



Jim Cleaves

*The origin of life from prebiotic chemistry
to the progenote*

1
00:00:00,720 --> 00:00:11,140

[Music]

2
00:00:15,050 --> 00:00:13,310

I'm throwing my pleasure to be here

3
00:00:19,130 --> 00:00:15,060

today to tell you about some of the work

4
00:00:21,290 --> 00:00:19,140

we do at LC I'm going to cover the the

5
00:00:23,900 --> 00:00:21,300

topic of how we go from the origin of

6
00:00:25,910 --> 00:00:23,910

life to something a little more

7
00:00:28,430 --> 00:00:25,920

complicated that we think could have

8
00:00:31,670 --> 00:00:28,440

been the ancestor of all the living

9
00:00:34,010 --> 00:00:31,680

things we see on the planet today I am a

10
00:00:36,610 --> 00:00:34,020

chemist so I tend to think of this in

11
00:00:39,439 --> 00:00:36,620

chemical terms as a chemical problem so

12
00:00:41,960 --> 00:00:39,449

bear that in mind so the central

13
00:00:43,369 --> 00:00:41,970

question we're trying to understand we

14

00:00:45,140 --> 00:00:43,379

heard a lot of talks this morning about

15

00:00:48,049 --> 00:00:45,150

how planets form and how the atmosphere

16

00:00:50,030 --> 00:00:48,059

and oceans originated but how we went

17

00:00:54,829 --> 00:00:50,040

from a primitive earth that had no life

18

00:00:56,119 --> 00:00:54,839

on it was just Rock and water and gas to

19

00:00:58,369 --> 00:00:56,129

the kind of planet we live on today

20

00:01:00,799 --> 00:00:58,379

right which is just covered in living

21

00:01:03,880 --> 00:01:00,809

things doing incredibly complex

22

00:01:05,840 --> 00:01:03,890

ecosystems all kinds of amazing

23

00:01:07,910 --> 00:01:05,850

organisms that are doing interesting

24

00:01:12,350 --> 00:01:07,920

things to stay alive and make copies of

25

00:01:15,130 --> 00:01:12,360

themselves in the oceans on dry land

26
00:01:17,929 --> 00:01:15,140
tropical jungles and even if we get down

27
00:01:20,870 --> 00:01:17,939
to the microscopic level there's an

28
00:01:24,649 --> 00:01:20,880
incredible diversity and richness of

29
00:01:26,929 --> 00:01:24,659
life at the microscopic scale right this

30
00:01:29,899 --> 00:01:26,939
is very complex so the question is how

31
00:01:31,730 --> 00:01:29,909
did we get to that from this lifeless

32
00:01:37,370 --> 00:01:31,740
state and it's really quite a vexing

33
00:01:40,130 --> 00:01:37,380
problem so Charles Darwin when he was

34
00:01:43,999 --> 00:01:40,140
formulating his theory of evolution by

35
00:01:46,370 --> 00:01:44,009
natural selection came up with the idea

36
00:01:48,770 --> 00:01:46,380
that organisms changed through time and

37
00:01:50,989 --> 00:01:48,780
a an ancestor organism can give rise to

38
00:01:54,200 --> 00:01:50,999

say two different types of organism

39

00:01:57,469 --> 00:01:54,210

right but if you reverse that and go

40

00:02:01,130 --> 00:01:57,479

backwards in time the implication is

41

00:02:03,620 --> 00:02:01,140

that all these organisms at the tip that

42

00:02:06,200 --> 00:02:03,630

are alive today have a common ancestor

43

00:02:08,419 --> 00:02:06,210

all right and in fact they shouldn't

44

00:02:12,230 --> 00:02:08,429

have a single origin if they're all

45

00:02:15,200 --> 00:02:12,240

related and he wrote that in the first

46

00:02:17,180 --> 00:02:15,210

edition of his book very eloquently

47

00:02:19,100 --> 00:02:17,190

there is grandeur in this view of life

48

00:02:22,190 --> 00:02:19,110

with its several powers having been

49

00:02:25,580 --> 00:02:22,200

originally breathed into a few

50

00:02:27,740 --> 00:02:25,590

worms were into one and then once you

51

00:02:30,170 --> 00:02:27,750

have that first thing it is free to

52

00:02:32,180 --> 00:02:30,180

become many new things but this question

53

00:02:34,759 --> 00:02:32,190

of how you make that first thing it's

54

00:02:36,020 --> 00:02:34,769

very complicated all right we have a

55

00:02:40,120 --> 00:02:36,030

general scheme for how we think this

56

