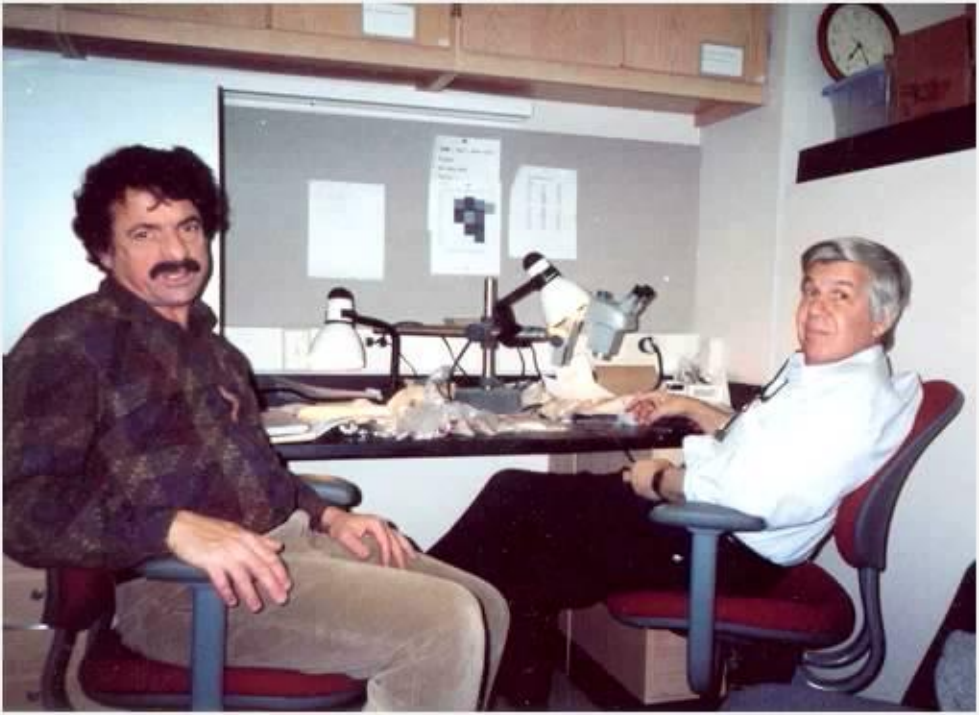
2. Mineral Chiral Selection



Glenn Goodfriend with Steve Gould

1
00:00:06,320 --> 00:00:03,679
to the astrobiology seminar some of you

2
00:00:09,049 --> 00:00:06,330
were able to attend the lecture last

3
00:00:12,799 --> 00:00:09,059
night well before we get to today next

4
00:00:15,519 --> 00:00:12,809
week let's say may eight we have Brad

5
00:00:17,540 --> 00:00:15,529
Dalton from NASA Ames Research Center

6
00:00:21,080 --> 00:00:17,550
who will be talking about spectroscopy

7
00:00:23,990 --> 00:00:21,090
of Europa's surface terms of the salts

8
00:00:26,929 --> 00:00:24,000
and possibly organics and so forth that

9
00:00:29,660 --> 00:00:26,939
are on the surface of Europa so that'll

10
00:00:32,150 --> 00:00:29,670
be the astrobiology seminar next week

11
00:00:33,799 --> 00:00:32,160
and then there'll be a a gap it will be

12
00:00:39,410 --> 00:00:33,809
three weeks after that will be the last

13
00:00:42,590 --> 00:00:39,420

of the year will be Joker shrink from

14
00:00:43,670 --> 00:00:42,600
Caltech and I don't know exactly what

15
00:00:47,170 --> 00:00:43,680
his title is but he's always a

16
00:00:49,700 --> 00:00:47,180
fascinating speaker but today's speaker

17
00:00:52,220 --> 00:00:49,710
as I say last night many of you heard

18
00:00:54,889 --> 00:00:52,230
Bob Hazen give a fascinating public

19
00:00:58,459 --> 00:00:54,899
lecture on an approach to the origin of

20
00:00:59,720 --> 00:00:58,469
life wide-ranging lecture excellent

21
00:01:02,959 --> 00:00:59,730
questions and so forth there was a

22
00:01:03,799 --> 00:01:02,969
really quite an evening and today we're

23
00:01:06,080 --> 00:01:03,809
delighted to have him to give a

24
00:01:08,840 --> 00:01:06,090
technical lecture to the astrobiology

25
00:01:11,230 --> 00:01:08,850
community but for those of you that were

26
00:01:14,270 --> 00:01:11,240
not there let me just briefly say that

27
00:01:16,370 --> 00:01:14,280
he's a Renaissance kind of guy he's a

28
00:01:18,560 --> 00:01:16,380
professional trumpeter he's played with

29
00:01:22,010 --> 00:01:18,570
National Symphony Boston Symphony he's

30
00:01:23,749 --> 00:01:22,020
written 19 books on a wide variety of

31
00:01:25,789 --> 00:01:23,759
topics most of them popular science

32
00:01:30,039 --> 00:01:25,799
books but other books such as the

33
00:01:34,819 --> 00:01:30,049
history of brass bands in America the

34
00:01:38,660 --> 00:01:34,829
sewers many other things here the poetry

35
00:01:42,499 --> 00:01:38,670
of geology why aren't black holes black

36
00:01:44,510 --> 00:01:42,509
the diamond makers etc etc he's also

37
00:01:48,080 --> 00:01:44,520
extremely interested in science literacy

38
00:01:49,389 --> 00:01:48,090

issues and with Jim trifle he's written

39
00:01:52,940 --> 00:01:49,399
two books that are quite well known

40
00:01:55,550 --> 00:01:52,950
science matters achieving scientific

41
00:01:57,980 --> 00:01:55,560
literacy and a text book called the

42
00:02:00,139 --> 00:01:57,990
sciences and integrated approach which

43
00:02:02,920 --> 00:02:00,149
is used in introductory science courses

44
00:02:05,690 --> 00:02:02,930
where you want to have what are the key

45
00:02:07,190 --> 00:02:05,700
topics that should be known from all of

46
00:02:09,020 --> 00:02:07,200
the different areas of science it's not

47
00:02:11,180 --> 00:02:09,030
just describing 101 but you're looking

48
00:02:13,400 --> 00:02:11,190
for a student they must have a semester

49
00:02:18,140 --> 00:02:13,410
where they come away with key

50
00:02:19,280 --> 00:02:18,150
concepts in all of the sciences so we're

51
00:02:21,410 --> 00:02:19,290
delighted that he could be here today

52
00:02:23,690 --> 00:02:21,420
and he's going to be talking about the

53
00:02:25,190 --> 00:02:23,700
origin of chirality which he touched on

54
00:02:28,430 --> 00:02:25,200
last night but we'll get into more of

55
00:02:31,760 --> 00:02:28,440
the technical details now so take it

56
00:02:34,460 --> 00:02:31,770
away Bob Thank You woody and it's really

57
00:02:35,840 --> 00:02:34,470
fun to be able to talk about this aspect

58
00:02:39,310 --> 00:02:35,850
of our research at the Carnegie

59
00:02:42,830 --> 00:02:39,320
Institution on the origins of

60
00:02:44,990 --> 00:02:42,840
biochemical homo chirality and I want to

61
00:02:47,060 --> 00:02:45,000
start by just giving a list of some of

62
00:02:48,980 --> 00:02:47,070
our collaborators we have so many

63
00:02:51,740 --> 00:02:48,990

wonderful people at work with the thing

64
00:02:53,570 --> 00:02:51,750
is striking to me about this list then

65
00:02:55,550 --> 00:02:53,580
this will not be at all surprised to you

66
00:02:56,810 --> 00:02:55,560
at the University of Washington is not

67
00:02:58,910 --> 00:02:56,820
that there are so many people from so

68
00:03:01,430 --> 00:02:58,920
many institutions but the range of

69
00:03:03,170 --> 00:03:01,440
disciplines the backgrounds that these

70
00:03:05,750 --> 00:03:03,180
individuals have we have people in

71
00:03:08,210 --> 00:03:05,760
organic chemistry in microbiology and

72
00:03:11,180 --> 00:03:08,220
ecology fixing chemistry and molecular

73
00:03:12,860 --> 00:03:11,190
modeling even a philosopher in this list

74
00:03:14,630 --> 00:03:12,870
so the idea of having research

75
00:03:16,460 --> 00:03:14,640
collaborators from many different fields

76
00:03:20,420 --> 00:03:16,470
are coming together to try to tackle

77
00:03:23,090 --> 00:03:20,430
these questions is so critical and I

78
00:03:24,740 --> 00:03:23,100
certainly want to thank them for their

79
00:03:26,690 --> 00:03:24,750
contributions and many of the things

80
00:03:29,330 --> 00:03:26,700
I'll talk about today come from the work

81
00:03:32,360 --> 00:03:29,340
of these individuals I want to look at

82
00:03:33,680 --> 00:03:32,370
two possibly related questions today the

83
00:03:36,440 --> 00:03:33,690
first has to do with this the

84
00:03:38,600 --> 00:03:36,450
interaction of crystals and organic

85
00:03:42,080 --> 00:03:38,610
molecules and I think that's a very

86
00:03:43,670 --> 00:03:42,090
general and broad question but we're

87
00:03:47,420 --> 00:03:43,680
also going to look specifically in the

88
00:03:49,370 --> 00:03:47,430

origin of life and what process the

89
00:03:51,229 --> 00:03:49,380
early Earth geochemical environments

90
00:03:52,970 --> 00:03:51,239
might have selected and concentrated

91
00:03:56,180 --> 00:03:52,980
certain molecules out of a prebiotic

92
00:03:57,979 --> 00:03:56,190
soup so that particular idea this idea

93
00:03:59,990 --> 00:03:57,989
of crystal molecule interactions that

94
00:04:03,860 --> 00:04:00,000
has tremendous applications the whole

95
00:04:05,660 --> 00:04:03,870
wide range of disciplines and some of

96
00:04:07,910 --> 00:04:05,670
them maybe is sort of surprised you but

97
00:04:10,340 --> 00:04:07,920
just think about molecules and crystals

98
00:04:12,020 --> 00:04:10,350
teeth and bones their composite

99
00:04:16,190 --> 00:04:12,030
materials formed

100
00:04:18,370 --> 00:04:16,200
and for example hydroxyapatite you think

101
00:04:21,680 --> 00:04:18,380
about the process of biomineralization

102
00:04:23,900 --> 00:04:21,690
the way living things secrete minerals

103
00:04:25,300 --> 00:04:23,910
formation of shells for example or some

104
00:04:27,400 --> 00:04:25,310
microbes that do biomineralization

105
00:04:30,020 --> 00:04:27,410
formation of biofilms as well

106
00:04:32,690 --> 00:04:30,030
fossilization the transformation of a

107
00:04:34,460 --> 00:04:32,700
living thing into a rock and cause all

108
00:04:36,830 --> 00:04:34,470
sorts of mineral molecule interactions

109
00:04:39,020 --> 00:04:36,840
weathering and soil formation critically

110
00:04:40,610 --> 00:04:39,030
important indeed I've read some articles

111
00:04:43,370 --> 00:04:40,620
recently to indicate that microbial

112
00:04:45,950 --> 00:04:43,380
action accelerates weathering in many

113
00:04:47,659 --> 00:04:45,960

rocks by orders of magnitude so this is

114
00:04:50,750 --> 00:04:47,669
certainly a very important kind of

115
00:04:53,150 --> 00:04:50,760
interaction very practical technologies

116
00:04:55,340 --> 00:04:53,160
paints glues dyes anytime you have an

117
00:04:57,140 --> 00:04:55,350
organic material sticking to an

118
00:04:58,820 --> 00:04:57,150
inorganic material and as well as

119
00:05:00,860 --> 00:04:58,830
lubricants when you think about that's

120
00:05:02,890 --> 00:05:00,870
another kind of mineral molecule

121
00:05:05,690 --> 00:05:02,900
interaction in many situations

122
00:05:07,640 --> 00:05:05,700
environmental monitoring cleanup turns

123
00:05:09,560 --> 00:05:07,650
out understanding the interaction of

124
00:05:11,409 --> 00:05:09,570
organic materials and crystals can be

125
00:05:14,000 --> 00:05:11,419
very important in this regard

126
00:05:15,350 --> 00:05:14,010
nanotechnologies and this certainly will

127
00:05:18,170 --> 00:05:15,360
be an important future area to

128
00:05:19,700 --> 00:05:18,180
understand I'll talk later today and

129
00:05:22,190 --> 00:05:19,710
allude to drug synthesis and

130
00:05:25,010 --> 00:05:22,200
purification another place where this

131
00:05:27,380 --> 00:05:25,020
becomes important and I will argue also

132
00:05:29,600 --> 00:05:27,390
the origin of life all these fields and

133
00:05:31,340 --> 00:05:29,610
more are places where a fundamental

134
00:05:33,050 --> 00:05:31,350
understanding of how crystalline

135
00:05:35,210 --> 00:05:33,060
materials on the one hand and organic

136
00:05:36,980 --> 00:05:35,220
molecules in a hand come together on the

137
00:05:40,400 --> 00:05:36,990
interactive molecular level it's

138
00:05:42,680 --> 00:05:40,410

fundamental to our understanding so let

139
00:05:44,540 --> 00:05:42,690
me give you just one fascinating example

140
00:05:46,909 --> 00:05:44,550
of how this can come into play and also

141
00:05:48,080 --> 00:05:46,919
how this idea can lead you in new

142
00:05:52,969 --> 00:05:48,090
directions you never would have expected

143
00:05:55,520 --> 00:05:52,979
this is a tiny portion of a bone and

144
00:05:58,850 --> 00:05:55,530
what you're seeing here in purple are

145
00:06:00,290 --> 00:05:58,860
five atoms of calcium that are part of a

146
00:06:04,040 --> 00:06:00,300
hydroxyapatite

147
00:06:07,399 --> 00:06:04,050
crystal in the Bowman bonded to this

148
00:06:09,670 --> 00:06:07,409
hydroxyapatite are two small parts of

149
00:06:12,080 --> 00:06:09,680
larger molecules called osteocalcin

150
00:06:14,480 --> 00:06:12,090
proteins that add some of the strengths

151
00:06:16,640 --> 00:06:14,490
and the characteristic properties due to

152
00:06:19,640 --> 00:06:16,650
bone so here you see to glutamic acid

153
00:06:22,490 --> 00:06:19,650
residues to from a second osteocalcin

154
00:06:24,529 --> 00:06:22,500
molecule and you see how in this Norton

155
00:06:25,999 --> 00:06:24,539
by pong at all which is published a few

156
00:06:28,369 --> 00:06:26,009
years ago in nature there's a very

157
00:06:30,649 --> 00:06:28,379
strong interaction between the mineral

158
00:06:33,230 --> 00:06:30,659
and the molecule a intimate interaction

159
00:06:36,980 --> 00:06:33,240
between glutamic acid and those calcium

160
00:06:39,649 --> 00:06:36,990
