

Emergent behavior



1
00:00:12,080 --> 00:00:08,780
okay welcome to the afternoon /

2
00:00:13,940 --> 00:00:12,090
afternoon session of at broadcom 2016 my

3
00:00:16,670 --> 00:00:13,950
name is Tessa Fisher I'm a PhD student

4
00:00:19,550 --> 00:00:16,680
at Arizona State University and I will

5
00:00:21,620 --> 00:00:19,560
be doing the warm-up talks for the

6
00:00:24,050 --> 00:00:21,630
origin of life and during computation

7
00:00:25,609 --> 00:00:24,060
sessions and then also chairing half of

8
00:00:26,929 --> 00:00:25,619
the theory computation session before I

9
00:00:30,109 --> 00:00:26,939
have to score your way to the airport to

10
00:00:33,620 --> 00:00:30,119
go to another conference um so anyways

11
00:00:34,910 --> 00:00:33,630
without further ado so the fundamental

12
00:00:40,069 --> 00:00:34,920
questions are going to be talking this

13
00:00:43,130 --> 00:00:40,079

afternoon or basically know what is life

14

00:00:45,290 --> 00:00:43,140

and how do we get from non-life to life

15

00:00:47,540 --> 00:00:45,300

how do we go from inanimate manner to

16

00:00:50,150 --> 00:00:47,550

something that we can all more or less

17

00:00:52,250 --> 00:00:50,160

agree is a living organism admittedly

18

00:00:55,420 --> 00:00:52,260

what exactly a living organism is is

19

00:00:58,369 --> 00:00:55,430

also up to debate which we'll get into

20

00:00:59,810 --> 00:00:58,379

so for this afternoon anyways there's at

21

00:01:03,049 --> 00:00:59,820

least two major purchase we're looking

22

00:01:07,100 --> 00:01:03,059

at one is based off of prebiotic

23

00:01:08,390 --> 00:01:07,110

chemistry which is sort of the some of

24

00:01:12,950 --> 00:01:08,400

the stuff that we saw earlier today as

25

00:01:15,410 --> 00:01:12,960

well and then also information dairy so

26

00:01:17,300 --> 00:01:15,420

for the first approach I'll be talking

27

00:01:18,740 --> 00:01:17,310

about is going to be proud of chemistry

28

00:01:20,780 --> 00:01:18,750

because that's a little more concrete it

29

00:01:24,020 --> 00:01:20,790

doesn't get quite as mathematical and

30

00:01:25,910 --> 00:01:24,030

nebulous and that's at its core is

31

00:01:27,469 --> 00:01:25,920

basically the idea of saying okay how do

32

00:01:28,850 --> 00:01:27,479

we go from these elements carbon

33

00:01:30,859 --> 00:01:28,860

hydrogen oxygen nitrogen phosphorus

34

00:01:34,850 --> 00:01:30,869

sulfur and phosphorus plus some trace

35

00:01:36,770 --> 00:01:34,860

elements to simple organic compounds and

36

00:01:40,460 --> 00:01:36,780

then from that living systems sometimes

37

00:01:43,490 --> 00:01:40,470

referred to as abiogenesis and sort of

38

00:01:44,990 --> 00:01:43,500

the classic experiment for prebiotic

39

00:01:46,609 --> 00:01:45,000

chemistry is the miller-urey experiment

40

00:01:49,160 --> 00:01:46,619

which i'm sure most of you have heard of

41

00:01:52,850 --> 00:01:49,170

but if you haven't or need a refresher

42

00:01:56,030 --> 00:01:52,860

the basic idea is that you create this

43

00:01:58,399 --> 00:01:56,040

glass apparatus fill it with a series of

44

00:02:00,410 --> 00:01:58,409

reducing gases methane ammonia water

45

00:02:04,060 --> 00:02:00,420

vapor and hydrogen and then run it

46

00:02:07,310 --> 00:02:04,070

through a system which heats it cools it

47

00:02:08,359 --> 00:02:07,320

subjects it to electrical discharge

48

00:02:10,729 --> 00:02:08,369

which is supposed to simulate lightning

49

00:02:12,110 --> 00:02:10,739

strikes the whole idea is basically are

50

00:02:14,390 --> 00:02:12,120

simulating and

51
00:02:16,369 --> 00:02:14,400
the earth environments of you know

52
00:02:17,630 --> 00:02:16,379
heating and cooling and changes in

53
00:02:19,399 --> 00:02:17,640
weather and tides and all stuff like

54
00:02:21,589 --> 00:02:19,409
that and the cool thing about this is if