00:02:42,559 --> 00:02:40,130

process occurs and what we think happens

57

00:02:44,089 --> 00:02:42,569

is we have some sort of chemistry that

58

00:02:45,740 --> 00:02:44,099

takes place before you have living

59

00:02:48,470 --> 00:02:45,750

things this is chemistry that the

60

00:02:51,199 --> 00:02:48,480

environment does I'll show you some

61

00:02:53,630 --> 00:02:51,209

examples of that there's some process

62

00:02:56,990 --> 00:02:53,640

here that we don't understand very well

63

00:02:59,600 --> 00:02:57,000

at all that gives rise to a first living

64

00:03:01,490 --> 00:02:59,610

thing that first living thing may be

65

00:03:04,250 --> 00:03:01,500

very different from living things as we

66

00:03:06,559 --> 00:03:04,260

recognize them today but it goes through

67

00:03:08,809 --> 00:03:06,569

some period of work of evolution until

68

00:03:10,850 --> 00:03:08,819

it gave rise to what we call Luca or the

69

00:03:14,449 --> 00:03:10,860

last Universal common ancestor and

70

00:03:17,120 --> 00:03:14,459

that's that putative organism is the

71

00:03:20,690 --> 00:03:17,130

thing that gave rise to all the species

72

00:03:22,699 --> 00:03:20,700

we see today okay and which is

73

00:03:25,039 --> 00:03:22,709

contemporary biochemistry so things we

74

00:03:28,400 --> 00:03:25,049

don't know what kinds of chemicals are

75

00:03:30,259 --> 00:03:28,410

necessary for this process and how those

76

00:03:32,690 --> 00:03:30,269

chemicals come together to make living

77

00:03:36,530 --> 00:03:32,700

systems without the assistance of other

78

00:03:39,410 --> 00:03:36,540

living systems there's two ways you can

79

00:03:41,270 --> 00:03:39,420

think about this um one is this sort of

80

00:03:43,160 --> 00:03:41,280

bottom-up approach so you're if you're a

81

00:03:45,650 --> 00:03:43,170

chemist you say okay what chemicals do I

82

00:03:48,590 --> 00:03:45,660

have how can I put them together to do

83

00:03:50,569 --> 00:03:48,600

interesting reactions if you're a

84

00:03:53,270 --> 00:03:50,579

biologist we you can do what's called a

85

00:03:55,220 --> 00:03:53,280

top-down approach you can say what sorts

86

00:03:57,830 --> 00:03:55,230

of things do all modern organisms have

87

00:03:59,360 --> 00:03:57,840

in common and if you say ok with only

88

00:04:02,180 --> 00:03:59,370

the ones that they have in common or the

89

00:04:04,340 --> 00:04:02,190

the crucial ones which ones of those can

90

00:04:07,390 --> 00:04:04,350

we cut away can we design a simpler

91

00:04:13,039 --> 00:04:07,400

first organism so you're comparing

92

00:04:16,039 --> 00:04:13,049

modern biology ok so we know a little

93

00:04:18,560 --> 00:04:16,049

bit about when we think this happened we

94

00:04:20,000 --> 00:04:18,570

can date the earth pretty well at this

95

00:04:22,460 --> 00:04:20,010

point we know the earth is about four

96

00:04:25,430 --> 00:04:22,470

and a half billion years old so we're

97

00:04:27,500 --> 00:04:25,440

going back in time along this axis we

98

00:04:30,560 --> 00:04:27,510

are here alright this is the present day

99

00:04:33,380 --> 00:04:30,570

0 years in the past if we look at the

100

00:04:34,679 --> 00:04:33,390

geological record we have evidence for

101
00:04:35,820 --> 00:04:34,689
biology

102
00:04:39,209 --> 00:04:35,830
going back about three and a half

103
00:04:41,339 --> 00:04:39,219
billion years ago that's it's quite

104
00:04:43,649 --> 00:04:41,349
remarkable what we do see things that we

105
00:04:47,069 --> 00:04:43,659
can agree are evidence of living

106
00:04:49,139 --> 00:04:47,079
organisms we also have some indication

107
00:04:51,179 --> 00:04:49,149
of one there was liquid surface water on

108
00:04:55,289 --> 00:04:51,189
the earth so we think all living things

109
00:04:58,559 --> 00:04:55,299
need water so that the planet had to

110
00:05:01,619 --> 00:04:58,569
cool enough for that to exist and what

111
00:05:05,039 --> 00:05:01,629