atoms that's fascinating but it leads to

161
00:06:42,170 --> 00:06:39,659
some consequences about osteocalcin in

162
00:06:44,420 --> 00:06:42,180
the fossil record turns out that because

163
00:06:46,580 --> 00:06:44,430

of the strong interaction the protein

164
00:06:48,740 --> 00:06:46,590
osteocalcin can survive for tens of

165
00:06:50,059 --> 00:06:48,750
thousands of years in a fossil bone

166
00:06:52,010 --> 00:06:50,069
whereas if it were just an isolated

167
00:06:53,360 --> 00:06:52,020
protein it would be natured very quickly

168
00:06:55,550 --> 00:06:53,370
you would break down you'd never see it

169
00:06:58,219 --> 00:06:55,560
but because it survives in fossil bones

170
00:07:01,129 --> 00:06:58,229
you can take fossils of bison or ox or

171
00:07:03,890 --> 00:07:01,139
other animals you can extract the

172
00:07:06,110 --> 00:07:03,900
osteocalcin you can sequence it that

173
00:07:08,089 --> 00:07:06,120
actually get phylogenetic information

174
00:07:12,499 --> 00:07:08,099
and what our people are now doing is

175
00:07:15,409 --> 00:07:12,509
creating phylogenetic trees for extinct

176
00:07:17,209 --> 00:07:15,419
mammals and they're doing it by

177
00:07:18,830 --> 00:07:17,219
sequencing the proteins that are

178
00:07:21,110 --> 00:07:18,840
preserved in those positive bones you

179
00:07:23,300 --> 00:07:21,120
may have seen recent articles about the

180
00:07:25,339 --> 00:07:23,310
preservation of collagen in much more

181
00:07:27,230 --> 00:07:25,349
ancient dinosaur bones as against the

182
00:07:29,119 --> 00:07:27,240
criminal kind of thing this would not be

183
00:07:31,279 --> 00:07:29,129
possible where it not for the strong

184
00:07:33,050 --> 00:07:31,289
interaction of the molecules with the

185
00:07:35,240 --> 00:07:33,060
mineral substrate which protects

186
00:07:37,309 --> 00:07:35,250
preserves and prevents the degradation

187
00:07:38,959 --> 00:07:37,319
of the phone so that's just one example

188
00:07:43,339 --> 00:07:38,969

we're learning things about the

189
00:07:46,999 --> 00:07:43,349
evolution of macro fauna from the

190
00:07:48,230 --> 00:07:47,009
consequence of interactions now today

191
00:07:49,909 --> 00:07:48,240
I'm going to talk about the origin of

192
00:07:52,010 --> 00:07:49,919
life and just to review kind of give you

193
00:07:53,659 --> 00:07:52,020
an echo of last night's lecture I make a

194
00:07:55,129 --> 00:07:53,669
few basic assumptions when I talked

195
00:07:57,140 --> 00:07:55,139
about origin of life the first is that

196
00:07:58,909 --> 00:07:57,150
the original life forms were based on

197
00:08:01,839 --> 00:07:58,919
organic molecules their carbon based

198
00:08:04,670 --> 00:08:01,849
lifeforms the raw materials oceans

199
00:08:07,550 --> 00:08:04,680
atmospheres rocks and minerals those are

200
00:08:09,290 --> 00:08:07,560
your building blocks and that the origin

201
00:08:09,980 --> 00:08:09,300
of life required as I talked about in

202
00:08:12,410 --> 00:08:09,990
detail less

203
00:08:14,330 --> 00:08:12,420
a sequence of emergent steps where you

204
00:08:16,010 --> 00:08:14,340
go from simplicity of a G chemical world

205
00:08:17,350 --> 00:08:16,020
to the complexity of a biochemical world

206
00:08:21,410 --> 00:08:17,360
through a series of chemical

207
00:08:23,170 --> 00:08:21,420
complexification in specific the four

208
00:08:25,400 --> 00:08:23,180
steps that I talked about last night

209
00:08:26,990 --> 00:08:25,410
first the emergence of the simple

210
00:08:29,810 --> 00:08:27,000
biomolecules the building blocks the

211
00:08:32,420 --> 00:08:29,820
amino acids the sugars the lipids the

212
00:08:34,100 --> 00:08:32,430
bases of DNA and RNA and so forth the

213
00:08:36,110 --> 00:08:34,110

second step which are going to focus on

214
00:08:38,210 --> 00:08:36,120
today is this emergence of organized

215
00:08:41,120 --> 00:08:38,220
molecular systems in the selection and

216
00:08:43,820 --> 00:08:41,130
concentration of a few molecules from

217
00:08:45,410 --> 00:08:43,830
many the third step you'll recall was

218
00:08:47,360 --> 00:08:45,420
the emergence of self-replication

219
00:08:50,150 --> 00:08:47,370
molecules that make copies in themselves

220
00:08:52,400 --> 00:08:50,160
in a system and finally the emergence of

221
00:08:54,680 --> 00:08:52,410
natural selection those four steps are

222
00:08:56,540 --> 00:08:54,690
key but we're going to be looking at the

223
00:09:00,020 --> 00:08:56,550
second problem the origin of

224
00:09:02,690 --> 00:09:00,030
biomolecules the problem fundamental

225
00:09:04,730 --> 00:09:02,700
aspect of life is a high degree of

226
00:09:07,250 --> 00:09:04,740
molecular selectivity if you go into the

227
00:09:08,840 --> 00:09:07,260
databases for e.coli for example you'll

228
00:09:12,410 --> 00:09:08,850
find that there are only a few hundred

229
00:09:14,240 --> 00:09:12,420
different small molecules in e.coli out

230
00:09:17,390 --> 00:09:14,250
of all the millions of small molecules

231
00:09:19,190 --> 00:09:17,400
that are in veal stock prebiotic

232
00:09:21,410 --> 00:09:19,200
synthesis is basically indiscriminate

233
00:09:24,350 --> 00:09:21,420
you make hundreds of thousands millions

234
00:09:27,200 --> 00:09:24,360
perhaps more small molecules life uses

235
00:09:29,300 --> 00:09:27,210
only a few so the question becomes what

236
00:09:32,450 --> 00:09:29,310
prebiotic processes could have selected

237
00:09:33,830 --> 00:09:32,460
and organized that vast array of organic

238
00:09:35,180 --> 00:09:33,840

molecules to give you just the right

239
00:09:36,920 --> 00:09:35,190
ones that are organized through

240
00:09:40,280 --> 00:09:36,930
synthesized down what's your definition

241
00:09:43,370 --> 00:09:40,290
is small small molecules 8 10 12 carbon

242
00:09:46,100 --> 00:09:43,380
atoms maximum so we're talking about

243
00:09:48,500 --> 00:09:46,110
things really monomers if you will in in

244
00:09:50,480 --> 00:09:48,510
the biological see let's look at amino

245
00:09:51,770 --> 00:09:50,490
acids just as an example of what I'm

246
00:09:53,000 --> 00:09:51,780
talking about if you look at merchants

247
00:09:54,640 --> 00:09:53,010
and meteorite there are over 90

248
00:09:56,750 --> 00:09:54,650
different amino acids so far identified

249
00:10:00,470 --> 00:09:56,760
compared to the only 20 in biological

250
00:10:02,240 --> 00:10:00,480
systems those amino acids and biological

251
00:10:03,049 --> 00:10:02,250
systems are restricted to alpha hydrogen

252
00:10:05,239 --> 00:10:03,059
I mean why

253
00:10:06,889 --> 00:10:05,249
as opposed to merchants in which for

254
00:10:09,349 --> 00:10:06,899
example is a great many Alfred methyl

255
00:10:11,089 --> 00:10:09,359
amino acids and and finally this

256
00:10:13,449 --> 00:10:11,099
question of homo chirality the

257
00:10:15,529 --> 00:10:13,459
handedness that in living systems

258
00:10:17,809 --> 00:10:15,539
overwhelmingly you have left-handed

259
00:10:20,869 --> 00:10:17,819
amino acids where it is in murcheson and

260
00:10:23,059 --> 00:10:20,879
other natural products there is a more

261
00:10:25,729 --> 00:10:23,069
equal ratio murcheson is interesting

262
00:10:27,919 --> 00:10:25,739
that it seems to have a slight excess of

263
00:10:30,529 --> 00:10:27,929

else Amel amino acids and we can talk

264
00:10:32,809 --> 00:10:30,539
about that later on but the basic point

265
00:10:34,579 --> 00:10:32,819
is that in an early earth where the

266
00:10:36,049 --> 00:10:34,589
amino acids would have had a long time

267
00:10:38,239 --> 00:10:36,059
to sit in an environment where they can

268
00:10:40,009 --> 00:10:38,249
flip back and forth you predominantly

269
00:10:42,499 --> 00:10:40,019
would have had a 50-50 mixture of amino

270
00:10:44,719 --> 00:10:42,509
acids from which to select and yet life

271
00:10:47,589 --> 00:10:44,729
is predominantly left-handed how do you

272
00:10:52,039 --> 00:10:47,599
get this selectivity here's the problem

273
00:10:54,799 --> 00:10:52,049
Omar chirality life's molecules come in

274
00:10:57,019 --> 00:10:54,809
left and right-handed forms the

275
00:11:00,319 --> 00:10:57,029
prebiotic processes is produced 50-50

276
00:11:01,969 --> 00:11:00,329
mixtures and yet life is largely homo

277
00:11:04,699 --> 00:11:01,979
chiral that's the question we're asking

278
00:11:06,199 --> 00:11:04,709
how did this happen and even if I can't

279
00:11:08,119 --> 00:11:06,209
give you an answer even if you're not

280
00:11:10,429 --> 00:11:08,129
convinced by what I say today in terms

281
00:11:13,969 --> 00:11:10,439
of homework orality as I alluded to last

282
00:11:16,519 --> 00:11:13,979
night the chiral drug industry is 200

283
00:11:18,259 --> 00:11:16,529
billion dollars a year and it's because

284
00:11:20,779 --> 00:11:18,269
to purify left and right-handed

285
00:11:22,639 --> 00:11:20,789
molecules is very important for our

286
00:11:24,349 --> 00:11:22,649
medicinal purposes with biological

287
00:11:26,179 --> 00:11:24,359
purposes our bodies respond differently

288
00:11:28,429 --> 00:11:26,189

to left and right-handed molecules and

289
00:11:30,379 --> 00:11:28,439
left to right handed drugs let me give

290
00:11:32,449 --> 00:11:30,389
you some basic vocabulary because I slip

291
00:11:34,669 --> 00:11:32,459
into these words very easily and may be

292
00:11:37,099 --> 00:11:34,679
unfamiliar to you so just to give us a

293
00:11:39,679 --> 00:11:37,109
common ground the word chiral is

294
00:11:42,199 --> 00:11:39,689
synonymous with an anti-american or

295
00:11:43,639 --> 00:11:42,209
handed so but I got a chiral molecule

296
00:11:45,589 --> 00:11:43,649
talk about a left or right-handed

297
00:11:47,330 --> 00:11:45,599
molecule for example mirror image pairs

298
00:11:49,550 --> 00:11:47,340
of molecules

299
00:11:51,410 --> 00:11:49,560
the designation for a so called

300
00:11:53,300 --> 00:11:51,420
right-handed molecule which is a rather

301
00:11:55,460 --> 00:11:53,310
arbitrary definition in any case

302
00:11:57,800 --> 00:11:55,470
sometimes they're called D dextrose

303
00:11:59,420 --> 00:11:57,810
sometimes they're called are and you'll

304
00:12:00,920 --> 00:11:59,430
see those interchangeable similar for

305
00:12:04,400 --> 00:12:00,930
left-handed molecules sometimes just the

306
00:12:06,440 --> 00:12:04,410
L and sometimes you see s the word

307
00:12:09,770 --> 00:12:06,450
sinister is related to that same route

308
00:12:11,300 --> 00:12:09,780
for s homo chiral means that you have

309
00:12:12,890 --> 00:12:11,310
all the same handedness in the

310
00:12:15,710 --> 00:12:12,900
collection of molecules header chiral is

311
00:12:19,430 --> 00:12:15,720
a mixture of the ended messed up racemic

312
00:12:21,950 --> 00:12:19,440
is the word for a 50-50 mixture so if I

313
00:12:23,450 --> 00:12:21,960

talk about racemic molecules it means

314
00:12:26,480 --> 00:12:23,460
that they're equal numbers have left the

315
00:12:29,240 --> 00:12:26,490
right-handed molecules in the mix and

316
00:12:31,970 --> 00:12:29,250
symmetry breaking symmetry breaking is

317
00:12:34,790 --> 00:12:31,980
the process by which you take a racemic

318
00:12:36,800 --> 00:12:34,800
mixture and separate out the left and

319
00:12:39,980 --> 00:12:36,810
