 --> 00:20:21,280

thing the the one thing he did not see

597

00:20:25,190 --> 00:20:22,880

because at the time it didn't exist was

598

00:20:27,990 --> 00:20:25,200

the computational aspect and the and the

599

00:20:30,070 --> 00:20:28,000

really the link to um you know to to to

600

00:20:32,070 --> 00:20:30,080

this as as a kind of neuroscience done

601
00:20:35,110 --> 00:20:32,080
in another space in amorphous space that

602
00:20:37,029 --> 00:20:35,120
i think is is new but but uh

603
00:20:39,669 --> 00:20:37,039
people had already had these ideas and

604
00:20:41,430 --> 00:20:39,679
it needed the technology to really make

605
00:20:43,510 --> 00:20:41,440
it to really prove them out and to

606
00:20:45,510 --> 00:20:43,520
really see how it works

607
00:20:47,190 --> 00:20:45,520
i'll be showing people some overlays of

608
00:20:50,310 --> 00:20:47,200
some of the cells with the blue and

609
00:20:52,549 --> 00:20:50,320
green and red voltage colors now voltage

610
00:20:54,789 --> 00:20:52,559
is actually fairly abstract

611
00:20:56,070 --> 00:20:54,799
for most people but what's not abstract

612
00:20:58,789 --> 00:20:56,080
is something like an electron people can

613
00:21:00,950 --> 00:20:58,799

fathom that that has a certain charge so

614

00:21:02,549 --> 00:21:00,960

when someone is looking at these

615

00:21:05,350 --> 00:21:02,559

videos of voltage gradients and they're

616

00:21:06,710 --> 00:21:05,360

colored what is one seeing essentially

617

00:21:08,549 --> 00:21:06,720

i'm asking you to explain what voltage

618

00:21:09,590 --> 00:21:08,559

is simply but in terms of electrons in

619

00:21:11,270 --> 00:21:09,600

terms of something that people can

620

00:21:12,470 --> 00:21:11,280

understand yeah in order to understand

621

00:21:13,830 --> 00:21:12,480

both you have to understand potential

622

00:21:14,950 --> 00:21:13,840

and you also have to understand fields

623

00:21:18,070 --> 00:21:14,960

technically if you want to understand

624

00:21:19,510 --> 00:21:18,080

that correctly yeah um it's not so bad

625

00:21:21,750 --> 00:21:19,520

you don't need to really do much with

626

00:21:23,110 --> 00:21:21,760

fields in this one all because because

627

00:21:25,590 --> 00:21:23,120

all of the things that i'm talking about

628

00:21:28,630 --> 00:21:25,600

are really not fundamentally fields per

629

00:21:30,630 --> 00:21:28,640

se they're just spatial distributions of

630

00:21:32,149 --> 00:21:30,640

voltage gradients and and to understand

631

00:21:35,029 --> 00:21:32,159

a voltage gradient it's it's pretty

632

00:21:36,870 --> 00:21:35,039

simple instead of electrons life i mean

633

00:21:38,710 --> 00:21:36,880

life uses electrons too but mostly the

634

00:21:40,390 --> 00:21:38,720

kinds of stuff that we're talking about

635

00:21:41,270 --> 00:21:40,400

uses a different charged particle they

636

00:21:45,110 --> 00:21:41,280

use

637

00:21:47,669 --> 00:21:45,120

potassium chloride sodium and protons

638

00:21:49,510 --> 00:21:47,679

okay but otherwise same same deal and so

639

00:21:51,590 --> 00:21:49,520

any cell has a cell membrane around it

640

00:21:53,029 --> 00:21:51,600

the outer surface and it has these ion

641

00:21:55,590 --> 00:21:53,039

channels which are these little portals

642

00:21:57,830 --> 00:21:55,600

these little proteins that can open and

643

00:22:00,149 --> 00:21:57,840

close and let specific ions like

644

00:22:02,070 --> 00:22:00,159

potassium or sodium in and out these

645

00:22:03,830 --> 00:22:02,080

potassium so potassium and sodium are

646

00:22:05,510 --> 00:22:03,840

both positively charged so you can

647

00:22:07,909 --> 00:22:05,520

imagine that

648

00:22:09,750 --> 00:22:07,919

if you if you're a cell and you let a

649

00:22:12,149 --> 00:22:09,760

bunch of your positively charged

650

00:22:14,470 --> 00:22:12,159

potassiums out you can have an imbalance

651
00:22:16,310 --> 00:22:14,480
more positives out here less positives

652
00:22:19,029 --> 00:22:16,320
inside so now there's going to be a

653
00:22:20,390 --> 00:22:19,039
voltage gradient basically a battery in

654
00:22:21,909 --> 00:22:20,400
effect i mean that's basically what a

655
00:22:23,750 --> 00:22:21,919
battery is right it's a it's a membrane

656
00:22:25,669 --> 00:22:23,760
with a with a charged disk balance on

657
00:22:27,590 --> 00:22:25,679
across it that's that's all this is so

658
00:22:30,549 --> 00:22:27,600
every cell is a battery it achieves that

659
00:22:32,789 --> 00:22:30,559
by using energy to pump ions in a

660
00:22:34,149 --> 00:22:32,799
particular direction and as a result you

661
00:22:35,590 --> 00:22:34,159
if you were to take a tiny little volt

662
00:22:37,190 --> 00:22:35,600
meter and put it across and people

663
00:22:39,029 --> 00:22:37,200

that's exactly what electrophysiologists

664

00:22:40,390 --> 00:22:39,039

do you put it across that cell membrane

665

00:22:42,070 --> 00:22:40,400

you're going to read a voltage of some

666

00:22:43,909 --> 00:22:42,080

sort you know it's usually somewhere

667

00:22:45,669 --> 00:22:43,919

between i don't know between 20

668

00:22:47,669 --> 00:22:45,679

millivolts and and

669

00:22:49,350 --> 00:22:47,679

70 millivolts something like that right

670

00:22:51,270 --> 00:22:49,360

that's all it is and so now you imagine

671

00:22:53,029 --> 00:22:51,280

doing that for every cell in the tissue

672

00:22:54,789 --> 00:22:53,039

that you're looking at

673

00:22:56,630 --> 00:22:54,799

and you're just going to color every

674

00:22:58,470 --> 00:22:56,640

cell depending on how big that voltage

675

00:23:00,070 --> 00:22:58,480

difference is it's you're going to color

676

00:23:01,590 --> 00:23:00,080

it red if the voltage difference is

677

00:23:03,350 --> 00:23:01,600

quite small that's called being

678

00:23:04,950 --> 00:23:03,360

depolarized meaning there's just not

679

00:23:06,230 --> 00:23:04,960

that much imbalance it's pretty much

680

00:23:07,830 --> 00:23:06,240

it's quite simple you know the ions

681

00:23:09,750 --> 00:23:07,840

inside and outside are pretty similar so

682

00:23:11,350 --> 00:23:09,760

you're going to color those red and then

683

00:23:12,950 --> 00:23:11,360

the ones that are really different where

684

00:23:14,310 --> 00:23:12,960

there's a ton of

685

00:23:15,909 --> 00:23:14,320

positive charges that have been kicked

686

00:23:18,310 --> 00:23:15,919

out so the cell is really pretty

687

00:23:20,310 --> 00:23:18,320

negative that compared to the outside

688

00:23:23,029 --> 00:23:20,320

space that you're going to color those

689

00:23:24,230 --> 00:23:23,039

you're going to color those blue

690

00:23:25,590 --> 00:23:24,240

and that's and that's what and that's

691

00:23:26,950 --> 00:23:25,600

what you're looking at

692

00:23:28,470 --> 00:23:26,960

great okay so now we have some

693

00:23:30,070 --> 00:23:28,480

background as to what

694

00:23:31,909 --> 00:23:30,080

so dna calls for proteins and you can

695

00:23:33,350 --> 00:23:31,919

think of that as low level and then what

696

00:23:34,789 --> 00:23:33,360

you're discovering and you and your

697

00:23:36,390 --> 00:23:34,799

teams and the teams that you collaborate

698

00:23:38,149 --> 00:23:36,400

with are discovering is that there's

699

00:23:40,549 --> 00:23:38,159

these non-neural bioelectric signals and

700

00:23:42,149 --> 00:23:40,559

those are somewhat like large-scale code

701

00:23:44,230 --> 00:23:42,159

some of the implications are

702

00:23:46,470 --> 00:23:44,240

regeneration of limbs barely touched on

703

00:23:48,070 --> 00:23:46,480

that's okay we touched on generation of

704

00:23:49,750 --> 00:23:48,080

actual so generation of eyes not

705

00:23:52,310 --> 00:23:49,760

regeneration of eyes and then you were

706

00:23:53,669 --> 00:23:52,320

about to get into cancer so do you mind

707

00:23:54,950 --> 00:23:53,679

yeah um

708

00:23:57,510 --> 00:23:54,960

so so

709

00:24:00,870 --> 00:23:57,520

so the just just real quick to say the

710

00:24:03,029 --> 00:24:00,880

analogy is that i i think a good analogy

711

00:24:04,390 --> 00:24:03,039

is this the dna is what encodes the

712

00:24:07,190 --> 00:24:04,400

hardware

713

00:24:09,510 --> 00:24:07,200

okay and the electrical dynamics are the

714

00:24:10,630 --> 00:24:09,520

software now a lot of people get upset

715

00:24:12,630 --> 00:24:10,640

at this because they say ah living

716

00:24:14,470 --> 00:24:12,640

things are not like a computer so i am

717

00:24:16,310 --> 00:24:14,480

certainly not claiming that living

718

00:24:17,990 --> 00:24:16,320

things are like the kind of computers

719

00:24:19,990 --> 00:24:18,000

that you and i use on a daily basis

720

00:24:22,549 --> 00:24:20,000

these right this architecture is not

721

00:24:24,070 --> 00:24:22,559

what life is using however the deeper

722

00:24:26,950 --> 00:24:24,080

concept from computer science which is

723

00:24:28,789 --> 00:24:26,960

the idea of reprogrammable hardware and

724

00:24:31,430 --> 00:24:28,799

the idea of software multi-layer

725

00:24:33,350 --> 00:24:31,440

software where you could be programming

726

00:24:35,269 --> 00:24:33,360

at the in the in machine code or you

727

00:24:37,029 --> 00:24:35,279

could be looking for higher level

728

00:24:39,350 --> 00:24:37,039

subroutines and higher level

729

00:24:41,190 --> 00:24:39,360

languages that i think is quite quite

730

00:24:43,909 --> 00:24:41,200

realistic and i think what we're looking

731

00:24:45,350 --> 00:24:43,919

for here is to understand basically to

732

00:24:46,549 --> 00:24:45,360

to to find the

733

00:24:47,590 --> 00:24:46,559

the best

734

00:24:49,590 --> 00:24:47,600

um

735

00:24:52,390 --> 00:24:49,600

the best representation of that software

736

00:24:54,470 --> 00:24:52,400

so that we can manipulate it as uh as as

737

00:24:55,990 --> 00:24:54,480

you know to to advantage basically and

738

00:24:58,230 --> 00:24:56,000

and to understand how evolution

739

00:24:59,269 --> 00:24:58,240

manipulates it and so and so the other

740

00:25:01,110 --> 00:24:59,279

you know you had asked for three

741

00:25:02,549 --> 00:25:01,120

examples so so there are three basic

742

00:25:04,470 --> 00:25:02,559

examples i wanted to give so so the

743

00:25:06,149 --> 00:25:04,480

electric face was one there's a cancer

744

00:25:08,470 --> 00:25:06,159

example and then there's a planarian uh

745

00:25:10,390 --> 00:25:08,480

flatworm regeneration example so the

746

00:25:11,990 --> 00:25:10,400

cancer the cancer example would look

747

00:25:14,070 --> 00:25:12,000

like this um

748

00:25:16,630 --> 00:25:14,080

one of the things about

749

00:25:19,669 --> 00:25:16,640

cancer the the the one way to think

750

00:25:22,230 --> 00:25:19,679

about cancer is to ask the question

751
00:25:23,669 --> 00:25:22,240
why is there ever anything but cancer in

752
00:25:25,510 --> 00:25:23,679
other words

753
00:25:27,110 --> 00:25:25,520
individual cells like amoebas are

754
00:25:29,350 --> 00:25:27,120
extremely competent on their own they

755
00:25:31,750 --> 00:25:29,360
handle single cell level goals quite

756
00:25:33,909 --> 00:25:31,760
well why do they ever get together to

757
00:25:35,830 --> 00:25:33,919
form something like a kidney or a liver

758
00:25:37,029 --> 00:25:35,840
because when you have when when there's

759
00:25:38,470 --> 00:25:37,039
a cancer what you're seeing is a

760
00:25:40,310 --> 00:25:38,480
defection from that process you're

761
00:25:42,870 --> 00:25:40,320
seeing cells that normally should be

762
00:25:44,789 --> 00:25:42,880
working on making a nice organ in store

763
00:25:46,149 --> 00:25:44,799

up keeping a nice organ in an adult

764

00:25:48,630 --> 00:25:46,159

instead of that they go off and they

765

00:25:51,029 --> 00:25:48,640

basically revert to a single cell kind

766

00:25:52,710 --> 00:25:51,039

of existence they they

767

00:25:54,070 --> 00:25:52,720

basically become like an amoeba they

768

00:25:55,510 --> 00:25:54,080

treat the rest of the body as just

769

00:25:57,269 --> 00:25:55,520

environment it's like external

770

00:25:59,190 --> 00:25:57,279

environment so you can think of that

771

00:26:02,390 --> 00:25:59,200

that computational boundary between

772

00:26:04,149 --> 00:26:02,400

between self and world can shrink it can

773

00:26:05,750 --> 00:26:04,159

grow when a bunch of amoebas a bunch of

774

00:26:07,590 --> 00:26:05,760

amoeba-like cells get together and they

775

00:26:09,190 --> 00:26:07,600

build something like an organ or a whole

776

00:26:11,029 --> 00:26:09,200

body that that computational boundary

777

00:26:13,990 --> 00:26:11,039

grows but can also shrink because an

778

00:26:15,590 --> 00:26:14,000

individual cell can say uh uh i'm i'm

779

00:26:17,669 --> 00:26:15,600

not working on this anymore i'm just an

780

00:26:19,430 --> 00:26:17,679

amoeba and i'm gonna do what amoebas do

781

00:26:21,269 --> 00:26:19,440

what do they do they they become two

782

00:26:23,190 --> 00:26:21,279

amoebas and two amoebas become four and

783

00:26:25,110 --> 00:26:23,200

so on they over proliferate and they go

784

00:26:26,789 --> 00:26:25,120

where life is good so they metastasize

785

00:26:29,750 --> 00:26:26,799

to wherever they wherever they want to

786

00:26:31,190 --> 00:26:29,760

go so that's so that's cancer so

787

00:26:33,029 --> 00:26:31,200

so if you think about it that way that

788

00:26:36,710 --> 00:26:33,039

that cancer is this is this like

789

00:26:39,669 --> 00:26:36,720

defection from multicellular cooperation

790

00:26:41,430 --> 00:26:39,679

you can you ask yourself okay so what is

791

00:26:45,269 --> 00:26:41,440

the process that normally keeps them

792

00:26:47,110 --> 00:26:45,279

harnessed towards specific goals and

793

00:26:48,789 --> 00:26:47,120

and so if you ask yourself what what

794

00:26:51,269 --> 00:26:48,799

what what do we know that's a process

795

00:26:53,669 --> 00:26:51,279

that harnesses individual competent

796

00:26:56,070 --> 00:26:53,679

subunits towards larger scale goals

797

00:26:58,149 --> 00:26:56,080

that's very clear that's that's uh the

798

00:27:00,789 --> 00:26:58,159

neural like processing because you have

799

00:27:02,549 --> 00:27:00,799

individual neurons which are cells

800

00:27:04,950 --> 00:27:02,559

but you connect them together into a

801
00:27:06,789 --> 00:27:04,960
network and this amazing computation

802
00:27:08,710 --> 00:27:06,799
starts to take place that can do things

803
00:27:10,470 --> 00:27:08,720
like plan for the future and have

804
00:27:12,870 --> 00:27:10,480
memories and have preferences and goals

805
00:27:14,870 --> 00:27:12,880
on a large scale you know you as an

806
00:27:17,350 --> 00:27:14,880
organism can have goals and memories

807
00:27:19,190 --> 00:27:17,360
that your individual cells don't have so

808
00:27:21,190 --> 00:27:19,200
so we know that electrical networks are

809
00:27:23,669 --> 00:27:21,200
really good at binding

810
00:27:25,990 --> 00:27:23,679
small competent subunits into larger

811
00:27:27,350 --> 00:27:26,000
scale computational agents we do we we

812
00:27:28,950 --> 00:27:27,360
take advantage of that in computer

813
00:27:32,149 --> 00:27:28,960

science we take it evolution takes

814

00:27:33,990 --> 00:27:32,159

advantage of it in in making neurons

815

00:27:35,750 --> 00:27:34,000

so um so we asked the following question

816

00:27:37,909 --> 00:27:35,760

okay could that be the basis of cancer

817

00:27:39,430 --> 00:27:37,919

and now i must say that of course we're

818

00:27:41,750 --> 00:27:39,440

not the first to have this idea okay

819

00:27:42,950 --> 00:27:41,760

again harold burr um had this said this

820

00:27:44,389 --> 00:27:42,960

in the 30s

821

00:27:46,870 --> 00:27:44,399

but so we did we did three things we

822

00:27:49,750 --> 00:27:46,880

said okay first of all when this process

823

00:27:53,669 --> 00:27:49,760

happens can you see using the voltage

824

00:27:56,149 --> 00:27:53,679

dyes can you see the cells defecting

825

00:27:57,669 --> 00:27:56,159

from the electrical network and in fact

826

00:27:59,510 --> 00:27:57,679

that's then in fact you can so what you

827

00:28:01,269 --> 00:27:59,520

can what you can do is you before it

828

00:28:03,110 --> 00:28:01,279

happens so so you can inject a human

829

00:28:06,310 --> 00:28:03,120

oncogene which is going to form a tumor

830

00:28:07,190 --> 00:28:06,320

in a tadpole you inject that into

831

00:28:09,830 --> 00:28:07,200

um

832

00:28:13,029 --> 00:28:09,840

you inject that into a uh

833

00:28:14,630 --> 00:28:13,039

into a tadpole they make a um

834

00:28:16,870 --> 00:28:14,640

they make a they make a you know it

835

00:28:20,950 --> 00:28:16,880

makes a tumor and even before that tumor

836

00:28:23,190 --> 00:28:20,960

becomes uh becomes apparent you can

837

00:28:25,190 --> 00:28:23,200

uh you can see with a voltage die you

838

00:28:26,950 --> 00:28:25,200

can see that those cells become become

839

00:28:28,950 --> 00:28:26,960

highly depolarized they electrically

840

00:28:30,549 --> 00:28:28,960

uncouple from the rest of the tissue and

841

00:28:31,909 --> 00:28:30,559

they go on their way and they just treat

842

00:28:33,590 --> 00:28:31,919

to them the rest of the animal is just

843

00:28:35,029 --> 00:28:33,600

external environment at that point so

844

00:28:36,630 --> 00:28:35,039

they become electrically uncoupled and

845

00:28:38,630 --> 00:28:36,640

that's that's the first thing that that

846

00:28:40,549 --> 00:28:38,640

oncogenes do is electrically isolate the

847

00:28:43,430 --> 00:28:40,559

cell from its neighbors from that

848

00:28:45,350 --> 00:28:43,440

collection of of signals that normally

849

00:28:47,350 --> 00:28:45,360

tell the cell what to do in a larger

850

00:28:49,590 --> 00:28:47,360

context so that's the first thing we did

851
00:28:51,750 --> 00:28:49,600
the second thing we did we said well

852
00:28:52,710 --> 00:28:51,760
if that if that's a potential cause of

853
00:28:54,549 --> 00:28:52,720
cancer

854
00:28:58,710 --> 00:28:54,559
could we

855
00:29:01,110 --> 00:28:58,720
but just by disrupting the electrical

856
00:29:03,190 --> 00:29:01,120
communication directly no no oncogenes

857
00:29:05,269 --> 00:29:03,200
no carcinogens no dna damage no

858
00:29:08,310 --> 00:29:05,279
mutations nothing wrong with the cells

859
00:29:09,430 --> 00:29:08,320
that any molecular biology test could

860
00:29:11,269 --> 00:29:09,440
see

861
00:29:12,789 --> 00:29:11,279
and could we could we cause cancer

862
00:29:14,870 --> 00:29:12,799
because because remember the standard

863
00:29:16,950 --> 00:29:14,880

model in the field for years has been

864

00:29:18,710 --> 00:29:16,960

that cancer is the cause of genetic

865

00:29:20,389 --> 00:29:18,720

damage basically right that it's that

866

00:29:22,230 --> 00:29:20,399

it's a genetic disruption that makes a

867

00:29:23,669 --> 00:29:22,240

rogue cell that has other mutations and

868

00:29:25,269 --> 00:29:23,679

so on so we said fine no we're going to

869

00:29:26,470 --> 00:29:25,279

take completely normal cells nothing

870

00:29:28,470 --> 00:29:26,480

wrong with them and we're going to

871

00:29:30,230 --> 00:29:28,480

simply prevent them from talking to

872

00:29:31,750 --> 00:29:30,240

other cells electrically okay we're just

873

00:29:33,830 --> 00:29:31,760

going to manipulate that and so we did

874

00:29:36,470 --> 00:29:33,840

that and sure enough we made metastatic

875

00:29:38,070 --> 00:29:36,480

metastatic melanoma in tadpoles so so

876

00:29:39,269 --> 00:29:38,080

that tells you that you there doesn't

877

00:29:42,230 --> 00:29:39,279

have to be anything wrong with the

878

00:29:44,389 --> 00:29:42,240

hardware in order to have cancer it can

879

00:29:46,389 --> 00:29:44,399

be a purely physiological phenomenon it

880

00:29:47,669 --> 00:29:46,399

can be caused at the software level

881

00:29:49,430 --> 00:29:47,679

which a lot of people who study

882

00:29:51,669 --> 00:29:49,440

stress-induced cancers and things like

883

00:29:53,190 --> 00:29:51,679

this they kind of already knew but but

884

00:29:54,789 --> 00:29:53,200

but really the paradigm has been that

885

00:29:56,870 --> 00:29:54,799

there has to be a genetic defect at the

886

00:29:58,149 --> 00:29:56,880

at the root of this somewhere okay and

887

00:30:00,149 --> 00:29:58,159

then the third thing we found which is

888

00:30:01,269 --> 00:30:00,159

of course the most exciting thing

889

00:30:03,190 --> 00:30:01,279

which is you can go in the opposite

890

00:30:05,190 --> 00:30:03,200

direction you can you can inject a

891

00:30:07,830 --> 00:30:05,200

really powerful human occaging like a

892

00:30:09,350 --> 00:30:07,840

p53 mutation oncogene for those who are

893

00:30:11,990 --> 00:30:09,360

listening it's just a gene that causes

894

00:30:14,549 --> 00:30:12,000

cancer yeah an oncogene is a is a is a

895

00:30:16,870 --> 00:30:14,559

mutation in a in the normal gene that

896

00:30:19,430 --> 00:30:16,880

causes that that are that is that is

897

00:30:21,830 --> 00:30:19,440

thought to cause uh cancer

898

00:30:23,909 --> 00:30:21,840

transformation to cancer yeah okay so

899

00:30:26,549 --> 00:30:23,919

you can inject that and then if you do

900

00:30:28,470 --> 00:30:26,559

that into into a tadpole

901
00:30:29,830 --> 00:30:28,480
if you at the same time inject an ion

902
00:30:32,149 --> 00:30:29,840
channel that

903
00:30:34,710 --> 00:30:32,159
forces the cell to remain in an

904
00:30:36,870 --> 00:30:34,720
electrical state where it's connected to

905
00:30:38,470 --> 00:30:36,880
its neighbors and it doesn't depolarize

906
00:30:40,870 --> 00:30:38,480
then even though that oncogene is

907
00:30:42,630 --> 00:30:40,880
blazingly strongly expressed there's no

908
00:30:44,389 --> 00:30:42,640
there you you won't you won't have a you

909
00:30:46,710 --> 00:30:44,399
won't have a tumor because you're

910
00:30:48,389 --> 00:30:46,720
overriding that there's a hardware

911
00:30:50,470 --> 00:30:48,399
problem but it doesn't matter because

912
00:30:51,830 --> 00:30:50,480
you're overriding it and saying yeah i

913
00:30:53,350 --> 00:30:51,840

know you want to depolarize but you

914

00:30:54,389 --> 00:30:53,360

can't you have to stay connected to

915

00:30:56,630 --> 00:30:54,399

these neighbors and you're just going to

916

00:30:59,029 --> 00:30:56,640

be part of this and and and we can

917

00:31:03,590 --> 00:30:59,039

override that way a variety of different

918

00:31:06,870 --> 00:31:05,190

okay so i was just having an analogy in

919

00:31:08,310 --> 00:31:06,880

my head it's almost like imagine you

920

00:31:09,750 --> 00:31:08,320

have these kids and they're misbehaved

921

00:31:11,269 --> 00:31:09,760