that leaves us with is about a billion

112
00:05:07,350 --> 00:05:05,049
year window for this process of life to

113
00:05:08,879 --> 00:05:07,360

originate right now it doesn't mean life

114

00:05:12,719 --> 00:05:08,889

didn't start earlier we just don't have

115

00:05:14,579 --> 00:05:12,729

evidence for it okay and really the big

116

00:05:17,629 --> 00:05:14,589

question is we don't know if this

117

00:05:20,549 --> 00:05:17,639

process takes a week or a billion years

118

00:05:21,899 --> 00:05:20,559

all right it could it could be that it's

119

00:05:23,579 --> 00:05:21,909

just something that takes an incredibly

120

00:05:28,049 --> 00:05:23,589

long amount of time it will be very

121

00:05:31,519 --> 00:05:28,059

difficult to observe in a laboratory so

122

00:05:34,439 --> 00:05:31,529

this is a this is a fundamental unknown

123

00:05:36,539 --> 00:05:34,449

okay so just to give you some context

124

00:05:39,809 --> 00:05:36,549

for why it is so difficult for us to

125

00:05:41,969 --> 00:05:39,819

know when life started because the earth

126
00:05:43,769 --> 00:05:41,979
is such a dynamic planet which we heard

127
00:05:46,409 --> 00:05:43,779
today about the process of tectonics

128
00:05:49,109 --> 00:05:46,419
that rocks are constantly being made in

129
00:05:50,909 --> 00:05:49,119
these are called mid-ocean ridges in the

130
00:05:52,790 --> 00:05:50,919
middle of the ocean we have new rock

131
00:05:55,379 --> 00:05:52,800
coming up from the interior of the earth

132
00:05:57,479 --> 00:05:55,389
cycling out like a conveyor belt and

133
00:05:59,549 --> 00:05:57,489
eventually being pushed back down into

134
00:06:02,129 --> 00:05:59,559
the earth in fact all of this rock is

135
00:06:04,139 --> 00:06:02,139
fairly young maybe the oldest oceanic

136
00:06:09,089 --> 00:06:04,149
crust is four hundred million years old

137
00:06:11,819 --> 00:06:09,099
right so it's not very old at all the

138
00:06:15,239 --> 00:06:11,829

rocks that make up the continents can be

139

00:06:17,429 --> 00:06:15,249

quite a bit older but these little

140

00:06:20,759 --> 00:06:17,439

regions in purple here are the oldest

141

00:06:23,249 --> 00:06:20,769

you know large domains of rocks we know

142

00:06:25,889 --> 00:06:23,259

of there are only about three and three

143

00:06:27,329 --> 00:06:25,899

and a half billion years old okay so the

144

00:06:30,179 --> 00:06:27,339

point is because the earth is constantly

145

00:06:32,850 --> 00:06:30,189

doing this recycling the oldest rocks

146

00:06:34,079 --> 00:06:32,860

really aren't available to us which are

147

00:06:36,389 --> 00:06:34,089

the rocks we would be the most

148

00:06:38,669 --> 00:06:36,399

interested in there are a couple of

149

00:06:40,769 --> 00:06:38,679

regions where we have rocks that are

150

00:06:43,649 --> 00:06:40,779

almost four billion years old but

151
00:06:45,959 --> 00:06:43,659
they're heavily they've been heated if

152
00:06:46,959 --> 00:06:45,969
they've been put under pressure and we

153
00:06:48,939 --> 00:06:46,969
don't think that we're

154
00:06:53,919 --> 00:06:48,949
to be able to find evidence of life very

155
00:06:55,569 --> 00:06:53,929
easily in these kinds of rocks okay so

156
00:06:58,119 --> 00:06:55,579
so again switching to this sort of

157
00:07:00,279 --> 00:06:58,129
top-down approach we can look at what we

158
00:07:01,989 --> 00:07:00,289
think is a simplest form of life that we

159
00:07:05,769 --> 00:07:01,999
see today there's something like a

160
00:07:07,779 --> 00:07:05,779
bacterial cell actually it's a pretty

161
00:07:11,129 --> 00:07:07,789
sophisticated little machine that's

162
00:07:13,809 --> 00:07:11,139
function is making more bacteria right

163
00:07:16,659 --> 00:07:13,819

and if you're not familiar with the

164

00:07:18,579 --> 00:07:16,669

shape the structure of a cell the cell

165

00:07:23,109 --> 00:07:18,589

has a cell membrane it is a wall that

166

00:07:25,359 --> 00:07:23,119