the right from each other you break the

320
00:12:41,750 --> 00:12:39,990
symmetry of this collection of molecules

321
00:12:44,180 --> 00:12:41,760
so those are words that I'll be

322
00:12:46,160 --> 00:12:44,190
referring to throughout the talk let's

323
00:12:48,260 --> 00:12:46,170
look at why chiro purity is important

324
00:12:50,600 --> 00:12:48,270
here's this case of limonene the

325
00:12:52,730 --> 00:12:50,610
flavoring that where the right-handed

326
00:12:55,100 --> 00:12:52,740
former smells like oranges and is used

327
00:12:57,200 --> 00:12:55,110
in that context but the left-handed form

328
00:12:59,720 --> 00:12:57,210
smells like lemons that's because the

329
00:13:01,850 --> 00:12:59,730
taste receptors in our mouths are shaped

330
00:13:02,960 --> 00:13:01,860
such that they're handed and a left and

331
00:13:05,840 --> 00:13:02,970
right-handed molecule will fit

332
00:13:07,640 --> 00:13:05,850
differently into that receptor and I

333
00:13:09,530 --> 00:13:07,650
mentioned thalidomide last night this

334
00:13:11,420 --> 00:13:09,540
tragic case where the right-handed form

335
00:13:13,040 --> 00:13:11,430
was given to women to cure morning

336
00:13:15,650 --> 00:13:13,050
sickness but the left-handed form cause

337
00:13:17,960 --> 00:13:15,660
birth defects and indeed even if you

338
00:13:23,240 --> 00:13:17,970

took a chiral e pure form of thalidomide

339
00:13:25,460 --> 00:13:23,250
in your body it rasa mieses it it flips

340
00:13:27,500 --> 00:13:25,470
from left to right very quickly so that

341
00:13:30,020 --> 00:13:27,510
the right-handed form in part becomes

342
00:13:32,180 --> 00:13:30,030
left-handed form while it's in your body

343
00:13:35,390 --> 00:13:32,190
and therefore there's no way of taking a

344
00:13:37,610 --> 00:13:35,400
thalidomide safely and only recently has

345
00:13:40,340 --> 00:13:37,620
come back on the market for a very

346
00:13:41,750 --> 00:13:40,350
limited use in treating certain kinds of

347
00:13:44,000 --> 00:13:41,760
cancers it turns out to be very very

348
00:13:47,960 --> 00:13:44,010
effective for for cancer called multiple

349
00:13:50,390 --> 00:13:47,970
myeloma but you my my mother who had

350
00:13:53,240 --> 00:13:50,400
that disease and was given thalidomide

351
00:13:54,770 --> 00:13:53,250
towards the end of her life she was 80

352
00:13:56,180 --> 00:13:54,780
years old and she had to sign a sworn

353
00:14:00,880 --> 00:13:56,190
statement that she would not

354
00:14:03,860 --> 00:14:00,890
get pregnant for legal reasons there's a

355
00:14:06,290 --> 00:14:03,870
very sad irony in that I thought but

356
00:14:10,370 --> 00:14:06,300
that's that's the story enantioselective

357
00:14:12,410 --> 00:14:10,380
chemistry the problem facing the drug

358
00:14:14,540 --> 00:14:12,420
industry is the same problem facing

359
00:14:16,580 --> 00:14:14,550
early life how do you start with a

360
00:14:19,130 --> 00:14:16,590
racemic mixture and get a pure product

361
00:14:21,560 --> 00:14:19,140
and there are two ways to do this the

362
00:14:23,840 --> 00:14:21,570
first is an anti oh selective separation

363
00:14:26,540 --> 00:14:23,850

where you start with a 50-50 mixture

364
00:14:28,790 --> 00:14:26,550
synthesized by some normal process and

365
00:14:31,130 --> 00:14:28,800
then you pass it over a column or some

366
00:14:34,280 --> 00:14:31,140
kind of environment that's chiral which

367
00:14:35,720 --> 00:14:34,290
separates out typically by time the left

368
00:14:37,280 --> 00:14:35,730
and the right handed molecule so you

369
00:14:40,450 --> 00:14:37,290
collect the right-handed molecules then

370
00:14:42,620 --> 00:14:40,460
you collect the left molecules through a

371
00:14:46,370 --> 00:14:42,630
chromatographic technique of some sort

372
00:14:48,140 --> 00:14:46,380
the other equally important form is

373
00:14:50,360 --> 00:14:48,150
called in any way selective synthesis

374
00:14:53,150 --> 00:14:50,370
where you start with reactants that are

375
00:14:54,950 --> 00:14:53,160
themselves not chiral they're not handed

376
00:14:56,930 --> 00:14:54,960
but they have the potential if you add

377
00:14:59,360 --> 00:14:56,940
just one more component to them they

378
00:15:02,000 --> 00:14:59,370
will become handed and if you have a

379
00:15:05,480 --> 00:15:02,010
chiral catalyst it turns out that you

380
00:15:07,430 --> 00:15:05,490
can take some pro cairo reactants move

381
00:15:09,950 --> 00:15:07,440
them over the chiro catalyst and the

382
00:15:11,660 --> 00:15:09,960
product will be chiral epure so that's

383
00:15:14,420 --> 00:15:11,670
another way of doing it and actually

384
00:15:17,150 --> 00:15:14,430
each of these possibilities may have

385
00:15:19,580 --> 00:15:17,160
obtained in a prebiotic setting as well

386
00:15:22,880 --> 00:15:19,590
but one component would be two ways to

387
00:15:25,940 --> 00:15:22,890
edit two ways and just basically if you

388
00:15:27,740 --> 00:15:25,950

add it over here it's it's and it has to

389
00:15:29,720 --> 00:15:27,750
do with if you have a carbon atom that

390
00:15:31,910 --> 00:15:29,730
has three things bonded to it and you

391
00:15:35,090 --> 00:15:31,920
add a fourth you can either add it to

392
00:15:36,680 --> 00:15:35,100
this side or to this side what's a way

393
00:15:40,280 --> 00:15:36,690
to distinguish I mean chemically how

394
00:15:42,890 --> 00:15:40,290
does one do that you use a particular

395
00:15:45,890 --> 00:15:42,900
chiral environment that happens to bond

396
00:15:48,590 --> 00:15:45,900
to the pro chiral reactants and it can

397
00:15:51,320 --> 00:15:48,600
only stick on the other component from

398
00:15:53,090 --> 00:15:51,330
one side it just so you have for example

399
00:15:55,970 --> 00:15:53,100
hydrogen atom over here you have an

400
00:15:59,090 --> 00:15:55,980
amino acid / amino group over here you

401
00:16:00,290 --> 00:15:59,100
want to add on a phenyl group and the

402
00:16:02,810 --> 00:16:00,300
phenyl group is sitting on the surface

403
00:16:04,610 --> 00:16:02,820
like this and this is the only way that

404
00:16:06,740 --> 00:16:04,620
the three vinyl thing comes

405
00:16:08,360 --> 00:16:06,750
they're a double bond becomes a single

406
00:16:09,770 --> 00:16:08,370
bond you now have a four bonded carbon

407
00:16:12,320 --> 00:16:09,780
which is a chiral Center so there's

408
00:16:16,250 --> 00:16:12,330
there's ways and engineers can actually

409
00:16:17,870 --> 00:16:16,260
figure this out in great detail but in a

410
00:16:19,250 --> 00:16:17,880
prebiotic sense we have to sort of start

411
00:16:24,860 --> 00:16:19,260
from scratch and see what might have

412
00:16:27,020 --> 00:16:24,870
happened so here is the problem again

413
00:16:29,120 --> 00:16:27,030

just in a nutshell prebiotic synthesis

414
00:16:31,490 --> 00:16:29,130
processes mixtures of left and right

415
00:16:33,140 --> 00:16:31,500
life demonstrates this kyra selectivity

416
00:16:35,480 --> 00:16:33,150
what is the mechanism of symmetry

417
00:16:37,310 --> 00:16:35,490
breaking and there's a huge literature

418
00:16:40,070 --> 00:16:37,320
on this it goes back almost a hundred

419
00:16:42,320 --> 00:16:40,080
years and there are many different kinds

420
00:16:44,600 --> 00:16:42,330
of hypotheses some of them have to do

421
00:16:47,270 --> 00:16:44,610
with global mechanisms or universal

422
00:16:49,130 --> 00:16:47,280
mechanisms the idea that the left-handed

423
00:16:50,870 --> 00:16:49,140
amino acids that we see on earth were

424
00:16:53,870 --> 00:16:50,880
predetermined that this is a

425
00:16:55,190 --> 00:16:53,880
deterministic aspect of life in some

426
00:16:57,620 --> 00:16:55,200
cases it has to do with the

427
00:16:59,690 --> 00:16:57,630
deterministic aspect of our region of

428
00:17:01,400 --> 00:16:59,700
the galaxy for example there's a rapidly

429
00:17:03,500 --> 00:17:01,410
rotating neutron star producing

430
00:17:06,100 --> 00:17:03,510
circularly polarized radiation that

431
00:17:08,570 --> 00:17:06,110
could selectively photo lies

432
00:17:10,580 --> 00:17:08,580
right-handed amino acids so the only

433
00:17:12,110 --> 00:17:10,590
left-handed amino acids survive and

434
00:17:13,820 --> 00:17:12,120
presumably there are other regions of

435
00:17:15,980 --> 00:17:13,830
the galaxy where the opposite fatalis

436
00:17:17,510 --> 00:17:15,990
asst would have occurred so but we

437
00:17:19,280 --> 00:17:17,520
happen to be in a region where you get

438
00:17:24,430 --> 00:17:19,290

this preponderance of left-handed amino

439
00:17:26,720 --> 00:17:24,440
acids in the nebula miliar now another

440
00:17:29,210 --> 00:17:26,730
example and this is discussed by

441
00:17:31,490 --> 00:17:29,220
physicists this is the one symmetry

442
00:17:33,080 --> 00:17:31,500
universal symmetry breaking aspect and

443
00:17:35,360 --> 00:17:33,090
basically you can think of it when you

444
00:17:37,040 --> 00:17:35,370
have beta decay an electron is released

445
00:17:39,290 --> 00:17:37,050
and that electron is circularly

446
00:17:42,410 --> 00:17:39,300
polarized it always spirals in one

447
00:17:44,870 --> 00:17:42,420
direction so there is a slight chiral

448
00:17:47,150 --> 00:17:44,880
bias when that electron hits another

449
00:17:49,130 --> 00:17:47,160
molecule or if it gets involved in a

450
00:17:51,200 --> 00:17:49,140
chemical reaction it will bias that

451
00:17:53,210 --> 00:17:51,210
chemical reaction slightly very very

452
00:17:55,100 --> 00:17:53,220
small energies involved here I am

453
00:17:57,530 --> 00:17:55,110
unconvinced by this mechanism but there

454
00:17:59,810 --> 00:17:57,540
are some physicists that will point to

455
00:18:02,480 --> 00:17:59,820
this as the one sort of handedness of

456
00:18:04,340 --> 00:18:02,490
the one thing that would not be mirror

457
00:18:06,500 --> 00:18:04,350
symmetry in if you looked in a mirror

458
00:18:07,580 --> 00:18:06,510
the through the looking-glass analogy

459
00:18:10,190 --> 00:18:07,590
that the other side of the mirror

460
00:18:13,280 --> 00:18:10,200
universe looks identical to ours except

461
00:18:14,700 --> 00:18:13,290
for this one physical attribute the

462
00:18:16,919 --> 00:18:14,710
handedness of the rotation

463
00:18:19,470 --> 00:18:16,929

beta decay those are global or universal

464
00:18:21,720 --> 00:18:19,480
mechanisms but they're also local chiral

465
00:18:23,760 --> 00:18:21,730
microenvironments and if you will accept

466
00:18:25,919 --> 00:18:23,770
the idea that the origin of life is a

467
00:18:27,480 --> 00:18:25,929
chemical event that occurred in a micro

468
00:18:28,889 --> 00:18:27,490
environment at some point the

469
00:18:30,450 --> 00:18:28,899
juxtaposition of just the right

470
00:18:33,210 --> 00:18:30,460
molecules and maybe just the right

471
00:18:35,070 --> 00:18:33,220
surfaces then you have to think about

472
00:18:36,750 --> 00:18:35,080
are their local environments that are

473
00:18:40,380 --> 00:18:36,760
chiral II biased and indeed there are

474
00:18:42,409 --> 00:18:40,390
very strong local chiral environment one

475
00:18:45,510 --> 00:18:42,419
of them is the chiral molecule itself I

476
00:18:47,399 --> 00:18:45,520
think a very plausible idea when I'm not

477
00:18:49,159 --> 00:18:47,409
going to talk about today very plausible

478