so you can say well it's the kids who

922

00:31:13,190 --> 00:31:11,279

are the problem and they cause havoc in

923

00:31:14,789 --> 00:31:13,200

the house but if you have an adult who's

924

00:31:16,710 --> 00:31:14,799

stern enough they can override the

925

00:31:18,549 --> 00:31:16,720

misbehaved kids if you leave the kids

926
00:31:20,230 --> 00:31:18,559
without the adult and the hustle bean

927
00:31:21,669 --> 00:31:20,240
shambles in this analogy the adult is

928
00:31:23,669 --> 00:31:21,679
like the electrical communication so you

929
00:31:25,350 --> 00:31:23,679
can force that electrical communication

930
00:31:27,350 --> 00:31:25,360
that standard adaptive electrical

931
00:31:28,950 --> 00:31:27,360
communication

932
00:31:31,269 --> 00:31:28,960
yeah yeah you can you can think of it

933
00:31:33,190 --> 00:31:31,279
that way i mean the the the thing where

934
00:31:35,350 --> 00:31:33,200
i think it it it breaks down a little

935
00:31:37,909 --> 00:31:35,360
bit is that is that you we're not

936
00:31:40,149 --> 00:31:37,919
introducing an extra element that keeps

937
00:31:42,149 --> 00:31:40,159
everybody else in line right we're we're

938
00:31:44,710 --> 00:31:42,159

in effect it's like um

939

00:31:45,909 --> 00:31:44,720

you know it's like it's like it's like

940

00:31:47,750 --> 00:31:45,919

you have a bunch of kids that know what

941

00:31:49,830 --> 00:31:47,760

to do and you've got one that's wearing

942

00:31:51,509 --> 00:31:49,840

uh you know dark glasses and you can't

943

00:31:52,710 --> 00:31:51,519

see and he's causing all kinds of

944

00:31:54,549 --> 00:31:52,720

trouble because you can't see what he's

945

00:31:55,830 --> 00:31:54,559

doing well you can you can sort of you

946

00:31:57,590 --> 00:31:55,840

could put a camera on him or take the

947

00:31:59,830 --> 00:31:57,600

glasses off or something so that he just

948

00:32:01,509 --> 00:31:59,840

goes right back into the into the

949

00:32:04,070 --> 00:32:01,519

interactions with with the you know in

950

00:32:05,190 --> 00:32:04,080

the in the with the rest of the uh

951
00:32:06,630 --> 00:32:05,200
you know the rest of the group it's

952
00:32:07,750 --> 00:32:06,640
about it's about communication it's

953
00:32:10,230 --> 00:32:07,760
about

954
00:32:12,870 --> 00:32:10,240
uh binding the individual competent

955
00:32:14,789 --> 00:32:12,880
subunits towards a larger goal your goal

956
00:32:16,630 --> 00:32:14,799
is not simply to grow as much as you can

957
00:32:19,029 --> 00:32:16,640
the way an amoeba is your goal is to

958
00:32:20,630 --> 00:32:19,039
build a hand or a liver or an eye or

959
00:32:22,789 --> 00:32:20,640
something else it's really about the

960
00:32:25,269 --> 00:32:22,799
scale up of goals and electrical

961
00:32:26,870 --> 00:32:25,279
networks are great for this

962
00:32:29,430 --> 00:32:26,880
does your work have any implications for

963
00:32:31,190 --> 00:32:29,440

what it means to have an identity so

964

00:32:33,350 --> 00:32:31,200

right now you were talking about cancer

965

00:32:34,710 --> 00:32:33,360

as if it's dissociating from the larger

966

00:32:36,230 --> 00:32:34,720

cells yeah and then there are gap

967

00:32:38,230 --> 00:32:36,240

junctions which you've referenced in

968

00:32:39,669 --> 00:32:38,240

your other work and they effectively

969

00:32:42,230 --> 00:32:39,679

make an equivalence class between

970

00:32:43,750 --> 00:32:42,240

signals that i generate as a cell or my

971

00:32:45,350 --> 00:32:43,760

environment or signals from connected

972

00:32:47,669 --> 00:32:45,360

cells i'm unable to tell the difference

973

00:32:48,789 --> 00:32:47,679

between them yep

974

00:32:49,990 --> 00:32:48,799

because i'm unable to tell the

975

00:32:51,830 --> 00:32:50,000

difference between myself and my

976

00:32:53,909 --> 00:32:51,840

neighbor it's as if i'm identified with

977

00:32:55,669 --> 00:32:53,919

them so it has plenty of bearing at

978

00:32:58,070 --> 00:32:55,679

least i see it has plenty of bearings

979

00:33:00,470 --> 00:32:58,080

for what it means for the eye or the ego

980

00:33:01,990 --> 00:33:00,480

in a non-pejorative manner

981

00:33:04,310 --> 00:33:02,000

so what are the implications of your

982

00:33:05,990 --> 00:33:04,320

work for the concept of identity

983

00:33:08,870 --> 00:33:06,000

yeah yeah no you you put your finger

984

00:33:10,470 --> 00:33:08,880

exactly on it so so so two two years ago

985

00:33:12,870 --> 00:33:10,480

i wrote this paper called on the

986

00:33:15,509 --> 00:33:12,880

boundary of the self and it's exactly

987

00:33:17,909 --> 00:33:15,519

this idea it's the way to to uh to

988

00:33:21,190 --> 00:33:17,919

define what is a self at different

989

00:33:23,509 --> 00:33:21,200

scales and uh how does the boundary the

990

00:33:25,190 --> 00:33:23,519

size of that self change okay or over

991

00:33:26,789 --> 00:33:25,200

time and that's exactly the kind of

992

00:33:29,029 --> 00:33:26,799

thing that you that you're talking about

993

00:33:31,269 --> 00:33:29,039

it's having having communication

994

00:33:34,149 --> 00:33:31,279

channels that partially wipe the

995

00:33:36,310 --> 00:33:34,159

metadata on information so that i no

996

00:33:38,549 --> 00:33:36,320

longer know whether it came from you or

997

00:33:40,710 --> 00:33:38,559

or whether it came from me right gives

998

00:33:43,110 --> 00:33:40,720

us a partial mind melt because now it's

999

00:33:44,470 --> 00:33:43,120

really hard to keep an identity if i

1000

00:33:46,310 --> 00:33:44,480

can't tell which are my memories and

1001
00:33:48,549 --> 00:33:46,320
which are your memories it's really hard

1002
00:33:50,950 --> 00:33:48,559
for us to keep uh to keep distinct

1003
00:33:52,710 --> 00:33:50,960
identities we become partially unified

1004
00:33:55,509 --> 00:33:52,720
and that's that's exactly the sort of

1005
00:33:58,070 --> 00:33:55,519
process that evolution exploits to build

1006
00:33:59,430 --> 00:33:58,080
larger cells out of um small competent

1007
00:34:02,230 --> 00:33:59,440
ones

1008
00:34:03,509 --> 00:34:02,240
another astounding experiment of yours

1009
00:34:04,789 --> 00:34:03,519
i'm not sure if i should be calling it

1010
00:34:06,149 --> 00:34:04,799
an experiment was where you took skin

1011
00:34:08,550 --> 00:34:06,159
cells of a frog and then it has

1012
00:34:09,669 --> 00:34:08,560
locomotion can you outline what the heck

1013
00:34:10,869 --> 00:34:09,679

did you do there and why is that

1014

00:34:12,069 --> 00:34:10,879

important

1015

00:34:13,510 --> 00:34:12,079

yeah yeah no it's definitely an

1016

00:34:15,669 --> 00:34:13,520

experiment um

1017

00:34:17,990 --> 00:34:15,679

so so you're talking about our zenobots

1018

00:34:20,470 --> 00:34:18,000

uh i think and

1019

00:34:22,149 --> 00:34:20,480

the question was that the question that

1020

00:34:25,510 --> 00:34:22,159

we're interested in addressing is is

1021

00:34:29,030 --> 00:34:25,520

basically this um

1022

00:34:31,109 --> 00:34:29,040

where do anatomical goals come from and

1023

00:34:32,389 --> 00:34:31,119

in order to illustrate why that's even a

1024

00:34:33,990 --> 00:34:32,399

good question i want to talk about

1025

00:34:35,190 --> 00:34:34,000

plenaria for just a moment and then and

1026

00:34:36,790 --> 00:34:35,200

then you'll see why this this is

1027

00:34:37,750 --> 00:34:36,800

important for the xenobots

1028

00:34:41,109 --> 00:34:37,760

um

1029

00:34:44,149 --> 00:34:41,119

we are we are used to the fact that

1030

00:34:46,470 --> 00:34:44,159

uh each species has a specific shape

1031

00:34:48,790 --> 00:34:46,480

that is associated with it and that frog

1032

00:34:50,550 --> 00:34:48,800

eggs make frogs and and zebra fish eggs

1033

00:34:52,629 --> 00:34:50,560

make zebrafish and so on so we're kind

1034

00:34:55,909 --> 00:34:52,639

of we're kind of used to that but

1035

00:34:57,670 --> 00:34:55,919

the actual question of how do cellular

1036

00:35:00,390 --> 00:34:57,680

collectives decide what they're going to

1037

00:35:02,630 --> 00:35:00,400

build and when do they stop building

1038

00:35:05,109 --> 00:35:02,640

that's very much an open question

1039

00:35:06,870 --> 00:35:05,119

and so so one way you can see how how

1040

00:35:08,550 --> 00:35:06,880

far we are away from a good

1041

00:35:11,030 --> 00:35:08,560

understanding of this is in in a very

1042

00:35:12,069 --> 00:35:11,040

simple um very simple experiment

1043

00:35:13,990 --> 00:35:12,079

uh

1044

00:35:15,270 --> 00:35:14,000

there are there are around so so

1045

00:35:16,870 --> 00:35:15,280

planaria are these flat worms that

1046

00:35:18,390 --> 00:35:16,880

regenerate when you cut them into pieces

1047

00:35:20,230 --> 00:35:18,400

every piece builds whatever's missing

1048

00:35:21,910 --> 00:35:20,240

and they regenerate okay that's that's

1049

00:35:23,910 --> 00:35:21,920

plenary you can cut them into pieces and

1050

00:35:26,950 --> 00:35:23,920

they every piece regenerates to a normal

1051
00:35:29,829 --> 00:35:26,960
plenary so there are species of planaria

1052
00:35:32,790 --> 00:35:29,839
that have round heads and those type

1053
00:35:35,109 --> 00:35:32,800
those cells are really good at building

1054
00:35:37,670 --> 00:35:35,119
a round head and then stopping so they

1055
00:35:39,430 --> 00:35:37,680
stop when a round head is complete okay

1056
00:35:41,030 --> 00:35:39,440
then you got another species of plenaria

1057
00:35:43,349 --> 00:35:41,040
that has a very pointy head a truck kind

1058
00:35:44,950 --> 00:35:43,359
of a triangular head and those cells are

1059
00:35:46,550 --> 00:35:44,960
very good at point at making a

1060
00:35:47,910 --> 00:35:46,560
triangular head when you cut it off it

1061
00:35:50,550 --> 00:35:47,920
makes a triangular head and then it

1062
00:35:51,910 --> 00:35:50,560
stops so i have a simple question if i

1063
00:35:53,910 --> 00:35:51,920

take a bunch of the cells from the

1064

00:35:55,990 --> 00:35:53,920

round-headed guy and i stick them into

1065

00:35:57,990 --> 00:35:56,000

the body of the triangular guy and i let

1066

00:35:59,109 --> 00:35:58,000

them sort of get you know get

1067

00:36:00,950 --> 00:35:59,119

comfortable and sit around for a little

1068

00:36:02,790 --> 00:36:00,960

while then i cut the head off what head

1069

00:36:04,550 --> 00:36:02,800

shape are we going to have are we going

1070

00:36:06,150 --> 00:36:04,560

to have is one of the head shapes

1071

00:36:08,630 --> 00:36:06,160

dominant to the other are we going to

1072

00:36:10,230 --> 00:36:08,640

have an intermediate shape or are we

1073

00:36:12,390 --> 00:36:10,240

going to have a planarian that never

1074

00:36:14,310 --> 00:36:12,400

stops regenerating because neither set

1075

00:36:15,750 --> 00:36:14,320

of cells is ever happy about the shape

1076

00:36:17,910 --> 00:36:15,760

they're never that stop condition is

1077

00:36:19,190 --> 00:36:17,920

never said okay so now so now look the

1078

00:36:21,109 --> 00:36:19,200

the important thing is not the answer

1079

00:36:23,030 --> 00:36:21,119

the the important thing is

1080

00:36:24,950 --> 00:36:23,040

despite all of the

1081

00:36:27,109 --> 00:36:24,960

uh papers in nature and science about

1082

00:36:28,950 --> 00:36:27,119

the molecular pathways of control of

1083

00:36:31,030 --> 00:36:28,960

stem cells and planaria and all these

1084

00:36:32,950 --> 00:36:31,040

kinds of high resolution transcriptomics

1085

00:36:34,069 --> 00:36:32,960

and all this stuff there is not a single

1086

00:36:35,990 --> 00:36:34,079

model in the field that makes a

1087

00:36:38,390 --> 00:36:36,000

prediction on this experiment

1088

00:36:41,190 --> 00:36:38,400

why because every piece of data out

1089

00:36:43,670 --> 00:36:41,200

there now addresses the hardware that

1090

00:36:45,430 --> 00:36:43,680

enables individual cells to do cell

1091

00:36:48,069 --> 00:36:45,440

things fine

1092

00:36:49,910 --> 00:36:48,079

but we have no understanding of what

1093

00:36:52,470 --> 00:36:49,920

happens when the cells join together

1094

00:36:54,390 --> 00:36:52,480

into a larger scale self that makes

1095

00:36:56,069 --> 00:36:54,400

large scale decisions about head shape

1096

00:36:57,990 --> 00:36:56,079

head number things like that in

1097

00:36:59,670 --> 00:36:58,000

morphospace that navigates morph space

1098

00:37:01,589 --> 00:36:59,680

by making these large scale decisions we

1099

00:37:03,829 --> 00:37:01,599

have absolutely no idea how those

1100

00:37:06,310 --> 00:37:03,839

algorithms work and the fact that we

1101
00:37:09,030 --> 00:37:06,320
know how the stem cells work and have

1102
00:37:10,310 --> 00:37:09,040
lots of molecular biology about that

1103
00:37:12,390 --> 00:37:10,320
really hasn't affected this other

1104
00:37:14,069 --> 00:37:12,400
question much at all we we just have no

1105
00:37:16,390 --> 00:37:14,079
no models for this because it's too

1106
00:37:19,109 --> 00:37:16,400
computationally complex or some other in

1107
00:37:20,390 --> 00:37:19,119
principle reason i don't think it's well

1108
00:37:21,829 --> 00:37:20,400
no i don't think it's because it's too

1109
00:37:24,310 --> 00:37:21,839
complex although it is too complex to

1110
00:37:26,630 --> 00:37:24,320
calculate out directly i think it's

1111
00:37:27,910 --> 00:37:26,640
because conceptually we haven't found

1112
00:37:31,430 --> 00:37:27,920
the right

1113
00:37:33,349 --> 00:37:31,440

think about how cellular collectives

1114

00:37:34,710 --> 00:37:33,359

make decisions this is this is a

1115

00:37:36,470 --> 00:37:34,720

collective intelligence problem this is

1116

00:37:37,990 --> 00:37:36,480

not a molecular biology problem we've

1117

00:37:39,750 --> 00:37:38,000

been thinking about this as a molecular

1118

00:37:42,470 --> 00:37:39,760

biology problem that's not what this is

1119

00:37:44,950 --> 00:37:42,480

this is this is trying to read the mind

1120

00:37:46,710 --> 00:37:44,960

of a collective intelligence now people

1121

00:37:48,950 --> 00:37:46,720

think of collective intelligences as

1122

00:37:50,470 --> 00:37:48,960

exotic things like anthills and and you

1123

00:37:52,310 --> 00:37:50,480

know bb colonies and things like this

1124

00:37:54,870 --> 00:37:52,320

these are collective intelligences

1125

00:37:56,790 --> 00:37:54,880

um i want to remind everybody that we

1126
00:37:58,630 --> 00:37:56,800
are all collective intelligences we are

1127
00:38:00,950 --> 00:37:58,640
all bags of cells

1128
00:38:02,230 --> 00:38:00,960
no there is no cognitive agent that is

1129
00:38:04,390 --> 00:38:02,240
like this

1130
00:38:05,910 --> 00:38:04,400
single diamond that's that's not made of

1131
00:38:07,990 --> 00:38:05,920
parts that's sort of unchanging we're

1132
00:38:10,470 --> 00:38:08,000
all made of parts any cognitive agent is

1133
00:38:12,950 --> 00:38:10,480
made of parts and so your goal is to ask

1134
00:38:15,270 --> 00:38:12,960
how do those parts bind together to make

1135
00:38:16,550 --> 00:38:15,280
decisions as a collective individual

1136
00:38:18,310 --> 00:38:16,560
cells don't know what a head is they

1137
00:38:19,910 --> 00:38:18,320
don't know what round round means they

1138
00:38:21,829 --> 00:38:19,920

don't know what triangular means right

1139

00:38:23,670 --> 00:38:21,839

but the collective sure does and so the

1140

00:38:24,950 --> 00:38:23,680

collective is able to navigate morph of

1141

00:38:26,470 --> 00:38:24,960

space in this way that we don't

1142

00:38:28,230 --> 00:38:26,480

understand the algorithm so if we don't

1143

00:38:31,109 --> 00:38:28,240

even we don't even know how to um how to

1144

00:38:34,950 --> 00:38:31,119

think about this okay so

1145

00:38:37,270 --> 00:38:34,960

um so so so this this is very isomorphic

1146

00:38:39,910 --> 00:38:37,280

to problems in neuroscience to problems

1147

00:38:41,829 --> 00:38:39,920

in in artificial intelligence it's uh

1148

00:38:45,589 --> 00:38:41,839

trying to understand the scaling of of

1149

00:38:47,510 --> 00:38:45,599

minds and in in trying to do that we we

1150

00:38:49,829 --> 00:38:47,520

pose the following problem

1151

00:38:52,310 --> 00:38:49,839

okay standard

1152

00:38:54,230 --> 00:38:52,320

tadpoles make you know standard frog

1153

00:38:55,910 --> 00:38:54,240

eggs make it make frog embryos and

1154

00:38:58,069 --> 00:38:55,920

everybody's kind of used to that even

1155

00:38:59,750 --> 00:38:58,079

even though you know you can remind i

1156

00:39:01,750 --> 00:38:59,760

always remind my students did you

1157

00:39:03,349 --> 00:39:01,760

realize that that if i gave you the frog

1158

00:39:04,790 --> 00:39:03,359

genome you couldn't tell me what a frog

1159

00:39:06,630 --> 00:39:04,800

looked like right

1160

00:39:07,750 --> 00:39:06,640

you could compare it to other genomes

1161

00:39:09,030 --> 00:39:07,760

yeah you didn't know what but that was

1162

00:39:11,589 --> 00:39:09,040

that's cheating you know

1163

00:39:12,790 --> 00:39:11,599

so so so okay so we asked we asked a

1164

00:39:15,190 --> 00:39:12,800

simple question

1165

00:39:17,270 --> 00:39:15,200

where does the goal of making a frog or

1166

00:39:19,349 --> 00:39:17,280

tadpole really come from and how

1167

00:39:20,950 --> 00:39:19,359

hardwired is that so what we did was we

1168

00:39:22,790 --> 00:39:20,960

took some skin

1169

00:39:25,589 --> 00:39:22,800

that we scraped off of an early frog

1170

00:39:28,230 --> 00:39:25,599

embryo we set it aside in a different

1171

00:39:29,750 --> 00:39:28,240

environment and we said okay now you're

1172

00:39:32,150 --> 00:39:29,760

free to sort of reboot your

1173

00:39:34,790 --> 00:39:32,160

multicellularity you're here we've we've

1174

00:39:37,030 --> 00:39:34,800

we've relieved all of the constraints of

1175

00:39:39,190 --> 00:39:37,040

the rest of the embryo you're no longer

1176

00:39:40,950 --> 00:39:39,200

getting constructive signals from from

1177

00:39:43,030 --> 00:39:40,960

from endoderm and from mesoderm from all

1178

00:39:45,109 --> 00:39:43,040

these other things you're no longer

1179

00:39:47,109 --> 00:39:45,119

subject to all these other signals

1180

00:39:48,470 --> 00:39:47,119

what are you going to do what

1181

00:39:50,310 --> 00:39:48,480

what's what's your new what you know

1182

00:39:51,510 --> 00:39:50,320

what what do you want to do and there's

1183

00:39:52,550 --> 00:39:51,520

a couple of

1184

00:39:54,790 --> 00:39:52,560

different options that could have

1185

00:39:57,510 --> 00:39:54,800

happened the cells could have

1186

00:39:59,349 --> 00:39:57,520

died they could have wandered off and

1187

00:40:01,270 --> 00:39:59,359

and sort of when each cell go its own

1188

00:40:02,950 --> 00:40:01,280

way they could have made a monolayer of

1189

00:40:04,710 --> 00:40:02,960

cells in a dish the way you get in cell

1190

00:40:06,069 --> 00:40:04,720

culture all kinds of things they could

1191

00:40:09,190 --> 00:40:06,079

have done they didn't do any of that

1192

00:40:11,990 --> 00:40:09,200

what they did instead was to combine

1193

00:40:14,390 --> 00:40:12,000

together and to form a little ball

1194

00:40:16,390 --> 00:40:14,400

that grew cilia these little motile

1195

00:40:17,349 --> 00:40:16,400

hairs on the outer surface

1196

00:40:19,349 --> 00:40:17,359

now

1197

00:40:21,190 --> 00:40:19,359

cilia are normally sitting on the

1198

00:40:23,190 --> 00:40:21,200

outside of embryos and they're there to

1199

00:40:25,270 --> 00:40:23,200

kind of redistribute the mucus around

1200

00:40:27,349 --> 00:40:25,280

and to you know make the pathogens sort

1201
00:40:30,150 --> 00:40:27,359
of keep moving and not stick to the skin

1202
00:40:32,150 --> 00:40:30,160
they're used to they're used to um

1203
00:40:32,950 --> 00:40:32,160
keep the surface of the of the tadpole

1204
00:40:35,990 --> 00:40:32,960
clean

1205
00:40:39,109 --> 00:40:36,000
uh but instead these cells basically

1206
00:40:40,309 --> 00:40:39,119
repurposed that genetically encoded

1207
00:40:42,230 --> 00:40:40,319
hardware the cilia themselves are

1208
00:40:43,990 --> 00:40:42,240
genetically encoded all the proteins

1209
00:40:46,150 --> 00:40:44,000
necessary to make a psyllium are in the

1210
00:40:49,190 --> 00:40:46,160
genome and they so so they have that

1211
00:40:52,950 --> 00:40:49,200
already but what they did was they

1212
00:40:55,109 --> 00:40:52,960
assembled themselves into a new um

1213
00:40:56,790 --> 00:40:55,119

into a new kind of uh a new kind of

1214

00:40:58,790 --> 00:40:56,800

architecture this this this spherical

1215

00:41:00,309 --> 00:40:58,800

thing which and and then and then they

1216

00:41:01,510 --> 00:41:00,319

use the cilia to propel themselves so

1217

00:41:03,270 --> 00:41:01,520

they started running around they started

1218

00:41:05,670 --> 00:41:03,280

moving around and so we have these

1219

00:41:07,510 --> 00:41:05,680

amazing videos of them moving around

1220

00:41:10,069 --> 00:41:07,520

singly moving around in groups

1221

00:41:12,230 --> 00:41:10,079

interacting we're going through a maze

1222

00:41:14,309 --> 00:41:12,240

going back and forth in various

1223

00:41:15,990 --> 00:41:14,319

configurations they have all kinds of

1224

00:41:18,390 --> 00:41:16,000

behaviors they have all kinds they can

1225

00:41:19,990 --> 00:41:18,400

regenerate if you if you cut them

1226

00:41:22,630 --> 00:41:20,000

almost entirely in half they will like

1227

00:41:25,030 --> 00:41:22,640

join back and and and make a

1228

00:41:27,270 --> 00:41:25,040

you know make a uh uh

1229

00:41:28,309 --> 00:41:27,280

make a make a zenobot again

1230

00:41:34,309 --> 00:41:28,319

and

1231

00:41:36,390 --> 00:41:34,319

way we don't know their cognitive

1232

00:41:38,309 --> 00:41:36,400

capacities yet okay we don't we we're

1233

00:41:39,750 --> 00:41:38,319

only beginning now to start to see can

1234

00:41:41,510 --> 00:41:39,760

they learn can they do they have

1235

00:41:43,190 --> 00:41:41,520

preferences all these kinds of things we

1236

00:41:44,710 --> 00:41:43,200

don't know yet but the coolest thing

1237

00:41:46,069 --> 00:41:44,720

about them is that to my knowledge

1238

00:41:48,470 --> 00:41:46,079

they're the only

1239

00:41:49,910 --> 00:41:48,480

creature on the planet that doesn't

1240

00:41:52,790 --> 00:41:49,920

really have

1241

00:41:54,950 --> 00:41:52,800

an evolutionary backstory the individual

1242

00:41:57,109 --> 00:41:54,960

cells do okay the cells have a long

1243

00:41:59,270 --> 00:41:57,119

evolutionary history on earth

1244

00:42:00,630 --> 00:41:59,280

but they were selected for that genome

1245

00:42:02,309 --> 00:42:00,640

was selected for the ability of these

1246

00:42:04,230 --> 00:42:02,319