55
00:02:25,190 --> 00:02:21,599
you let it run for you know 24 hours or

56
00:02:30,080 --> 00:02:25,200
so at the end you get down here this

57
00:02:32,869 --> 00:02:30,090
nice monkey collection of organic brown

58
00:02:35,180 --> 00:02:32,879
goo full chock full of organic molecules

59
00:02:36,619 --> 00:02:35,190
now the problem with this as it turns

60
00:02:38,630 --> 00:02:36,629
out and this was a major breakthrough

61
00:02:40,640 --> 00:02:38,640
when it was discovered but it's less so

62
00:02:41,899 --> 00:02:40,650
now is that we now have reason to

63
00:02:43,220 --> 00:02:41,909

believe that the atmosphere the early

64

00:02:45,020 --> 00:02:43,230

Earth actually didn't look much like

65

00:02:47,030 --> 00:02:45,030

this it was probably more nitrogen and

66

00:02:50,199 --> 00:02:47,040

carbon dioxide not reducing compounds

67

00:02:52,880 --> 00:02:50,209

like methane and ammonia so obviously

68

00:02:55,039 --> 00:02:52,890

we're going to rethink how proud but

69

00:02:56,240 --> 00:02:55,049

prebiotic chemistry works because the

70

00:02:57,920 --> 00:02:56,250

nice thing about a reducing environment

71

00:02:59,949 --> 00:02:57,930

is that it does lend itself very well

72

00:03:03,170 --> 00:02:59,959

for the reduction of organic molecules

73

00:03:04,759 --> 00:03:03,180

so we got to look at specific niches

74

00:03:07,809 --> 00:03:04,769

instead of trying to assume that it's

75

00:03:10,220 --> 00:03:07,819

just sort of this vast primordial soup

76
00:03:11,509 --> 00:03:10,230
everywhere on the planet and there have

77
00:03:13,729 --> 00:03:11,519
been a lot of different environments

78
00:03:15,860 --> 00:03:13,739
that have been suggested for this first

79
00:03:17,390 --> 00:03:15,870
one hydrothermal vents you have very

80
00:03:19,900 --> 00:03:17,400
reducing conditions to the methane and

81
00:03:22,699 --> 00:03:19,910
hydrogen sulfide admit it you've got

82
00:03:26,229 --> 00:03:22,709
very strong kennel temperature gradients

83
00:03:30,770 --> 00:03:26,239
between hot and cold you know from over

84
00:03:32,390 --> 00:03:30,780
boiling to near freezing and you also

85
00:03:33,830 --> 00:03:32,400
get a lot of interesting geochemistry

86
00:03:36,589 --> 00:03:33,840
that happens here which will give you a

87
00:03:38,750 --> 00:03:36,599
good feedstock to build molecules and

88
00:03:40,250 --> 00:03:38,760

you also will get later they also got

89

00:03:43,250 --> 00:03:40,260

some interesting gradients second set up

90

00:03:46,039 --> 00:03:43,260

as well another one that's been talked

91

00:03:48,110 --> 00:03:46,049

about is ice ice is really good at

92

00:03:50,900 --> 00:03:48,120

concentrating things because as water

93

00:03:52,430 --> 00:03:50,910

freezes the impurities tend to be the

94

00:03:54,500 --> 00:03:52,440

last things that freeze and therefore

95

00:03:56,599 --> 00:03:54,510

you get them in little pockets so that's

96

00:03:58,430 --> 00:03:56,609

really good for if you wanna force

97

00:04:00,890 --> 00:03:58,440

reactions have ordinarily wouldn't occur

98

00:04:02,360 --> 00:04:00,900

by simply increasing the concentration

99

00:04:05,270 --> 00:04:02,370

so much that they suddenly become

100

00:04:07,250 --> 00:04:05,280

thermodynamically favorable clay

101
00:04:09,379 --> 00:04:07,260
crystals and molecules have also been

102
00:04:11,089 --> 00:04:09,389
suggested as a potential matrix or

103
00:04:12,319 --> 00:04:11,099
lattice for the formation of organic

104
00:04:15,129 --> 00:04:12,329
molecules I also have some nifty

105
00:04:19,640 --> 00:04:15,139
self-replicating properties which have

106
00:04:21,050 --> 00:04:19,650
been given some interest and then my

107
00:04:22,850 --> 00:04:21,060
personal favorite the radioactive beach

108
00:04:25,130 --> 00:04:22,860
and this is a newer theory that came out