00:18:53,250 --> 00:18:49,169
idea is that a chiral molecule itself

479
00:18:55,769 --> 00:18:53,260
attracts chiral similar molecules in

480
00:18:57,600 --> 00:18:55,779
that so for perhaps a chain of peptide

481
00:18:59,940 --> 00:18:57,610
peptide chain and long chain of amino

482
00:19:03,000 --> 00:18:59,950
acids maybe it forms preferentially with

483
00:19:05,340 --> 00:19:03,010
all L and aldi molecules as opposed to a

484
00:19:07,590 --> 00:19:05,350
mix-up of l's and DS maybe that just

485
00:19:09,630 --> 00:19:07,600
doesn't bond as easily or form as easily

486
00:19:13,799 --> 00:19:09,640
or maybe there's a selective hydrolysis

487
00:19:17,190 --> 00:19:13,809
that LL and DD bonds and amino acids are

488
00:19:19,169 --> 00:19:17,200

stronger and last longer than a dl bond

489
00:19:21,180 --> 00:19:19,179
which if it's selectively hydrolyzed

490
00:19:23,340 --> 00:19:21,190
ultimately you win are those out and you

491
00:19:25,470 --> 00:19:23,350
get home okay roll sequences that's

492
00:19:27,299 --> 00:19:25,480
possible and people is speculate on that

493
00:19:29,130 --> 00:19:27,309
there's not a whole lot of experimental

494
00:19:30,419 --> 00:19:29,140
work to show one way or another and I'm

495
00:19:32,700 --> 00:19:30,429
not going to discuss that possibility

496
00:19:34,950 --> 00:19:32,710
but it certainly is out there another

497
00:19:36,120 --> 00:19:34,960
option another very strong chiral

498
00:19:40,380 --> 00:19:36,130
environment which I will talk about

499
00:19:42,360 --> 00:19:40,390
today are mineral surfaces so to give

500
00:19:44,610 --> 00:19:42,370
you my prejudice here it's not that

501
00:19:46,620 --> 00:19:44,620
minerals are the answer to the problem

502
00:19:48,810 --> 00:19:46,630
of life's homo chirality so the minerals

503
00:19:50,730 --> 00:19:48,820
provide very strong local chiral

504
00:19:53,190 --> 00:19:50,740
environments and they also have the

505
00:19:55,230 --> 00:19:53,200
ability to select and organize molecules

506
00:19:56,789 --> 00:19:55,240
on their surface in a way that could

507
00:19:59,580 --> 00:19:56,799
lead to higher levels of organization

508
00:20:02,549 --> 00:19:59,590
and so I think we have to look at these

509
00:20:04,049 --> 00:20:02,559
environments just as is an intrinsically

510
00:20:05,700 --> 00:20:04,059
interesting property something that

511
00:20:08,100 --> 00:20:05,710
might have very important commercial or

512
00:20:10,350 --> 00:20:08,110
industrial applications and also one

513
00:20:12,060 --> 00:20:10,360

that to me is as good a possibility as

514
00:20:13,620 --> 00:20:12,070
any for the origin of whites homo

515
00:20:16,049 --> 00:20:13,630
chirality necessary for incoming further

516
00:20:17,370 --> 00:20:16,059
so the hypothesis is that minerals work

517
00:20:18,930 --> 00:20:17,380
in this regard that left and

518
00:20:21,570 --> 00:20:18,940
right-handed phases of mineral

519
00:20:24,120 --> 00:20:21,580
if you will will selectively concentrate

520
00:20:27,000 --> 00:20:24,130
left and right-handed molecules and what

521
00:20:28,590 --> 00:20:27,010
I want to do is go through this i will

522
00:20:30,450 --> 00:20:28,600
tell you briefly that our recent work

523
00:20:32,040 --> 00:20:30,460
shows that in fact this is true we can

524
00:20:33,600 --> 00:20:32,050
demonstrate this experimentally i'll

525
00:20:37,170 --> 00:20:33,610
give you some more insight on that these

526
00:20:39,360 --> 00:20:37,180
are just some of the Selective left and

527
00:20:42,810 --> 00:20:39,370
right-handed molecules the TC is a try

528
00:20:44,100 --> 00:20:42,820
carboxylic acid on calcite zone feldspar

529
00:20:45,960 --> 00:20:44,110
and quartz we're talking about the

530
00:20:48,000 --> 00:20:45,970
Communist of rock-forming minerals hear

531
00:20:49,620 --> 00:20:48,010
things that appear in all sorts of

532
00:20:52,230 --> 00:20:49,630
geological environments today I'm going

533
00:20:53,850 --> 00:20:52,240
to do four things so the structure of

534
00:20:55,890 --> 00:20:53,860
the talking I first examined the

535
00:20:58,230 --> 00:20:55,900
occurrence of chiral mineral surfaces in

536
00:20:59,790 --> 00:20:58,240
nature how common are they what is the

537
00:21:01,110 --> 00:20:59,800
likelihood that a geochemical

538
00:21:04,530 --> 00:21:01,120

environment you're going to find a

539
00:21:07,110 --> 00:21:04,540
carnal service I'm then going to look at

540
00:21:09,780 --> 00:21:07,120
this process chiral selectivity and

541
00:21:11,880 --> 00:21:09,790
demonstrate experimentally that in fact

542
00:21:13,830 --> 00:21:11,890
selection occurs left and right-handed

543
00:21:15,840 --> 00:21:13,840
molecules can be separated by minerals

544
00:21:17,610 --> 00:21:15,850
third is the looking through a

545
00:21:20,220 --> 00:21:17,620
theoretical analysis first-principles

546
00:21:22,230 --> 00:21:20,230
calculations of exactly what's happening

547
00:21:24,360 --> 00:21:22,240
at the molecular scale why would one

548
00:21:26,730 --> 00:21:24,370
molecule stick to one particular surface

549
00:21:28,350 --> 00:21:26,740
preferential and finally I'm going to

550
00:21:30,000 --> 00:21:28,360
propose a more general way of

551
00:21:33,870 --> 00:21:30,010
approaching this problem using a

552
00:21:36,480 --> 00:21:33,880
combinatorial based on DNA microarray

553
00:21:38,910 --> 00:21:36,490
technology where we can study literally

554
00:21:41,520 --> 00:21:38,920
thousands of mineral molecule pairs in a

555
00:21:44,460 --> 00:21:41,530
single experiment which really makes our

556
00:21:47,940 --> 00:21:44,470
life a lot easier okay so first natural

557
00:21:50,940 --> 00:21:47,950
chiral surfaces now thank natural chiral

558
00:21:52,980 --> 00:21:50,950
surfaces occur insert three variants I'm

559
00:21:54,840 --> 00:21:52,990
only going to be talking today about the

560
00:21:56,610 --> 00:21:54,850
first one but that's the least likely to

561
00:21:57,930 --> 00:21:56,620
occur in a natural environment and I

562
00:21:59,280 --> 00:21:57,940
admit that up front that's just a

563
00:22:01,770 --> 00:21:59,290

crystal termination that sort of

564
00:22:04,530 --> 00:22:01,780
idealized as the set of almost planar

565
00:22:07,080 --> 00:22:04,540
mount of atoms coming to a service on a

566
00:22:09,000 --> 00:22:07,090
flat surface much more likely you have

567
00:22:11,310 --> 00:22:09,010
stepped surfaces because of growth

568
00:22:13,530 --> 00:22:11,320
defects or even more likely kinked

569
00:22:15,540 --> 00:22:13,540
surfaces where you have those kinks

570
00:22:17,640 --> 00:22:15,550
sites are chiral in nature the very

571
00:22:19,890 --> 00:22:17,650
essence of a site like this is a perfect

572
00:22:23,130 --> 00:22:19,900
place for a small molecule to nestle in

573
00:22:24,750 --> 00:22:23,140
an environment that's handed and this we

574
00:22:27,060 --> 00:22:24,760
see over and over again even the metal

575
00:22:29,310 --> 00:22:27,070
surfaces now let's just look at one of

576
00:22:30,000 --> 00:22:29,320
these King surfaces it turns out that

577
00:22:31,890 --> 00:22:30,010
the chem

578
00:22:33,870 --> 00:22:31,900
Engineers they primarily study things

579
00:22:36,930 --> 00:22:33,880
that are close packed cubic structures

580
00:22:38,550 --> 00:22:36,940
like platinum or gold or copper and the

581
00:22:40,020 --> 00:22:38,560
reason is is those are highly catalytic

582
00:22:42,000 --> 00:22:40,030
and they can also prepare them quite

583
00:22:44,010 --> 00:22:42,010
easily could you save with G close pack

584
00:22:45,150 --> 00:22:44,020
services hi would they be chiral the

585
00:22:46,770 --> 00:22:45,160
chiral be because they have all these

586
00:22:49,530 --> 00:22:46,780
kinks sites if you have a high angle

587
00:22:52,620 --> 00:22:49,540
surface like the 643 surface of a metal

588
00:22:54,720 --> 00:22:52,630

then you have the left-handed face which

589
00:22:56,550 --> 00:22:54,730
is non-superimposable in terms of his

590
00:22:57,720 --> 00:22:56,560
King structure the right hand of faces

591
00:22:59,370 --> 00:22:57,730
so you have all these little nooks and

592
00:23:01,530 --> 00:22:59,380
crannies for either left or right-handed

593
00:23:04,350 --> 00:23:01,540
molecules fit and for the last decade or

594
00:23:07,260 --> 00:23:04,360
so people have modeled using theoretical

595
00:23:09,390 --> 00:23:07,270
approaches small molecules nestling into

596
00:23:11,700 --> 00:23:09,400
these kink sites that have shown how you

597
00:23:14,130 --> 00:23:11,710
can get a selective absorption can

598
00:23:15,870 --> 00:23:14,140
typically half kilo calorie per mole is

599
00:23:17,910 --> 00:23:15,880
the preferential energy of a leftover

600
00:23:21,060 --> 00:23:17,920
right-handed molecule on this kind of

601
00:23:23,190 --> 00:23:21,070
surface here's another calculation of

602
00:23:24,960 --> 00:23:23,200
what might happen experiments are much

603
00:23:26,910 --> 00:23:24,970
much more difficult in this case but

604
00:23:29,520 --> 00:23:26,920
calculations at least indicate the

605
00:23:30,930 --> 00:23:29,530
theoretical possibility but buzzell what

606
00:23:33,360 --> 00:23:30,940
is the difference between the two

607
00:23:35,580 --> 00:23:33,370
surfaces prevent what we're seeing here

608
00:23:37,740 --> 00:23:35,590
is just whether the kink sites basically

609
00:23:39,630 --> 00:23:37,750
come in from the left or the right so so

610
00:23:42,660 --> 00:23:39,640
if you have a crystal of a metal and you

611
00:23:44,820 --> 00:23:42,670
polish one surface if King sites are

612
00:23:46,680 --> 00:23:44,830
going to be facing this way and if you

613
00:23:47,940 --> 00:23:46,690

polish the opposite surface the King

614
00:23:50,130 --> 00:23:47,950
sites are facing the opposite direction

615
00:23:52,860 --> 00:23:50,140
they basically are mirror symmetry forms

616
00:23:55,200 --> 00:23:52,870
and as I showed in this this video you

617
00:23:57,750 --> 00:23:55,210
go to back look at the black versus the

618
00:23:59,220 --> 00:23:57,760
Red King structure those those two kinks

619
00:24:01,830 --> 00:23:59,230
represen the left and the right handed

620
00:24:03,950 --> 00:24:01,840
face can't superimpose on each other

621
00:24:05,970 --> 00:24:03,960
just like your two hands can superimpose

622
00:24:07,580 --> 00:24:05,980
so that's what we're talking about we

623
00:24:09,750 --> 00:24:07,590
say left in a right-handed face

624
00:24:11,640 --> 00:24:09,760
presumably if there's any selection

625
00:24:14,010 --> 00:24:11,650
right-handed molecules would go on one

626
00:24:15,750 --> 00:24:14,020
side left-handed molecules on the other

627
00:24:18,180 --> 00:24:15,760
side and that's what the calculations

628
00:24:20,550 --> 00:24:18,190
show with a preference of about half a

629
00:24:22,980 --> 00:24:20,560
kilocalorie per mole that's typical for

630
00:24:25,050 --> 00:24:22,990
for small molecules on these kinked

631
00:24:27,960 --> 00:24:25,060
surfaces and fundamentally makes it not

632
00:24:29,700 --> 00:24:27,970
be a just a regular corrugation um it's

633
00:24:31,770 --> 00:24:29,710
it's just because you have an offset of

634
00:24:34,920 --> 00:24:31,780
one versus two there are three different

635
00:24:35,680 --> 00:24:34,930
kinds of contacts between of clothes