encloses the contents of the organism it

167

00:07:27,219 --> 00:07:25,369

has a genetic molecule called DNA which

168

00:07:30,399 --> 00:07:27,229

stores the information for making copies

169

00:07:32,619 --> 00:07:30,409

of the cell and it has various small

170

00:07:34,529 --> 00:07:32,629

molecules that help integrate the

171

00:07:36,459 --> 00:07:34,539

functions of these different components

172

00:07:38,769 --> 00:07:36,469

all right and here's an electron

173

00:07:41,289 --> 00:07:38,779

micrograph of a bacterial cell just so

174

00:07:42,789 --> 00:07:41,299

you get a sense unlike a machine that

175

00:07:43,959 --> 00:07:42,799

you're more familiar with all of the

176

00:07:47,499 --> 00:07:43,969

parts are mixed together

177

00:07:48,850 --> 00:07:47,509

right they work in it by even though

178

00:07:52,540 --> 00:07:48,860

they're always diffusing around and

179

00:07:54,129 --> 00:07:52,550

moving in space and time okay so just to

180

00:07:57,279 --> 00:07:54,139

give you some appreciation if you can

181

00:08:00,189 --> 00:07:57,289

play this video this is a approximately

182

00:08:02,889 --> 00:08:00,199

real-time animation of the process by

183

00:08:05,019 --> 00:08:02,899

which DNA in our bodies and bacterial

184

00:08:06,819 --> 00:08:05,029

bodies and all living things bodies gets

185

00:08:09,639 --> 00:08:06,829

converted to another molecule called RNA

186

00:08:12,040 --> 00:08:09,649

so this is copying of information by a

187

00:08:14,350 --> 00:08:12,050

protein a series of protein enzymes all

188

00:08:15,969 --> 00:08:14,360

right so you're gonna see this protein

189

00:08:18,279 --> 00:08:15,979

enzyme coming here it's moving along the

190

00:08:20,679 --> 00:08:18,289

DNA which is the red strand and it is

191

00:08:24,459 --> 00:08:20,689

copying an RNA molecule which is the

192

00:08:26,919 --> 00:08:24,469

yellow stand this is approximately how

193

00:08:28,600 --> 00:08:26,929

fast this occurs in in real time and

194

00:08:31,449 --> 00:08:28,610

yourselves so this is all going on right

195

00:08:34,990 --> 00:08:31,459

now and inside of us very quickly that

196

00:08:37,629 --> 00:08:35,000

RNA strands then gets picked up by a

197

00:08:39,999 --> 00:08:37,639

rather complicated other machine within

198

00:08:42,909 --> 00:08:40,009

the cell called the ribosome which takes

199

00:08:45,189 --> 00:08:42,919

that information using adapter molecules

200

00:08:48,579 --> 00:08:45,199

and turns it into a third kind of

201
00:08:55,150 --> 00:08:48,589
polymer called a protein all right so

202
00:08:56,799 --> 00:08:55,160
you see in a second here there's the

203
00:08:58,700 --> 00:08:56,809
protein starting to emerge from this

204
00:09:00,380 --> 00:08:58,710
large machine

205
00:09:01,579 --> 00:09:00,390
so it's a very complicated process right

206
00:09:03,500 --> 00:09:01,589
there's there's a way of translating

207
00:09:05,630 --> 00:09:03,510
from one language to another language to

208
00:09:09,560 --> 00:09:05,640
a third language very precisely and very

209
00:09:12,079 --> 00:09:09,570
quickly all right is very difficult to

210
00:09:15,019 --> 00:09:12,089
understand how a process that complex

211
00:09:17,180 --> 00:09:15,029
could have arisen by itself so we think

212
00:09:19,730 --> 00:09:17,190
we're looking for simpler types of

213
00:09:23,360 --> 00:09:19,740

chemistry that eventually became more

214

00:09:27,440 --> 00:09:23,370

complex over time so there was a

215

00:09:30,110 --> 00:09:27,450

hungarian theoretician named tea borg

216

00:09:33,410 --> 00:09:30,120

aunty who came up with this notion of

217

00:09:35,480 --> 00:09:33,420

you can think of a cell in a very

218

00:09:41,030 --> 00:09:35,490

idealized way as just being three

219

00:09:43,310 --> 00:09:41,040

systems okay one of those systems is a

220

00:09:46,940 --> 00:09:43,320

container that keeps everything together

221

00:09:50,269 --> 00:09:46,950