109
00:04:25,640 --> 00:04:25,140
year or two ago which is the idea is

110
00:04:27,020 --> 00:04:25,650
that the

111
00:04:29,659 --> 00:04:27,030
early earth would have been much more

112
00:04:31,370 --> 00:04:29,669
volcanically active and much richer in

113
00:04:33,379 --> 00:04:31,380

radioactive elements since most of them

114

00:04:35,210 --> 00:04:33,389

have decayed between now and then and

115

00:04:36,890 --> 00:04:35,220

there for all these radioactive

116

00:04:39,409 --> 00:04:36,900

sediments would have gotten concentrated

117

00:04:41,420 --> 00:04:39,419

at the high-water line of the beaches of

118

00:04:43,400 --> 00:04:41,430

planet Earth and you would have had

119

00:04:44,810 --> 00:04:43,410

essentially this very energetic zone

120

00:04:46,370 --> 00:04:44,820

where all sorts of really radio

121

00:04:47,659 --> 00:04:46,380

chemistry would be going on don't know

122

00:04:52,520 --> 00:04:47,669

how likely it is but I thought it was

123

00:04:53,930 --> 00:04:52,530

really cool so okay we've got places

124

00:04:56,870 --> 00:04:53,940

where we can make really nifty organic

125

00:04:58,820 --> 00:04:56,880

compounds now what well like I said we

126

00:05:01,909 --> 00:04:58,830

don't exactly have a great definition or

127

00:05:04,430 --> 00:05:01,919

agreed-upon definition anyways for what

128

00:05:06,260 --> 00:05:04,440

a living organism is but we do have a

129

00:05:08,570 --> 00:05:06,270

fair number of traits that most people

130

00:05:11,779 --> 00:05:08,580

can agree most living organisms so far

131

00:05:14,420 --> 00:05:11,789

as we know have replication metabolism

132

00:05:16,250 --> 00:05:14,430

and compartmentalization and there is a

133

00:05:17,600 --> 00:05:16,260

bit of a debate in the origin of life

134

00:05:21,100 --> 00:05:17,610

improve a lot of chemistry community

135

00:05:23,960 --> 00:05:21,110

about which came first for replication

136

00:05:26,270 --> 00:05:23,970

you have compounds called auto catalysts

137

00:05:29,240 --> 00:05:26,280

which are essentially chemical compounds

138

00:05:30,560 --> 00:05:29,250

that can catalyze their own formation

139

00:05:32,839 --> 00:05:30,570

you know essentially replicate

140

00:05:34,760 --> 00:05:32,849

themselves in a very simple manner one

141

00:05:37,550 --> 00:05:34,770

auto catalyst of particular interest is

142

00:05:40,040 --> 00:05:37,560

a RNA which is still used nor

143

00:05:42,529 --> 00:05:40,050

biochemistry to this day but has the

144

00:05:45,950 --> 00:05:42,539

nifty feature of essentially being able

145

00:05:47,899 --> 00:05:45,960

to synthesize more of itself so

146

00:05:50,990 --> 00:05:47,909

essentially it's very easy for to

147

00:05:52,219 --> 00:05:51,000

self-replicate and it's strongly

148

00:05:54,110 --> 00:05:52,229

suspected that was probably the

149

00:05:55,640 --> 00:05:54,120

forerunner for the more stable and

150

00:05:58,100 --> 00:05:55,650

harder to replicate DNA that we

151
00:05:59,810 --> 00:05:58,110
currently use although however it's also

152
00:06:01,879 --> 00:05:59,820
been argued that from an evolutionary

153
00:06:03,320 --> 00:06:01,889
point of view just being able an RNA

154
00:06:05,689 --> 00:06:03,330
molecule that could turn out more our

155
00:06:08,330 --> 00:06:05,699
name allah cules may not exactly be

156
00:06:09,950 --> 00:06:08,340
advantageous if you don't actually hook

157
00:06:12,589 --> 00:06:09,960
it up to something like say metabolism

158
00:06:13,969 --> 00:06:12,599
which brings us to the next part so

159
00:06:16,070 --> 00:06:13,979
metabolism is basically being able to

160
00:06:17,180 --> 00:06:16,080
take energy in your environment in one

161
00:06:21,140 --> 00:06:17,190
form or another and using it to

162
00:06:25,370 --> 00:06:21,150
synthesize more compounds or replicate

163