636
00:24:38,379 --> 00:24:35,690
packed

637
00:24:40,090 --> 00:24:38,389
sphere and its neighbors and if you have

638
00:24:41,470 --> 00:24:40,100

one kind of contact this way a second

639
00:24:43,480 --> 00:24:41,480
kind of contact this way into third kind

640
00:24:45,639 --> 00:24:43,490
of contact this way that gives you a

641
00:24:48,220 --> 00:24:45,649
handed thing where the two halves are

642
00:24:50,499 --> 00:24:48,230
are mirror images that's the King sites

643
00:24:52,330 --> 00:24:50,509
basically our mirror image hair is just

644
00:24:54,249 --> 00:24:52,340
like holding your three fingers this way

645
00:24:57,399 --> 00:24:54,259
is here that's that's how they messing

646
00:24:59,860 --> 00:24:57,409
like and it's not not intuitively

647
00:25:01,600 --> 00:24:59,870
obvious I mean I just just in fact no

648
00:25:04,389 --> 00:25:01,610
mineralogist even thought about minerals

649
00:25:07,749 --> 00:25:04,399
in this way for prior to the work we've

650
00:25:10,480 --> 00:25:07,759
been doing so except for the case of

651
00:25:12,190 --> 00:25:10,490
quartz quartz is the one common

652
00:25:14,619 --> 00:25:12,200
rock-forming minerals it occurs in left

653
00:25:19,269 --> 00:25:14,629
and right-handed forms and the crystals

654
00:25:21,249 --> 00:25:19,279
actually show little forms where these

655
00:25:22,930 --> 00:25:21,259
are called window faces and if this

656
00:25:24,639 --> 00:25:22,940
little face goes up to the right of the

657
00:25:26,590 --> 00:25:24,649
right-handed crystal if this little base

658
00:25:28,600 --> 00:25:26,600
goes up to the left it's a left-handed

659
00:25:31,710 --> 00:25:28,610
crystal and the difference structurally

660
00:25:34,990 --> 00:25:31,720
is that they're sio for silicon

661
00:25:37,299 --> 00:25:35,000
tetrahedra that basically are connected

662
00:25:40,149 --> 00:25:37,309
in hela ceased and the helix can go to

663
00:25:41,470 --> 00:25:40,159

the left or it can go to the right so

664
00:25:44,200 --> 00:25:41,480
you have left and right-handed quartz

665
00:25:46,600 --> 00:25:44,210
crystals I've got an example here this

666
00:25:50,710 --> 00:25:46,610
happens to be a a left-handed crystal

667
00:25:52,450 --> 00:25:50,720
and these grow and perfusion and you can

668
00:25:53,860 --> 00:25:52,460
find fifty percent left-hand crystals

669
00:25:55,600 --> 00:25:53,870
the 50 years and right-handed crystals

670
00:25:57,070 --> 00:25:55,610
I'll pass this around so you have a

671
00:25:59,259 --> 00:25:57,080
chance of stuff they'll look more

672
00:26:01,269 --> 00:25:59,269
closely at the kinds of crystals and for

673
00:26:02,950 --> 00:26:01,279
almost a hundred years people use these

674
00:26:04,659 --> 00:26:02,960
and tragically what they do is they take

675
00:26:07,570 --> 00:26:04,669
the crystal and they powder them they

676
00:26:09,460 --> 00:26:07,580
crush them to a fine fine powder so

677
00:26:13,960 --> 00:26:09,470
you're increasing the surface area of

678
00:26:15,700 --> 00:26:13,970
your left or right handed crystal sounds

679
00:26:17,860 --> 00:26:15,710
good in principle I suppose but it's a

680
00:26:20,019 --> 00:26:17,870
terrible terrible thing to do not only

681
00:26:22,509 --> 00:26:20,029
does it destroy beautiful crystals which

682
00:26:24,279 --> 00:26:22,519
I hate to see as a mineralogist but also

683
00:26:25,769 --> 00:26:24,289
you're destroying all the information

684
00:26:28,930 --> 00:26:25,779
that you might get from the surface

685
00:26:30,850 --> 00:26:28,940
here's the specimen of course I

686
00:26:32,499 --> 00:26:30,860
collected when I was a teenager Paterson

687
00:26:34,509 --> 00:26:32,509
New Jersey as a mineral collector and i

688
00:26:37,180 --> 00:26:34,519

found this fascinating crystal which

689
00:26:39,100 --> 00:26:37,190
there are very faint coatings of iron

690
00:26:40,480 --> 00:26:39,110
oxide on different courts faces but if

691
00:26:41,629 --> 00:26:40,490
you look closely you'll see that some

692
00:26:44,209 --> 00:26:41,639
faces are coated in some

693
00:26:47,569 --> 00:26:44,219
are not ports as a trigonal mineral has

694
00:26:50,149 --> 00:26:47,579
threefold symmetry and the the 101 faces

695
00:26:52,399 --> 00:26:50,159
are coated the 011 faces are not

696
00:26:54,139 --> 00:26:52,409
indicating that different faces have

697
00:26:55,940 --> 00:26:54,149
different surface structures different

698
00:26:57,709 --> 00:26:55,950
absorption processes in terms of

699
00:26:59,299 --> 00:26:57,719
molecules it's just as likely to the

700
00:27:01,099 --> 00:26:59,309
left-handed molecule will be absorbed in

701
00:27:02,299 --> 00:27:01,109
one face and a right-handed molecule

702
00:27:04,249 --> 00:27:02,309
another face because they're completely

703
00:27:06,199 --> 00:27:04,259
different surface structures nothing

704
00:27:08,089 --> 00:27:06,209
intrinsically left-handed or

705
00:27:09,889 --> 00:27:08,099
right-handed about the faces it's just

706
00:27:12,199 --> 00:27:09,899
an arrangement of atoms and so you have

707
00:27:13,819 --> 00:27:12,209
to look at face by face you crush the

708
00:27:16,249 --> 00:27:13,829
crystal you destroy all the information

709
00:27:18,199 --> 00:27:16,259
so we don't do that we look at

710
00:27:20,359 --> 00:27:18,209
individual crystal faces and try to

711
00:27:22,459 --> 00:27:20,369
characterize those faces as carefully as

712
00:27:24,259 --> 00:27:22,469
we can here is the wonderful drawing by

713
00:27:25,699 --> 00:27:24,269

Steve Parker which sort of shows the

714
00:27:27,649 --> 00:27:25,709
quartz crystal whether it's different

715
00:27:30,889 --> 00:27:27,659
surface structures you can see that

716
00:27:33,619 --> 00:27:30,899
every face is a different termination

717
00:27:36,019 --> 00:27:33,629
with yellow oxygens and red silicon's

718
00:27:38,749 --> 00:27:36,029
I've been doing this as well here here

719
00:27:40,879 --> 00:27:38,759
we have oxygen shown in red the X is

720
00:27:42,680 --> 00:27:40,889
marked the atoms that are closest to the

721
00:27:45,199 --> 00:27:42,690
surface and you'll see that here's the

722
00:27:47,089 --> 00:27:45,209
termination of a quartz 100 face that's

723
00:27:50,329 --> 00:27:47,099
the prismatic faces of the courts and

724
00:27:53,359 --> 00:27:50,339
very interestingly those are not uniform

725
00:27:54,529 --> 00:27:53,369
heights where these oxygens intersect

726
00:27:56,119 --> 00:27:54,539
the surface you have quite a bit of

727
00:27:57,680 --> 00:27:56,129
topography so this is kind of an

728
00:28:00,079 --> 00:27:57,690
interesting surface of spiral and it

729
00:28:02,979 --> 00:28:00,089
also has docking sites and those sort of

730
00:28:06,649 --> 00:28:02,989
grooves and wedges on the surface but

731
00:28:10,639 --> 00:28:06,659
look at the 101 face this is the one

732
00:28:13,759 --> 00:28:10,649
that absorbs iron oxide it's a chiral

733
00:28:15,560 --> 00:28:13,769
mineral but the surface manifestation

734
00:28:16,879 --> 00:28:15,570
the atoms is very flat furthermore

735
00:28:19,579 --> 00:28:16,889
there's a mirror that runs right down

736
00:28:22,539 --> 00:28:19,589
the center that so this is not a chiral

737
00:28:25,190 --> 00:28:22,549
face even though it's a chiral mineral

738
00:28:29,269 --> 00:28:25,200

there's no point in studying the 101

739
00:28:31,639 --> 00:28:29,279
face with chiral molecules so it doesn't

740
00:28:33,529 --> 00:28:31,649
get you anything and here's the 01 one

741
00:28:35,180 --> 00:28:33,539
face and it's got some surface

742
00:28:37,219 --> 00:28:35,190
irregularities in the distribution of

743
00:28:38,930 --> 00:28:37,229
surface oxygen also is is slightly

744
00:28:40,940 --> 00:28:38,940
chiral but that's course court does not

745
00:28:42,289 --> 00:28:40,950
turns out not to be very interesting

746
00:28:44,560 --> 00:28:42,299
mineral in terms of its ability to

747
00:28:46,639 --> 00:28:44,570
separate left and right-handed molecules

748
00:28:48,680 --> 00:28:46,649
feldspar however is much more

749
00:28:51,169 --> 00:28:48,690
interesting feldspar is a very very

750
00:28:51,769 --> 00:28:51,179
common mineral here's a crystal that has

751
00:28:53,690 --> 00:28:51,779
these

752
00:28:55,339 --> 00:28:53,700
than right-handed faces hung mirror

753
00:28:57,979 --> 00:28:55,349
plane running right down the center here

754
00:28:59,299 --> 00:28:57,989
gives you two faces with mirror image

755
00:29:01,190 --> 00:28:59,309
and perhaps left the right-handed

756
00:29:05,409 --> 00:29:01,200
molecules could be separated on a face

757
00:29:07,940 --> 00:29:05,419
like this when we look at that quartz

758
00:29:09,560 --> 00:29:07,950
crystal structure you see that there's

759
00:29:12,379 --> 00:29:09,570
quite a bit of surface topography and

760
00:29:14,450 --> 00:29:12,389
furthermore some of these blue atoms

761
00:29:17,839 --> 00:29:14,460
those are an alkali atoms it could be a

762
00:29:21,109 --> 00:29:17,849
potassium or sodium or calcium in the

763
00:29:22,999 --> 00:29:21,119

case of a plan Jake place felt smart you

764
00:29:24,799 --> 00:29:23,009
get both positive and negative bonding

765
00:29:26,839 --> 00:29:24,809
centers close to the surface so there's

766
00:29:28,369 --> 00:29:26,849
a much more interesting bonding

767
00:29:29,659 --> 00:29:28,379
environment and feldspar so this is

768
00:29:31,849 --> 00:29:29,669
something we want to look closely yeah

769
00:29:35,899 --> 00:29:31,859
diopside the communists mineral

770
00:29:37,869 --> 00:29:35,909
magnesium and iron has also some service

771
00:29:40,849 --> 00:29:37,879
irregular Aryan also has both positive

772
00:29:42,950 --> 00:29:40,859
calcium's and/or magnesium and a

773
00:29:44,989 --> 00:29:42,960
negative oxygen atoms near the surface

774
00:29:46,549 --> 00:29:44,999
quite a bit of topography again very

775
00:29:49,099 --> 00:29:46,559
interesting bonding environments for

776
00:29:52,940 --> 00:29:49,109
organic molecules and my favorite the

777
00:29:55,489 --> 00:29:52,950
mineral that is so important in terms of

778
00:29:58,129 --> 00:29:55,499
biomineralization forming shells of

779
00:30:01,249 --> 00:29:58,139
clams and snails and the kind of germs

780
00:30:04,609 --> 00:30:01,259
and all sorts of things calcite and

781
00:30:09,259 --> 00:30:04,619
calcite the common is crystal form this

782
00:30:12,109 --> 00:30:09,269
214 faces you see here typically you'll

783
00:30:14,989 --> 00:30:12,119
get a crystal that comes to a point like

784
00:30:18,169 --> 00:30:14,999
this and there are six of these faces

785
00:30:19,700 --> 00:30:18,179
that form coming to that point three of

786
00:30:21,229 --> 00:30:19,710
those faces are left handed three of

787
00:30:24,680 --> 00:30:21,239
them are right handed and the surface

788
00:30:28,310 --> 00:30:24,690

structure is very strongly chiral that

789
00:30:30,289 --> 00:30:28,320
is DB ace strongly from any mirror

790
00:30:31,940 --> 00:30:30,299
symmetry you have both positive calcium

791
00:30:33,950 --> 00:30:31,950
atoms negative oxygen atoms near the

792
00:30:36,229 --> 00:30:33,960
surface you also have a very strong

793
00:30:38,930 --> 00:30:36,239
topography with grooves that are about

794
00:30:41,479 --> 00:30:38,940
to long strums deep running along the