all right one of those systems is again

222

00:09:54,040 --> 00:09:50,279

some sort of metabolism or machinery for

223

00:09:56,329 --> 00:09:54,050

making the parts and the third system is

224

00:09:58,460 --> 00:09:56,339

something like a blueprint it contains

225

00:10:00,920 --> 00:09:58,470

the information for making the other

226

00:10:04,220 --> 00:10:00,930

parts and those things all have to be

227

00:10:05,720 --> 00:10:04,230

connected together in order for the

228

00:10:09,620 --> 00:10:05,730

whole system to propagate itself

229

00:10:11,449 --> 00:10:09,630

together but the important you know

230

00:10:13,250 --> 00:10:11,459

message here is maybe you could make

231

00:10:15,140 --> 00:10:13,260

these kind of machines these kinds of

232

00:10:17,750 --> 00:10:15,150

systems out of completely different

233

00:10:21,519 --> 00:10:17,760

types of chemicals than modern

234

00:10:25,070 --> 00:10:24,079

and indeed you know we might expect if

235

00:10:27,230 --> 00:10:25,080

we went to look for life on other

236

00:10:29,570 --> 00:10:27,240

planets it might have evolved into a

237

00:10:32,150 --> 00:10:29,580

pretty different configuration than the

238

00:10:33,470 --> 00:10:32,160

way our life is so let's take a little

239

00:10:36,470 --> 00:10:33,480

bit about where we get the chemicals

240

00:10:38,120 --> 00:10:36,480

from to start this process so space is

241

00:10:39,650 --> 00:10:38,130

one source we have things like comets

242

00:10:42,410 --> 00:10:39,660

and meteorites they're always coming in

243

00:10:44,840 --> 00:10:42,420

so it's actually a image captured from a

244

00:10:47,000 --> 00:10:44,850

dashboard camera on a car of a meteorite

245

00:10:49,220 --> 00:10:47,010

that exploded over Russia a few years

246

00:10:51,140 --> 00:10:49,230

ago these kind of processes are

247

00:10:53,240 --> 00:10:51,150

happening today we know something about

248

00:10:56,210 --> 00:10:53,250

the contents of these materials in terms

249

00:10:57,620 --> 00:10:56,220

of chemicals we believe these things

250

00:11:01,000 --> 00:10:57,630

were happening more frequently on the

251

00:11:03,890 --> 00:11:01,010

early Earth another possibility is that

252

00:11:05,690 --> 00:11:03,900

storms and sorts of processing of the

253

00:11:07,880 --> 00:11:05,700

Earth's atmosphere generated different

254

00:11:10,370 --> 00:11:07,890

kinds of chemicals it's a view of

255

00:11:13,340 --> 00:11:10,380

lightning storms from space these little

256

00:11:15,230 --> 00:11:13,350

purple flashes again there's there's

257

00:11:16,519 --> 00:11:15,240

lightning on earth all the time we

258

00:11:19,100 --> 00:11:16,529

believe that's been happening for

259

00:11:21,620 --> 00:11:19,110

billions of years and you can get some

260

00:11:24,500 --> 00:11:21,630

very interesting chemistry taking place

261

00:11:26,630 --> 00:11:24,510

in the region right next to a lightning

262

00:11:28,610 --> 00:11:26,640

bolt it's very hot it's able to do

263

00:11:30,710 --> 00:11:28,620

interesting chemistry and there's a

264

00:11:34,970 --> 00:11:30,720

third possibility these are not mutually

265

00:11:37,820 --> 00:11:34,980

exclusive in fact because the earth is

266

00:11:40,100 --> 00:11:37,830

releasing heat from its interior that

267

00:11:44,079 --> 00:11:40,110

heat comes into contact with ocean water

268

00:11:48,500 --> 00:11:44,089

and rock deep in the Earth's surface so

269

00:11:49,940 --> 00:11:48,510

sucking ocean water down here comes into

270

00:11:53,240 --> 00:11:49,950

contact with hot rock and it gets

271

00:11:54,290 --> 00:11:53,250

ejected as extremely hot water that is

272

00:11:56,870 --> 00:11:54,300

also able to do very interesting

273

00:11:59,360 --> 00:11:56,880

chemistry right so there's a lot of ways

274

00:12:03,050 --> 00:11:59,370

we think we can make chemicals on a

275

00:12:05,180 --> 00:12:03,060

primitive lifeless planet just to give