00:06:26,779 --> 00:06:25,380

or whatever and there are people who

164

00:06:28,100 --> 00:06:26,789

believe that metabolism actually came

165

00:06:29,750 --> 00:06:28,110

first one not I always thought was

166

00:06:30,950 --> 00:06:29,760

particularly cool and some of the people

167

00:06:33,080 --> 00:06:30,960

in this room without she worked on it

168

00:06:34,339 --> 00:06:33,090

was like I mentioned at vents you can

169

00:06:36,110 --> 00:06:34,349

have these really interesting gradients

170

00:06:38,269 --> 00:06:36,120

that set up and in particular in some

171

00:06:39,380 --> 00:06:38,279

cases depending on how acidic or basic

172

00:06:41,300 --> 00:06:39,390

the

173

00:06:43,340 --> 00:06:41,310

vent fluid is you can end up getting

174

00:06:48,020 --> 00:06:43,350

these weird electrochemical gray or onyx

175

00:06:49,370 --> 00:06:48,030

gradients which are of real interest if

176
00:06:52,490 --> 00:06:49,380
you have background in biology because

177
00:06:54,620 --> 00:06:52,500
pretty much all living organisms on the

178
00:06:56,120 --> 00:06:54,630
planet are ultimately powered by these

179
00:06:58,580 --> 00:06:56,130
sorts of electrochemical gradients

180
00:06:59,870 --> 00:06:58,590
protein pumps and whatnot so it's kind

181
00:07:01,550 --> 00:06:59,880
of like well maybe this is where that

182
00:07:03,470 --> 00:07:01,560
started that you have these naturally

183
00:07:05,930 --> 00:07:03,480
occurring gradients that molecules

184
00:07:08,330 --> 00:07:05,940
learned for lack of a better term how to

185
00:07:10,820 --> 00:07:08,340
harvest and use that as sort of a way to

186
00:07:12,440 --> 00:07:10,830
power the construction of more and more

187
00:07:14,440 --> 00:07:12,450
elaborate molecules and eventually ones

188
00:07:16,970 --> 00:07:14,450

that were capable self-replication

189

00:07:18,590 --> 00:07:16,980

lastly compartmentalization obviously a

190

00:07:20,780 --> 00:07:18,600

major part of being a living organism is

191

00:07:23,000 --> 00:07:20,790

being able to separate you from the rest

192

00:07:24,650 --> 00:07:23,010

of the world or at least being able to

193

00:07:26,150 --> 00:07:24,660

control what comes in from your

194

00:07:27,950 --> 00:07:26,160

environment into you and what goes out

195

00:07:32,060 --> 00:07:27,960

otherwise you just kind of end up

196

00:07:33,560 --> 00:07:32,070

dissolving into this mess now the useful

197

00:07:35,270 --> 00:07:33,570

thing about commitment or the neat thing

198

00:07:37,190 --> 00:07:35,280

about compartmentalization is that it's

199

00:07:38,660 --> 00:07:37,200

actually pretty easy to set up there are

200

00:07:41,720 --> 00:07:38,670

a lot of organic compounds protein

201
00:07:43,850 --> 00:07:41,730
proteins for example that in aqueous

202
00:07:47,480 --> 00:07:43,860
conditions will kind of naturally just

203
00:07:48,770 --> 00:07:47,490
roll up in the nice little spheres so

204
00:07:50,090 --> 00:07:48,780
this one isn't quite as challenging as

205
00:07:51,980 --> 00:07:50,100
some of the other ones now of course

206
00:07:53,210 --> 00:07:51,990
there's no reason these ought to be

207
00:07:55,730 --> 00:07:53,220
mutually exclusive it's quite likely

208
00:07:57,740 --> 00:07:55,740
that they probably all happened more

209
00:08:00,200 --> 00:07:57,750
about the same time or in very close

210
00:08:02,210 --> 00:08:00,210
proximity to each other but you know

211
00:08:06,200 --> 00:08:02,220
still there they all had to have

212
00:08:08,870 --> 00:08:06,210
happened for us to get here so that's

213
00:08:10,910 --> 00:08:08,880

kind of like with the baseline starting

214

00:08:13,730 --> 00:08:10,920

point for okay we're now officially a

215

00:08:15,830 --> 00:08:13,740

living organism which brings this next

216

00:08:17,660 --> 00:08:15,840

point of okay how do we define what a

217