795
00:30:43,669 --> 00:30:41,489
surface all those crystals and this

796
00:30:45,859 --> 00:30:43,679
makes incredible docking sites for

797
00:30:49,089 --> 00:30:45,869
organic molecules we have positive and

798
00:30:52,519 --> 00:30:49,099
negative charges distributed in a very

799
00:30:57,320 --> 00:30:52,529
asymmetric non mirror symmetry way plus

800
00:30:59,060 --> 00:30:57,330
grooves which the ducklings so cal say

801
00:31:00,589 --> 00:30:59,070
it becomes extremely interesting now I

802
00:31:01,670 --> 00:31:00,599
can sort of describe these in a

803
00:31:03,260 --> 00:31:01,680
qualitative sense

804
00:31:05,690 --> 00:31:03,270
but it's much more interesting to be

805
00:31:07,820 --> 00:31:05,700
able to quantify the degree to which the

806
00:31:09,500 --> 00:31:07,830
surface might be able to select chiral

807
00:31:12,620 --> 00:31:09,510
molecules and so we have developed

808
00:31:16,670 --> 00:31:12,630
what's called a chiral index an index of

809
00:31:19,280 --> 00:31:16,680
space this is when you have a structure

810
00:31:22,250 --> 00:31:19,290
surface structure and you fold it on top

811
00:31:24,590 --> 00:31:22,260
of itself how closely do they fit

812
00:31:26,870 --> 00:31:24,600
together they match precisely in which

813
00:31:28,850 --> 00:31:26,880

case the chiral index is 0 do they

814
00:31:31,190 --> 00:31:28,860
mismatch a lot in which case the

815
00:31:33,380 --> 00:31:31,200
chironex gets larger if you have a

816
00:31:36,110 --> 00:31:33,390
mirror symmetry as in the calcite 10

817
00:31:37,760 --> 00:31:36,120
force surface you see here the chiral

818
00:31:40,960 --> 00:31:37,770
index is 0 because there is a mirror

819
00:31:44,420 --> 00:31:40,970
symmetry built in but if you have a very

820
00:31:47,300 --> 00:31:44,430
non mirror symmetric Seraph surface like

821
00:31:48,920 --> 00:31:47,310
the calcite 214 the surfaces don't match

822
00:31:50,480 --> 00:31:48,930
at all when you fold it over and so you

823
00:31:53,870 --> 00:31:50,490
have a high chiral index since you can

824
00:31:55,670 --> 00:31:53,880
quantify these either these are all

825
00:31:57,890 --> 00:31:55,680
chiral indices they're given an options

826
00:32:00,200 --> 00:31:57,900
that has to do with how closely adams

827
00:32:02,510 --> 00:32:00,210
when you fold things over match with

828
00:32:04,490 --> 00:32:02,520
each other and the average displacement

829
00:32:08,320 --> 00:32:04,500
tells you in op Strom's the average

830
00:32:10,700 --> 00:32:08,330
distance between the mirror image pairs

831
00:32:13,160 --> 00:32:10,710
the maximum displacement tells you the

832
00:32:16,570 --> 00:32:13,170
maximum displacement of an atom when you

833
00:32:20,210 --> 00:32:16,580
fold it over on itself you see quartz

834
00:32:23,330 --> 00:32:20,220
here it's 0 point four point five not a

835
00:32:25,130 --> 00:32:23,340
very high chiral index copper or the

836
00:32:27,260 --> 00:32:25,140
metal is much much better that's what

837
00:32:29,240 --> 00:32:27,270
the chemical engineers use so they see

838
00:32:31,400 --> 00:32:29,250

an average displacement of point eight

839
00:32:34,070 --> 00:32:31,410
for August rims and a maximum

840
00:32:36,230 --> 00:32:34,080
displacement in almost 1.3 but look at

841
00:32:39,020 --> 00:32:36,240
calcite this is the highest chiral index

842
00:32:40,640 --> 00:32:39,030
of any material we've seen much higher

843
00:32:42,980 --> 00:32:40,650
than that of metals and makes this an

844
00:32:44,630 --> 00:32:42,990
extremely interesting material not only

845
00:32:46,280 --> 00:32:44,640
for origin of life studies and just

846
00:32:48,680 --> 00:32:46,290
other basic stays in chirality but also

847
00:32:51,260 --> 00:32:48,690
for industrial processes that you can

848
00:32:52,640 --> 00:32:51,270
get a surface like calcite to select the

849
00:32:55,280 --> 00:32:52,650
molecule that you want you're going to

850
00:32:57,170 --> 00:32:55,290
have a very good selection indeed so

851
00:32:59,840 --> 00:32:57,180
basically conclusions there are lots of

852
00:33:03,020 --> 00:32:59,850
chiral mineral surfaces in nature indeed

853
00:33:05,660 --> 00:33:03,030
any rock that you see on the ocean floor

854
00:33:06,909 --> 00:33:05,670
anytime you split open a rock it's just

855
00:33:08,950 --> 00:33:06,919
loaded the chiral

856
00:33:11,619 --> 00:33:08,960
kisses are all over it so Carl surfaces

857
00:33:14,349 --> 00:33:11,629
are everywhere yes but given that

858
00:33:19,060 --> 00:33:14,359
different services have different car

859
00:33:21,430 --> 00:33:19,070
allottee disease what fraction of the

860
00:33:23,320 --> 00:33:21,440
surface area is like that one face it

861
00:33:25,419 --> 00:33:23,330
could be a tiny little basically partly

862
00:33:29,310 --> 00:33:25,429
it's really going to depend on the rock

863
00:33:31,509 --> 00:33:29,320

and the rocks fabric but in many cases

864
00:33:34,029 --> 00:33:31,519
you're going to find that more than half

865
00:33:37,330 --> 00:33:34,039
of the surface this expose will be your

866
00:33:38,979 --> 00:33:37,340
chiral in fact the majority of surfaces

867
00:33:40,450 --> 00:33:38,989
unless you have a crystal growth face

868
00:33:42,279 --> 00:33:40,460
that happens to have a mirror symmetry

869
00:33:44,289 --> 00:33:42,289
running right down to the majority of

870
00:33:45,849 --> 00:33:44,299
growth surfaces and the majority of

871
00:33:48,820 --> 00:33:45,859
fracture surfaces are going to be chiral

872
00:33:52,060 --> 00:33:48,830
so if you have a porous rock you talking

873
00:33:53,799 --> 00:33:52,070
about huge areas of chiral surfaces on

874
00:33:56,289 --> 00:33:53,809
which you can do absorption experiments

875
00:34:01,029 --> 00:33:56,299
this is a really significant part of the

876
00:34:03,070 --> 00:34:01,039
natural environment it's interesting to

877
00:34:05,229 --> 00:34:03,080
meet the intrinsically chiral surfaces

878
00:34:07,359 --> 00:34:05,239
of quartz possess relatively low chiral

879
00:34:09,549 --> 00:34:07,369
indices and make quartz less interesting

880
00:34:11,740 --> 00:34:09,559
than some other minerals whereas in

881
00:34:14,049 --> 00:34:11,750
oxides and silicates you see much much

882
00:34:16,539 --> 00:34:14,059
larger car indices if you have both

883
00:34:18,369 --> 00:34:16,549
positive and negative Lee charged atoms

884
00:34:19,659 --> 00:34:18,379
near the surface as you do at a calcite

885
00:34:24,099 --> 00:34:19,669
is you doin diopside as you do in

886
00:34:26,020 --> 00:34:24,109
feldspar and also the relatively large

887
00:34:28,690 --> 00:34:26,030
chiral indices are often associated with

888
00:34:30,760 --> 00:34:28,700

stepped and king structures as we see in

889
00:34:32,619 --> 00:34:30,770
the metals but this also means that in

890
00:34:34,720 --> 00:34:32,629
the real world when you have natural

891
00:34:36,669 --> 00:34:34,730
growth features on the mineral natural

892
00:34:38,950 --> 00:34:36,679
minerals are not perfectly flat they

893
00:34:41,230 --> 00:34:38,960
have helix they have etch pits they have

894
00:34:43,329 --> 00:34:41,240
all these surface topographies and those

895
00:34:45,760 --> 00:34:43,339
may be far more important in this

896
00:34:47,470 --> 00:34:45,770
process even than the idealized surfaces

897
00:34:49,270 --> 00:34:47,480
that I'm going to be talking about for

898
00:34:51,190 --> 00:34:49,280
much of today's talk so that keep that

899
00:34:53,379 --> 00:34:51,200
in mind that that we recognize there's

900
00:34:56,680 --> 00:34:53,389
all kinds of chiral environments

901
00:34:57,760 --> 00:34:56,690
microenvironments mineral surfaces now I

902
00:34:59,530 --> 00:34:57,770
want to talk about briefly the

903
00:35:00,940 --> 00:34:59,540
experiments I've done in Kyra mental

904
00:35:03,160 --> 00:35:00,950
mineral selection and this we're done

905
00:35:05,170 --> 00:35:03,170
with my dear friend Glenn good

906
00:35:07,780 --> 00:35:05,180
friend he was a lifelong collaborator

907
00:35:12,789 --> 00:35:07,790
with Steve cool and many other noble

908
00:35:14,890 --> 00:35:12,799
people both Glennon's Steve died about

909
00:35:16,180 --> 00:35:14,900
three years ago and we were in the

910
00:35:18,760 --> 00:35:16,190
middle of these experiments and it was

911
00:35:20,680 --> 00:35:18,770
really a tragic loss for science for

912
00:35:24,010 --> 00:35:20,690
both his people but glendon particular

913
00:35:26,260 --> 00:35:24,020

heum he was a master at analyzing left

914
00:35:28,839 --> 00:35:26,270
and right-handed amino acid mixtures and

915
00:35:30,520 --> 00:35:28,849
getting Precision's and accuracies and

916
00:35:32,799 --> 00:35:30,530
his measurements that no one else I've

917
00:35:35,650 --> 00:35:32,809
ever seen has been able to match truly

918
00:35:37,839 --> 00:35:35,660
astonishing I give him blanks and in all

919
00:35:40,210 --> 00:35:37,849
sorts of sort of test cases just slip

920
00:35:42,880 --> 00:35:40,220
them into my runs and it was amazing how

921
00:35:45,309 --> 00:35:42,890
he was you know 20 right in all his

922
00:35:47,319 --> 00:35:45,319
experiments he was just a master at this

923
00:35:48,549 --> 00:35:47,329
analysis what we did is we took calcite

924
00:35:50,170 --> 00:35:48,559
crystals much like the one that's

925
00:35:52,809 --> 00:35:50,180
passing around took the crystal dumped

926
00:35:54,849 --> 00:35:52,819
it into a beaker it has a 50-50 mixture

927
00:35:57,940 --> 00:35:54,859
of left and right-handed aspartic acid

928
00:36:00,609 --> 00:35:57,950
that's an amino acid that is known to

929
00:36:02,380 --> 00:36:00,619
absorb strongly on the calcite we let it

930
00:36:05,650 --> 00:36:02,390
sit overnight we pulled a crystal out we

931
00:36:07,150 --> 00:36:05,660
wash it off we then have six phases

932
00:36:09,490 --> 00:36:07,160
coming to a point three or left handed

933
00:36:11,589 --> 00:36:09,500
to your right hand meticulously take a

934
00:36:14,950 --> 00:36:11,599
pipette this is all done in clean rooms

935
00:36:16,780 --> 00:36:14,960
with with total body covering is the

936
00:36:18,990 --> 00:36:16,790
slightest contamination will skew our

937
00:36:20,859 --> 00:36:19,000
results carefully put a little bit of

938
00:36:23,170 --> 00:36:20,869

hydrochloric acid on each surface

939
00:36:25,480 --> 00:36:23,180
pipetted off print in a vial and then

940
00:36:27,880 --> 00:36:25,490
one by one analyze those surfaces repeat

941
00:36:29,380 --> 00:36:27,890
that three times on multiple crystals

942
00:36:31,059 --> 00:36:29,390
over and over again to make sure we're

943
00:36:32,710 --> 00:36:31,069
not somehow fooling ourselves that we're

944
00:36:35,680 --> 00:36:32,720
seeing in effect do we hope to see

945
00:36:38,289 --> 00:36:35,690
here's when it blends GC analyses what

946
00:36:40,599 --> 00:36:38,299
you see here is the baseline and the

947
00:36:42,520 --> 00:36:40,609
aspartic acid doublet blowing that up

948
00:36:44,770 --> 00:36:42,530
you see how clean is baseline wise you

949
00:36:46,359 --> 00:36:44,780
see the separation about 15 seconds for

950
00:36:48,579 --> 00:36:46,369
the left and the right handed aspartic

951
00:36:51,400 --> 00:36:48,589
acid and it's the area ratio of those

952
00:36:54,670 --> 00:36:51,410
two peaks that tells you the d2l ratio