cells to sit quietly on the outside of

1247

00:42:05,910 --> 00:42:04,240

the frog and keep out the pathogens they

1248

00:42:07,829 --> 00:42:05,920

were not selected specifically to be

1249

00:42:09,990 --> 00:42:07,839

able to get together and run around in a

1250

00:42:11,829 --> 00:42:10,000

separate in a separate configuration

1251
00:42:14,309 --> 00:42:11,839
away from the embryo where did that all

1252
00:42:16,870 --> 00:42:14,319
come from and in fact one of the one of

1253
00:42:18,150 --> 00:42:16,880
the things about it is people people

1254
00:42:18,950 --> 00:42:18,160
often say well you know when are you

1255
00:42:20,550 --> 00:42:18,960
going to buy when you're going to

1256
00:42:22,790 --> 00:42:20,560
engineer these things you know knock in

1257
00:42:24,870 --> 00:42:22,800
various synthetic biology circuits right

1258
00:42:27,190 --> 00:42:24,880
make them do things and we absolutely

1259
00:42:29,990 --> 00:42:27,200
will do that but my goal before we do

1260
00:42:32,150 --> 00:42:30,000
any of that my goal was to show people

1261
00:42:34,230 --> 00:42:32,160
what what can happen while the diversity

1262
00:42:37,109 --> 00:42:34,240
that can happen from the exact same

1263
00:42:38,870 --> 00:42:37,119

genome with no manipulations whatsoever

1264

00:42:40,390 --> 00:42:38,880

because if you because the thing about

1265

00:42:42,230 --> 00:42:40,400

these cinnabots is they just have a

1266

00:42:43,750 --> 00:42:42,240

normal frog genome they have no other

1267

00:42:45,430 --> 00:42:43,760

they have no transgenes no genomic

1268

00:42:47,270 --> 00:42:45,440

editing there's nothing different about

1269

00:42:49,349 --> 00:42:47,280

them there what we're seeing is the

1270

00:42:51,190 --> 00:42:49,359

plasticity of

1271

00:42:53,109 --> 00:42:51,200

of this collective intelligence that is

1272

00:42:55,589 --> 00:42:53,119

able to make a new functional

1273

00:42:57,270 --> 00:42:55,599

proto-organism in a novel way out of the

1274

00:42:59,270 --> 00:42:57,280

exact same parts

1275

00:43:01,589 --> 00:42:59,280

so there's no genomic editing there did

1276
00:43:03,829 --> 00:43:01,599
you manipulate its morphogenetic code

1277
00:43:05,190 --> 00:43:03,839
the electrical signals at all not yet no

1278
00:43:06,870 --> 00:43:05,200
we're going to we're certainly going to

1279
00:43:08,710 --> 00:43:06,880
that's all to come no at this point we

1280
00:43:11,109 --> 00:43:08,720
haven't done that this is this is this

1281
00:43:14,390 --> 00:43:11,119
is purely native plasticity this is what

1282
00:43:16,550 --> 00:43:14,400
these cells already know how to do we we

1283
00:43:19,510 --> 00:43:16,560
we scrape them we scrape them off of the

1284
00:43:21,510 --> 00:43:19,520
frog and we put them in little holes the

1285
00:43:23,270 --> 00:43:21,520
little little sort of depressions

1286
00:43:24,870 --> 00:43:23,280
and

1287
00:43:26,390 --> 00:43:24,880
i should back up there are two types of

1288
00:43:28,790 --> 00:43:26,400

cinnabots okay the one i'm describing

1289

00:43:30,390 --> 00:43:28,800

now we literally did almost nothing you

1290

00:43:32,470 --> 00:43:30,400

scrape them off the embryo you set them

1291

00:43:33,750 --> 00:43:32,480

aside and you say fine now liberated

1292

00:43:37,030 --> 00:43:33,760

from all the signals that would have

1293

00:43:38,870 --> 00:43:37,040

turned you into uh various uh various

1294

00:43:40,950 --> 00:43:38,880

things what do you want to do and this

1295

00:43:42,550 --> 00:43:40,960

is what they do on their own

1296

00:43:44,150 --> 00:43:42,560

there's another type of zen about which

1297

00:43:45,829 --> 00:43:44,160

is actually the one we started with

1298

00:43:46,790 --> 00:43:45,839

where we sculpted them a little bit we

1299

00:43:48,069 --> 00:43:46,800

um

1300

00:43:50,470 --> 00:43:48,079

and this is by the way this is all work

1301

00:43:52,470 --> 00:43:50,480

done in in collaboration with uh with

1302

00:43:54,230 --> 00:43:52,480

bongard lab at university of vermont and

1303

00:43:55,829 --> 00:43:54,240

sam kriegman did did all the

1304

00:43:57,030 --> 00:43:55,839

computational model modeling for this

1305

00:43:59,190 --> 00:43:57,040

and then um

1306

00:44:01,190 --> 00:43:59,200

doug blackiston did the uh did all the

1307

00:44:03,349 --> 00:44:01,200

all the microsurgery and everything we

1308

00:44:05,349 --> 00:44:03,359

we sculpted them a bit to give them legs

1309

00:44:07,030 --> 00:44:05,359

so you basically just it's subtractive

1310

00:44:08,309 --> 00:44:07,040

like subtractive sculpting you just cut

1311

00:44:09,670 --> 00:44:08,319

away some stuff so that you're you're

1312

00:44:12,069 --> 00:44:09,680

left with kind of an ottoman that has

1313

00:44:13,829 --> 00:44:12,079

like four or four legs you know and uh

1314

00:44:15,670 --> 00:44:13,839

and and we and and we put in a little

1315

00:44:17,349 --> 00:44:15,680

bit of a little bit of of muscle and

1316

00:44:18,390 --> 00:44:17,359

then it learned to walk so so the muscle

1317

00:44:20,150 --> 00:44:18,400

would contract and the thing would

1318

00:44:22,390 --> 00:44:20,160

basically walk along that's that's the

1319

00:44:24,390 --> 00:44:22,400

first set of xenobots we made the second

1320

00:44:26,550 --> 00:44:24,400

one has no muscle it has no nerve it

1321

00:44:29,270 --> 00:44:26,560

only it's only skin and those can get

1322

00:44:31,510 --> 00:44:29,280

around perfectly well on their own using

1323

00:44:33,270 --> 00:44:31,520

these cilia and their our interventions

1324

00:44:35,030 --> 00:44:33,280

are extremely minimal

1325

00:44:36,790 --> 00:44:35,040

it's important that it was taken off of

1326
00:44:38,150 --> 00:44:36,800
embryos or it doesn't matter if you took

1327
00:44:39,510 --> 00:44:38,160
it off of a frog much later in

1328
00:44:40,870 --> 00:44:39,520
development

1329
00:44:43,270 --> 00:44:40,880
um

1330
00:44:45,829 --> 00:44:43,280
we haven't we haven't taken it off a

1331
00:44:47,270 --> 00:44:45,839
frog later in development but we we have

1332
00:44:49,829 --> 00:44:47,280
we have other evidence that i can't

1333
00:44:51,430 --> 00:44:49,839
really talk about yet that uh suggests

1334
00:44:52,550 --> 00:44:51,440
that it doesn't matter that it's a frog

1335
00:44:55,030 --> 00:44:52,560
and it doesn't matter that it's an

1336
00:44:56,790 --> 00:44:55,040
embryo we have we have we we have data

1337
00:44:59,430 --> 00:44:56,800
on adult cells now

1338
00:45:02,309 --> 00:44:59,440

what occurs to me is

1339

00:45:04,790 --> 00:45:03,750

if this has implications for what it

1340

00:45:06,950 --> 00:45:04,800

means to be

1341

00:45:08,550 --> 00:45:06,960

alive in the colloquial sense so forget

1342

00:45:10,150 --> 00:45:08,560

about in the biological sense so we

1343

00:45:11,910 --> 00:45:10,160

think of our skin as dead and our bones

1344

00:45:13,430 --> 00:45:11,920

are dead and perhaps dead isn't the

1345

00:45:16,150 --> 00:45:13,440

right term but let's say animated

1346

00:45:17,910 --> 00:45:16,160

animated with life with vim with brielle

1347

00:45:20,230 --> 00:45:17,920

yet you showed that somehow you can

1348

00:45:22,069 --> 00:45:20,240

still trigger vim and brio

1349

00:45:23,829 --> 00:45:22,079

not via this electrical manipulation i

1350

00:45:25,270 --> 00:45:23,839

thought it was that but does this have

1351
00:45:27,670 --> 00:45:25,280
any bearing as to what we consider to be

1352
00:45:29,349 --> 00:45:27,680
alive or it's a dif or it's a are

1353
00:45:31,990 --> 00:45:29,359
unrelated

1354
00:45:34,309 --> 00:45:32,000
um i'll tell you that uh one of the

1355
00:45:36,790 --> 00:45:34,319
things that this kind of work does is

1356
00:45:39,190 --> 00:45:36,800
really illustrate the

1357
00:45:41,510 --> 00:45:39,200
insufficiency of our vocabulary so

1358
00:45:43,270 --> 00:45:41,520
people often argue for example i mean

1359
00:45:46,069 --> 00:45:43,280
alive is a funny thing i don't i don't

1360
00:45:47,990 --> 00:45:46,079
actually know what alive really i don't

1361
00:45:49,829 --> 00:45:48,000
have a good definition the these cells

1362
00:45:51,510 --> 00:45:49,839
and these organisms are for sure alive

1363
00:45:52,950 --> 00:45:51,520

in the traditional sense i mean the the

1364

00:45:54,790 --> 00:45:52,960

cells are alive there's no there's no

1365

00:45:56,790 --> 00:45:54,800

getting around that but but but people

1366

00:46:00,710 --> 00:45:56,800

will often argue for example are they

1367

00:46:02,630 --> 00:46:00,720

robots are they organisms are they uh

1368

00:46:05,349 --> 00:46:02,640

you know these are they machines these

1369

00:46:06,870 --> 00:46:05,359

kinds of things and and and we we josh

1370

00:46:08,390 --> 00:46:06,880

bongard and i wrote a paper addressing

1371

00:46:09,190 --> 00:46:08,400

this question basically pointing out

1372

00:46:14,870 --> 00:46:09,200

that

1373

00:46:16,950 --> 00:46:14,880

useless now it was it was great 50 years

1374

00:46:18,870 --> 00:46:16,960

ago when you could

1375

00:46:21,270 --> 00:46:18,880

you when when it was really easy to tell

1376
00:46:23,510 --> 00:46:21,280
apart machines that were that were that

1377
00:46:24,390 --> 00:46:23,520
were boring predictable they were they

1378
00:46:26,710 --> 00:46:24,400
were

1379
00:46:29,109 --> 00:46:26,720
designed right and living things which

1380
00:46:31,910 --> 00:46:29,119
were surprising and interesting and warm

1381
00:46:34,309 --> 00:46:31,920
and wet and um and evolved those things

1382
00:46:36,950 --> 00:46:34,319
are now so intermixed

1383
00:46:39,349 --> 00:46:36,960
that with modern with modern techniques

1384
00:46:41,190 --> 00:46:39,359
of digital evolution and bioengineering

1385
00:46:43,349 --> 00:46:41,200
and synthetic morphology that

1386
00:46:45,030 --> 00:46:43,359
distinction does not exist anymore and

1387
00:46:46,390 --> 00:46:45,040
so it used to be that you can sort of

1388
00:46:48,069 --> 00:46:46,400

like you could knock on something and if

1389

00:46:49,910 --> 00:46:48,079

you hear a hollow metallic sound and you

1390

00:46:51,589 --> 00:46:49,920

say ah yeah that that came off a factory

1391

00:46:54,150 --> 00:46:51,599

that's a machine and i'm you know

1392

00:46:55,670 --> 00:46:54,160

morally um uh okay with taking it apart

1393

00:46:57,190 --> 00:46:55,680

and doing whatever i want with it and if

1394

00:46:59,190 --> 00:46:57,200

you were to do this and and it was sort

1395

00:47:01,190 --> 00:46:59,200

of so soft and squishy then you would

1396

00:47:03,349 --> 00:47:01,200

say that's evolved and it's living and i

1397

00:47:05,990 --> 00:47:03,359

better i better be nice to it that right

1398

00:47:08,230 --> 00:47:06,000

though that easy distinction is just

1399

00:47:09,910 --> 00:47:08,240

that doesn't exist anymore so we need we

1400

00:47:11,589 --> 00:47:09,920

need a better vocabulary i mean they're

1401

00:47:13,030 --> 00:47:11,599

they're alive for sure but if you want

1402

00:47:15,750 --> 00:47:13,040

to ask questions about whether they are

1403

00:47:18,630 --> 00:47:15,760

machines or robots or living organisms

1404

00:47:20,549 --> 00:47:18,640

or that that all that stretches the

1405

00:47:21,829 --> 00:47:20,559

vocabulary which is no longer up to the

1406

00:47:23,670 --> 00:47:21,839

task

1407

00:47:25,829 --> 00:47:23,680

is there a relationship between

1408

00:47:27,030 --> 00:47:25,839

perception and this morphogenetic code

1409

00:47:29,510 --> 00:47:27,040

and i know i keep using that word

1410

00:47:30,870 --> 00:47:29,520

morphogenetic code and yeah forgive me

1411

00:47:32,309 --> 00:47:30,880

if i'm abusing the terminology but is

1412

00:47:34,470 --> 00:47:32,319

there a relationship between perception

1413

00:47:36,549 --> 00:47:34,480

and morphogenetic code i'll give you my

1414

00:47:38,230 --> 00:47:36,559

reasoning behind it right now what i see

1415

00:47:40,230 --> 00:47:38,240

is i recognize a monitor i see a

1416

00:47:42,549 --> 00:47:40,240

microphone i see you you have eyebrows i

1417

00:47:43,670 --> 00:47:42,559

see large scale structures then the

1418

00:47:46,630 --> 00:47:43,680

question is well is there anything

1419

00:47:48,069 --> 00:47:46,640

special about your eyebrows

1420

00:47:49,750 --> 00:47:48,079

well

1421

00:47:50,710 --> 00:47:49,760

other than you're an attractive man

1422

00:47:53,109 --> 00:47:50,720

let's say

1423

00:47:54,150 --> 00:47:53,119

physically speaking physics would say

1424

00:47:55,670 --> 00:47:54,160

there's nothing special about this

1425

00:47:57,670 --> 00:47:55,680

microphone or 10 percent of the

1426
00:48:00,470 --> 00:47:57,680
microphone or 10 of the microphone plus

1427
00:48:01,910 --> 00:48:00,480
the air slightly around it it's more a

1428
00:48:03,990 --> 00:48:01,920
pragmatic matter

1429
00:48:06,870 --> 00:48:04,000
that it's a practical that it matters

1430
00:48:08,150 --> 00:48:06,880
that i can use this

1431
00:48:10,710 --> 00:48:08,160
however when you're talking about this

1432
00:48:13,190 --> 00:48:10,720
non-neural bioelectric code it's as if

1433
00:48:15,109 --> 00:48:13,200
these large-scale structures that we

1434
00:48:16,630 --> 00:48:15,119
recognize as salient and significant

1435
00:48:18,309 --> 00:48:16,640
such as a low resolution facet like a

1436
00:48:19,990 --> 00:48:18,319
child's drawings of eyebrows nose head

1437
00:48:22,870 --> 00:48:20,000
placement and so on that those are there

1438
00:48:25,510 --> 00:48:22,880

in the code so somehow what we perceive

1439

00:48:27,109 --> 00:48:25,520

is also what is encoded

1440

00:48:29,190 --> 00:48:27,119

and i'm curious well is that is there a

1441

00:48:30,710 --> 00:48:29,200

confounding factor that influences both

1442

00:48:33,030 --> 00:48:30,720

does the morphogenetic code influence

1443

00:48:35,109 --> 00:48:33,040

our perceptions

1444

00:48:36,630 --> 00:48:35,119

perhaps i can give a better analogy if i

1445

00:48:38,790 --> 00:48:36,640

a computer science analogy where we have

1446

00:48:40,069 --> 00:48:38,800

machine code and then you have like

1447

00:48:42,790 --> 00:48:40,079

what builds a top that builds the top

1448

00:48:44,390 --> 00:48:42,800

library is jquery and on html5 and so on

1449

00:48:45,990 --> 00:48:44,400

so we have a function bounce which takes

1450

00:48:48,390 --> 00:48:46,000

an image and bounces it or texts and

1451

00:48:50,870 --> 00:48:48,400

bounces it or one that plays mpeg so the

1452

00:48:53,829 --> 00:48:50,880

question is well what makes bounce

1453

00:48:55,829 --> 00:48:53,839

or mpeg playing more fundamental well to

1454

00:48:58,230 --> 00:48:55,839

me i would say nothing it's us it's what

1455

00:49:02,950 --> 00:48:58,240

we use however it's strange that

1456

00:49:05,109 --> 00:49:02,960

objectively there's this code for it

1457

00:49:07,750 --> 00:49:05,119

yeah yeah um well there's a there's a

1458

00:49:10,390 --> 00:49:07,760

lot there and what you just said uh

1459

00:49:13,109 --> 00:49:10,400

certainly um perception is a part of

1460

00:49:15,589 --> 00:49:13,119

this whole process because in order to

1461

00:49:18,390 --> 00:49:15,599

have this kind of um

1462

00:49:21,990 --> 00:49:18,400

anatomical homeostasis where

1463

00:49:23,510 --> 00:49:22,000

you you uh you you you you damage in you

1464

00:49:25,430 --> 00:49:23,520

know an organism like a salamander which

1465

00:49:26,790 --> 00:49:25,440

can regenerate most of its organs or a

1466

00:49:29,270 --> 00:49:26,800

planarian which can regenerate all of

1467

00:49:31,109 --> 00:49:29,280

its organs you you damage it and then it

1468

00:49:33,430 --> 00:49:31,119

grows with the right thing and then it

1469

00:49:35,430 --> 00:49:33,440

stops when it's done that loop that

1470

00:49:37,829 --> 00:49:35,440

homeostatic loop has to have a

1471

00:49:40,069 --> 00:49:37,839

perception component because it has to

1472

00:49:42,309 --> 00:49:40,079

be able to recognize when it's done so

1473

00:49:44,470 --> 00:49:42,319

it has to be able to perceive am i a

1474

00:49:46,069 --> 00:49:44,480

correct planarian or not and if i'm not

1475

00:49:47,349 --> 00:49:46,079

i'm going to keep remodeling until i am

1476

00:49:49,589 --> 00:49:47,359

and at that point so it's an error

1477

00:49:51,670 --> 00:49:49,599

minimization scheme and in order to

1478

00:49:53,430 --> 00:49:51,680

achieve that error minimization you have

1479

00:49:55,670 --> 00:49:53,440

to be able to perceive around you in

1480

00:49:57,510 --> 00:49:55,680

anatomical space and to say am i in the

1481

00:49:59,349 --> 00:49:57,520

right region of space here is my head

1482

00:50:02,230 --> 00:49:59,359

and the right size is do do i have the

1483

00:50:05,589 --> 00:50:02,240

right number of eyes um all of that

1484

00:50:09,030 --> 00:50:05,599

you need to perceive that and people um

1485

00:50:10,950 --> 00:50:09,040

people like grossberg uh and uh at bu

1486

00:50:13,109 --> 00:50:10,960

had written years ago about the

1487

00:50:14,790 --> 00:50:13,119

relationship between retinal information

1488

00:50:16,470 --> 00:50:14,800

processing and development and i

1489

00:50:18,230 --> 00:50:16,480

actually think he was he was really on

1490

00:50:20,870 --> 00:50:18,240

to something in the sense that i think

1491

00:50:22,790 --> 00:50:20,880

most epithelia are basically like a big

1492

00:50:24,309 --> 00:50:22,800

retina and that what they're doing is

1493

00:50:27,030 --> 00:50:24,319

they're they're they're constantly

1494

00:50:28,950 --> 00:50:27,040

surveilling the rest of the animal

1495

00:50:31,349 --> 00:50:28,960

or the rest of the body

1496

00:50:34,069 --> 00:50:31,359

and making decisions about large-scale

1497

00:50:35,829 --> 00:50:34,079

features so not just individual pixels

1498

00:50:37,190 --> 00:50:35,839

but things like in the in the retina

1499

00:50:38,230 --> 00:50:37,200

you'd be talking about edge detection

1500

00:50:39,670 --> 00:50:38,240

motion

1501
00:50:41,030 --> 00:50:39,680
things like that and that's what they're

1502
00:50:42,790 --> 00:50:41,040
doing they're looking at large scale

1503
00:50:44,309 --> 00:50:42,800
features that individual cells cannot

1504
00:50:45,910 --> 00:50:44,319
detect so

1505
00:50:48,069 --> 00:50:45,920
one way to look at this is that we have

1506
00:50:49,750 --> 00:50:48,079
a precedent for this from neuroscience

1507
00:50:52,150 --> 00:50:49,760
and from visual from the science of

1508
00:50:53,990 --> 00:50:52,160
visual processing the probably the more

1509
00:50:55,750 --> 00:50:54,000
accurate way to look at it is yeah that

1510
00:50:57,430 --> 00:50:55,760
guess where the retina learned its

1511
00:50:59,270 --> 00:50:57,440
tricks right and guess where where

1512
00:51:02,390 --> 00:50:59,280
brains learn their visual processing

1513
00:51:04,790 --> 00:51:02,400

tricks by far more ancient mechanisms of

1514

00:51:06,230 --> 00:51:04,800

cellular groups navigating morphospace

1515

00:51:08,470 --> 00:51:06,240

that that's that's what it used to be

1516

00:51:10,069 --> 00:51:08,480

before it became the before it became

1517

00:51:11,670 --> 00:51:10,079

vision basically

1518

00:51:13,750 --> 00:51:11,680

do you believe that the problem of

1519

00:51:16,630 --> 00:51:13,760

senescence to the degree can be called a

1520

00:51:18,309 --> 00:51:16,640

problem is largely a disruption of

1521

00:51:20,230 --> 00:51:18,319

this electrical blueprint rather than

1522

00:51:22,549 --> 00:51:20,240

oxidative stress and damage to dna and

1523

00:51:25,030 --> 00:51:22,559

so on that or telomeric length that

1524

00:51:28,069 --> 00:51:25,040

people think

1525

00:51:29,750 --> 00:51:28,079

um i don't have any evidence yet that

1526

00:51:31,349 --> 00:51:29,760

there's a bioelectric component to this

1527

00:51:32,710 --> 00:51:31,359

i mean i suspect there is but but we

1528

00:51:34,950 --> 00:51:32,720

don't have any evidence on it we haven't

1529

00:51:36,870 --> 00:51:34,960

really worked on aging per se

1530

00:51:39,030 --> 00:51:36,880

i will say that i don't think it's

1531

00:51:41,670 --> 00:51:39,040

anything as fundamental as

1532

00:51:43,109 --> 00:51:41,680

uh this kind of like thermodynamic decay

1533

00:51:45,670 --> 00:51:43,119

or anything like that because the

1534

00:51:48,549 --> 00:51:45,680

planaria are immortal they don't have a

1535

00:51:50,390 --> 00:51:48,559

a life span limit they live forever and

1536

00:51:53,430 --> 00:51:50,400

so they are telling us that it's

1537

00:51:56,309 --> 00:51:53,440

possible to be a complex regenerative

1538

00:51:59,109 --> 00:51:56,319

organism with uh learning capacity and

1539

00:52:01,270 --> 00:51:59,119

so on and not age so so so it's clearly

1540

00:52:03,030 --> 00:52:01,280

possible so so the rest is details right

1541

00:52:05,349 --> 00:52:03,040

the rest is i i don't think it's

1542

00:52:07,510 --> 00:52:05,359

anything as fundamental as

1543

00:52:09,109 --> 00:52:07,520

the the the theories that say well look

1544

00:52:10,710 --> 00:52:09,119

when you copy things you inevitably make

1545

00:52:13,109 --> 00:52:10,720

mistakes so eventually stuff whereas it

1546

00:52:15,109 --> 00:52:13,119

wears out if that were true

1547

00:52:16,150 --> 00:52:15,119

you wouldn't have plenary so so i don't

1548

00:52:17,270 --> 00:52:16,160

think i don't think it's anything like

1549

00:52:20,390 --> 00:52:17,280

that i think it's something much more

1550

00:52:22,470 --> 00:52:20,400

contingent much more specific uh and and

1551
00:52:24,390 --> 00:52:22,480
thus i i'm optimistic that we can

1552
00:52:26,630 --> 00:52:24,400
overcome it so there's some work you're

1553
00:52:28,150 --> 00:52:26,640
outlining in a previous talk with uh as

1554
00:52:29,510 --> 00:52:28,160
i think it was a couple years ago at the

1555
00:52:31,030 --> 00:52:29,520
time it was an undergraduate her name

1556
00:52:33,829 --> 00:52:31,040
was maya though i don't recall her last

1557
00:52:35,349 --> 00:52:33,839
name and she changed between three types

1558
00:52:36,309 --> 00:52:35,359
of planaria head

1559
00:52:39,190 --> 00:52:36,319
like

1560
00:52:40,630 --> 00:52:39,200
i think it was felina mediterranean doro

1561
00:52:41,829 --> 00:52:40,640
i don't recall how to pronounce it but

1562
00:52:44,309 --> 00:52:41,839
there were about tens of millions of

1563
00:52:45,030 --> 00:52:44,319

years apart evolutionarily and that to

1564

00:52:46,870 --> 00:52:45,040

me

1565

00:52:48,309 --> 00:52:46,880

implies that there

1566

00:52:50,630 --> 00:52:48,319

perhaps our structures that are

1567

00:52:51,589 --> 00:52:50,640

unfathomably submerged in us from our

1568

00:52:52,710 --> 00:52:51,599

past

1569

00:52:54,069 --> 00:52:52,720

and then i'm

1570

00:52:55,750 --> 00:52:54,079

curious if there's a relationship