00:08:20,470 --> 00:08:17,670

living organism is anyways and for this

218

00:08:24,020 --> 00:08:20,480

we're gonna get a bit more abstract so

219

00:08:25,460 --> 00:08:24,030

the one technique that's getting more

220

00:08:27,710 --> 00:08:25,470

and more popular is using sort of

221

00:08:30,200 --> 00:08:27,720

approach that space top of information

222

00:08:32,719 --> 00:08:30,210

theory and it examines life and

223

00:08:35,180 --> 00:08:32,729

evolution and more abstract level you

224

00:08:36,680 --> 00:08:35,190

know mathematically but the advantage of

225

00:08:40,420 --> 00:08:36,690

that is that it allows us to quantify

226

00:08:43,010 --> 00:08:40,430

the emergence and evolution of life

227

00:08:45,380 --> 00:08:43,020

since it's all done mathematically on

228

00:08:48,410 --> 00:08:45,390

computers you can actually get specific

229

00:08:50,480 --> 00:08:48,420

figures and data as it goes through and

230

00:08:52,700 --> 00:08:50,490

if what is a particular interest to

231

00:08:54,950 --> 00:08:52,710

scientists to study this are complexity

232

00:08:58,220 --> 00:08:54,960

and emergence complexity is essentially

233

00:09:00,830 --> 00:08:58,230

the where a system is the sum is greater

234

00:09:02,900 --> 00:09:00,840

than the whole of its parts the sub

235

00:09:05,680 --> 00:09:02,910

components of the system do not have the

236

00:09:08,210 --> 00:09:05,690

same properties as the system as a whole

237

00:09:13,670 --> 00:09:08,220

emergence on the other hand is the

238

00:09:15,830 --> 00:09:13,680

tendency for in some systems for very

239

00:09:18,770 --> 00:09:15,840

simple rules to give rise to very

240

00:09:20,930 --> 00:09:18,780

complex behavior and phenomena a classic

241

00:09:23,540 --> 00:09:20,940

example is schooling fish none of these

242

00:09:25,220 --> 00:09:23,550

fish are leading the other fish they are

243

00:09:27,020 --> 00:09:25,230

all reacting to the same basic stimuli

244

00:09:28,790 --> 00:09:27,030

proximity to each other approximately

245

00:09:32,720 --> 00:09:28,800

predators proximity to food and they're

246

00:09:34,960 --> 00:09:32,730

all independently deciding where to move

247

00:09:37,490 --> 00:09:34,970

however when you put them together

248

00:09:40,520 --> 00:09:37,500

essentially all those small decisions

249

00:09:42,020 --> 00:09:40,530

add up to a much larger decision that is

250

00:09:44,030 --> 00:09:42,030

able to exhibit this really cool

251
00:09:46,340 --> 00:09:44,040
synchronized behavior and predator

252
00:09:47,750 --> 00:09:46,350
avoidance so that gives you an idea and

253
00:09:51,140 --> 00:09:47,760
emergence shows up all the times in

254
00:09:53,780 --> 00:09:51,150
biology you have it in ant high or ant

255
00:09:56,900 --> 00:09:53,790
nests and other social insects and gene

256
00:09:59,720 --> 00:09:56,910
regulatory networks in cells and more

257
00:10:02,780 --> 00:09:59,730
than likely in consciousness being the

258
00:10:03,950 --> 00:10:02,790
emergent property of how the neurons in

259
00:10:06,230 --> 00:10:03,960
our brain are wired although that's

260
00:10:09,260 --> 00:10:06,240
still debated that's a whole other

261
00:10:11,210 --> 00:10:09,270
conference another cool way to study

262
00:10:12,560 --> 00:10:11,220
these and I know they'll be at least one

263
00:10:16,250 --> 00:10:12,570

talk this afternoon we'll discuss it is

264

00:10:19,360 --> 00:10:16,260

a cellular automata which again looking

265

00:10:22,750 --> 00:10:19,370

at systems that can become emergent is

266

00:10:25,520 --> 00:10:22,760

these very deterministic binary systems

267

00:10:27,850 --> 00:10:25,530

that use simple discrete rules and can

268

00:10:30,410 --> 00:10:27,860

be you sort of as a toy model for life

269

00:10:32,090 --> 00:10:30,420

they aren't obviously quite as complex