276

00:12:08,900 --> 00:12:05,190

you an example I actually do work on

277

00:12:10,730 --> 00:12:08,910

meteorites as part of my job this is

278

00:12:12,410 --> 00:12:10,740

this is not my my personal work but we

279

00:12:14,720 --> 00:12:12,420

do this kind of thing you can take

280

00:12:16,610 --> 00:12:14,730

meteorites and you can extract the

281

00:12:20,000 --> 00:12:16,620

organic chemicals from them and analyze

282

00:12:21,530 --> 00:12:20,010

them and there's a device called a mass

283

00:12:23,870 --> 00:12:21,540

spectrometer which essentially allows

284

00:12:27,620 --> 00:12:23,880

you to weigh the types of chemicals that

285

00:12:29,390 --> 00:12:27,630

are in it and what you end up with this

286

00:12:32,329 --> 00:12:29,400

is an example of a meteorite that fell

287

00:12:34,020 --> 00:12:32,339

in Australia there are thousands and

288

00:12:36,150 --> 00:12:34,030

thousands and thousands of calm

289

00:12:37,920 --> 00:12:36,160

pounds with distinct weights okay so

290

00:12:40,470 --> 00:12:37,930

they're all different types of organic

291

00:12:42,480 --> 00:12:40,480

compounds and just as there might be

292

00:12:45,750 --> 00:12:42,490

more than one person in this room always

293

00:12:48,390 --> 00:12:45,760

say 75 kilograms there may be multiple

294

00:12:52,140 --> 00:12:48,400

chemicals that have the same weight so

295

00:12:54,300 --> 00:12:52,150

in fact this is probably tens of

296

00:12:56,460 --> 00:12:54,310

millions of distinct types of organic

297

00:13:00,950 --> 00:12:56,470

compounds right very very complex

298

00:13:08,010 --> 00:13:04,950

another example this is something you

299

00:13:10,860 --> 00:13:08,020

can do in the lab if you put some simple

300

00:13:14,550 --> 00:13:10,870

gases like methane ammonia and water and

301

00:13:17,130 --> 00:13:14,560

a flask and we pass a little electric

302

00:13:20,010 --> 00:13:17,140

discharge here says electric discharge

303

00:13:23,280 --> 00:13:20,020

generator the spark simulating lightning

304

00:13:25,620 --> 00:13:23,290

after a couple of days that gas gets

305

00:13:27,570 --> 00:13:25,630

turned in again to a very very very

306

00:13:29,940 --> 00:13:27,580

complex mixture of organic compounds

307

00:13:33,240 --> 00:13:29,950

right this is something you can witness

308

00:13:35,250 --> 00:13:33,250

over you know days in the laboratory and

309

00:13:37,440 --> 00:13:35,260

it's simply because in that electric

310

00:13:39,630 --> 00:13:37,450

discharge these molecules get ripped

311

00:13:42,180 --> 00:13:39,640

apart and recombined and then undergo

312

00:13:45,000 --> 00:13:42,190

more complex chemistry that eventually

313

00:13:48,690 --> 00:13:45,010

gives rise to again millions of

314

00:13:50,520 --> 00:13:48,700

different types organic compounds so how

315

00:13:54,600 --> 00:13:50,530

do we put those things together to

316

00:13:56,850 --> 00:13:54,610

actually make a living thing that is a

317

00:13:58,530 --> 00:13:56,860

much more complex question yeah

318

00:14:00,570 --> 00:13:58,540

one of the things we think might be

319

00:14:02,880 --> 00:14:00,580

really important in this process is in a

320

00:14:05,360 --> 00:14:02,890

very general sense it's something in

321

00:14:06,660 --> 00:14:05,370

chemistry that we call Auto catalysis

322

00:14:09,360 --> 00:14:06,670

all right

323

00:14:10,950 --> 00:14:09,370

and auto catalysis is simply this when a

324

00:14:12,510 --> 00:14:10,960

chemical reaction you can think you have

325

00:14:15,840 --> 00:14:12,520

you have things that you mix together

326

00:14:18,810 --> 00:14:15,850

and you get a product right in an auto

327

00:14:21,750 --> 00:14:18,820

catalytic process the product of the

328

00:14:25,230 --> 00:14:21,760

reaction actually goes back and speeds

329

00:14:27,390 --> 00:14:25,240

up the reaction right so it's a catalyst

330

00:14:30,000 --> 00:14:27,400