1571

00:52:57,109 --> 00:52:55,760

between that

1572

00:52:59,190 --> 00:52:57,119

between these

1573

00:53:01,030 --> 00:52:59,200

let's say these electric blueprints even

1574

00:53:03,109 --> 00:53:01,040

though so whatever these electric

1575

00:53:05,109 --> 00:53:03,119

blueprints and union archetypes to go

1576

00:53:06,710 --> 00:53:05,119

off on a huge speculative jump is the

1577

00:53:08,470 --> 00:53:06,720

relationship between them

1578

00:53:10,710 --> 00:53:08,480

boy uh that's that's

1579

00:53:12,470 --> 00:53:10,720

that's a good that's a great question um

1580

00:53:15,430 --> 00:53:12,480

i think that uh

1581

00:53:16,230 --> 00:53:15,440

if if one were to

1582

00:53:18,470 --> 00:53:16,240

if

1583

00:53:19,430 --> 00:53:18,480

let's run it backwards let's say let's

1584

00:53:21,750 --> 00:53:19,440

say that

1585

00:53:23,990 --> 00:53:21,760

we underst we we have a conception of

1586

00:53:26,150 --> 00:53:24,000

jungian archetypes for

1587

00:53:28,630 --> 00:53:26,160

neuroscience and psychology

1588

00:53:30,870 --> 00:53:28,640

and now somebody could say yeah but

1589

00:53:33,349 --> 00:53:30,880

you're saying that all of all of you

1590

00:53:35,190 --> 00:53:33,359

know you know neuro neuro psychology

1591

00:53:37,190 --> 00:53:35,200

comes from earlier

1592

00:53:39,270 --> 00:53:37,200

somatic bioelectrics what would the

1593

00:53:41,270 --> 00:53:39,280

jungian what would that look like then

1594

00:53:43,109 --> 00:53:41,280

in that right in in that case what would

1595

00:53:44,710 --> 00:53:43,119

the jungian archetypes look like in this

1596

00:53:47,109 --> 00:53:44,720

other pre-neural

1597

00:53:49,109 --> 00:53:47,119

type of of bioelectrics because we do

1598

00:53:51,349 --> 00:53:49,119

this all the time we we ask things like

1599

00:53:53,190 --> 00:53:51,359

what does memory look like before it was

1600

00:53:55,589 --> 00:53:53,200

brain memory what does

1601
00:53:57,349 --> 00:53:55,599
bistable visual illusions look like

1602
00:53:59,030 --> 00:53:57,359
before they were before there were

1603
00:54:00,710 --> 00:53:59,040
brains all of these things that we see

1604
00:54:02,630 --> 00:54:00,720
in neuroscience you can ask what the

1605
00:54:04,069 --> 00:54:02,640
what the older somatic equivalent look

1606
00:54:05,349 --> 00:54:04,079
like so you can do the same thing here

1607
00:54:06,870 --> 00:54:05,359
it's an interesting question i've never

1608
00:54:08,230 --> 00:54:06,880
thought about it that way but you can

1609
00:54:10,549 --> 00:54:08,240
you can ask that question if you ask

1610
00:54:11,670 --> 00:54:10,559
that question you get to exactly the

1611
00:54:13,750 --> 00:54:11,680
kind of thing you're talking about and

1612
00:54:15,670 --> 00:54:13,760
what i would say is well probably in

1613
00:54:17,589 --> 00:54:15,680

morphospace there are these stable

1614

00:54:19,349 --> 00:54:17,599

attractors corresponding to different

1615

00:54:21,430 --> 00:54:19,359

types of shapes of heads different

1616

00:54:23,510 --> 00:54:21,440

numbers of eyes different planaria body

1617

00:54:26,150 --> 00:54:23,520

plans different all different kinds of

1618

00:54:28,230 --> 00:54:26,160

things and what you can do is you can

1619

00:54:31,270 --> 00:54:28,240

dial in those different

1620

00:54:33,349 --> 00:54:31,280

uh stable attractors by by in in the

1621

00:54:36,390 --> 00:54:33,359

state space of the electric circuit by

1622

00:54:39,670 --> 00:54:36,400

by shifting that electric circuit state

1623

00:54:41,190 --> 00:54:39,680

so uh yeah i think i think that's a fair

1624

00:54:43,670 --> 00:54:41,200

i think that's a that's that's a totally

1625

00:54:46,230 --> 00:54:43,680

fair way to think about it

1626

00:54:48,230 --> 00:54:46,240

your work is so

1627

00:54:49,750 --> 00:54:48,240

it's like to me it's like the discovery

1628

00:54:52,150 --> 00:54:49,760

of dna

1629

00:54:54,950 --> 00:54:52,160

and maybe you're too modest to accept

1630

00:54:57,990 --> 00:54:54,960

that as a compliment but i see it as

1631

00:54:59,750 --> 00:54:58,000

as that seminal and i wanna well

1632

00:55:01,190 --> 00:54:59,760

i'm gonna put this out there i'm gonna

1633

00:55:02,950 --> 00:55:01,200

say in the beginning i think this guy's

1634

00:55:04,390 --> 00:55:02,960

gonna win a nobel prize

1635

00:55:05,750 --> 00:55:04,400

he has not said that like this is not

1636

00:55:07,349 --> 00:55:05,760

him saying that i'm saying that well

1637

00:55:09,030 --> 00:55:07,359

thank you so much yeah that's that's

1638

00:55:10,309 --> 00:55:09,040

that's very kind um there are lots of

1639

00:55:12,789 --> 00:55:10,319

people i mean i i think it's important

1640

00:55:14,789 --> 00:55:12,799

to say that uh

1641

00:55:17,109 --> 00:55:14,799

yeah it's not none of my friend right

1642

00:55:19,349 --> 00:55:17,119

now well it's on on two levels so so so

1643

00:55:20,710 --> 00:55:19,359

first of all none of this uh came out of

1644

00:55:23,750 --> 00:55:20,720

thin air i didn't think of any of this

1645

00:55:27,510 --> 00:55:23,760

stuff just you know from nothing i i i i

1646

00:55:30,870 --> 00:55:27,520

built this these ideas uh on on on many

1647

00:55:33,109 --> 00:55:30,880

other ideas of of really uh kind of uh

1648

00:55:35,030 --> 00:55:33,119

really pioneering folks that work for

1649

00:55:37,270 --> 00:55:35,040

years and many of them um didn't really

1650

00:55:38,789 --> 00:55:37,280

get uh you know didn't get a lot of uh

1651
00:55:40,230 --> 00:55:38,799
acceptance from the community so that's

1652
00:55:42,150 --> 00:55:40,240
that's important to say is that is that

1653
00:55:43,349 --> 00:55:42,160
there's a lot of that out there and uh

1654
00:55:45,750 --> 00:55:43,359
and of course the people in our lab

1655
00:55:47,589 --> 00:55:45,760
right the the postdocs and and and for

1656
00:55:49,349 --> 00:55:47,599
phd students and techs who do the work i

1657
00:55:50,549 --> 00:55:49,359
mean it's certainly not not just me

1658
00:55:52,069 --> 00:55:50,559
doing all this work there are a lot of

1659
00:55:54,870 --> 00:55:52,079
people in this field and a lot of people

1660
00:55:56,870 --> 00:55:54,880
in my group so um lots of people um

1661
00:55:59,829 --> 00:55:56,880
contribute to push this all forward

1662
00:56:01,270 --> 00:55:59,839
we'll get to the audience questions

1663
00:56:02,549 --> 00:56:01,280

okay so this one comes from rupert

1664

00:56:03,910 --> 00:56:02,559

sheldrake

1665

00:56:08,470 --> 00:56:03,920

how does he think

1666

00:56:10,390 --> 00:56:08,480

morphogenetic fields relates to mine

1667

00:56:13,109 --> 00:56:10,400

referring to rupert

1668

00:56:14,549 --> 00:56:13,119

yeah uh interesting question um

1669

00:56:17,430 --> 00:56:14,559

so

1670

00:56:18,789 --> 00:56:17,440

basically our morphogenetic fields that

1671

00:56:22,069 --> 00:56:18,799

we work on

1672

00:56:25,030 --> 00:56:22,079

uh are completely physical in other

1673

00:56:26,470 --> 00:56:25,040

words they take place entirely within

1674

00:56:28,309 --> 00:56:26,480

the body of the organism they're

1675

00:56:29,430 --> 00:56:28,319

generated by the cells we can measure

1676

00:56:31,990 --> 00:56:29,440

them using

1677

00:56:34,309 --> 00:56:32,000

current technology

1678

00:56:37,270 --> 00:56:34,319

i don't know if that's true of the kinds

1679

00:56:39,190 --> 00:56:37,280

of things that rupert is talking about

1680

00:56:41,430 --> 00:56:39,200

i kind of suspect that those would have

1681

00:56:44,470 --> 00:56:41,440

to have quite a bit different properties

1682

00:56:46,309 --> 00:56:44,480

but just to be clear our fields are

1683

00:56:48,230 --> 00:56:46,319

uh and in fact in fact the things that

1684

00:56:50,789 --> 00:56:48,240

we deal with are strictly speaking not

1685

00:56:52,789 --> 00:56:50,799

even fields right so so we work with

1686

00:56:56,069 --> 00:56:52,799

spatial distributions of resting

1687

00:56:57,270 --> 00:56:56,079

potentials so it's not clear to me that

1688

00:57:00,230 --> 00:56:57,280

these are really fields in the

1689

00:57:02,230 --> 00:57:00,240

mathematical sense of of the word field

1690

00:57:04,870 --> 00:57:02,240

but these are distributions of

1691

00:57:06,870 --> 00:57:04,880

electrical potentials of living cells in

1692

00:57:08,069 --> 00:57:06,880

in a particular body so they are

1693

00:57:10,069 --> 00:57:08,079

they're they're very physical they're

1694

00:57:11,510 --> 00:57:10,079

local they're you know kind of quite

1695

00:57:13,030 --> 00:57:11,520

quite traditional distributions of

1696

00:57:14,710 --> 00:57:13,040

voltage

1697

00:57:16,710 --> 00:57:14,720

another application that i've heard you

1698

00:57:18,710 --> 00:57:16,720

mentioned though it was i don't know if

1699

00:57:20,630 --> 00:57:18,720

it was more on the speculative side or

1700

00:57:23,109 --> 00:57:20,640

if you've developed this

1701

00:57:24,309 --> 00:57:23,119

it was some organism of the potential of

1702

00:57:26,710 --> 00:57:24,319

creating some organism that

1703

00:57:28,150 --> 00:57:26,720

spontaneously and temperamentally goes

1704

00:57:31,030 --> 00:57:28,160

out and cleans up the environment it's

1705

00:57:33,589 --> 00:57:31,040

engineered to remove certain toxins

1706

00:57:35,910 --> 00:57:33,599

can you speak more about that

1707

00:57:39,270 --> 00:57:35,920

yeah that's probably was referring to

1708

00:57:42,069 --> 00:57:39,280

our zenobots so we have this uh

1709

00:57:43,750 --> 00:57:42,079

this technology where we're we're

1710

00:57:45,510 --> 00:57:43,760

creating synthetic living

1711

00:57:47,990 --> 00:57:45,520

proto-organisms made in this in this

1712

00:57:49,349 --> 00:57:48,000

case made of frog skin so these are frog

1713

00:57:51,109 --> 00:57:49,359

skin cells that in different

1714

00:57:53,109 --> 00:57:51,119

environments self-organized to be these

1715

00:57:55,349 --> 00:57:53,119

these little motile creatures

1716

00:57:57,750 --> 00:57:55,359

and at least one of many possible

1717

00:58:00,870 --> 00:57:57,760

applications in the future is to program

1718

00:58:02,710 --> 00:58:00,880

them for some sort of collection

1719

00:58:04,390 --> 00:58:02,720

tasks so that they would go out and

1720

00:58:07,349 --> 00:58:04,400

maybe collect

1721

00:58:09,670 --> 00:58:07,359

useful useful molecules or maybe they

1722

00:58:12,150 --> 00:58:09,680

would clean up toxins maybe they would

1723

00:58:13,270 --> 00:58:12,160

detect various various other chemicals

1724

00:58:15,510 --> 00:58:13,280

in the environment that you would want

1725

00:58:17,910 --> 00:58:15,520

to know about so these are all potential

1726

00:58:19,589 --> 00:58:17,920

uh applications of of the practical sort

1727

00:58:20,950 --> 00:58:19,599

of use of these kinds of synthetic

1728

00:58:22,390 --> 00:58:20,960

living machines

1729

00:58:24,309 --> 00:58:22,400

you mentioned quite a few times that

1730

00:58:26,470 --> 00:58:24,319

it's important when you're dealing with

1731

00:58:28,710 --> 00:58:26,480

the manipulation of this electric

1732

00:58:31,109 --> 00:58:28,720

field or voltage gradient that you don't

1733

00:58:33,030 --> 00:58:31,119

use external electric fields you

1734

00:58:36,230 --> 00:58:33,040

actually manipulate the cellular ion

1735

00:58:38,150 --> 00:58:36,240

channels directly yeah okay so then i

1736

00:58:40,230 --> 00:58:38,160

was wondering does this mean you know

1737

00:58:43,190 --> 00:58:40,240

how some people say 5g

1738

00:58:45,430 --> 00:58:43,200

that we should be scared of 5g because

1739

00:58:46,789 --> 00:58:45,440

well for various reasons

1740

00:58:48,710 --> 00:58:46,799

but then other people say it's

1741

00:58:50,230 --> 00:58:48,720

non-ionizings and that's and that's all

1742

00:58:52,950 --> 00:58:50,240

that matters well is that all that

1743

00:58:55,990 --> 00:58:52,960

matters is there some validity to being

1744

00:58:58,870 --> 00:58:56,000

concerned about 5g

1745

00:59:01,270 --> 00:58:58,880

um so so i think i think both of those

1746

00:59:04,630 --> 00:59:01,280

viewpoints are a little bit off and the

1747

00:59:06,069 --> 00:59:04,640

truth is somewhere in the middle so so

1748

00:59:08,309 --> 00:59:06,079

let's let's just start with the ionizing

1749

00:59:10,549 --> 00:59:08,319

business so so i i think the evidence is

1750

00:59:12,710 --> 00:59:10,559

quite clear that electromagnetic

1751
00:59:14,630 --> 00:59:12,720
radiation does not need to be ionizing

1752
00:59:17,430 --> 00:59:14,640
and in fact it is not to be particularly

1753
00:59:19,670 --> 00:59:17,440
strong in order to in some way affect

1754
00:59:21,030 --> 00:59:19,680
living cells so living things so living

1755
00:59:23,750 --> 00:59:21,040
things are sensitive to all sorts of

1756
00:59:25,990 --> 00:59:23,760
electromagnetic radiation uh in many

1757
00:59:27,910 --> 00:59:26,000
ways that do not require ionization or

1758
00:59:29,190 --> 00:59:27,920
heat or anything like that at the same

1759
00:59:32,150 --> 00:59:29,200
time

1760
00:59:33,990 --> 00:59:32,160
i think i don't have any reason to be

1761
00:59:35,430 --> 00:59:34,000
concerned about 5g first of all the

1762
00:59:37,430 --> 00:59:35,440
kinds of things that we study so these

1763
00:59:40,069 --> 00:59:37,440

bioelectric signaling

1764

00:59:42,710 --> 00:59:40,079

pathways are not particularly affected

1765

00:59:44,309 --> 00:59:42,720

by external electromagnetic fields if

1766

00:59:46,549 --> 00:59:44,319

they were we would be using these kinds

1767

00:59:47,589 --> 00:59:46,559

of things in the lab to manipulate the

1768

00:59:50,870 --> 00:59:47,599

electrical

1769

00:59:52,069 --> 00:59:50,880

it's not a great way to control

1770

00:59:53,750 --> 00:59:52,079

bioelectric

1771

00:59:55,589 --> 00:59:53,760

signaling within tissue it's it just

1772

00:59:57,109 --> 00:59:55,599

doesn't do a very good job of it so i

1773

00:59:59,910 --> 00:59:57,119

don't have any particular reason to be

1774

01:00:01,510 --> 00:59:59,920

worried about 5g i have a feeling that

1775

01:00:04,309 --> 01:00:01,520

uh for most people that are worried

1776

01:00:06,390 --> 01:00:04,319

about it you have far bigger dangers and

1777

01:00:08,710 --> 01:00:06,400

stressors in your life you know uh if

1778

01:00:10,069 --> 01:00:08,720

you eat certain things if you uh engage

1779

01:00:12,630 --> 01:00:10,079

in certain behaviors

1780

01:00:14,710 --> 01:00:12,640

this is far more of an issue for you

1781

01:00:17,349 --> 01:00:14,720

statistically than than 5g ever will be

1782

01:00:19,910 --> 01:00:17,359

so so i'm i'm not particularly worried

1783

01:00:21,589 --> 01:00:19,920

about 5g on a on a practical level in

1784

01:00:23,030 --> 01:00:21,599

the in the grand scheme of things that i

1785

01:00:24,549 --> 01:00:23,040

worry about in the things that we all do

1786

01:00:26,390 --> 01:00:24,559

in our life that are sort of not optimal

1787

01:00:27,750 --> 01:00:26,400

for health i think 5g is probably way

1788

01:00:30,069 --> 01:00:27,760

down on the list of things for you to

1789

01:00:31,910 --> 01:00:30,079

worry about however i think it's it's

1790

01:00:33,430 --> 01:00:31,920

not true to say that uh because it's

1791

01:00:35,589 --> 01:00:33,440

non-ionizing we don't need to worry

1792

01:00:37,510 --> 01:00:35,599

about it i think that's actually false

1793

01:00:39,589 --> 01:00:37,520

okay speaking about diet you mentioned

1794

01:00:40,710 --> 01:00:39,599

eating and then in one of your talks you

1795

01:00:43,030 --> 01:00:40,720

also mentioned there's a connection

1796

01:00:44,950 --> 01:00:43,040

between the microbiome and this

1797

01:00:46,390 --> 01:00:44,960

morphogenetic field but i didn't hear

1798

01:00:48,950 --> 01:00:46,400

more elaboration on that so if you don't

1799

01:00:50,390 --> 01:00:48,960

mind elaborating they'll be great

1800

01:00:52,789 --> 01:00:50,400

yeah well

1801

01:00:54,309 --> 01:00:52,799

the general point is that

1802

01:00:58,870 --> 01:00:54,319

any sort of

1803

01:01:00,950 --> 01:00:58,880

modality that that controls the behavior

1804

01:01:03,270 --> 01:01:00,960

of cells in an organism automatically

1805

01:01:05,990 --> 01:01:03,280

becomes the target of an evolutionary

1806

01:01:08,390 --> 01:01:06,000

arms race of other organisms that live

1807

01:01:10,950 --> 01:01:08,400

near you on you within you and so on

1808

01:01:13,109 --> 01:01:10,960

because they can potentially manipulate

1809

01:01:15,270 --> 01:01:13,119

those controls to make specific things

1810

01:01:16,630 --> 01:01:15,280

happen in the body right so so anything

1811

01:01:18,390 --> 01:01:16,640

including chemical signaling

1812

01:01:21,190 --> 01:01:18,400

neurotransmitters we already know that

1813

01:01:22,950 --> 01:01:21,200

the microbiome is affecting mood and

1814

01:01:24,789 --> 01:01:22,960

behavior and things like that by

1815

01:01:27,109 --> 01:01:24,799

plugging into the neurotransmitter

1816

01:01:28,069 --> 01:01:27,119

pathways so there's this gut brain axis

1817

01:01:30,549 --> 01:01:28,079

and so on

1818

01:01:32,789 --> 01:01:30,559

so the same is true of bioelectric so so

1819

01:01:34,549 --> 01:01:32,799

in general you we could certainly assume

1820

01:01:35,829 --> 01:01:34,559

that various microbes that live in the

1821

01:01:38,390 --> 01:01:35,839

body and various other kinds of

1822

01:01:41,109 --> 01:01:38,400

parasites would have ways of tweaking

1823

01:01:43,109 --> 01:01:41,119

ion channel activities meaning probably

1824

01:01:44,470 --> 01:01:43,119

using some sort of you know chemicals

1825

01:01:46,470 --> 01:01:44,480

that they would be putting out to

1826
01:01:47,510 --> 01:01:46,480
manipulate your tissues way in ways that

1827
01:01:50,150 --> 01:01:47,520
would be

1828
01:01:51,910 --> 01:01:50,160
evolutionarily advantageous to them now

1829
01:01:53,510 --> 01:01:51,920
it just so happens we have a practical

1830
01:01:55,510 --> 01:01:53,520
example of this that we studied a couple

1831
01:01:57,029 --> 01:01:55,520
years ago in planaria

1832
01:01:57,829 --> 01:01:57,039
where and this was done in collaboration

1833
01:02:00,549 --> 01:01:57,839
with

1834
01:02:02,950 --> 01:02:00,559
ben wolf's lab at tufts where we showed

1835
01:02:05,270 --> 01:02:02,960
that there are bacteria that live on

1836
01:02:07,430 --> 01:02:05,280
these planaria and these bacteria are

1837
01:02:09,109 --> 01:02:07,440
actually able to manipulate the worms to

1838
01:02:11,349 --> 01:02:09,119

for example alter the structure of their

1839

01:02:14,230 --> 01:02:11,359

visual system to have multiple heads and

1840

01:02:16,789 --> 01:02:14,240

so on and that is because these uh these

1841

01:02:18,549 --> 01:02:16,799

bacteria are able to

1842

01:02:20,150 --> 01:02:18,559

tweak the same kinds of controls that

1843

01:02:21,910 --> 01:02:20,160

the worm tissues are using in the first

1844

01:02:23,270 --> 01:02:21,920

place to make decisions about how many

1845

01:02:24,870 --> 01:02:23,280

heads you're supposed to have what what

1846

01:02:27,349 --> 01:02:24,880

your visual system should look like so

1847

01:02:29,430 --> 01:02:27,359

it's it's it's on the one hand uh kind

1848

01:02:31,750 --> 01:02:29,440

of amazing that that these microbes have

1849

01:02:33,910 --> 01:02:31,760

a say in the structure of this uh

1850

01:02:35,430 --> 01:02:33,920

kind of organism that they live in on

1851

01:02:37,190 --> 01:02:35,440

the other hand from an evolutionary

1852

01:02:38,470 --> 01:02:37,200

point of view is completely expected

1853

01:02:40,069 --> 01:02:38,480

that they would have discovered ways to

1854

01:02:41,510 --> 01:02:40,079

do that

1855

01:02:43,270 --> 01:02:41,520

earlier in our talk you mentioned that

1856

01:02:45,109 --> 01:02:43,280

when you were looking for these voltage

1857

01:02:47,029 --> 01:02:45,119

gradients when you did this die the

1858

01:02:49,190 --> 01:02:47,039

voltage die you saw something that it

1859

01:02:50,710 --> 01:02:49,200

was a conspicuous face on the frog and

1860

01:02:52,470 --> 01:02:50,720

then you also mentioned well

1861

01:02:55,430 --> 01:02:52,480

you don't imagine that the code will be

1862

01:02:57,430 --> 01:02:55,440

that obvious for the majority of what we

1863

01:02:59,190 --> 01:02:57,440

care about especially for humans how is

1864

01:03:01,109 --> 01:02:59,200

it that you go about finding out or

1865

01:03:02,789 --> 01:03:01,119

decoding this code

1866

01:03:04,950 --> 01:03:02,799

and also what other factors matter is it

1867

01:03:06,950 --> 01:03:04,960

the do they pulse the voltage pulses and

1868

01:03:08,549 --> 01:03:06,960

then so the frequency of pulsing matters

1869

01:03:10,069 --> 01:03:08,559

doesn't move like what are the factors

1870

01:03:11,670 --> 01:03:10,079

that go in to

1871

01:03:13,029 --> 01:03:11,680

determining the code and then how do you

1872

01:03:16,150 --> 01:03:13,039

decode it

1873

01:03:18,230 --> 01:03:16,160

yeah um we don't know many of the things

1874

01:03:20,390 --> 01:03:18,240

about it so for example at the moment it

1875

01:03:22,710 --> 01:03:20,400

doesn't look like there's pulsing and

1876

01:03:24,470 --> 01:03:22,720

that the the temporal aspects of it are

1877

01:03:26,150 --> 01:03:24,480

particularly critical but that's

1878

01:03:27,910 --> 01:03:26,160

probably more a function of the fact

1879

01:03:29,510 --> 01:03:27,920

that we haven't really dug into it yet

1880

01:03:31,910 --> 01:03:29,520

but it's entirely possible that when we

1881

01:03:34,230 --> 01:03:31,920

we dig into the temporal aspects we will

1882

01:03:35,990 --> 01:03:34,240

find out that the time dependent changes

1883

01:03:37,589 --> 01:03:36,000

are really important it's possible at

1884

01:03:39,349 --> 01:03:37,599

the moment we've been completely

1885

01:03:41,109 --> 01:03:39,359

occupied with the spatial aspects and it

1886

01:03:43,349 --> 01:03:41,119

doesn't look at least to our technology

1887

01:03:45,750 --> 01:03:43,359

it doesn't look like it's uh

1888

01:03:47,829 --> 01:03:45,760

pulsing in in that particular way but we

1889

01:03:49,750 --> 01:03:47,839

may have simply not found it yet

1890

01:03:51,990 --> 01:03:49,760

uh in terms of in terms of how do you

1891

01:03:53,990 --> 01:03:52,000

how do you crack the code so

1892

01:03:56,710 --> 01:03:54,000

um there's a few there's a few pieces to

1893

01:03:58,390 --> 01:03:56,720

this one piece is simply observation

1894

01:03:59,589 --> 01:03:58,400

right so it's almost everything in

1895

01:04:01,510 --> 01:03:59,599

science starts with some sort of

1896

01:04:03,589 --> 01:04:01,520

observation and really just getting a