270

00:10:34,700 --> 00:10:32,100

as living organisms but they have some

271

00:10:36,500 --> 00:10:34,710

of the same properties classic example

272

00:10:37,970 --> 00:10:36,510

of them is Conway's Game of Life which

273

00:10:40,750 --> 00:10:37,980

some of you may have heard of it's

274

00:10:43,130 --> 00:10:40,760

pretty simple you have a grid of squares

275

00:10:45,140 --> 00:10:43,140

very simple rules determine whether or

276

00:10:47,450 --> 00:10:45,150

not a particular square is black or

277

00:10:49,070 --> 00:10:47,460

white usually based on its proximity to

278

00:10:52,190 --> 00:10:49,080

other squares with depending if they're

279

00:10:53,960 --> 00:10:52,200

black or white and while the rule set is

280

00:10:56,180 --> 00:10:53,970

very simply content on the page you can

281

00:10:57,320 --> 00:10:56,190

get this really really complex and

282

00:10:59,020 --> 00:10:57,330

interesting phenomenon and

283

00:11:01,730 --> 00:10:59,030

self-replication sustaining

284

00:11:03,790 --> 00:11:01,740

self-sustaining and just all sorts of

285

00:11:05,449 --> 00:11:03,800

really cool stable and unstable states

286

00:11:06,829 --> 00:11:05,459

and

287

00:11:08,299 --> 00:11:06,839

as a result you know from these very

288

00:11:10,009 --> 00:11:08,309

simple rules you have a great platform

289

00:11:12,350 --> 00:11:10,019

to sort of mathematically analyze

290

00:11:14,329 --> 00:11:12,360

evolution emergent behavior and also

291

00:11:17,119 --> 00:11:14,339

phase transitions you know when you go

292

00:11:18,499 --> 00:11:17,129

from a very different regime for example

293

00:11:20,960 --> 00:11:18,509

one where you're not getting a whole lot

294

00:11:21,829 --> 00:11:20,970

of complexity to one where all of a

295

00:11:24,710 --> 00:11:21,839

sudden there's an explosion of

296

00:11:27,559 --> 00:11:24,720

complexity which like I said I will be

297

00:11:29,179 --> 00:11:27,569

discussed in one of our later talks and

298

00:11:32,179 --> 00:11:29,189

a lot of this like I said it's ground an

299

00:11:33,679 --> 00:11:32,189

information theory and the idea that

300

00:11:35,419 --> 00:11:33,689

life itself can be defined as an

301
00:11:37,970 --> 00:11:35,429
information theory or information

302
00:11:41,389 --> 00:11:37,980
process rather now information theorists

303
00:11:45,109 --> 00:11:41,399
love appropriating other Sciences words

304
00:11:47,030 --> 00:11:45,119
and giving them new definitions so for

305
00:11:48,530 --> 00:11:47,040
our for the purposes of an information

306
00:11:51,230 --> 00:11:48,540
scientist information specifically

307
00:11:54,109 --> 00:11:51,240
refers the reduction in uncertainty

308
00:11:57,109 --> 00:11:54,119
about a state of a particular component

309
00:11:59,569 --> 00:11:57,119
in a system transfer entropy for example

310
00:12:02,809 --> 00:11:59,579
refers to if you have to sub components

311
00:12:04,819 --> 00:12:02,819
of a system how knowing the state of one

312
00:12:06,829 --> 00:12:04,829
sis one sub component reduces the

313
00:12:08,600 --> 00:12:06,839

uncertainty of knowing the state of the

314

00:12:13,309 --> 00:12:08,610

other sub component if you have to

315

00:12:14,869 --> 00:12:13,319

protect it so that's basically how much

316

00:12:16,220 --> 00:12:14,879

are they sharing information on how much

317

00:12:17,989 --> 00:12:16,230

does information flowing between them

318

00:12:20,900 --> 00:12:17,999

active information is kind of same idea

319

00:12:22,850 --> 00:12:20,910

except it's Tim poorly it's essentially

320

00:12:25,400 --> 00:12:22,860

a fancy term for memory if you know the

321

00:12:26,600 --> 00:12:25,410

past state of a system how much does

322

00:12:27,889 --> 00:12:26,610

that reduce the uncertainty for being

323

00:12:30,609 --> 00:12:27,899

able predicts the future state or