for its own production and if you look

331

00:14:33,570 --> 00:14:30,010

at the amount of product over time it

332

00:14:36,450 --> 00:14:33,580

actually increases and increases over

333

00:14:38,700 --> 00:14:36,460

time right that's it the more C you have

334

00:14:40,020 --> 00:14:38,710

the more of it you can make the which

335

00:14:42,840 --> 00:14:40,030

gives you more C which means you can

336

00:14:43,800 --> 00:14:42,850

make more C and so on and so forth there

337

00:14:46,140 --> 00:14:43,810

are different ways you can think about

338

00:14:47,130 --> 00:14:46,150

doing this but that basic process of

339

00:14:48,990 --> 00:14:47,140

amplification

340

00:14:51,900 --> 00:14:49,000

through Auto catalysis maybe a very

341

00:14:53,430 --> 00:14:51,910

important thing in biology and if you

342

00:14:57,150 --> 00:14:53,440

want to think about that in a biological

343

00:14:59,370 --> 00:14:57,160

terms you know you take carrots and you

344

00:15:00,780 --> 00:14:59,380

give it to rabbits you give them rabbits

345

00:15:02,340 --> 00:15:00,790

and you get more rabbits which can eat

346

00:15:03,720 --> 00:15:02,350

more carrots to make more rabbits Steve

347

00:15:06,480 --> 00:15:03,730

more carrots make more rabbits and so on

348

00:15:09,230 --> 00:15:06,490

and so on so that is a it feels like a

349

00:15:11,280 --> 00:15:09,240

very biological process to us yeah we

350

00:15:13,560 --> 00:15:11,290

have different ways we can we can

351

00:15:16,550 --> 00:15:13,570

simulate these sort of processes in

352

00:15:20,550 --> 00:15:16,560

computers so sort of reaction diffusion

353

00:15:23,009 --> 00:15:20,560

processes where you can actually have

354

00:15:25,019 --> 00:15:23,019

two of these systems coupled where the

355

00:15:28,019 --> 00:15:25,029

product of one reaction becomes the food

356

00:15:30,540 --> 00:15:28,029

for the next and you can see that you

357

00:15:32,490 --> 00:15:30,550

can get very complex sort of lifelike

358

00:15:36,300 --> 00:15:32,500

behavior and a computer from these very

359

00:15:37,620 --> 00:15:36,310

simple reaction models yeah so things

360

00:15:40,139 --> 00:15:37,630

that seem to make copies of themselves

361

00:15:43,170 --> 00:15:40,149

by converting food into their own

362

00:15:45,900 --> 00:15:43,180

substance so I'll give you one more kind

363

00:15:48,210 --> 00:15:45,910

of real-world example this is so we take

364

00:15:51,650 --> 00:15:48,220

two two simple molecules

365

00:15:54,840 --> 00:15:51,660

HCN hydrogen cyanide and formaldehyde

366

00:15:56,790 --> 00:15:54,850

it's a HCHO it's one has three atoms

367

00:15:59,130 --> 00:15:56,800

when I was four atoms put it in water

368

00:16:01,110 --> 00:15:59,140

we're gonna look at this reaction under

369

00:16:03,689 --> 00:16:01,120

a microscope all right this is about two

370

00:16:06,540 --> 00:16:03,699

millimeters across and then we're

371

00:16:08,069 --> 00:16:06,550

speeding this up to about five hours the

372

00:16:11,519 --> 00:16:08,079

molecules are smaller than you can see

373

00:16:13,410 --> 00:16:11,529

with a microscope but over time you'll

374

00:16:17,810 --> 00:16:13,420

notice you start seeing some little

375

00:16:23,420 --> 00:16:20,930

and it gets faster over time and it gets

376

00:16:24,740 --> 00:16:23,430

faster and faster over time you start

377

00:16:27,490 --> 00:16:24,750

seeing more and more and more and more

378

00:16:29,780 --> 00:16:27,500

of these so it turns into a complete

379

00:16:34,370 --> 00:16:29,790

snowstorm of something being formed

380

00:16:38,540 --> 00:16:36,890

essentially it seems to be an

381

00:16:39,830 --> 00:16:38,550

autocatalytic process and it's a very

382

00:16:43,530 --> 00:16:39,840

interesting one I'll show you a little

383

00:16:49,650 --> 00:16:48,449

more more more MORE until you at some

384

00:16:51,530 --> 00:16:49,660

point you start running out of the

385