953
00:36:56,380 --> 00:36:54,680
of left right-handed amino acids here

954
00:36:58,270 --> 00:36:56,390
are the results of one set of

955
00:37:01,030 --> 00:36:58,280
experiments and what you see here is

956
00:37:03,010 --> 00:37:01,040
kind of an unusual graph you see six

957
00:37:04,990 --> 00:37:03,020
vertical column is representing six

958
00:37:07,870 --> 00:37:05,000
phases coming to a point on the crystal

959
00:37:12,549 --> 00:37:07,880
three of them are right-handed the other

960
00:37:13,700 --> 00:37:12,559
three are left handed we measure the d2l

961
00:37:16,670 --> 00:37:13,710
ratio

962
00:37:20,660 --> 00:37:16,680
the solution itself is very close to one

963
00:37:24,020 --> 00:37:20,670

a 50-50 mixture so this would be XML

964
00:37:27,650 --> 00:37:24,030
bebs x SD the key here is we start with

965
00:37:28,849 --> 00:37:27,660
a 50-50 mixture have we seen an LX s on

966
00:37:31,700 --> 00:37:28,859
a few crystals that would mean

967
00:37:33,829 --> 00:37:31,710
absolutely nothing because the entire

968
00:37:35,900 --> 00:37:33,839
environment of our laboratory of our

969
00:37:37,849 --> 00:37:35,910
lives is contaminated with l-amino acids

970
00:37:41,420 --> 00:37:37,859
what we need to see is an equal and

971
00:37:44,359 --> 00:37:41,430
opposite separation of DX s on one set

972
00:37:46,370 --> 00:37:44,369
of faces and lxs on the other set of

973
00:37:49,060 --> 00:37:46,380
faces without that equal opposite

974
00:37:51,530 --> 00:37:49,070
separation there is no result here

975
00:37:54,680 --> 00:37:51,540
furthermore we ran many tests on

976
00:37:56,630 --> 00:37:54,690
cleavage planes which have no Cairo bias

977
00:37:58,790 --> 00:37:56,640
and those all better come out very close

978
00:38:00,920 --> 00:37:58,800
to that horizontal line or again we're

979
00:38:03,260 --> 00:38:00,930
fooling ourselves so what we found

980
00:38:05,990 --> 00:38:03,270
systematically over and over again is a

981
00:38:08,690 --> 00:38:06,000
slight excess of d-amino acids on the

982
00:38:11,359 --> 00:38:08,700
right-handed faces a slight excess of

983
00:38:12,710 --> 00:38:11,369
l-amino acids on the left-handed faces

984
00:38:14,930 --> 00:38:12,720
and this paper which was published at

985
00:38:16,910 --> 00:38:14,940
pnas some years ago is the first

986
00:38:18,980 --> 00:38:16,920
experimental demonstration of the

987
00:38:22,579 --> 00:38:18,990
separation of left and right-handed

988
00:38:23,930 --> 00:38:22,589

molecules on a crystal and face you

989
00:38:26,839 --> 00:38:23,940
subsequently done this in a number of

990
00:38:28,730 --> 00:38:26,849
other minerals and molecule pairs but

991
00:38:32,450 --> 00:38:28,740
the conclusions is that we can separate

992
00:38:34,220 --> 00:38:32,460
left and right-handed molecules we see

993
00:38:36,020 --> 00:38:34,230
the separation of aspartic acid on

994
00:38:37,970 --> 00:38:36,030
calcite but we do not see a similar

995
00:38:40,430 --> 00:38:37,980
separation of either glutamic acid or

996
00:38:43,460 --> 00:38:40,440
alanine on calcium so the question is

997
00:38:46,130 --> 00:38:43,470
why do we see one and not the other the

998
00:38:48,920 --> 00:38:46,140
maximum absorption also occurs on faces

999
00:38:50,540 --> 00:38:48,930
that have terraces or steps it makes us

1000
00:38:53,030 --> 00:38:50,550
wonder whether the effect we're seeing

1001
00:38:56,570 --> 00:38:53,040
might not be amplified by step edges

1002
00:38:59,030 --> 00:38:56,580
where these molecules may be nestled in

1003
00:39:00,589 --> 00:38:59,040
along a specific linear feature which is

1004
00:39:03,530 --> 00:39:00,599
really interesting because of course if

1005
00:39:05,030 --> 00:39:03,540
you will lie in amino acids and then can

1006
00:39:06,920 --> 00:39:05,040
bond them together then you form a

1007
00:39:08,870 --> 00:39:06,930
peptide chain and it's the chains going

1008
00:39:11,079 --> 00:39:08,880
to be homo chiral all the same chirality

1009
00:39:14,120 --> 00:39:11,089
so that's a very interesting possibility

1010
00:39:16,250 --> 00:39:14,130
okay so now the third step is to model

1011
00:39:17,780 --> 00:39:16,260
these experimental not experiment but

1012
00:39:19,579 --> 00:39:17,790
theoretically trying to understand how

1013
00:39:21,560 --> 00:39:19,589

the molecules are nestling in on the

1014
00:39:23,360 --> 00:39:21,570
surface why would you get

1015
00:39:25,340 --> 00:39:23,370
candidate aspartic acid is bonding to a

1016
00:39:27,470 --> 00:39:25,350
face but not right-handed aspartic acid

1017
00:39:29,630 --> 00:39:27,480
and that's what we want to find out so

1018
00:39:31,910 --> 00:39:29,640
we're basically going to use density

1019
00:39:33,590 --> 00:39:31,920
functional theory experiments can't

1020
00:39:36,530 --> 00:39:33,600
really help us about the details of the

1021
00:39:39,020 --> 00:39:36,540
molecular interactions and this kind of

1022
00:39:41,330 --> 00:39:39,030
modeling then is is what I'll be

1023
00:39:43,250 --> 00:39:41,340
describing in this section this is work

1024
00:39:46,730 --> 00:39:43,260
done with air vanessa giri who is a

1025
00:39:48,170 --> 00:39:46,740
graduate student at Carnegie Mellon and

1026
00:39:49,790 --> 00:39:48,180
the chemical engineering department then

1027
00:39:51,980 --> 00:39:49,800
came to work with me as a postdoc and

1028
00:39:55,070 --> 00:39:51,990
now as a professor at University of

1029
00:39:57,680 --> 00:39:55,080
Florida what you do is you start with a

1030
00:40:00,310 --> 00:39:57,690
model this is a model that's generated

1031
00:40:02,750 --> 00:40:00,320
by computer in which you have an alanine

1032
00:40:05,030 --> 00:40:02,760
molecule for example floating above a

1033
00:40:06,950 --> 00:40:05,040
calcite surface is an idealized calcite

1034
00:40:08,720 --> 00:40:06,960
surface and with density functional

1035
00:40:10,550 --> 00:40:08,730
theory you model the basically the

1036
00:40:12,380 --> 00:40:10,560
behavior of all the electrons in this

1037
00:40:14,270 --> 00:40:12,390
system except for the core electrons

1038
00:40:15,830 --> 00:40:14,280

which are treated by pseudopotential so

1039
00:40:18,860 --> 00:40:15,840
basically you allow the whole system

1040
00:40:21,080 --> 00:40:18,870
that to minimize its energy it's a very

1041
00:40:23,030 --> 00:40:21,090
time-consuming process it involves a lot

1042
00:40:25,730 --> 00:40:23,040
of computer code parabens and expert in

1043
00:40:27,200 --> 00:40:25,740
this and this is what he found so we use

1044
00:40:28,820 --> 00:40:27,210
this first principle methods we're by

1045
00:40:30,980 --> 00:40:28,830
the way we're ignoring water in this

1046
00:40:33,740 --> 00:40:30,990
particular experiment which one can

1047
00:40:35,720 --> 00:40:33,750
argue actually makes the modeling not

1048
00:40:37,850 --> 00:40:35,730
necessarily valid for our aqueous

1049
00:40:39,530 --> 00:40:37,860
solutions but what we find over and over

1050
00:40:41,510 --> 00:40:39,540
again is that the amino acids are in

1051
00:40:43,940 --> 00:40:41,520
fact bonding primarily to the surface

1052
00:40:46,850 --> 00:40:43,950
not through any intermediate hydroxides

1053
00:40:48,740 --> 00:40:46,860
or hydrogen so so we think that this

1054
00:40:50,990 --> 00:40:48,750
does give us a valid picture of what's

1055
00:40:52,760 --> 00:40:51,000
going on and we have to look at numerous

1056
00:40:54,290 --> 00:40:52,770
plausible configurations you have to

1057
00:40:56,990 --> 00:40:54,300
start with the molecule in all sorts of

1058
00:40:59,210 --> 00:40:57,000
orientations above the crystal surface

1059
00:41:00,410 --> 00:40:59,220
in all different places and so we sort

1060
00:41:02,270 --> 00:41:00,420
of have to have an intuition of what

1061
00:41:04,100 --> 00:41:02,280
might be a plausible starting point and

1062
00:41:05,600 --> 00:41:04,110
then you minimize those so we looked at

1063
00:41:07,880 --> 00:41:05,610

dozens and dozens of plausible

1064
00:41:10,630 --> 00:41:07,890
configurations and really quickly zeroed

1065
00:41:14,240 --> 00:41:10,640
in what were the logical bonding sites

1066
00:41:16,880 --> 00:41:14,250
for an amino acid on a calcite surface

1067
00:41:19,610 --> 00:41:16,890
we find all the stable configurations

1068
00:41:21,680 --> 00:41:19,620
involve farming strong calcium oxygen

1069
00:41:25,130 --> 00:41:21,690
bonds calcium of the calcite to an

1070
00:41:30,720 --> 00:41:28,620
okay so you begin by taking a deal any

1071
00:41:33,960 --> 00:41:30,730
molecule bring it to an unreal act

1072
00:41:35,850 --> 00:41:33,970
surface and then you find in the final

1073
00:41:38,990 --> 00:41:35,860
configuration that you're forming two

1074
00:41:44,280 --> 00:41:39,000
strong bonds one oxygen hydrogen bond

1075
00:41:46,680 --> 00:41:44,290
that's from here to here the other in

1076
00:41:48,690 --> 00:41:46,690
calcium oxygen bond from here to here

1077
00:41:51,090 --> 00:41:48,700
and this is how Allen comes to the

1078
00:41:53,550 --> 00:41:51,100
surface notice also the relaxation in

1079
00:41:57,180 --> 00:41:53,560
the calcite surface here's for example a

1080
00:41:59,310 --> 00:41:57,190
co 3 group and see how it rotates see

1081
00:42:01,890 --> 00:41:59,320
also that the calcium atoms which are

1082
00:42:03,510 --> 00:42:01,900
aligned here become staggered over here

1083
00:42:08,970 --> 00:42:03,520
this all has to do with the interaction

1084
00:42:10,830 --> 00:42:08,980
the molecule and the surface so so it

1085
00:42:13,560 --> 00:42:10,840
rotates around just to accommodate the

1086
00:42:15,390 --> 00:42:13,570
size of the missus basing a legit

1087
00:42:17,460 --> 00:42:15,400
because you particles yes and if you go

1088
00:42:19,320 --> 00:42:17,470

down two unit cells there's no

1089
00:42:21,180 --> 00:42:19,330
distortion of the calcite to speak of

1090
00:42:23,100 --> 00:42:21,190
it's only right at the surface that when

1091
00:42:25,800 --> 00:42:23,110
the molecule comes in it causes this

1092
00:42:27,750 --> 00:42:25,810
surface distortion rotation right at the

1093
00:42:28,920 --> 00:42:27,760
surface area so so this is the kind of

1094
00:42:30,960 --> 00:42:28,930
interaction which has been well

1095
00:42:33,390 --> 00:42:30,970
documented other materials is not at all

1096
00:42:36,540 --> 00:42:33,400
surprising but here is a particular

1097
00:42:40,980 --> 00:42:36,550
docking site of alanine onto a calcite

1098
00:42:43,560 --> 00:42:40,990
214 surface and here is why you don't

1099
00:42:46,140 --> 00:42:43,570
get cairo selection here's the deal

1100
00:42:49,950 --> 00:42:46,150
inning and an l alanine bonded to this

1101
00:42:52,040 --> 00:42:49,960
two and four surface two bonds for the d

1102
00:42:54,570 --> 00:42:52,050
alanine two bonds for the ln e

1103
00:42:56,760 --> 00:42:54,580
essentially identical configurations and

1104
00:42:59,640 --> 00:42:56,770
this is just as if you took your thumb

1105
00:43:03,000 --> 00:42:59,650
and forefinger and trying to touch a

1106
00:43:04,650 --> 00:43:03,010
surface they're identical the energies

1107
00:43:07,920 --> 00:43:04,660
are identical there's no difference and

1108
00:43:09,570 --> 00:43:07,930
you could pick up an object with these

1109
00:43:11,580 --> 00:43:09,580
two fingers of these fingers equally