1897

01:04:05,510 --> 01:04:03,599

database or a profile of different

1898

01:04:07,190 --> 01:04:05,520

tissues under different conditions a

1899

01:04:08,870 --> 01:04:07,200

bioelectric profile of different tissues

1900

01:04:11,430 --> 01:04:08,880

under different different conditions

1901

01:04:13,190 --> 01:04:11,440

will be absolutely crucial to decoding

1902

01:04:15,829 --> 01:04:13,200

this because we need the same way that

1903

01:04:19,829 --> 01:04:15,839

we currently have databases of gene

1904

01:04:22,309 --> 01:04:19,839

expression of proteomics of um

1905

01:04:24,309 --> 01:04:22,319

all all these kind of biochemical and

1906

01:04:25,990 --> 01:04:24,319

and genetic profilings of tissues and

1907

01:04:28,150 --> 01:04:26,000

health and disease and different cells

1908

01:04:30,150 --> 01:04:28,160

of the body and so on uh we need the

1909

01:04:32,870 --> 01:04:30,160

exact same thing for bioelectric so we

1910

01:04:34,230 --> 01:04:32,880

need a kind of physiomic profiling where

1911

01:04:36,950 --> 01:04:34,240

there ought to be a database where we

1912

01:04:39,430 --> 01:04:36,960

can go and say this particular tissue

1913

01:04:41,910 --> 01:04:39,440

under these conditions should be in this

1914

01:04:44,470 --> 01:04:41,920

we have this bioelectric pattern and

1915

01:04:46,630 --> 01:04:44,480

here are the sort of range of normal and

1916

01:04:48,789 --> 01:04:46,640

here's how a difference between between

1917

01:04:50,230 --> 01:04:48,799

people and between the organisms in

1918

01:04:51,670 --> 01:04:50,240

different states and so on so that

1919

01:04:53,990 --> 01:04:51,680

that's that's the first thing and so we

1920

01:04:55,109 --> 01:04:54,000

only have that for very small number of

1921

01:04:56,630 --> 01:04:55,119

cases

1922

01:04:58,870 --> 01:04:56,640

we certainly don't have anything like a

1923

01:05:00,710 --> 01:04:58,880

full physiomic profiling yet

1924

01:05:02,870 --> 01:05:00,720

then what you need to do is you need to

1925

01:05:05,270 --> 01:05:02,880

build computational models that help you

1926

01:05:07,990 --> 01:05:05,280

explain why the electrical pattern is

1927

01:05:10,069 --> 01:05:08,000

the way it is given the various channels

1928

01:05:11,910 --> 01:05:10,079

and pumps that are

1929

01:05:13,589 --> 01:05:11,920

that are expressed in that tissue and

1930

01:05:15,109 --> 01:05:13,599

then you begin the hard work of

1931

01:05:16,950 --> 01:05:15,119

functional experiments so you open and

1932

01:05:19,670 --> 01:05:16,960

close some channels you observe what

1933

01:05:22,230 --> 01:05:19,680

happens and you build up uh a theory

1934

01:05:23,589 --> 01:05:22,240

based on an improved computational model

1935

01:05:25,910 --> 01:05:23,599

of how that

1936

01:05:27,670 --> 01:05:25,920

particular bioelectric pattern triggers

1937

01:05:29,349 --> 01:05:27,680

the downstream effects that it has so

1938

01:05:31,430 --> 01:05:29,359

for example we know now there's a

1939

01:05:33,029 --> 01:05:31,440

pattern that corresponds to make an eye

1940

01:05:35,910 --> 01:05:33,039

there's another pattern that corresponds

1941

01:05:38,470 --> 01:05:35,920

to build whatever goes at this location

1942

01:05:41,029 --> 01:05:38,480

of a wound we have a pattern that says

1943

01:05:42,870 --> 01:05:41,039

build a nice sharp brain the edge of a

1944

01:05:45,029 --> 01:05:42,880

brain and so we have a pattern that says

1945

01:05:47,510 --> 01:05:45,039

um don't be a tumor be normal tissue and

1946

01:05:49,750 --> 01:05:47,520

so on these kinds of um

1947

01:05:51,990 --> 01:05:49,760

these kinds of patterns need to be uh

1948

01:05:52,950 --> 01:05:52,000

need to be identified and that can only

1949

01:05:55,910 --> 01:05:52,960

be done

1950

01:05:57,589 --> 01:05:55,920

with uh this kind of mapping of of

1951

01:05:59,190 --> 01:05:57,599

pattern to the particular outcome and

1952

01:06:01,270 --> 01:05:59,200

then there's a lot of computational work

1953

01:06:03,190 --> 01:06:01,280

that goes in between

1954

01:06:05,190 --> 01:06:03,200

do you think psychedelics have any role

1955

01:06:07,270 --> 01:06:05,200

to play in

1956

01:06:09,670 --> 01:06:07,280

in changing or altering the

1957

01:06:10,630 --> 01:06:09,680

morphogenetic morphological code what i

1958

01:06:12,549 --> 01:06:10,640

mean is

1959

01:06:14,630 --> 01:06:12,559

you know after a single initial dose

1960

01:06:16,230 --> 01:06:14,640

there's markedly increased openness and

1961

01:06:17,910 --> 01:06:16,240

i'm wondering well is that because

1962

01:06:21,510 --> 01:06:17,920

there's a change in some non-neural

1963

01:06:27,109 --> 01:06:24,630

i have no idea uh i i've been no

1964

01:06:29,029 --> 01:06:27,119

expertise in in psychedelics whatsoever

1965

01:06:31,029 --> 01:06:29,039

i can tell you that much like in the

1966

01:06:33,910 --> 01:06:31,039

brain um

1967

01:06:35,589 --> 01:06:33,920

there is there's a really uh nice

1968

01:06:37,510 --> 01:06:35,599

connection between neurotransmitter

1969

01:06:38,950 --> 01:06:37,520

activity in the rest of the body and the

1970

01:06:41,430 --> 01:06:38,960

electrical signals that move these

1971

01:06:43,750 --> 01:06:41,440

neurotransmitters around so i would not

1972

01:06:45,910 --> 01:06:43,760

be at all shocked if there was some

1973

01:06:49,270 --> 01:06:45,920

connection and in fact we've certainly

1974

01:06:51,750 --> 01:06:49,280

used various compounds that are normally

1975

01:06:54,150 --> 01:06:51,760

uh utilized to target uh to target the

1976

01:06:56,710 --> 01:06:54,160

brains and so so things like anxiety

1977

01:06:58,390 --> 01:06:56,720

lytics and ssris and

1978

01:06:59,750 --> 01:06:58,400

various kinds of drugs that are normally

1979

01:07:02,630 --> 01:06:59,760

used in the nervous system we've used

1980

01:07:04,950 --> 01:07:02,640

them in in embryogenesis

1981

01:07:06,150 --> 01:07:04,960

uh in regeneration to to try to tweak

1982

01:07:07,829 --> 01:07:06,160

some of these pathways outside the

1983

01:07:09,349 --> 01:07:07,839

nervous system so that that's that's for

1984

01:07:11,029 --> 01:07:09,359

sure a thing you can do

1985

01:07:13,109 --> 01:07:11,039

whether or not it has anything to do

1986

01:07:14,789 --> 01:07:13,119

with the mental states induced by these

1987

01:07:15,589 --> 01:07:14,799

kind of compounds in humans i have no

1988

01:07:17,109 --> 01:07:15,599

idea

1989

01:07:18,549 --> 01:07:17,119

i know these questions are desolatory

1990

01:07:20,150 --> 01:07:18,559

they keep

1991

01:07:23,349 --> 01:07:20,160

going from subject to subject it's just

1992

01:07:25,510 --> 01:07:23,359

how my notes were but well regardless

1993

01:07:28,150 --> 01:07:25,520

you mentioned one time i think it was to

1994

01:07:29,829 --> 01:07:28,160

sean carroll that you can use daniel

1995

01:07:30,870 --> 01:07:29,839

dennett's way of speaking of intention

1996

01:07:33,029 --> 01:07:30,880

that is

1997

01:07:34,390 --> 01:07:33,039

i believe it was give as much intention

1998

01:07:36,069 --> 01:07:34,400

as you like to a system in order to

1999

01:07:38,390 --> 01:07:36,079

explain what's happening and when i say

2000

01:07:39,670 --> 01:07:38,400

intention i mean act as if it's willing

2001

01:07:41,349 --> 01:07:39,680

to do something

2002

01:07:44,069 --> 01:07:41,359

and then you also mention that when one

2003

01:07:46,549 --> 01:07:44,079

scales down one's theological projection

2004

01:07:48,950 --> 01:07:46,559

to smaller particles like pan psychics

2005

01:07:50,870 --> 01:07:48,960

might do then it leads naturally to

2006

01:07:52,950 --> 01:07:50,880

quantum indeterminacy and the least

2007

01:07:54,630 --> 01:07:52,960

action principle okay so let's start

2008

01:07:56,710 --> 01:07:54,640

from the beginning uh the

2009

01:08:00,789 --> 01:07:56,720

dan dennett's intentional stance

2010

01:08:02,870 --> 01:08:00,799

is the basically the following idea that

2011

01:08:05,510 --> 01:08:02,880

the real answer

2012

01:08:07,670 --> 01:08:05,520

to whether due to how much

2013

01:08:08,950 --> 01:08:07,680

intentionality but you know he usually

2014

01:08:11,670 --> 01:08:08,960

talks about consciousness but but

2015

01:08:13,270 --> 01:08:11,680

intentionality cognition intelligence

2016

01:08:15,990 --> 01:08:13,280

whatever whatever you're interested in

2017

01:08:18,709 --> 01:08:16,000

the real question of how much of that

2018

01:08:20,870 --> 01:08:18,719

some particular system has is not to be

2019

01:08:22,390 --> 01:08:20,880

found by sort of armchair philosophy

2020

01:08:23,910 --> 01:08:22,400

right to just assume and you know people

2021

01:08:25,910 --> 01:08:23,920

say this all time they say things like

2022

01:08:27,990 --> 01:08:25,920

well thermostats can't possibly have any

2023

01:08:29,669 --> 01:08:28,000

intention or you know

2024

01:08:32,229 --> 01:08:29,679

so so this is this is a decision that

2025

01:08:34,870 --> 01:08:32,239

somebody had made it has made just by uh

2026

01:08:37,349 --> 01:08:34,880

by fiat basically and and dan's

2027

01:08:39,030 --> 01:08:37,359

point is is very important it's that

2028

01:08:41,349 --> 01:08:39,040

it's an empirical question you can't

2029

01:08:43,590 --> 01:08:41,359

just you can't just decide and the way

2030

01:08:46,470 --> 01:08:43,600

that you discover this is simply this

2031

01:08:48,229 --> 01:08:46,480

you take a particular stance and you say

2032

01:08:49,590 --> 01:08:48,239

here's my system i think it has this

2033

01:08:51,749 --> 01:08:49,600

much intelligence or i think it's

2034

01:08:52,390 --> 01:08:51,759

capable of learning or i think it's able

2035

01:08:54,550 --> 01:08:52,400

to

2036

01:08:55,829 --> 01:08:54,560

uh have preferences in the you know or i

2037

01:08:57,269 --> 01:08:55,839

think it's a goal directed system

2038

01:08:59,269 --> 01:08:57,279

whatever whatever

2039

01:09:00,630 --> 01:08:59,279

wherever you choose to uh to start on

2040

01:09:04,070 --> 01:09:00,640

that continuum

2041

01:09:05,910 --> 01:09:04,080

and using that stance you do empirical

2042

01:09:08,070 --> 01:09:05,920

experiments to see how well that stands

2043

01:09:10,149 --> 01:09:08,080

helps you to understand what and control

2044

01:09:13,030 --> 01:09:10,159

whatever you're dealing with and so the

2045

01:09:14,789 --> 01:09:13,040

point being that we can't simply assume

2046

01:09:16,630 --> 01:09:14,799

that something is a non-intelligent

2047

01:09:19,030 --> 01:09:16,640

system because of what it's how it's

2048

01:09:20,709 --> 01:09:19,040

made or because of how it looks you have

2049

01:09:22,070 --> 01:09:20,719

to actually ask

2050

01:09:24,550 --> 01:09:22,080

does

2051

01:09:26,950 --> 01:09:24,560

what is the optimal way of looking at

2052

01:09:29,829 --> 01:09:26,960

that system so just to give you a simple

2053

01:09:34,229 --> 01:09:29,839

a simple analogy if you have a ball on

2054

01:09:35,990 --> 01:09:34,239

top of a hill you are pretty well um

2055

01:09:38,070 --> 01:09:36,000

you're going to do pretty well using the

2056

01:09:39,749 --> 01:09:38,080

newton's laws to ask how it's going to

2057

01:09:41,430 --> 01:09:39,759

roll down the hill and if you have

2058

01:09:43,110 --> 01:09:41,440

additional theories about the hopes and

2059

01:09:45,269 --> 01:09:43,120

dreams of this ball as it rolls down the

2060

01:09:46,709 --> 01:09:45,279

hill they're not going to do you much

2061

01:09:49,669 --> 01:09:46,719

good right they're not going to give you

2062

01:09:51,189 --> 01:09:49,679

any improved ability to uh to to

2063

01:09:52,950 --> 01:09:51,199

understand and control what's going to

2064

01:09:55,110 --> 01:09:52,960

happen on the other hand if you start

2065

01:09:56,550 --> 01:09:55,120

off with a with a with a live mouse at

2066

01:09:58,310 --> 01:09:56,560

the top of a hill and you think you're

2067

01:10:00,229 --> 01:09:58,320

going to apply newton's laws you're not

2068

01:10:02,550 --> 01:10:00,239

going to do very well uh because you're

2069

01:10:05,189 --> 01:10:02,560

going to need some other laws and so you

2070

01:10:07,430 --> 01:10:05,199

might decide that the system is is

2071

01:10:09,270 --> 01:10:07,440

minimally intelligent and see how you do

2072

01:10:11,189 --> 01:10:09,280

you might decide that the system is very

2073

01:10:12,310 --> 01:10:11,199

intelligent and it has memories of of

2074

01:10:13,830 --> 01:10:12,320

what happened when you put it on the

2075

01:10:14,709 --> 01:10:13,840

hill last week and it might do something

2076

01:10:16,149 --> 01:10:14,719

different

2077

01:10:17,669 --> 01:10:16,159

the point is it's an empirical

2078

01:10:20,310 --> 01:10:17,679

experiment you can't just decide what

2079

01:10:23,750 --> 01:10:20,320

it's going to be you have to uh you have

2080

01:10:25,030 --> 01:10:23,760

to choose a a level of abstraction of

2081

01:10:26,950 --> 01:10:25,040

some type of

2082

01:10:28,630 --> 01:10:26,960

learning agent maybe maybe all maybe

2083

01:10:30,470 --> 01:10:28,640

very little maybe quite a lot and see

2084

01:10:32,149 --> 01:10:30,480

how you do so so that's uh so that's

2085

01:10:34,390 --> 01:10:32,159

that's the intentional stance is that

2086

01:10:36,709 --> 01:10:34,400

that everything is to be decided by the

2087

01:10:38,950 --> 01:10:36,719

quality of the predictions and the

2088

01:10:41,669 --> 01:10:38,960

amount of control you gain by viewing

2089

01:10:43,750 --> 01:10:41,679

your system in a particular light right

2090

01:10:45,510 --> 01:10:43,760

so so so everything is in a way

2091

01:10:46,550 --> 01:10:45,520

observer dependent and it's dependent on

2092

01:10:48,790 --> 01:10:46,560

the on the

2093

01:10:51,030 --> 01:10:48,800

experimental context in which you want

2094

01:10:52,709 --> 01:10:51,040

to examine the system you know a human

2095

01:10:54,390 --> 01:10:52,719

brain is very intelligent in a certain

2096

01:10:56,709 --> 01:10:54,400

context it also makes a great

2097

01:10:58,550 --> 01:10:56,719

paperweight and if and if that's the the

2098

01:11:00,870 --> 01:10:58,560

how you choose to look at it then you're

2099

01:11:02,790 --> 01:11:00,880

you don't need uh to understand to

2100

01:11:04,390 --> 01:11:02,800

attribute much intelligence to it if

2101
01:11:06,310 --> 01:11:04,400
you're examining the problem space of

2102
01:11:07,750 --> 01:11:06,320
keeping down some papers in a wind then

2103
01:11:09,430 --> 01:11:07,760
then it doesn't come up

2104
01:11:11,590 --> 01:11:09,440
so so that's so that's so that's that

2105
01:11:13,030 --> 01:11:11,600
and so my uh where where i intersect

2106
01:11:14,950 --> 01:11:13,040
with this is that

2107
01:11:17,830 --> 01:11:14,960
i basically point out that

2108
01:11:21,669 --> 01:11:17,840
uh this is a really essential

2109
01:11:23,990 --> 01:11:21,679
looking at things when

2110
01:11:26,229 --> 01:11:24,000
traditional phylogenetics

2111
01:11:28,630 --> 01:11:26,239
is is not a great guide and this is

2112
01:11:31,350 --> 01:11:28,640
meaning that when we are confronted with

2113
01:11:33,030 --> 01:11:31,360

novel creatures they might be novel

2114

01:11:35,430 --> 01:11:33,040

bioengineered creatures they might be

2115

01:11:36,950 --> 01:11:35,440

chimeras they might be uh something that

2116

01:11:38,950 --> 01:11:36,960

you find in space somewhere some

2117

01:11:41,030 --> 01:11:38,960

exobiological agent they might be

2118

01:11:42,229 --> 01:11:41,040

artificial intelligences that we create

2119

01:11:43,590 --> 01:11:42,239

whatever it is

2120

01:11:45,189 --> 01:11:43,600

when you are confronted with something

2121

01:11:47,430 --> 01:11:45,199

that you cannot simply place on the

2122

01:11:50,070 --> 01:11:47,440

familiar evolutionary tree of life in on

2123

01:11:52,310 --> 01:11:50,080

earth and say oh yeah this thing is uh

2124

01:11:53,350 --> 01:11:52,320

closely related to a fish therefore i'm

2125

01:11:56,630 --> 01:11:53,360

going to

2126
01:11:58,470 --> 01:11:56,640
cognition of other fish that i've known

2127
01:12:01,030 --> 01:11:58,480
so when you are

2128
01:12:02,630 --> 01:12:01,040
cr either creating or reverse

2129
01:12:04,870 --> 01:12:02,640
engineering

2130
01:12:07,590 --> 01:12:04,880
novel creatures the intentional stance

2131
01:12:09,669 --> 01:12:07,600
becomes completely essential because you

2132
01:12:11,669 --> 01:12:09,679
can't know a priori what the cognitive

2133
01:12:13,990 --> 01:12:11,679
capacities of this thing are going to be

2134
01:12:15,990 --> 01:12:14,000
and they might be uh it might behoove

2135
01:12:17,510 --> 01:12:16,000
you to really attribute quite a lot of

2136
01:12:19,189 --> 01:12:17,520
cognition to it or maybe not at all

2137
01:12:20,149 --> 01:12:19,199
depending on

2138
01:12:24,310 --> 01:12:20,159

how

2139

01:12:26,390 --> 01:12:24,320

empirical success so having said that

2140

01:12:28,470 --> 01:12:26,400

then the natural question might come up

2141

01:12:31,590 --> 01:12:28,480

is there a zero on this scale so if

2142

01:12:34,070 --> 01:12:31,600

you've got a scale uh a a continuum of

2143

01:12:35,830 --> 01:12:34,080

cognition or of intelligence that that

2144

01:12:38,229 --> 01:12:35,840

is a smooth gradient where different

2145

01:12:39,990 --> 01:12:38,239

types of systems might might land right

2146

01:12:41,990 --> 01:12:40,000

and so the question is is there in fact

2147

01:12:43,669 --> 01:12:42,000

a zero and so what i was saying is is

2148

01:12:45,510 --> 01:12:43,679

simply this that

2149

01:12:47,830 --> 01:12:45,520

if you

2150

01:12:49,510 --> 01:12:47,840

uh if if somebody if somebody had said

2151
01:12:53,430 --> 01:12:49,520
to me um

2152
01:12:57,189 --> 01:12:54,950
what would you have to have an absolute

2153
01:12:59,270 --> 01:12:57,199
minimum in order to be on this scale at

2154
01:13:00,709 --> 01:12:59,280
all right so so to be somewhere on the

2155
01:13:01,990 --> 01:13:00,719
scale of cognitive creatures what's the

2156
01:13:03,830 --> 01:13:02,000
what's the basement right what's what's

2157
01:13:06,229 --> 01:13:03,840
the minimal version that you would have

2158
01:13:07,750 --> 01:13:06,239
to have i would say probably the minimum

2159
01:13:10,709 --> 01:13:07,760
you would have to have two things you

2160
01:13:12,709 --> 01:13:10,719
would have to have some ability to do

2161
01:13:15,189 --> 01:13:12,719
goal directed behavior so you would have

2162
01:13:17,430 --> 01:13:15,199
to have some kind of ability to to

2163
01:13:19,910 --> 01:13:17,440

pursue goal states and you would have

2164

01:13:23,750 --> 01:13:19,920

you would have to have some kind of uh

2165

01:13:25,270 --> 01:13:23,760

internal uh control such that your

2166

01:13:27,430 --> 01:13:25,280

um

2167

01:13:29,990 --> 01:13:27,440

your your behavior and the things you do

2168

01:13:32,070 --> 01:13:30,000

are not perfectly described by all the

2169

01:13:33,590 --> 01:13:32,080

external influences around you at a

2170

01:13:35,430 --> 01:13:33,600

given time

2171

01:13:37,189 --> 01:13:35,440

right in other words in other words if

2172

01:13:40,229 --> 01:13:37,199

if i can if i can look at all of the

2173

01:13:41,430 --> 01:13:40,239

forces impinging on you and know exactly

2174

01:13:44,470 --> 01:13:41,440

what's going to happen then you're

2175

01:13:46,229 --> 01:13:44,480

probably a marble running down you know

2176
01:13:47,910 --> 01:13:46,239
some kind of an incline plane otherwise

2177
01:13:49,350 --> 01:13:47,920
otherwise if if you're if you're more

2178
01:13:50,790 --> 01:13:49,360
complex than that

2179
01:13:52,310 --> 01:13:50,800
then i would have to take into account

2180
01:13:54,229 --> 01:13:52,320
things that happened before things that

2181
01:13:55,830 --> 01:13:54,239
might happen in the future all kinds of

2182
01:13:57,430 --> 01:13:55,840
things that are not immediately what's

2183
01:14:00,310 --> 01:13:57,440
what's what's there so so what that

2184
01:14:02,950 --> 01:14:00,320
boils down to is some sort of internally

2185
01:14:04,630 --> 01:14:02,960
uh internally uh initiated action some

2186
01:14:06,229 --> 01:14:04,640
some some quote-unquote freedom and

2187
01:14:07,910 --> 01:14:06,239
that's you know that's a whole other

2188
01:14:09,510 --> 01:14:07,920

story to really dig into that but this

2189

01:14:11,030 --> 01:14:09,520

idea that that you would be able to

2190

01:14:12,790 --> 01:14:11,040

initiate things on your own you're not

2191

01:14:14,790 --> 01:14:12,800

just a responding you're not you're not

2192

01:14:16,870 --> 01:14:14,800

just a passive responder to forces

2193

01:14:18,790 --> 01:14:16,880

around you at that time and so having

2194

01:14:22,630 --> 01:14:18,800

said that having said those two things

2195

01:14:24,950 --> 01:14:22,640

you realize that already uh particles

2196

01:14:26,470 --> 01:14:24,960

already have those two things because

2197

01:14:28,149 --> 01:14:26,480

because particles already exhibit

2198

01:14:29,990 --> 01:14:28,159

quantum indeterminacy where they do

2199

01:14:31,990 --> 01:14:30,000

things that are that are fundamentally

2200

01:14:33,270 --> 01:14:32,000

not caused by any of the things around

2201

01:14:35,830 --> 01:14:33,280

them right they're complete it's

2202

01:14:38,310 --> 01:14:35,840

completely uh sort of um

2203

01:14:40,390 --> 01:14:38,320

indeterminate and they have the ability

2204

01:14:43,510 --> 01:14:40,400

to pursue goals in a very

2205

01:14:45,030 --> 01:14:43,520

uh sort of a very primitive manner which

2206

01:14:46,709 --> 01:14:45,040

is which are these least action

2207

01:14:49,270 --> 01:14:46,719

principles and so

2208

01:14:51,990 --> 01:14:49,280

one of the benefits of people often say

2209

01:14:54,310 --> 01:14:52,000

that um that that pan psychism

2210

01:14:55,750 --> 01:14:54,320

is it's it's a bad theory because

2211

01:14:57,750 --> 01:14:55,760

because it doesn't lead anywhere it

2212

01:14:59,350 --> 01:14:57,760

doesn't give you anything and i think

2213

01:15:01,669 --> 01:14:59,360

it's certainly there's there's there's a

2214

01:15:03,110 --> 01:15:01,679

little bit of truth to that but

2215

01:15:05,110 --> 01:15:03,120

there's um

2216

01:15:07,030 --> 01:15:05,120

there's also the fact that if you were

2217

01:15:07,830 --> 01:15:07,040

to ask the question

2218

01:15:10,229 --> 01:15:07,840

uh

2219

01:15:12,390 --> 01:15:10,239

i think that even par if you were to say

2220

01:15:14,630 --> 01:15:12,400

that i think even particles should have

2221

01:15:16,790 --> 01:15:14,640

some degree of gold directed activity

2222

01:15:19,030 --> 01:15:16,800

you might make a prediction

2223

01:15:20,870 --> 01:15:19,040