00:16:53,610 --> 00:16:51,540

starting chemical when it's closed out

386

00:16:56,430 --> 00:16:53,620

so you have these very large and complex

387

00:16:58,079 --> 00:16:56,440

sort of structures that form you could

388

00:17:01,530 --> 00:16:58,089

pick those things and look at them under

389

00:17:04,919 --> 00:17:01,540

a higher power microscope and you see in

390

00:17:07,699 --> 00:17:04,929

fact that what they are is small kind of

391

00:17:12,120 --> 00:17:07,709

cell sized little capsules of chemicals

392

00:17:13,559 --> 00:17:12,130

all right they're hollow you can put

393

00:17:15,150 --> 00:17:13,569

stuff inside them when you put them

394

00:17:17,460 --> 00:17:15,160

under the high pressure or the low

395

00:17:20,250 --> 00:17:17,470

pressure of the electron microscope they

396

00:17:23,549 --> 00:17:20,260

explode sort of like the eggs in the

397

00:17:25,860 --> 00:17:23,559

alien or so you know they rupture you

398

00:17:28,710 --> 00:17:25,870

can drill holes in them we know they're

399

00:17:30,600 --> 00:17:28,720

hollow so there's this very interesting

400

00:17:32,970 --> 00:17:30,610

chemical phenomena that we don't

401
00:17:34,980 --> 00:17:32,980
understand very well that might be

402
00:17:37,380 --> 00:17:34,990
relevant to this sort of process there's

403
00:17:39,530 --> 00:17:37,390
auto catalytic they use very simple

404
00:17:41,730 --> 00:17:39,540
chemicals to become more complex things

405
00:17:44,460 --> 00:17:41,740
so on

406
00:17:46,140 --> 00:17:44,470
we know we're trying to understand the

407
00:17:50,100 --> 00:17:46,150
chemistry of these kind of systems which

408
00:17:53,340 --> 00:17:50,110
can be quite complex in this case this

409
00:17:55,560 --> 00:17:53,350
does seem to be a auto catalytic process

410
00:17:58,350 --> 00:17:55,570
it goes around it's cyclic it puts out a

411
00:18:00,390 --> 00:17:58,360
large molecule as a product so you can

412
00:18:02,310 --> 00:18:00,400
think of these the HCN as being the food

413
00:18:06,030 --> 00:18:02,320

in this case it feeds in at four places

414

00:18:08,130 --> 00:18:06,040

and the cycle the aldehyde is a catalyst

415

00:18:10,890 --> 00:18:08,140

it gets regenerated in a return of the

416

00:18:14,010 --> 00:18:10,900

cycle that thing outputs these little

417

00:18:16,140 --> 00:18:14,020

ball shaped things and the ball shaped

418

00:18:19,080 --> 00:18:16,150

things themselves seem to be a catalyst

419

00:18:21,810 --> 00:18:19,090

for the overall process so this is a

420

00:18:24,780 --> 00:18:21,820

form of to two types of nested auto

421

00:18:28,680 --> 00:18:24,790

catalysis yeah so oh where does that

422

00:18:31,110 --> 00:18:28,690

leave us I think we really don't know

423

00:18:33,900 --> 00:18:31,120

how life started or evolved to give the

424

00:18:36,090 --> 00:18:33,910

protein oh we have a lot of models we

425

00:18:37,470 --> 00:18:36,100

can test things in the laboratory see

426

00:18:40,940 --> 00:18:37,480

which ones are better and which ones are

427

00:18:47,250 --> 00:18:40,950

worse we know something about the timing

428

00:18:48,419 --> 00:18:47,260

plus or minus a billion years yeah we

429

00:18:50,190 --> 00:18:48,429

know something about the types of

430

00:18:51,870 --> 00:18:50,200

chemicals were involved not not

431

00:18:54,149 --> 00:18:51,880

everything not as much as we need to

432

00:18:56,760 --> 00:18:54,159

certainly we know something about

433

00:18:57,180 --> 00:18:56,770

self-assembly chemistry not everything

434

00:19:00,180 --> 00:18:57,190

we need

435

00:19:03,060 --> 00:19:00,190

no but something there are many many

436

00:19:05,760 --> 00:19:03,070

many very mysterious problems left to be

437

00:19:08,610 --> 00:19:05,770

solved in this field so hopefully we'll

438

00:19:16,000 --> 00:19:08,620

make some progress here and I lastly

439

00:19:32,270 --> 00:19:16,370

[Applause]

440

00:19:32,280 --> 00:19:46,960

[Music]