324

00:12:33,410 --> 00:12:30,619

current state of that particular system

325

00:12:35,509 --> 00:12:33,420

another thing that another two hundred

326

00:12:37,900 --> 00:12:35,519

toolbox graph and network graph theory

327

00:12:40,009 --> 00:12:37,910

networks this was discussed earlier

328

00:12:41,569 --> 00:12:40,019

drafts when we talk about graphs we

329

00:12:43,639 --> 00:12:41,579

don't mean pie charts we mean these

330

00:12:45,169 --> 00:12:43,649

sorts of network designs where you have

331

00:12:47,299 --> 00:12:45,179

a node which is just any particular

332

00:12:49,429 --> 00:12:47,309

system component and edges which are

333

00:12:50,780 --> 00:12:49,439

connections between nodes and these are

334

00:12:53,030 --> 00:12:50,790

really cool for examining the

335

00:12:54,379 --> 00:12:53,040

interactions within a system and

336

00:12:56,059 --> 00:12:54,389

different networks have different

337

00:12:58,730 --> 00:12:56,069

structures motifs which I'll get to and

338

00:13:00,530 --> 00:12:58,740

they have different patterns of flow of

339

00:13:02,780 --> 00:13:00,540

information which and doing this allows

340

00:13:04,759 --> 00:13:02,790

you to track that and analyze it for

341

00:13:06,379 --> 00:13:04,769

example you have very centralized

342

00:13:08,449 --> 00:13:06,389

networks for everything's rating off a

343

00:13:11,660 --> 00:13:08,459

central spoke you have decentralized

344

00:13:13,129 --> 00:13:11,670

networks where there's a couple of very

345

00:13:16,369 --> 00:13:13,139

centralized spokes but they're all

346

00:13:18,470 --> 00:13:16,379

connected to each other on airports the

347

00:13:19,190 --> 00:13:18,480

wheel ins spoke model for airports for

348

00:13:20,540 --> 00:13:19,200

examples of class

349

00:13:22,160 --> 00:13:20,550

example of that where you have a couple

350

00:13:24,320 --> 00:13:22,170

hubs and then a whole bunch of outlying

351

00:13:26,360 --> 00:13:24,330

airports that are in smaller areas and

352

00:13:28,190 --> 00:13:26,370

then distributed where everything's kind

353

00:13:29,390 --> 00:13:28,200

of connected with everything else now

354

00:13:32,540 --> 00:13:29,400

you can do some really cool stuff with

355

00:13:33,980 --> 00:13:32,550

us for astrobiology you can analyze gene

356

00:13:37,630 --> 00:13:33,990

regulatory networks this way you can

357

00:13:41,510 --> 00:13:37,640

analyze social insects you can analyze

358

00:13:44,210 --> 00:13:41,520

metabolic interactions in microbial or

359

00:13:46,040 --> 00:13:44,220

just general biological communities and

360

00:13:47,840 --> 00:13:46,050

also the chemical reaction networks of

361

00:13:49,070 --> 00:13:47,850

planets to give you an idea this is sort

362

00:13:51,500 --> 00:13:49,080

of a plug for what I'm probably end up

363

00:13:52,940 --> 00:13:51,510

doing for my dissertation so you have

364

00:13:55,280 --> 00:13:52,950

these chemical reaction networks for an

365

00:13:56,870 --> 00:13:55,290

atmosphere you know where do you have

366

00:14:01,510 --> 00:13:56,880

all these reactions and then put into a

367

00:14:04,610 --> 00:14:01,520

sort of graph form so this is the graph

368

00:14:06,190 --> 00:14:04,620

for the atmosphere of Mars this is the

369

00:14:09,050 --> 00:14:06,200

graph for the atmosphere of Earth and

370

00:14:12,230 --> 00:14:09,060

all the other plants and sources look

371

00:14:13,430 --> 00:14:12,240

like this except for earth so something

372

00:14:14,420 --> 00:14:13,440

interesting is going on here we don't

373

00:14:16,490 --> 00:14:14,430

know what yet i'll probably be

374

00:14:17,810 --> 00:14:16,500

presenting on that next year but just

375

00:14:19,820 --> 00:14:17,820

give the idea of what this stuff is

376

00:14:21,170 --> 00:14:19,830

capable if it's pretty cool so any