of of something like least action

2224

01:15:22,390 --> 01:15:20,880

principles existing and then you would

2225

01:15:23,669 --> 01:15:22,400

be right you would find you know they

2226

01:15:25,590 --> 01:15:23,679

that that model actually makes a

2227

01:15:28,229 --> 01:15:25,600

prediction that's completely not obvious

2228

01:15:30,070 --> 01:15:28,239

it is it isn't obvious that uh that that

2229

01:15:32,070 --> 01:15:30,080

when you have a um

2230

01:15:34,950 --> 01:15:32,080

a beam of light passing through a bunch

2231

01:15:36,310 --> 01:15:34,960

of lenses it's it's not obvious that you

2232

01:15:38,950 --> 01:15:36,320

can actually

2233

01:15:40,790 --> 01:15:38,960

forego the calculations of how the light

2234

01:15:42,310 --> 01:15:40,800

will interact at the at with the glass

2235

01:15:43,669 --> 01:15:42,320

at every point along the way and simply

2236

01:15:45,030 --> 01:15:43,679

say you know what i think i think it

2237

01:15:47,830 --> 01:15:45,040

wants to get where it's going with the

2238

01:15:49,430 --> 01:15:47,840

least amount of uh action right and so

2239

01:15:50,709 --> 01:15:49,440

and so you can you can make the correct

2240

01:15:52,470 --> 01:15:50,719

prediction of where it's going to go

2241

01:15:54,790 --> 01:15:52,480

simply by assuming that the light likes

2242

01:15:56,470 --> 01:15:54,800

to get where it's going

2243

01:15:59,030 --> 01:15:56,480

by minimizing and maximizing certain

2244

01:16:01,430 --> 01:15:59,040

things and you could predict something

2245

01:16:03,830 --> 01:16:01,440

like that if you had this idea that even

2246

01:16:05,110 --> 01:16:03,840

at the very bottom there would be some

2247

01:16:08,790 --> 01:16:05,120

type of

2248

01:16:10,870 --> 01:16:08,800

goal directed activity so if we ask what

2249

01:16:12,630 --> 01:16:10,880

does that look like what does agency and

2250

01:16:14,790 --> 01:16:12,640

intelligence look like in the very

2251

01:16:16,310 --> 01:16:14,800

minimal the the most minimal version

2252

01:16:18,229 --> 01:16:16,320

possible i think what you get is

2253

01:16:20,870 --> 01:16:18,239

something like like particles so from

2254

01:16:23,430 --> 01:16:20,880

that perspective i suspect there is no

2255

01:16:25,750 --> 01:16:23,440

zero on this scale because because even

2256

01:16:28,149 --> 01:16:25,760

particles are already on the scale

2257

01:16:29,990 --> 01:16:28,159

okay this zero was that the way that i

2258

01:16:31,910 --> 01:16:30,000

understand that is that that's like an

2259

01:16:32,830 --> 01:16:31,920

intelligence scale do you synonymize

2260

01:16:34,950 --> 01:16:32,840

that with

2261

01:16:38,390 --> 01:16:34,960

consciousness right that's that's a good

2262

01:16:39,750 --> 01:16:38,400

question uh i will say that um in my

2263

01:16:42,390 --> 01:16:39,760

um

2264

01:16:44,790 --> 01:16:42,400

writing on all of this stuff i've almost

2265

01:16:46,390 --> 01:16:44,800

completely avoided consciousness okay i

2266

01:16:48,709 --> 01:16:46,400

almost never talk about consciousness i

2267

01:16:51,590 --> 01:16:48,719

talk about cognition and and that's

2268

01:16:54,310 --> 01:16:51,600

that's kind of on purpose um i

2269

01:16:55,430 --> 01:16:54,320

don't have my my views on consciousness

2270

01:16:56,310 --> 01:16:55,440

are not

2271

01:16:58,229 --> 01:16:56,320

uh

2272

01:16:59,830 --> 01:16:58,239

fleshed out to the point where i'd be

2273

01:17:01,990 --> 01:16:59,840

interested in talking about them because

2274

01:17:03,750 --> 01:17:02,000

i don't think i can add anything yet

2275

01:17:05,990 --> 01:17:03,760

that a lot of other smart people haven't

2276

01:17:06,950 --> 01:17:06,000

already chewed over what i think i have

2277

01:17:09,030 --> 01:17:06,960

um

2278

01:17:10,550 --> 01:17:09,040

something to contribute is to the to the

2279

01:17:12,950 --> 01:17:10,560

questions of of cognition and

2280

01:17:14,630 --> 01:17:12,960

intelligence because those things are

2281

01:17:17,910 --> 01:17:14,640

empirically measurable they're absorbed

2282

01:17:19,910 --> 01:17:17,920

publicly observable behaviors and we can

2283

01:17:21,590 --> 01:17:19,920

we can have a research program focused

2284

01:17:22,790 --> 01:17:21,600

around them that i think is is different

2285

01:17:24,390 --> 01:17:22,800

than what other people have been doing

2286

01:17:27,270 --> 01:17:24,400

so that's what i've been talking about

2287

01:17:29,110 --> 01:17:27,280

consciousness is different um

2288

01:17:31,830 --> 01:17:29,120

in the sense that i think many of the

2289

01:17:33,590 --> 01:17:31,840

people who study who who say they study

2290

01:17:35,510 --> 01:17:33,600

consciousness in fact do not study

2291

01:17:38,310 --> 01:17:35,520

consciousness what they study at best

2292

01:17:41,669 --> 01:17:38,320

are correlates of consciousness or

2293

01:17:43,270 --> 01:17:41,679

oftentimes behaviors and properties that

2294

01:17:45,669 --> 01:17:43,280

may or may not have anything to do with

2295

01:17:47,430 --> 01:17:45,679

actual consciousness and so i think it's

2296

01:17:51,110 --> 01:17:47,440

very difficult to study actual

2297

01:17:53,830 --> 01:17:51,120

consciousness if you you have to

2298

01:17:55,430 --> 01:17:53,840

studying consciousness is a first person

2299

01:17:57,430 --> 01:17:55,440

activity it's not a third person

2300

01:17:59,270 --> 01:17:57,440

activity the way that you would study

2301
01:18:01,270 --> 01:17:59,280
anything in the external world meaning

2302
01:18:03,350 --> 01:18:01,280
studying it externally outside of

2303
01:18:05,189 --> 01:18:03,360
yourself i think fundamentally studying

2304
01:18:07,430 --> 01:18:05,199
consciousness requires

2305
01:18:09,430 --> 01:18:07,440
the subject of meaning you or whoever is

2306
01:18:12,550 --> 01:18:09,440
studying it to actually change during

2307
01:18:14,149 --> 01:18:12,560
during that that that process it's a

2308
01:18:16,470 --> 01:18:14,159
it's a completely different thing so so

2309
01:18:18,390 --> 01:18:16,480
i'm i'm i'm working on some things along

2310
01:18:20,229 --> 01:18:18,400
those lines it's a little early uh it's

2311
01:18:22,790 --> 01:18:20,239
a little early to talk about it

2312
01:18:24,070 --> 01:18:22,800
faraz hanarvar asks could the mapping

2313
01:18:25,669 --> 01:18:24,080

and thereby the treatment of the

2314

01:18:27,830 --> 01:18:25,679

signaling that is this electric

2315

01:18:29,590 --> 01:18:27,840

signaling differ between individuals

2316

01:18:31,750 --> 01:18:29,600

when we're talking about humans so does

2317

01:18:33,669 --> 01:18:31,760

the code is the code species dependent

2318

01:18:36,709 --> 01:18:33,679

or can it actually differ

2319

01:18:39,590 --> 01:18:36,719

based upon people

2320

01:18:41,750 --> 01:18:39,600

yeah um i don't think it's even species

2321

01:18:44,870 --> 01:18:41,760

dependent because we've seen that we can

2322

01:18:46,709 --> 01:18:44,880

induce let's say one species of flatworm

2323

01:18:49,270 --> 01:18:46,719

to form a head that belongs to a

2324

01:18:51,189 --> 01:18:49,280

completely different species simply by

2325

01:18:52,630 --> 01:18:51,199

by changing the distribution of gap

2326

01:18:55,030 --> 01:18:52,640

junctional connections

2327

01:18:57,350 --> 01:18:55,040

uh i suspect there are massive

2328

01:19:00,070 --> 01:18:57,360

uh conversations in the same way that

2329

01:19:02,070 --> 01:19:00,080

the biochemical and genetic codes are

2330

01:19:03,590 --> 01:19:02,080

are highly highly conserved

2331

01:19:05,990 --> 01:19:03,600

um are there going to be individual

2332

01:19:08,470 --> 01:19:06,000

differences among patients for sure and

2333

01:19:10,070 --> 01:19:08,480

we need to understand what those are we

2334

01:19:12,630 --> 01:19:10,080

do not yet know what those are that's a

2335

01:19:14,950 --> 01:19:12,640

major area for future research but i

2336

01:19:17,189 --> 01:19:14,960

think it's going to be conserved

2337

01:19:20,390 --> 01:19:17,199

sufficiently that we will be able to

2338

01:19:23,510 --> 01:19:20,400

have general purpose

2339

01:19:25,830 --> 01:19:23,520

electroceuticals however i think that

2340

01:19:27,990 --> 01:19:25,840

there will have to be some very serious

2341

01:19:30,550 --> 01:19:28,000

computational modeling that is going to

2342

01:19:32,630 --> 01:19:30,560

likely be personalized that is we're

2343

01:19:35,030 --> 01:19:32,640

going to have to take into account the

2344

01:19:36,790 --> 01:19:35,040

various physiological and

2345

01:19:38,070 --> 01:19:36,800

genetic states of the patient in terms

2346

01:19:40,149 --> 01:19:38,080

of do they have any ion channel

2347

01:19:41,750 --> 01:19:40,159

mutations what what other kinds of

2348

01:19:43,350 --> 01:19:41,760

physiological things are going on in

2349

01:19:45,750 --> 01:19:43,360

their blood in terms of ion content and

2350

01:19:47,350 --> 01:19:45,760

so on in order to perfect some of these

2351

01:19:49,590 --> 01:19:47,360

some of these treatments i think it will

2352

01:19:51,430 --> 01:19:49,600

be very much personalized but underneath

2353

01:19:53,189 --> 01:19:51,440

it all is going to be a highly conserved

2354

01:19:55,430 --> 01:19:53,199

bioelectric code

2355

01:19:56,470 --> 01:19:55,440

you mentioned electroceuticals which

2356

01:19:58,709 --> 01:19:56,480

reminds me of your company

2357

01:20:00,229 --> 01:19:58,719

morphocephicals so if you're allowed to

2358

01:20:03,110 --> 01:20:00,239

talk about that what's the state of it

2359

01:20:04,709 --> 01:20:03,120

what's the goal of it

2360

01:20:06,870 --> 01:20:04,719

yeah the goal of the goal so so

2361

01:20:09,669 --> 01:20:06,880

morphaceuticals inc is a it's a new

2362

01:20:12,070 --> 01:20:09,679

company that um i co-founded with david

2363

01:20:13,990 --> 01:20:12,080

kaplan who's uh head of biomedical

2364

01:20:15,669 --> 01:20:14,000

engineering at tufts uh he and i are

2365

01:20:17,030 --> 01:20:15,679

partners in this work we work very

2366

01:20:19,270 --> 01:20:17,040

closely together

2367

01:20:21,110 --> 01:20:19,280

and the right now the mission of

2368

01:20:24,070 --> 01:20:21,120

morphochemicals is focused around limb

2369

01:20:26,070 --> 01:20:24,080

regeneration so we are taking the things

2370

01:20:26,870 --> 01:20:26,080

we learned in the frog in terms of how

2371

01:20:28,790 --> 01:20:26,880

to

2372

01:20:30,790 --> 01:20:28,800

induce the regeneration of appendages in

2373

01:20:33,830 --> 01:20:30,800

the frog and trying to move it to

2374

01:20:35,510 --> 01:20:33,840

mammals so that someday towards humans

2375

01:20:37,590 --> 01:20:35,520

and so you know i can't really go into

2376

01:20:39,669 --> 01:20:37,600

details of how it's going but it's in

2377

01:20:42,070 --> 01:20:39,679

its very early days but i'm i'm very

2378

01:20:44,070 --> 01:20:42,080

optimistic that uh we will actually have

2379

01:20:45,430 --> 01:20:44,080

something something useful

2380

01:20:46,550 --> 01:20:45,440

so that's what we're doing are you

2381

01:20:49,030 --> 01:20:46,560

seeing more progress than you would

2382

01:20:51,030 --> 01:20:49,040

hoped or are you seeing less or

2383

01:20:53,270 --> 01:20:51,040

is it going pretty much how you expect

2384

01:20:54,950 --> 01:20:53,280

it basically going the way i thought it

2385

01:20:57,030 --> 01:20:54,960

would it's in the we're on track we're

2386

01:20:58,790 --> 01:20:57,040

on track given the the timeline that

2387

01:21:01,270 --> 01:20:58,800

we've envisioned and the basic science

2388

01:21:03,510 --> 01:21:01,280

that has to be done i mean this is let's

2389

01:21:05,189 --> 01:21:03,520

to be clear and and i receive all kinds

2390

01:21:07,510 --> 01:21:05,199

of um emails and phone calls from people

2391

01:21:09,669 --> 01:21:07,520

with with with really desperate medical

2392

01:21:11,750 --> 01:21:09,679

conditions and it's it's just it's an

2393

01:21:13,030 --> 01:21:11,760

amazing the need is incredible and and

2394

01:21:15,590 --> 01:21:13,040

unfortunately i have to say to all these

2395

01:21:17,270 --> 01:21:15,600

people every day that uh we're working

2396

01:21:18,390 --> 01:21:17,280

as fast as we can but it's still a basic

2397

01:21:20,310 --> 01:21:18,400

science

2398

01:21:21,830 --> 01:21:20,320

project it is we are not in clinical

2399

01:21:23,990 --> 01:21:21,840

trials we are not dealing with human

2400

01:21:26,470 --> 01:21:24,000

patients it is still very basic science

2401
01:21:28,070 --> 01:21:26,480
however it is now to the point where we

2402
01:21:29,830 --> 01:21:28,080
have commercial investment and it's

2403
01:21:32,229 --> 01:21:29,840
obvious that it's going to at some point

2404
01:21:34,310 --> 01:21:32,239
it's going to be real for patients

2405
01:21:36,709 --> 01:21:34,320
so um it's pretty much on track uh the

2406
01:21:37,669 --> 01:21:36,719
idea is uh this is quite simple uh david

2407
01:21:39,030 --> 01:21:37,679
um

2408
01:21:40,390 --> 01:21:39,040
david's group makes these wearable

2409
01:21:41,189 --> 01:21:40,400
bioreactors

2410
01:21:43,990 --> 01:21:41,199
and

2411
01:21:45,669 --> 01:21:44,000
uh you wear them on a limb amputation

2412
01:21:46,390 --> 01:21:45,679
site and they basically produce a kind

2413
01:21:49,110 --> 01:21:46,400

of

2414

01:21:51,110 --> 01:21:49,120

uh protective aqueous environment around

2415

01:21:53,189 --> 01:21:51,120

the around the wound and then my group

2416

01:21:54,709 --> 01:21:53,199

comes up with the payload which are the

2417

01:21:57,270 --> 01:21:54,719

drugs these are the electroceuticals

2418

01:21:59,110 --> 01:21:57,280

which are different types of ion channel

2419

01:22:01,590 --> 01:21:59,120

drugs and other other types of drugs

2420

01:22:03,590 --> 01:22:01,600

that are going to set the wound cells

2421

01:22:08,149 --> 01:22:03,600

towards a decision of let's let's

2422

01:22:11,990 --> 01:22:10,390

okay nadia wants to know would be very

2423

01:22:13,910 --> 01:22:12,000

interested in learning how the actual

2424

01:22:16,550 --> 01:22:13,920

algorithm works if he's even allowed to

2425

01:22:17,910 --> 01:22:16,560

share that information i guess it's some

2426

01:22:20,070 --> 01:22:17,920

form of pattern recognition but the

2427

01:22:21,750 --> 01:22:20,080

details would be cool to learn which

2428

01:22:23,430 --> 01:22:21,760

which which yeah i'm not sure which

2429

01:22:25,590 --> 01:22:23,440

algorithm was she talking about i think

2430

01:22:27,510 --> 01:22:25,600

she means the algorithm of when we

2431

01:22:29,270 --> 01:22:27,520

talked about decoding

2432

01:22:32,070 --> 01:22:29,280

decoding oh

2433

01:22:33,510 --> 01:22:32,080

like frog's face means frog's face

2434

01:22:35,590 --> 01:22:33,520

yeah

2435

01:22:38,149 --> 01:22:35,600

and then she has a sub question which

2436

01:22:39,669 --> 01:22:38,159

may be related also how do we know that

2437

01:22:41,750 --> 01:22:39,679

we are actually learning the cells

2438

01:22:43,910 --> 01:22:41,760

language and not just observing the

2439

01:22:46,149 --> 01:22:43,920

cause and effect because we only see

2440

01:22:49,590 --> 01:22:46,159

their behavior on the outside

2441

01:22:51,510 --> 01:22:49,600

well um i want i guess to go in order uh

2442

01:22:53,590 --> 01:22:51,520

the algorithm is still very much under

2443

01:22:54,709 --> 01:22:53,600

development part of the problem is that

2444

01:22:56,550 --> 01:22:54,719

traditional

2445

01:22:58,229 --> 01:22:56,560

machine learning algorithms require

2446

01:22:59,910 --> 01:22:58,239

incredible amounts of data meaning

2447

01:23:02,070 --> 01:22:59,920

meaning huge numbers of examples to

2448

01:23:03,669 --> 01:23:02,080

learn from we don't we don't have those

2449

01:23:05,750 --> 01:23:03,679

data so it's it's very expensive and

2450

01:23:07,669 --> 01:23:05,760

time consuming to get these images of

2451

01:23:09,990 --> 01:23:07,679

the electric pattern so we can't deploy

2452

01:23:10,790 --> 01:23:10,000

the typical types of algorithms that are

2453

01:23:12,950 --> 01:23:10,800

used

2454

01:23:16,149 --> 01:23:12,960

so we're still we're still a lot of the

2455

01:23:17,510 --> 01:23:16,159

early work was basically done by hand

2456

01:23:20,470 --> 01:23:17,520

and

2457

01:23:21,750 --> 01:23:20,480

we're at the moment uh still is that

2458

01:23:24,229 --> 01:23:21,760

we're still working on these algorithms

2459

01:23:26,709 --> 01:23:24,239

so that's still very much a uh kind of a

2460

01:23:29,270 --> 01:23:26,719

a story in progress uh with respect to

2461

01:23:32,070 --> 01:23:29,280

the second question i guess i'm not sure

2462

01:23:34,709 --> 01:23:32,080

what the distinction would be so if we

2463

01:23:36,709 --> 01:23:34,719

understand the bioelectric signals

2464

01:23:38,709 --> 01:23:36,719

sufficiently that we can put out

2465

01:23:40,950 --> 01:23:38,719

whatever whatever signal we want and get

2466

01:23:42,709 --> 01:23:40,960

the cells to do what we want i think by

2467

01:23:44,629 --> 01:23:42,719

definition that means we've communicated

2468

01:23:46,070 --> 01:23:44,639

correctly to the cells which means by

2469

01:23:47,830 --> 01:23:46,080

definition we've learned their

2470

01:23:49,350 --> 01:23:47,840

appropriate language i'm not sure what

2471

01:23:51,189 --> 01:23:49,360

it would mean to be able to do that and

2472

01:23:53,030 --> 01:23:51,199

yet not really have the language of the

2473

01:23:55,430 --> 01:23:53,040

cells

2474

01:23:57,669 --> 01:23:55,440

sam thompson wants to know do you think

2475

01:24:00,790 --> 01:23:57,679

biological self-organization and

2476
01:24:02,709 --> 01:24:00,800
emergence might be proto-algorithmic

2477
01:24:04,310 --> 01:24:02,719
and then what with the implications of

2478
01:24:06,229 --> 01:24:04,320
for that what would the implications be

2479
01:24:08,390 --> 01:24:06,239
for science

2480
01:24:10,229 --> 01:24:08,400
i don't know what proto-algorithmic

2481
01:24:13,750 --> 01:24:10,239
means in this context

2482
01:24:15,189 --> 01:24:13,760
um i can take i can take a stab at uh

2483
01:24:16,310 --> 01:24:15,199
i think what might be an interesting

2484
01:24:18,629 --> 01:24:16,320
sense of it but i'm not sure that

2485
01:24:20,550 --> 01:24:18,639
captures what he was asking

2486
01:24:23,189 --> 01:24:20,560
the kind of thing that i think is

2487
01:24:24,229 --> 01:24:23,199
important sort of foundationally to

2488
01:24:25,030 --> 01:24:24,239

think about

2489

01:24:26,229 --> 01:24:25,040

is

2490

01:24:29,110 --> 01:24:26,239

where

2491

01:24:32,149 --> 01:24:29,120

do the set points of various uh

2492

01:24:33,830 --> 01:24:32,159

homeostatic systems come from so so

2493

01:24:36,470 --> 01:24:33,840

whether you have physiological

2494

01:24:38,870 --> 01:24:36,480

homeostasis or anatomical homeostasis

2495

01:24:39,990 --> 01:24:38,880

the ability of a system to get back to

2496

01:24:41,590 --> 01:24:40,000

the same

2497

01:24:43,669 --> 01:24:41,600

state even though it's it's perturbed

2498

01:24:46,390 --> 01:24:43,679

right one might ask where is that

2499

01:24:49,110 --> 01:24:46,400

information and an easy thing to say is

2500

01:24:51,430 --> 01:24:49,120

that well it's it's evolution provides

2501

01:24:53,430 --> 01:24:51,440

it because certain types of um set

2502

01:24:55,590 --> 01:24:53,440

points are adaptive and other time other

2503

01:24:56,709 --> 01:24:55,600

types will will not you will not let you

2504

01:24:57,590 --> 01:24:56,719

survive

2505

01:25:00,229 --> 01:24:57,600

and

2506

01:25:02,709 --> 01:25:00,239

that's okay except that now what we see

2507

01:25:04,070 --> 01:25:02,719

with these synthetic organisms is that

2508

01:25:06,550 --> 01:25:04,080

for example with the xenobots we can

2509

01:25:09,189 --> 01:25:06,560

take these frog skin cells and put them

2510

01:25:10,790 --> 01:25:09,199

in a new environment and within 48 hours

2511

01:25:12,709 --> 01:25:10,800

or so they

2512

01:25:15,830 --> 01:25:12,719

self-assemble into a new organism with a

2513

01:25:17,590 --> 01:25:15,840

new anatomy a new behavior and various

2514

01:25:20,149 --> 01:25:17,600

new capabilities

2515

01:25:22,470 --> 01:25:20,159

they never existed before they have no

2516

01:25:24,790 --> 01:25:22,480

lengthy history of selection on earth

2517

01:25:26,550 --> 01:25:24,800

right the the cells themselves evolved

2518

01:25:28,310 --> 01:25:26,560

for being really good at sitting on the

2519

01:25:30,550 --> 01:25:28,320

outside of a frog or a tadpole and

2520

01:25:32,070 --> 01:25:30,560

keeping out the bacteria they did not

2521

01:25:33,510 --> 01:25:32,080

evolve for the ability to get together

2522

01:25:35,189 --> 01:25:33,520

and run around by themselves and do

2523

01:25:36,629 --> 01:25:35,199

various things so that raises the

2524

01:25:38,709 --> 01:25:36,639

interesting question of where does that

2525

01:25:40,070 --> 01:25:38,719

actually come from right what the the

2526

01:25:42,310 --> 01:25:40,080

it's clear that there's incredible

2527

01:25:43,830 --> 01:25:42,320

plasticity of the hardware that's

2528

01:25:46,070 --> 01:25:43,840

encoded by the genome it can do all

2529

01:25:48,390 --> 01:25:46,080

sorts of novel things but where does

2530

01:25:49,990 --> 01:25:48,400

where do the specific things come from

2531

01:25:51,990 --> 01:25:50,000

and i don't know if this is what he

2532

01:25:53,430 --> 01:25:52,000

meant by proto-algorithmic but

2533

01:25:55,669 --> 01:25:53,440

you can sort of think about it one of my

2534

01:25:57,669 --> 01:25:55,679

favorite analogies is this thing called

2535

01:25:59,510 --> 01:25:57,679

a galton board i don't know if everybody

2536

01:26:01,030 --> 01:25:59,520

knows what that is but imagine imagine a

2537

01:26:02,709 --> 01:26:01,040

vertical piece of wood like this it's a

2538

01:26:04,470 --> 01:26:02,719

vertical piece of wood and then you bang

2539

01:26:06,070 --> 01:26:04,480

a bunch of nails into it at you know

2540

01:26:08,149 --> 01:26:06,080

regularly spaced intervals you just bang

2541

01:26:09,990 --> 01:26:08,159

a bunch of nails into it you take them

2542

01:26:11,830 --> 01:26:10,000

you take a bucket of marbles and you

2543

01:26:13,110 --> 01:26:11,840

dump it into the top and they go boom

2544

01:26:14,870 --> 01:26:13,120

boom boom they all go and every marble

2545

01:26:15,830 --> 01:26:14,880

just sort of bounces stochastically back

2546

01:26:17,990 --> 01:26:15,840

and forth

2547

01:26:19,750 --> 01:26:18,000

if if if you've got enough marbles the

2548

01:26:20,550 --> 01:26:19,760

outcome is always going to be exactly

2549

01:26:22,629 --> 01:26:20,560

the same you're going to get this

2550

01:26:23,830 --> 01:26:22,639

beautiful bell curve

2551

01:26:24,950 --> 01:26:23,840

right if you just visualize and i

2552

01:26:26,310 --> 01:26:24,960

actually have toys of this you can

2553

01:26:28,550 --> 01:26:26,320

actually buy one on amazon it's like

2554

01:26:30,149 --> 01:26:28,560

twinkle from price is right yeah yeah

2555

01:26:31,990 --> 01:26:30,159

yeah very very similar very similar but

2556

01:26:33,270 --> 01:26:32,000

you dump a whole you see if you dump one

2557

01:26:34,629 --> 01:26:33,280

marble you have no idea where it's gonna

2558

01:26:36,550 --> 01:26:34,639

end up but if you dump a bunch of

2559

01:26:38,310 --> 01:26:36,560

marbles in then on average you're going

2560

01:26:40,310 --> 01:26:38,320

to get this beautiful bell curve and so

2561

01:26:42,470 --> 01:26:40,320

you can ask a simple question where is

2562

01:26:44,870 --> 01:26:42,480

the shape of this bell curve encoded

2563

01:26:46,790 --> 01:26:44,880

was it in the description of the wood no

2564

01:26:48,709 --> 01:26:46,800

was it in the layout of the nails no you

2565

01:26:51,030 --> 01:26:48,719

could put the nails almost any which way

2566

01:26:52,709 --> 01:26:51,040

you want was it in the in the recipe of

2567

01:26:55,110 --> 01:26:52,719

making this thing no

2568

01:26:57,430 --> 01:26:55,120

um where was it and so

2569

01:26:59,189 --> 01:26:57,440

you end up with this idea that

2570

01:27:01,430 --> 01:26:59,199

much like and this is certainly i'm not

2571

01:27:03,669 --> 01:27:01,440

the first person by far to to to say

2572

01:27:05,590 --> 01:27:03,679

this this is a very old you know maybe

2573

01:27:07,270 --> 01:27:05,600

maybe pythagoras or plato had similar

2574

01:27:09,590 --> 01:27:07,280

ideas where

2575

01:27:11,990 --> 01:27:09,600

you would say that somewhere in an

2576

01:27:14,709 --> 01:27:12,000

important sense there are laws laws of

2577

01:27:16,950 --> 01:27:14,719

mathematics laws of computation that

2578

01:27:19,270 --> 01:27:16,960

exist independent of

2579

01:27:21,270 --> 01:27:19,280

uh well independent they have an

2580

01:27:23,430 --> 01:27:21,280

independent existence and what happens

2581

01:27:25,910 --> 01:27:23,440

is that when we build specific kinds of

2582

01:27:28,149 --> 01:27:25,920

machines we couple to those laws and we

2583

01:27:28,870 --> 01:27:28,159

take advantage of them so for example if

2584

01:27:31,189 --> 01:27:28,880

you

2585

01:27:33,030 --> 01:27:31,199

build a a machine that looks like a

2586

01:27:35,110 --> 01:27:33,040

galton board you get to couple to the

2587

01:27:36,390 --> 01:27:35,120

rules of mathematics that give you this

2588

01:27:39,110 --> 01:27:36,400

beautiful shape you didn't have to

2589

01:27:42,229 --> 01:27:39,120

specify the shape ahead of time you get

2590

01:27:44,629 --> 01:27:42,239

the shape for free by building a device

2591

01:27:47,669 --> 01:27:44,639

that can couple to those laws if you

2592

01:27:49,750 --> 01:27:47,679

discover a transistor which is basically

2593

01:27:51,189 --> 01:27:49,760

just a uh voltage-gated current

2594

01:27:52,629 --> 01:27:51,199

conductance right it's so it's like a

2595

01:27:54,629 --> 01:27:52,639

little tiny synapse you know it's the

2596

01:27:56,950 --> 01:27:54,639

same as a gap junction an ion channel as

2597

01:27:58,870 --> 01:27:56,960

soon as you've made that little machine

2598

01:28:00,870 --> 01:27:58,880

you can couple to these amazing laws of

2599

01:28:03,189 --> 01:28:00,880

computation that tell you for example

2600

01:28:04,950 --> 01:28:03,199

that if you have a bunch of nand gates

2601

01:28:06,470 --> 01:28:04,960

you can build anything well where did

2602

01:28:08,390 --> 01:28:06,480

that fact come from you know these truth

2603

01:28:09,750 --> 01:28:08,400

tables or if you know two angles of a

2604

01:28:12,229 --> 01:28:09,760

triangle you automatically know the

2605

01:28:13,830 --> 01:28:12,239

third way where that come from so so

2606

01:28:15,830 --> 01:28:13,840

where is that so so maybe that's what he

2607

01:28:17,350 --> 01:28:15,840

meant by proto-algorithmic but it's the

2608

01:28:19,350 --> 01:28:17,360

idea that

2609

01:28:20,550 --> 01:28:19,360

there are these rules and some of the

2610

01:28:21,750 --> 01:28:20,560

some of them are physics some of them

2611

01:28:23,270 --> 01:28:21,760

are mathematics and some of them are

2612

01:28:24,790 --> 01:28:23,280

computation

2613

01:28:27,510 --> 01:28:24,800

you can if you make the right kind of

2614

01:28:29,030 --> 01:28:27,520

device you can reap the benefits of of

2615

01:28:31,750 --> 01:28:29,040

some of those laws and evolution does

2616

01:28:34,550 --> 01:28:31,760

this all the time evolution discovers

2617

01:28:37,910 --> 01:28:34,560

certain pieces of hardware that then let

2618

01:28:39,430 --> 01:28:37,920

you do amazing amazing things because

2619

01:28:40,550 --> 01:28:39,440

you're leveraging these laws that are

2620

01:28:43,430 --> 01:28:40,560

out there that are invisible to you

2621

01:28:44,870 --> 01:28:43,440

until you've built the right hardware

2622

01:28:46,709 --> 01:28:44,880

great we'll just get to four more

2623

01:28:48,870 --> 01:28:46,719

questions hopefully they're quick

2624

01:28:51,430 --> 01:28:48,880

feign is the evolutionary suppression of

2625

01:28:55,270 --> 01:28:51,440

regeneration in mammals an advantageous

2626

01:29:00,229 --> 01:28:57,510

wow uh i'm not sure about for the

2627

01:29:01,750 --> 01:29:00,239

accumulation of memory i i doubt it

2628

01:29:04,310 --> 01:29:01,760

because there are plenty of creatures

2629

01:29:06,790 --> 01:29:04,320

that uh it can do perfectly well with

2630

01:29:09,990 --> 01:29:06,800

memory that that are highly regenerative

2631

01:29:11,669 --> 01:29:10,000

so so i don't think that it's um you

2632

01:29:13,189 --> 01:29:11,679

need to you i don't think it's

2633

01:29:15,110 --> 01:29:13,199

impossible to have a regenerative

2634

01:29:17,830 --> 01:29:15,120

capacity and memory in the same animal

2635

01:29:18,709 --> 01:29:17,840

however um we can think about

2636

01:29:22,229 --> 01:29:18,719

why

2637

01:29:23,830 --> 01:29:22,239

regenerating their limbs so so nobody

2638

01:29:26,470 --> 01:29:23,840

knows but but i'll tell you a plausible

2639

01:29:29,030 --> 01:29:26,480

story that may or may not be correct

2640

01:29:30,870 --> 01:29:29,040

imagine that you are the ancestor of

2641

01:29:32,070 --> 01:29:30,880

mammals you're the tiny

2642

01:29:33,830 --> 01:29:32,080

thing that looks a little bit like a

2643

01:29:36,870 --> 01:29:33,840

mouse and you're running around the

2644

01:29:39,830 --> 01:29:36,880

forest and somebody bites your leg off

2645

01:29:42,950 --> 01:29:39,840

so the problem is that unlike a

2646

01:29:45,830 --> 01:29:42,960

salamander which can hang out in water

2647

01:29:48,870 --> 01:29:45,840

and take a long time to heal you have a

2648

01:29:51,590 --> 01:29:48,880

rapid metabolism you have a rapid

2649

01:29:54,070 --> 01:29:51,600

heartbeat and blood pressure and

2650

01:29:57,030 --> 01:29:54,080

you're going to bleed out long before

2651
01:29:59,669 --> 01:29:57,040
you get a chance to regenerate so your

2652
01:30:02,390 --> 01:29:59,679
job if you want to survive is to form a

2653
01:30:03,750 --> 01:30:02,400
scar and to have an inflammatory

2654
01:30:06,149 --> 01:30:03,760
response that's going to kill off with

2655
01:30:07,750 --> 01:30:06,159
some of the bacteria you need to not

2656
01:30:09,669 --> 01:30:07,760
bleed out so you need to seal the wound

2657
01:30:11,910 --> 01:30:09,679
immediately you need to make a scar and

2658
01:30:13,590 --> 01:30:11,920
by the way you are going to try to put

2659
01:30:15,590 --> 01:30:13,600
weight on it because you're walking on

2660
01:30:17,270 --> 01:30:15,600
it unlike unlike a salamander which has

2661
01:30:18,470 --> 01:30:17,280
the buoyancy of water to hold you up

2662
01:30:20,470 --> 01:30:18,480
you're going to try to put weight on it

2663
01:30:22,709 --> 01:30:20,480

which means that as soon as some kind of

2664

01:30:23,750 --> 01:30:22,719

delicate blastema is formed and these

2665

01:30:25,590 --> 01:30:23,760

cells are starting to grow you're going

2666

01:30:28,790 --> 01:30:25,600

to grind it into the forest floor so

2667

01:30:30,790 --> 01:30:28,800

that's not particularly conducive also

2668

01:30:32,709 --> 01:30:30,800

because you're you're in dry air instead

2669

01:30:33,910 --> 01:30:32,719

of water all of the electrical currents

2670

01:30:35,750 --> 01:30:33,920

that need to come out of that wound

2671

01:30:38,310 --> 01:30:35,760

epithelium to drive the electric states

2672

01:30:39,669 --> 01:30:38,320

they can't work because the dry air is a

2673

01:30:41,830 --> 01:30:39,679

is an insulator

2674

01:30:43,910 --> 01:30:41,840

so uh you might imagine that at that

2675

01:30:47,110 --> 01:30:43,920

point you might as well just shift the

2676
01:30:48,709 --> 01:30:47,120
scarring because the regeneration now

2677
01:30:50,790 --> 01:30:48,719
that story

2678
01:30:52,629 --> 01:30:50,800
has pros and cons um

2679
01:30:54,229 --> 01:30:52,639
one nice thing about that story is that

2680
01:30:56,629 --> 01:30:54,239
for example it fits with this really

2681
01:30:58,470 --> 01:30:56,639
weird fact why are

2682
01:31:00,790 --> 01:30:58,480
why are deer regenerative on their

2683
01:31:02,390 --> 01:31:00,800
antlers why can deer regenerate massive

2684
01:31:03,990 --> 01:31:02,400
amounts of bone and vasculature and

2685
01:31:05,510 --> 01:31:04,000
innervation every year

2686
01:31:06,950 --> 01:31:05,520
i mean what's interesting about the deer

2687
01:31:08,470 --> 01:31:06,960
is they're not putting weight on it

2688
01:31:10,070 --> 01:31:08,480

they're catering and carrying it around

2689

01:31:11,430 --> 01:31:10,080

and they never have to it never has to

2690

01:31:13,510 --> 01:31:11,440

worry that it's going to be disrupted

2691

01:31:15,189 --> 01:31:13,520

while it's trying to grow so so that's

2692

01:31:17,750 --> 01:31:15,199

that's one part you know that that that

2693

01:31:19,510 --> 01:31:17,760

fits what doesn't fit is questions like

2694

01:31:21,270 --> 01:31:19,520

well okay that explains why the limbs

2695

01:31:22,870 --> 01:31:21,280

don't regenerate how about internal

2696

01:31:24,790 --> 01:31:22,880

organs why don't they regenerate right

2697

01:31:26,629 --> 01:31:24,800

and we don't know so the you know so no

2698

01:31:27,750 --> 01:31:26,639

one knows and we can come up with some

2699

01:31:30,470 --> 01:31:27,760

ideas that

2700

01:31:32,310 --> 01:31:30,480

have sort of pros and cons

2701

01:31:34,870 --> 01:31:32,320

tom carrick asks well it says

2702

01:31:37,910 --> 01:31:34,880

fascinating are there overlaps with the

2703

01:31:40,229 --> 01:31:37,920

field of quantum biology what about orc

2704

01:31:41,990 --> 01:31:40,239

or that is i'm sure you've heard of

2705

01:31:44,709 --> 01:31:42,000

stewart hammeroffs and penrose's

2706

01:31:45,590 --> 01:31:44,719

orchestrated objective reduction

2707

01:31:47,910 --> 01:31:45,600

yeah

2708

01:31:49,270 --> 01:31:47,920

um

2709

01:31:51,510 --> 01:31:49,280

i don't know

2710

01:31:53,669 --> 01:31:51,520

i i can't say too many useful things

2711

01:31:55,510 --> 01:31:53,679

about that but but i will say sort of

2712

01:31:56,709 --> 01:31:55,520

one thing uh

2713

01:32:07,510 --> 01:31:56,719

2714

01:32:09,350 --> 01:32:07,520

one of the most profound

2715

01:32:11,669 --> 01:32:09,360

maybe maybe the only profound tool we

2716

01:32:13,030 --> 01:32:11,679

have to study actual consciousness right

2717

01:32:14,390 --> 01:32:13,040

that's we we don't have a lot of other

2718

01:32:16,229 --> 01:32:14,400

tools to study consciousness but

2719

01:32:17,990 --> 01:32:16,239

anesthesia is a pretty good one and the

2720

01:32:18,790 --> 01:32:18,000

interesting thing about anesthesia is

2721

01:32:21,110 --> 01:32:18,800

that

2722

01:32:22,950 --> 01:32:21,120

in general most general anesthetics are

2723

01:32:27,030 --> 01:32:22,960

gap junctional disruptors

2724

01:32:28,870 --> 01:32:27,040

now this this this has uh like many uh

2725

01:32:29,910 --> 01:32:28,880

facts as things that are that are easy

2726
01:32:32,790 --> 01:32:29,920
to understand and some things that are

2727
01:32:36,550 --> 01:32:32,800
deeply puzzling the e the kind of uh

2728
01:32:38,390 --> 01:32:36,560
thing that makes perfect sense is that

2729
01:32:41,189 --> 01:32:38,400
these these electrical networks in the

2730
01:32:45,270 --> 01:32:43,510
manifested various cognitive abilities

2731
01:32:48,229 --> 01:32:45,280
long before they were brains so these

2732
01:32:50,470 --> 01:32:48,239
gap junctions that enable body cells to

2733
01:32:52,470 --> 01:32:50,480
form networks are critical for these

2734
01:32:54,390 --> 01:32:52,480
networks to have memories memories of

2735
01:32:55,990 --> 01:32:54,400
body shape but to make decisions about

2736
01:32:59,189 --> 01:32:56,000
what they're going to grow and so on so

2737
01:33:01,350 --> 01:32:59,199
so the use of gap junctions to

2738
01:33:03,430 --> 01:33:01,360

make networks that can follow

2739

01:33:05,030 --> 01:33:03,440

large scale goals like make a limb and

2740

01:33:06,870 --> 01:33:05,040

make an organ and so on that's

2741

01:33:08,870 --> 01:33:06,880

evolutionarily ancient and it's not

2742

01:33:11,270 --> 01:33:08,880

surprising at all that what evolution

2743

01:33:14,470 --> 01:33:11,280

did when the nervous systems develop was

2744

01:33:16,709 --> 01:33:14,480

to use that same trick to create another

2745

01:33:18,470 --> 01:33:16,719

type of cognitive agent which which

2746

01:33:20,310 --> 01:33:18,480

lives basically central ascension

2747

01:33:22,709 --> 01:33:20,320

centered in the brain and use this the

2748

01:33:24,470 --> 01:33:22,719

exact same reuse the exact same hardware

2749

01:33:27,110 --> 01:33:24,480

for that so that makes sense and so it

2750

01:33:29,110 --> 01:33:27,120

makes total sense that that goes away

2751
01:33:31,590 --> 01:33:29,120
when when uh those gap generators are

2752
01:33:33,270 --> 01:33:31,600
disrupted by a general anesthetic it

2753
01:33:37,350 --> 01:33:33,280
also makes total sense that if we want

2754
01:33:39,669 --> 01:33:37,360
to turn a planarian it into the head of

2755
01:33:41,590 --> 01:33:39,679
make its head turn its head into uh the

2756
01:33:43,590 --> 01:33:41,600
head of a different species of planarian

2757
01:33:45,590 --> 01:33:43,600
guess what we use a general anesthetic

2758
01:33:47,510 --> 01:33:45,600
called octanol it's the exact same thing

2759
01:33:49,189 --> 01:33:47,520
it's a gap junctional disruptor so what

2760
01:33:51,669 --> 01:33:49,199
you're doing is you're basically

2761
01:33:53,590 --> 01:33:51,679
disrupting that proto-cognitive agent

2762
01:33:55,189 --> 01:33:53,600
the collective intelligence of the body

2763
01:33:57,750 --> 01:33:55,199

that normally remembers how to make a

2764

01:33:59,110 --> 01:33:57,760

particular kind of head you're basically

2765

01:34:02,229 --> 01:33:59,120

disrupting that with this general

2766

01:34:04,070 --> 01:34:02,239

anesthetic now the amazing thing about

2767

01:34:05,750 --> 01:34:04,080

general anesthetic is that any of us

2768

01:34:07,270 --> 01:34:05,760

ever come back from it being the same

2769

01:34:08,229 --> 01:34:07,280

person think about it you have this

2770

01:34:10,470 --> 01:34:08,239

brain

2771

01:34:12,470 --> 01:34:10,480

you have you have right it's a it it

2772

01:34:14,870 --> 01:34:12,480

supports the cognitive structures of a

2773

01:34:16,709 --> 01:34:14,880

very complex creature and then

2774

01:34:18,870 --> 01:34:16,719

for some number of hours you simply

2775

01:34:19,990 --> 01:34:18,880

disconnect most of the cells from being

2776

01:34:21,830 --> 01:34:20,000

electrically

2777

01:34:24,310 --> 01:34:21,840

in communication with each other and

2778

01:34:25,510 --> 01:34:24,320

then you let the connections reform

2779

01:34:27,270 --> 01:34:25,520

and you just sort of hope that

2780

01:34:29,430 --> 01:34:27,280

everything comes back to how it was

2781

01:34:30,709 --> 01:34:29,440

right if i didn't know

2782

01:34:32,390 --> 01:34:30,719

you know if we didn't know that the

2783

01:34:33,990 --> 01:34:32,400

general anesthetics work somebody were

2784

01:34:34,870 --> 01:34:34,000

to tell me that that's their plan i

2785

01:34:37,750 --> 01:34:34,880

would say

2786

01:34:39,030 --> 01:34:37,760

well you might get a living living human

2787

01:34:40,470 --> 01:34:39,040

out of it at the end but certainly not

2788

01:34:41,590 --> 01:34:40,480

going to be the patient that walked in

2789

01:34:43,189 --> 01:34:41,600

you you know you're going to bear no

2790

01:34:44,709 --> 01:34:43,199

resurrection yeah of course you're going

2791

01:34:47,830 --> 01:34:44,719

to completely wreck their mental state

2792

01:34:49,910 --> 01:34:47,840

and and so so one thing that's amazing

2793

01:34:51,669 --> 01:34:49,920

is that actually most people come out of

2794

01:34:53,109 --> 01:34:51,679

it being the more or less the same

2795

01:34:54,950 --> 01:34:53,119

person as they went in

2796

01:34:57,990 --> 01:34:54,960

but the other interesting thing is not

2797

01:34:59,590 --> 01:34:58,000

everybody so in fact um there is this is

2798

01:35:00,870 --> 01:34:59,600

why they don't give they don't like to

2799

01:35:02,390 --> 01:35:00,880

give general anaesthetic if they can

2800

01:35:05,189 --> 01:35:02,400

help it because some people have

2801
01:35:07,030 --> 01:35:05,199
permanent psychosis some people um in

2802
01:35:09,430 --> 01:35:07,040
fact many people have hallucinations on

2803
01:35:11,270 --> 01:35:09,440
their way out um out of it that

2804
01:35:13,830 --> 01:35:11,280
eventually resolve as the brain sort of

2805
01:35:15,430 --> 01:35:13,840
finds its its attractors that were there

2806
01:35:17,830 --> 01:35:15,440
before but if you watch you can go to

2807
01:35:19,590 --> 01:35:17,840
youtube and you can watch some really um

2808
01:35:21,030 --> 01:35:19,600
sort of funny videos of people coming

2809
01:35:22,470 --> 01:35:21,040
out of general anesthesia right and you

2810
01:35:23,910 --> 01:35:22,480
know people think they're pirates and

2811
01:35:25,669 --> 01:35:23,920
they're gangsters and they you know they

2812
01:35:27,109 --> 01:35:25,679
don't understand where where they've

2813
01:35:29,189 --> 01:35:27,119

been and they have all these crazy

2814

01:35:31,750 --> 01:35:29,199

stories about who they think they are

2815

01:35:33,350 --> 01:35:31,760

and eventually that sort of resolves and

2816

01:35:34,790 --> 01:35:33,360

not really that part's not really

2817

01:35:36,790 --> 01:35:34,800

surprising i'm shocked anybody ever

2818

01:35:37,990 --> 01:35:36,800

comes out of it you know properly that

2819

01:35:40,709 --> 01:35:38,000

it's amazing

2820

01:35:42,950 --> 01:35:40,719

so uh the planaria is exactly the same

2821

01:35:44,310 --> 01:35:42,960

thing so when you disrupt their um their

2822

01:35:45,590 --> 01:35:44,320

gap junctions

2823

01:35:48,709 --> 01:35:45,600

the first thing they do is they

2824

01:35:51,109 --> 01:35:48,719

regenerate random heads that belong

2825

01:35:53,830 --> 01:35:51,119

possibly to other species right and then

2826

01:35:55,750 --> 01:35:53,840

after about uh 30 days

2827

01:35:58,709 --> 01:35:55,760

those heads actually remodel back to the

2828

01:35:59,590 --> 01:35:58,719

correct species a species-specific shape

2829

01:36:02,790 --> 01:35:59,600

so

2830

01:36:06,070 --> 01:36:02,800

looks exactly like what happens when you

2831

01:36:08,550 --> 01:36:06,080

come out of general anesthesia

2832

01:36:10,070 --> 01:36:08,560

okay mo flow wants to know how does he

2833

01:36:14,310 --> 01:36:10,080

see his work relating to david

2834

01:36:19,109 --> 01:36:16,950

yeah um yeah interesting uh it's it's

2835

01:36:20,950 --> 01:36:19,119

funny i've been talking a lot i talked

2836

01:36:22,470 --> 01:36:20,960

to david recently and i uh i've been

2837

01:36:24,629 --> 01:36:22,480

thinking a lot about um people have been

2838

01:36:25,750 --> 01:36:24,639

asking me a lot about aging bioelectrics

2839

01:36:28,149 --> 01:36:25,760

of aging

2840

01:36:29,910 --> 01:36:28,159

um i i don't know i don't know what the

2841

01:36:31,430 --> 01:36:29,920

relationship between bioelectrics and

2842

01:36:32,470 --> 01:36:31,440

aging really is

2843

01:36:34,390 --> 01:36:32,480

um

2844

01:36:36,310 --> 01:36:34,400

i can tell you that

2845

01:36:38,149 --> 01:36:36,320

uh planaria as far as we can tell don't

2846

01:36:41,030 --> 01:36:38,159

age there's no such thing as an old

2847

01:36:43,750 --> 01:36:41,040

planarian they live forever if

2848

01:36:44,870 --> 01:36:43,760

you know if they're not injured and so

2849

01:36:48,550 --> 01:36:44,880

uh

2850

01:36:50,709 --> 01:36:48,560

i think what that tells us is that aging

2851

01:36:52,629 --> 01:36:50,719

it would be resolved if we could crank

2852

01:36:54,070 --> 01:36:52,639

up regenerative capacity to the point

2853

01:36:56,390 --> 01:36:54,080

where we would constantly be

2854

01:36:58,470 --> 01:36:56,400

regenerating any to any cells that that

2855

01:37:00,709 --> 01:36:58,480

aged right senescing cells would just be

2856

01:37:04,070 --> 01:37:00,719

regenerated the way planaria do

2857

01:37:06,550 --> 01:37:04,080

so my sis my strong suspicion is that

2858

01:37:08,790 --> 01:37:06,560

uh aging is a is a

2859

01:37:09,910 --> 01:37:08,800

a consequence of our poor ability to

2860

01:37:11,830 --> 01:37:09,920

stay

2861

01:37:13,830 --> 01:37:11,840

with the appropriate anatomical

2862

01:37:16,070 --> 01:37:13,840

structure through long periods of time

2863

01:37:18,070 --> 01:37:16,080

and if we cracked that problem we would

2864

01:37:20,709 --> 01:37:18,080

simultaneously get the answer to to

2865

01:37:22,390 --> 01:37:20,719

aging cancer degenerative disease and

2866

01:37:24,950 --> 01:37:22,400

traumatic injury i think it all comes

2867

01:37:27,189 --> 01:37:24,960

down to the ability to to to defend a

2868

01:37:29,189 --> 01:37:27,199

particular body plan over time

2869

01:37:30,870 --> 01:37:29,199

i know many people say that telomere

2870

01:37:32,709 --> 01:37:30,880

length has to do with aging well the

2871

01:37:34,470 --> 01:37:32,719

shortened telomere length and you're

2872

01:37:36,709 --> 01:37:34,480

suggesting well it could be that but

2873

01:37:38,390 --> 01:37:36,719

it's also related to this

2874

01:37:40,229 --> 01:37:38,400

morphogenetic code that you're referring

2875

01:37:43,109 --> 01:37:40,239

to and

2876

01:37:45,350 --> 01:37:43,119

yeah are they interrelated somehow

2877

01:37:48,070 --> 01:37:45,360

probably i mean i am not an expert on

2878

01:37:50,709 --> 01:37:48,080

telomeres i have no idea what's going on

2879

01:37:52,229 --> 01:37:50,719

with telomeres in planaria i'm assuming

2880

01:37:54,149 --> 01:37:52,239

somebody's studying it we certainly

2881

01:37:55,510 --> 01:37:54,159

haven't i'm assuming somebody must be

2882

01:37:57,750 --> 01:37:55,520

all i know is

2883

01:38:00,070 --> 01:37:57,760

this this story of

2884

01:38:01,750 --> 01:38:00,080

inevitable aging because you keep making

2885

01:38:03,350 --> 01:38:01,760

copies of things and fundamentally

2886

01:38:05,030 --> 01:38:03,360

things are the information is degrading

2887

01:38:07,189 --> 01:38:05,040

and eventually you you don't have it

2888

01:38:08,390 --> 01:38:07,199

anymore uh and it's degrading at the

2889

01:38:10,550 --> 01:38:08,400

ends because you know because that's

2890

01:38:11,990 --> 01:38:10,560

where you're eating that that clearly

2891

01:38:14,550 --> 01:38:12,000

cannot be the whole story because

2892

01:38:15,669 --> 01:38:14,560

planaria avoided permanently so whatever

2893

01:38:18,790 --> 01:38:15,679

they're doing

2894

01:38:21,830 --> 01:38:18,800

is uh is is is the way to get around

2895

01:38:24,709 --> 01:38:21,840

aging and i think it's more than a

2896

01:38:26,470 --> 01:38:24,719

coincidence that the species that is

2897

01:38:28,229 --> 01:38:26,480

immortal is also the species with the

2898

01:38:30,390 --> 01:38:28,239

greatest regenerative capacity or let's

2899

01:38:31,990 --> 01:38:30,400

say the set of species so i i don't

2900

01:38:33,669 --> 01:38:32,000

think that's a that's a that's a crazy

2901

01:38:35,030 --> 01:38:33,679

coincidence that i think there's there's

2902

01:38:36,950 --> 01:38:35,040

a reason for that

2903

01:38:39,990 --> 01:38:36,960

okay the last question

2904

01:38:41,590 --> 01:38:40,000

nate brundman can you imagine

2905

01:38:43,430 --> 01:38:41,600

referring to you michael can you imagine

2906

01:38:46,470 --> 01:38:43,440

a mental practice by which a person can

2907

01:38:49,189 --> 01:38:46,480

influence the goal state of the body for

2908

01:38:50,790 --> 01:38:49,199

example joe dispenza has made some

2909

01:38:53,189 --> 01:38:50,800

claims that he's healed his body in a

2910

01:38:55,510 --> 01:38:53,199

way that doctors say are impossible it

2911

01:38:57,430 --> 01:38:55,520

also a question i had for you earlier

2912

01:38:59,910 --> 01:38:57,440

which relates to this is

2913

01:39:01,510 --> 01:38:59,920

how your work is related to the placebo

2914

01:39:02,790 --> 01:39:01,520

effect

2915

01:39:03,910 --> 01:39:02,800

so

2916

01:39:05,350 --> 01:39:03,920

whether or not you see the connection

2917

01:39:06,790 --> 01:39:05,360

there i'm interested in the placebo

2918

01:39:08,790 --> 01:39:06,800

effect too i'm trying to sneak in two

2919

01:39:11,910 --> 01:39:08,800

questions for the pressure one

2920

01:39:14,229 --> 01:39:11,920

yeah um okay so so i i don't know

2921

01:39:16,070 --> 01:39:14,239

anything about uh joe dispenza i don't

2922

01:39:18,790 --> 01:39:16,080

know anything about the claims that he's

2923

01:39:20,790 --> 01:39:18,800

made or or any specific uh you know kind

2924

01:39:22,790 --> 01:39:20,800

of uh healing event

2925

01:39:24,229 --> 01:39:22,800

but i'll give you kind of a general

2926

01:39:25,669 --> 01:39:24,239

thought about this

2927

01:39:27,990 --> 01:39:25,679

it is

2928

01:39:29,590 --> 01:39:28,000

uncontroversial

2929

01:39:32,470 --> 01:39:29,600

that

2930

01:39:33,990 --> 01:39:32,480

your your thoughts whatever they may be

2931

01:39:35,990 --> 01:39:34,000

whether or not uh you know whatever

2932

01:39:37,590 --> 01:39:36,000

whatever you think thinking is it is

2933

01:39:40,310 --> 01:39:37,600

pretty uncontroversial that your

2934

01:39:41,750 --> 01:39:40,320

thoughts affect the physiological

2935

01:39:44,629 --> 01:39:41,760

functioning of your body i mean that's

2936

01:39:47,189 --> 01:39:44,639

obvious if you if you want to get up and

2937

01:39:50,550 --> 01:39:47,199

walk around your thoughts have now

2938

01:39:51,830 --> 01:39:50,560

activated various uh electrical pathways

2939

01:39:54,629 --> 01:39:51,840

they've triggered a bunch of muscle

2940

01:39:56,310 --> 01:39:54,639

motion if you have a tendency to you

2941

01:39:59,350 --> 01:39:56,320

know mentally work yourself up into an

2942

01:40:02,229 --> 01:39:59,360

anxious state you can certainly by by by

2943

01:40:04,229 --> 01:40:02,239

your thinking uh crank up various stress

2944

01:40:06,229 --> 01:40:04,239

enzyme production in your body right we

2945

01:40:08,310 --> 01:40:06,239

all know that you can do the opposite if

2946

01:40:09,669 --> 01:40:08,320

you if you've trained in techniques to

2947

01:40:12,390 --> 01:40:09,679

calm yourself down under various

2948

01:40:14,149 --> 01:40:12,400

circumstances you can uh reduce the

2949

01:40:17,030 --> 01:40:14,159

level of cortisol in your blood you can

2950

01:40:19,750 --> 01:40:17,040

reduce um various uh various fire and

2951

01:40:22,790 --> 01:40:19,760

flight responses so it's it's it's not

2952

01:40:25,189 --> 01:40:22,800

some some some weird um you know of a

2953

01:40:27,030 --> 01:40:25,199

voodoo kind of claim to uh to say that

2954

01:40:28,870 --> 01:40:27,040

that your thoughts absolutely affect the

2955

01:40:30,310 --> 01:40:28,880

biophysical processes of your body we do

2956

01:40:31,669 --> 01:40:30,320

it every day if that wasn't true you

2957

01:40:33,270 --> 01:40:31,679

couldn't get up in the morning when you

2958

01:40:35,030 --> 01:40:33,280

wanted to get up and go to work so so

2959

01:40:37,430 --> 01:40:35,040

it's it's that part's completely obvious

2960

01:40:40,229 --> 01:40:37,440

so from there it's a very

2961

01:40:40,950 --> 01:40:40,239

short uh hop skip and a jump to the idea

2962

01:40:42,790 --> 01:40:40,960

that

2963

01:40:45,189 --> 01:40:42,800

not only can you give commands to your

2964

01:40:46,149 --> 01:40:45,199

muscles and your glands to produce

2965

01:40:47,990 --> 01:40:46,159

various

2966

01:40:50,310 --> 01:40:48,000

hormones neurotransmitters and muscle

2967

01:40:51,910 --> 01:40:50,320

motion but you might be able to exert

2968

01:40:55,109 --> 01:40:51,920

some influence over other cells for

2969

01:40:57,590 --> 01:40:55,119

example skin cells um in your uh you

2970

01:40:59,430 --> 01:40:57,600

know at wounds and and uh and you and

2971

01:41:01,350 --> 01:40:59,440

your liver the in the way that it

2972

01:41:03,750 --> 01:41:01,360

processes information

2973

01:41:05,510 --> 01:41:03,760

i don't find it implausible whatsoever

2974

01:41:07,510 --> 01:41:05,520

so i don't again i'm not commenting on

2975

01:41:08,950 --> 01:41:07,520

any particular instance of anybody

2976

01:41:10,390 --> 01:41:08,960

having healed themselves of anything i'm

2977

01:41:13,510 --> 01:41:10,400

just saying that

2978

01:41:16,550 --> 01:41:13,520

it is it is uh it is it is not

2979

01:41:18,550 --> 01:41:16,560

uh it is not a stretch to think that not

2980

01:41:20,629 --> 01:41:18,560

only can you talk to your van

2981

01:41:22,070 --> 01:41:20,639

when i say talk i mean you know exert

2982

01:41:24,870 --> 01:41:22,080

exert influence

2983

01:41:26,790 --> 01:41:24,880

on your uh on your various glands that

2984

01:41:28,470 --> 01:41:26,800

that put out cortisol and adrenaline and

2985

01:41:30,310 --> 01:41:28,480

various other things

2986

01:41:32,709 --> 01:41:30,320

why can't why can't you send commands to

2987

01:41:34,950 --> 01:41:32,719

other cells i that that seems it seems

2988

01:41:36,790 --> 01:41:34,960

silly to think that that's impossible

2989

01:41:39,350 --> 01:41:36,800

so um

2990

01:41:42,310 --> 01:41:39,360

having said all that i think that uh the

2991

01:41:43,910 --> 01:41:42,320

placebo effect is extremely profound i

2992

01:41:46,390 --> 01:41:43,920

think that what it's telling us is that

2993

01:41:48,310 --> 01:41:46,400

there is a communication across levels

2994

01:41:49,910 --> 01:41:48,320

so you have meaning that you have a

2995

01:41:52,470 --> 01:41:49,920

level of organization that consists of

2996

01:41:54,310 --> 01:41:52,480

your body cells and that has a degree of

2997

01:41:55,910 --> 01:41:54,320

cognition and a degree of intelligence

2998

01:41:57,750 --> 01:41:55,920

but your body is also home to an

2999

01:42:00,149 --> 01:41:57,760

additional intelligence which lives

3000

01:42:02,390 --> 01:42:00,159

probably largely in the brain and it

3001

01:42:04,470 --> 01:42:02,400

appears that those two can uh can

3002

01:42:05,669 --> 01:42:04,480

communicate in various ways and i can

3003

01:42:07,910 --> 01:42:05,679

imagine that

3004

01:42:09,430 --> 01:42:07,920

there are new there are lots of things

3005

01:42:11,669 --> 01:42:09,440

to be discovered about ways to improve

3006

01:42:13,270 --> 01:42:11,679

that communication and have you know we

3007

01:42:15,030 --> 01:42:13,280

know we know there are certain practices

3008

01:42:17,510 --> 01:42:15,040

where people extend the amount of time

3009

01:42:19,669 --> 01:42:17,520

they can they can sit under water and

3010

01:42:21,669 --> 01:42:19,679

and uh change their body temperature and

3011

01:42:23,990 --> 01:42:21,679

and change their their pulse rate and

3012

01:42:27,189 --> 01:42:24,000

things like that i find it completely

3013

01:42:28,870 --> 01:42:27,199

plausible that that there are ways to uh

3014

01:42:29,910 --> 01:42:28,880

communicate in that way to other cells

3015

01:42:31,750 --> 01:42:29,920

in the body

3016

01:42:32,629 --> 01:42:31,760

also

3017

01:42:35,830 --> 01:42:32,639

uh

3018

01:42:38,950 --> 01:42:35,840

there is the there is the field of um

3019

01:42:40,709 --> 01:42:38,960

hypno dermatology where where people by

3020

01:42:42,310 --> 01:42:40,719

hypnosis try to treat various skin

3021

01:42:44,390 --> 01:42:42,320

diseases some of which have a neural

3022

01:42:46,229 --> 01:42:44,400

neuroimmune component some of which may

3023

01:42:49,270 --> 01:42:46,239

not have a neuroimmune component

3024

01:42:51,830 --> 01:42:49,280

so um the activity of of the mind which

3025

01:42:54,310 --> 01:42:51,840

is simply the execution of of the

3026
01:42:56,550 --> 01:42:54,320
physiological computations that happen

3027
01:42:58,229 --> 01:42:56,560
in the brain affect physiological

3028
01:42:59,830 --> 01:42:58,239
computations that happen outside the

3029
01:43:01,750 --> 01:42:59,840
brain i don't think that's i don't think

3030
01:43:03,109 --> 01:43:01,760
that's particularly a stretch

3031
01:43:04,790 --> 01:43:03,119
at all

3032
01:43:06,709 --> 01:43:04,800
one of your goals is an anatomical

3033
01:43:08,709 --> 01:43:06,719
compiler and then what you just said

3034
01:43:10,149 --> 01:43:08,719
made me think well some of these people

3035
01:43:13,430 --> 01:43:10,159
who are meditating or on the more

3036
01:43:15,189 --> 01:43:13,440
meditative side tend to work with

3037
01:43:16,470 --> 01:43:15,199
thoughts to heal oneself then i was

3038
01:43:19,669 --> 01:43:16,480

wondering hmm i wonder if your

3039

01:43:22,390 --> 01:43:19,679

anatomical compiler can advise some of

3040

01:43:24,229 --> 01:43:22,400

the more thought-based healing practices

3041

01:43:26,629 --> 01:43:24,239

here's an example you say well if you

3042

01:43:28,390 --> 01:43:26,639

were to think of this image it's more

3043

01:43:30,070 --> 01:43:28,400

likely to heal you than if you were to

3044

01:43:31,910 --> 01:43:30,080

think of this other image do you think

3045

01:43:33,830 --> 01:43:31,920

that's at all possible or that's way too

3046

01:43:35,189 --> 01:43:33,840

high level

3047

01:43:37,270 --> 01:43:35,199

i don't think it's i don't think it's

3048

01:43:38,709 --> 01:43:37,280

impossible no uh

3049

01:43:41,030 --> 01:43:38,719

again i'm not suggesting that there's

3050

01:43:43,109 --> 01:43:41,040

i'm not supporting any particular image

3051

01:43:45,669 --> 01:43:43,119

of as being a healing one but i don't

3052

01:43:46,470 --> 01:43:45,679

think it's it's impossible at all i mean

3053

01:43:51,189 --> 01:43:46,480

the

3054

01:43:52,629 --> 01:43:51,199

various types of um pulsed light stimuli

3055

01:43:53,910 --> 01:43:52,639

into the retina having some some

3056

01:43:55,990 --> 01:43:53,920

interesting neuro

3057

01:43:58,390 --> 01:43:56,000

neuroprotective effects in the brain and

3058

01:44:00,070 --> 01:43:58,400

so on um yeah all of this it's it's a

3059

01:44:01,910 --> 01:44:00,080

giant electrical network all of the

3060

01:44:03,910 --> 01:44:01,920

cells are communicating with each other

3061

01:44:06,310 --> 01:44:03,920

uh there's absolutely no reason why that

3062

01:44:07,910 --> 01:44:06,320

couldn't work but i think that um you

3063

01:44:10,229 --> 01:44:07,920

know to be clear this anatomical

3064

01:44:12,950 --> 01:44:10,239

compiler isn't just us you know

3065

01:44:15,590 --> 01:44:12,960

the anatomical compiler is a

3066

01:44:17,510 --> 01:44:15,600

it's a sort of practical um

3067

01:44:19,109 --> 01:44:17,520

personification of the goal that all of

3068

01:44:20,709 --> 01:44:19,119

us in the community are going for which

3069

01:44:22,310 --> 01:44:20,719

is the ability to control growth and

3070

01:44:23,750 --> 01:44:22,320

form right and and when we have that

3071

01:44:25,590 --> 01:44:23,760

ability that's when the anatomical

3072

01:44:26,790 --> 01:44:25,600

compiler becomes positive possible so

3073

01:44:28,550 --> 01:44:26,800

it's not just something that we you know

3074

01:44:31,270 --> 01:44:28,560

we in particular are working on

3075

01:44:33,270 --> 01:44:31,280

but i think that uh this is this is part

3076

01:44:36,149 --> 01:44:33,280

of all the things you're discussing now

3077

01:44:38,550 --> 01:44:36,159

are part of the deep reason why

3078

01:44:40,550 --> 01:44:38,560

cognitive science and consciousness and

3079

01:44:42,870 --> 01:44:40,560

all of those kinds of things are deeply

3080

01:44:44,790 --> 01:44:42,880

related to developmental biology and

3081

01:44:47,030 --> 01:44:44,800

physiology right they're they're

3082

01:44:49,350 --> 01:44:47,040

absolutely interrelated because they are

3083

01:44:52,310 --> 01:44:49,360

two sides of the same coin information

3084

01:44:54,310 --> 01:44:52,320

processing in goal-directed hierarchical

3085

01:44:56,149 --> 01:44:54,320

systems and when you understand the more

3086

01:44:58,390 --> 01:44:56,159

you understand about one the better you

3087

01:45:00,950 --> 01:44:58,400

are at managing the others this is this

3088

01:45:02,550 --> 01:45:00,960

is two sides of the same question

3089

01:45:05,109 --> 01:45:02,560

where can people find out more about you

3090

01:45:07,350 --> 01:45:05,119

and what's next for you

3091

01:45:09,750 --> 01:45:07,360

well uh they can find out uh i have a i

3092

01:45:10,750 --> 01:45:09,760

have a website um

3093

01:45:13,830 --> 01:45:10,760

at

3094

01:45:16,870 --> 01:45:13,840

drmik11.org uh we have a center website

3095

01:45:18,870 --> 01:45:16,880

which is allencenter.tufts.com

3096

01:45:20,550 --> 01:45:18,880

i have a twitter feed which is at

3097

01:45:22,550 --> 01:45:20,560

drmik11

3098

01:45:24,790 --> 01:45:22,560

and uh what's next uh it's a good

3099

01:45:26,310 --> 01:45:24,800

question i i don't you know i can't tell

3100

01:45:27,910 --> 01:45:26,320

you exactly what's going to happen next

3101

01:45:29,590 --> 01:45:27,920

but i certainly know the things that we

3102

01:45:30,390 --> 01:45:29,600

are trying to do and that we're working

3103

01:45:32,149 --> 01:45:30,400

on

3104

01:45:33,910 --> 01:45:32,159

and you can go to our website and see

3105

01:45:34,790 --> 01:45:33,920

all kinds of projects that we're working

3106

01:45:36,629 --> 01:45:34,800

on

3107

01:45:39,270 --> 01:45:36,639

in the um

3108

01:45:40,709 --> 01:45:39,280

in the areas of trying to lay a better

3109

01:45:42,950 --> 01:45:40,719

foundation for understanding basal

3110

01:45:45,189 --> 01:45:42,960

cognition and

3111

01:45:47,270 --> 01:45:45,199

understanding morphogenesis and

3112

01:45:50,149 --> 01:45:47,280

developing applications and birth birth

3113

01:45:51,830 --> 01:45:50,159

defects and regeneration and cancer

3114

01:45:53,830 --> 01:45:51,840

we're doing some work in machine

3115

01:45:56,310 --> 01:45:53,840

learning and trying to sort of close

3116

01:45:57,990 --> 01:45:56,320

that loop and understand how

3117

01:46:01,830 --> 01:45:58,000

we can use the principles that we learn

3118

01:46:04,629 --> 01:46:01,840

in biology to make better uh cognitive

3119

01:46:06,709 --> 01:46:04,639

to to make novel and better um cognitive

3120

01:46:08,149 --> 01:46:06,719

systems that are going to help us in in

3121

01:46:09,910 --> 01:46:08,159

various ways

3122

01:46:11,109 --> 01:46:09,920

and the links to everything that michael

3123

01:46:13,350 --> 01:46:11,119

just mentioned will be in the

3124

01:46:14,790 --> 01:46:13,360

description so please check that out you

3125

01:46:16,709 --> 01:46:14,800

mentioned two sides of the same coin but

3126

01:46:18,149 --> 01:46:16,719

i didn't quite understand that how is it

3127

01:46:19,669 --> 01:46:18,159

that developmental biology and

3128

01:46:21,030 --> 01:46:19,679

consciousness may be two sides because

3129

01:46:22,870 --> 01:46:21,040

you mentioned one is first and third

3130

01:46:24,550 --> 01:46:22,880

person is the other so how are they two

3131

01:46:27,430 --> 01:46:24,560

sides of the same coin

3132

01:46:28,629 --> 01:46:27,440

well in in in many ways uh first of all

3133

01:46:34,470 --> 01:46:28,639

uh

3134

01:46:36,870 --> 01:46:34,480

single cell and that cell self-assembles

3135

01:46:40,310 --> 01:46:36,880

into a creature that can later say i am

3136

01:46:42,229 --> 01:46:40,320

a centralized intelligence i am i i

3137

01:46:43,830 --> 01:46:42,239

a self yeah that may be but you're made

3138

01:46:45,990 --> 01:46:43,840

of a bunch of cells and in fact you used

3139

01:46:48,790 --> 01:46:46,000

to be one cell and then a ball of cells

3140

01:46:51,910 --> 01:46:48,800

and so that whole process of of how that

3141

01:46:55,270 --> 01:46:51,920

that that's that unified self is

3142

01:46:57,350 --> 01:46:55,280

arranged uh and and uh supported by a

3143

01:47:00,070 --> 01:46:57,360

collection of of competent agents these

3144

01:47:02,550 --> 01:47:00,080

being cells is very similar to uh how

3145

01:47:04,470 --> 01:47:02,560

the body is in the pattern of the body

3146

01:47:06,790 --> 01:47:04,480

is is arranged by the collective

3147

01:47:08,550 --> 01:47:06,800

intelligence of cells morphogenesis is a

3148

01:47:10,149 --> 01:47:08,560

collective intelligence problem it is

3149

01:47:11,830 --> 01:47:10,159

not a chemistry problem or a genetics

3150

01:47:14,070 --> 01:47:11,840

problem it's a problem of collective

3151
01:47:16,629 --> 01:47:14,080
intelligence and

3152
01:47:18,629 --> 01:47:16,639
those same kinds of issues arise when

3153
01:47:20,229 --> 01:47:18,639
you're trying to understand any kind of

3154
01:47:22,390 --> 01:47:20,239
a

3155
01:47:24,629 --> 01:47:22,400
intelligence

3156
01:47:27,430 --> 01:47:24,639
how does the information processing and

3157
01:47:29,510 --> 01:47:27,440
the capacities of lots of independent

3158
01:47:31,430 --> 01:47:29,520
subunits in the case of brains those

3159
01:47:33,270 --> 01:47:31,440
will be neurons but in the case of the

3160
01:47:36,310 --> 01:47:33,280
body there'll be other types of cells

3161
01:47:38,470 --> 01:47:36,320
how do they work together to pursue

3162
01:47:39,750 --> 01:47:38,480
goals and plans and have preferences

3163
01:47:42,149 --> 01:47:39,760

that don't belong to any of the

3164

01:47:44,390 --> 01:47:42,159

individual subunits themselves

3165

01:47:46,310 --> 01:47:44,400

right the making a limb is a goal that

3166

01:47:48,870 --> 01:47:46,320

no individual cell can can no no no

3167

01:47:50,470 --> 01:47:48,880

individual cell knows what a limb is or

3168

01:47:51,830 --> 01:47:50,480

you can can answer the question for how

3169

01:47:53,750 --> 01:47:51,840

many fingers are we supposed to have or

3170

01:47:56,470 --> 01:47:53,760

how long is the finger supposed to be

3171

01:47:58,149 --> 01:47:56,480

that is a piece of information that only

3172

01:48:00,390 --> 01:47:58,159

the cellular collective has right so

3173

01:48:02,390 --> 01:48:00,400

this ability of

3174

01:48:03,750 --> 01:48:02,400

pursuing large-scale goals of having and

3175

01:48:05,109 --> 01:48:03,760

having collective information that's

3176

01:48:07,270 --> 01:48:05,119

more than the sum of its parts is

3177

01:48:09,750 --> 01:48:07,280

exactly the same question of where does

3178

01:48:11,350 --> 01:48:09,760

intelligence uh and and and you know

3179

01:48:13,430 --> 01:48:11,360

sort of uh

3180

01:48:15,270 --> 01:48:13,440

cognitive capacity come from those are

3181

01:48:16,629 --> 01:48:15,280

all

3182

01:48:18,790 --> 01:48:16,639

those problems will be answered together

3183

01:48:20,310 --> 01:48:18,800

they will not be answered if either one

3184

01:48:22,709 --> 01:48:20,320

of these things remains mysterious we

3185

01:48:24,470 --> 01:48:22,719

won't have an answer to the other

3186

01:48:26,470 --> 01:48:24,480

thank you sir thank you so much for

3187

01:48:27,910 --> 01:48:26,480

spending so much thank you very much

3188

01:48:30,550 --> 01:48:27,920

yeah thank you for your questions i want

3189

01:48:33,350 --> 01:48:30,560

to make let everyone know that this i

3190

01:48:35,510 --> 01:48:33,360

think is nobel prize winning work so i i

3191

01:48:36,950 --> 01:48:35,520

will do my best to promote this and

3192

01:48:38,310 --> 01:48:36,960

and get you

3193

01:48:40,149 --> 01:48:38,320

get you some more attention man i hope

3194

01:48:43,030 --> 01:48:40,159

so thank you thank you very much that's

3195

01:48:44,950 --> 01:48:43,040

very kind thank you i appreciate it

3196

01:48:46,629 --> 01:48:44,960

the podcast is now finished if you'd

3197

01:48:49,189 --> 01:48:46,639

like to support conversations like this

3198

01:48:53,910 --> 01:48:49,199

then do consider going to [patreon.com](https://www.patreon.com)

3199

01:48:56,550 --> 01:48:53,920

slash c-u-r-t j-a-i-m-u-n-g-a-l

3200

01:48:58,390 --> 01:48:56,560

that is kurt jaimungle it's support from

3201

01:49:00,149 --> 01:48:58,400

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