1110
00:43:13,740 --> 00:43:11,590
well so there's no preference of a left

1111
00:43:15,870 --> 00:43:13,750
or right-handed molecule here now look

1112
00:43:18,930 --> 00:43:15,880
at aspartic acid totally different

1113
00:43:21,360 --> 00:43:18,940

situation the d aspartic acid bonds to

1114
00:43:24,120 --> 00:43:21,370
that calcite surface with three strong

1115
00:43:25,980 --> 00:43:24,130
bonds and in the two of them are calcium

1116
00:43:28,530 --> 00:43:25,990
oxygen bonds because of a fortuitous

1117
00:43:30,090 --> 00:43:28,540
spacing between this oxygen and this

1118
00:43:34,520 --> 00:43:30,100
oxygen compared to the two adjacent

1119
00:43:36,900 --> 00:43:34,530
calcium's and there's the third bottle

1120
00:43:40,890 --> 00:43:36,910
but if you have a left-handed aspartic

1121
00:43:43,470 --> 00:43:40,900
acid only two strong bonds form and

1122
00:43:45,570 --> 00:43:43,480
here's the key to chiral selection Carol

1123
00:43:48,360 --> 00:43:45,580
selection is like the classic problem of

1124
00:43:50,370 --> 00:43:48,370
a bowling ball if you go bowling you

1125
00:43:51,960 --> 00:43:50,380
can't if you're right-handed you can't

1126
00:43:54,060 --> 00:43:51,970
use the left-handed bowling ball there

1127
00:43:56,460 --> 00:43:54,070
three holes and they're not aligned

1128
00:43:59,250 --> 00:43:56,470
their non-collinear so this is a right

1129
00:44:04,160 --> 00:43:59,260
hand this is a left hand it turns out

1130
00:44:08,160 --> 00:44:04,170
just purely by fortuitous coincidence

1131
00:44:11,910 --> 00:44:08,170
you have a three strong charge centers

1132
00:44:13,470 --> 00:44:11,920
on the aspartic acid that match three

1133
00:44:16,470 --> 00:44:13,480
charge centers in the surface of the

1134
00:44:18,390 --> 00:44:16,480
calcite to 14 surface so the d aspartic

1135
00:44:21,210 --> 00:44:18,400
acid sticks really strongly to the

1136
00:44:24,030 --> 00:44:21,220
surface the AL aspartic acid not so much

1137
00:44:27,570 --> 00:44:24,040
and here we have an eight kilocalorie

1138
00:44:29,580 --> 00:44:27,580

per mole difference in bonding energy so

1139
00:44:31,440 --> 00:44:29,590
in terms of these particular sites at

1140
00:44:33,380 --> 00:44:31,450
room temperature that will correspond to

1141
00:44:35,640 --> 00:44:33,390
a ninety-nine point nine percent

1142
00:44:38,340 --> 00:44:35,650
preferential selection of one handedness

1143
00:44:40,080 --> 00:44:38,350
over the other we don't see that because

1144
00:44:42,030 --> 00:44:40,090
of their other experimental effects that

1145
00:44:43,980 --> 00:44:42,040
come into play with solutions and small

1146
00:44:45,600 --> 00:44:43,990
amounts of solution being left over and

1147
00:44:47,490 --> 00:44:45,610
so forth but in terms of cairo

1148
00:44:50,220 --> 00:44:47,500
selectivity this is by far the strongest

1149
00:44:51,570 --> 00:44:50,230
effect ever seen certainly in a

1150
00:44:53,670 --> 00:44:51,580
calculation and we think we can

1151
00:44:55,800 --> 00:44:53,680
understand in detail first of all why

1152
00:44:58,710 --> 00:44:55,810
alanine doesn't show chiral selection

1153
00:45:00,990 --> 00:44:58,720
Weiss partic does and why this is a very

1154
00:45:03,870 --> 00:45:01,000
strong effect so the conclusion is that

1155
00:45:05,850 --> 00:45:03,880
we can model the chiral interaction that

1156
00:45:09,600 --> 00:45:05,860
requires three strong points of

1157
00:45:11,640 --> 00:45:09,610
interaction that are non-collinear we

1158
00:45:13,890 --> 00:45:11,650
can see which molecule sticks to which

1159
00:45:15,720 --> 00:45:13,900
surface but it's idiosyncratic it has to

1160
00:45:19,050 --> 00:45:15,730
do just with a fortuitous distribution

1161
00:45:19,920 --> 00:45:19,060
of charge centers on the surface and now

1162
00:45:21,780 --> 00:45:19,930
we're going to look at a general

1163
00:45:23,640 --> 00:45:21,790

research strategy because I'll tell you

1164
00:45:25,950 --> 00:45:23,650
life is too short to take calcite

1165
00:45:28,290 --> 00:45:25,960
crystals and dump them into aspartic

1166
00:45:30,390 --> 00:45:28,300
acid and then dumped it into alanine and

1167
00:45:32,460 --> 00:45:30,400
then dump them into mutant macasaet this

1168
00:45:35,280 --> 00:45:32,470
experiment takes weeks or months the

1169
00:45:37,260 --> 00:45:35,290
analysis of each individual sample is

1170
00:45:39,120 --> 00:45:37,270
very meticulous we needed to find a

1171
00:45:43,380 --> 00:45:39,130
simpler way and so what we're going to

1172
00:45:45,599 --> 00:45:43,390
do is a combinatorial using microarray

1173
00:45:46,979 --> 00:45:45,609
technology my colleagues that Carney

1174
00:45:49,499 --> 00:45:46,989
you have helped me with this Jake mall

1175
00:45:51,989 --> 00:45:49,509
Andrew Steele Rebecca Martin all of whom

1176
00:45:53,609 --> 00:45:51,999
how training in the biological sciences

1177
00:45:55,620 --> 00:45:53,619
and here's a great place where

1178
00:45:58,109 --> 00:45:55,630
interdisciplinary research has paid off

1179
00:46:01,079 --> 00:45:58,119
chip writers our devices that have been

1180
00:46:03,029 --> 00:46:01,089
typically used to study different DNA

1181
00:46:06,569 --> 00:46:03,039
sequences or proteins and their

1182
00:46:08,700 --> 00:46:06,579
interaction the reactivity and so forth

1183
00:46:09,989 --> 00:46:08,710
this is the very important technology

1184
00:46:12,359 --> 00:46:09,999
that's coming along and medical

1185
00:46:14,009 --> 00:46:12,369
diagnosis and you will soon be able to

1186
00:46:16,589 --> 00:46:14,019
go to your doctor and he will have chips

1187
00:46:19,319 --> 00:46:16,599
that contain millions upon millions of

1188
00:46:21,749 --> 00:46:19,329

targeted DNA sequences that for example

1189
00:46:23,489 --> 00:46:21,759
relate to specific genetic diseases and

1190
00:46:25,950 --> 00:46:23,499
see whether you've got them are what you

1191
00:46:29,069 --> 00:46:25,960
don't but we can do is we could take up

1192
00:46:30,900 --> 00:46:29,079
to 126 one centimeter square chips and

1193
00:46:33,630 --> 00:46:30,910
minerals on each of those minerals we

1194
00:46:36,720 --> 00:46:33,640
can put up to forty nine thousand plus

1195
00:46:39,180 --> 00:46:36,730
spots tiny spots 100 microns in diameter

1196
00:46:42,059 --> 00:46:39,190
array them on the surface drawing from

1197
00:46:43,680 --> 00:46:42,069
up the 96 different wells so one could

1198
00:46:45,029 --> 00:46:43,690
have a spot left handed aspartic acid

1199
00:46:46,529 --> 00:46:45,039
one could have right in and aspartic

1200
00:46:48,120 --> 00:46:46,539
acid and all the other amino acids and

1201
00:46:50,609 --> 00:46:48,130
the pentose sugar is in the carboxylic

1202
00:46:52,170 --> 00:46:50,619
acids and whatever else you want lots of

1203
00:46:53,370 --> 00:46:52,180
different small molecules and on each of

1204
00:46:56,489 --> 00:46:53,380
these different mineral chips you can

1205
00:46:58,200 --> 00:46:56,499
array a series of spots varying in

1206
00:47:00,660 --> 00:46:58,210
concentration perhaps mixing different

1207
00:47:04,259 --> 00:47:00,670
molecules together to see selective

1208
00:47:05,940 --> 00:47:04,269
absorption to one over another and the

1209
00:47:09,900 --> 00:47:05,950
traditional way of analyzing these spots

1210
00:47:11,579 --> 00:47:09,910
is to use fluorescent tags so our first

1211
00:47:16,710 --> 00:47:11,589
experiments were just to show that we

1212
00:47:18,779 --> 00:47:16,720
could array spots 100 microns spots onto

1213
00:47:20,370 --> 00:47:18,789

a flat mineral surface of things like

1214
00:47:22,440 --> 00:47:20,380
amino acids which had never been done in

1215
00:47:26,370 --> 00:47:22,450
this way before so here is an array of

1216
00:47:28,559 --> 00:47:26,380
both basically fluorescently labeled

1217
00:47:30,180 --> 00:47:28,569
amino acids on glass slides to show that

1218
00:47:33,450 --> 00:47:30,190
we can make a raise of concentration

1219
00:47:35,279 --> 00:47:33,460
series the traditional way of analyzing

1220
00:47:37,019 --> 00:47:35,289
micro races through fluorescence where

1221
00:47:38,849 --> 00:47:37,029
you basically just look at fluorescent

1222
00:47:40,829 --> 00:47:38,859
markers and see which spots shine up in

1223
00:47:43,470 --> 00:47:40,839
which ones don't and we certainly

1224
00:47:45,120 --> 00:47:43,480
started without Eddie adheres are this

1225
00:47:48,180 --> 00:47:45,130
is quartz a left-handed and right-handed

1226
00:47:50,279 --> 00:47:48,190
quartz looking at a fluorescently

1227
00:47:53,249 --> 00:47:50,289
labeled ly seen and what you'll notice

1228
00:47:54,930 --> 00:47:53,259
is that the l-lysine sticks much more

1229
00:47:55,380 --> 00:47:54,940
strongly to the right-handed surface in

1230
00:47:58,589 --> 00:47:55,390
the left

1231
00:48:00,690 --> 00:47:58,599
surface in these experiments course is

1232
00:48:02,339 --> 00:48:00,700
interesting which is fun and which is

1233
00:48:05,339 --> 00:48:02,349
absolutely irrelevant to the origin of

1234
00:48:07,710 --> 00:48:05,349
life because even though we can print

1235
00:48:10,079 --> 00:48:07,720
these micro arrays these are fluorescent

1236
00:48:12,690 --> 00:48:10,089
tags that are themselves big molecules

1237
00:48:14,400 --> 00:48:12,700
sort of stuck onto the small molecule

1238
00:48:16,410 --> 00:48:14,410

and so you're seeing sticking on the

1239
00:48:18,120 --> 00:48:16,420
court surface is not left or

1240
00:48:19,680 --> 00:48:18,130
right-handed lysine is left or right

1241
00:48:21,089 --> 00:48:19,690
handed lysine with this great big thing

1242
00:48:22,920 --> 00:48:21,099
sticking on the side and that's really

1243
00:48:25,410 --> 00:48:22,930
what's interacting the surface so so

1244
00:48:28,049 --> 00:48:25,420
proof of concept is great but it doesn't

1245
00:48:29,220 --> 00:48:28,059
relate to origin of life at all so we

1246
00:48:32,400 --> 00:48:29,230
have to figure out a way to do this

1247
00:48:35,759 --> 00:48:32,410
without fluorescent tags oh here is

1248
00:48:38,220 --> 00:48:35,769
lysine without a fluorescent tag a raid

1249
00:48:41,809 --> 00:48:38,230
on to calcite and here you see spots

1250
00:48:45,240 --> 00:48:41,819
that are 100 150 microns in diameter

1251
00:48:47,309 --> 00:48:45,250
regular than the ninth round so this is

1252
00:48:52,680 --> 00:48:47,319
reflected light just showing where we've

1253
00:48:55,079 --> 00:48:52,690
done these these arrays and this is work

1254
00:48:56,910 --> 00:48:55,089
done with advis NC and Detlef roth's at

1255
00:48:58,380 --> 00:48:56,920
the smithsonian institution where they

1256
00:49:00,380 --> 00:48:58,390
have a tough six top senses

1257
00:49:02,819 --> 00:49:00,390
time-of-flight secondary ion mass

1258
00:49:05,519 --> 00:49:02,829
spectrometry it basically means you take

1259
00:49:08,789 --> 00:49:05,529
a beam of ions you directed at the

1260
00:49:11,640 --> 00:49:08,799
surface the ions will strip off and

1261
00:49:13,769 --> 00:49:11,650
fragment any molecules absorb to the

1262
00:49:15,210 --> 00:49:13,779
surface and then you collect in a mass

1263
00:49:16,950 --> 00:49:15,220

spectrometer the characteristic

1264
00:49:19,349 --> 00:49:16,960
fragments so if there's an amino acid

1265
00:49:23,130 --> 00:49:19,359
you'll see characteristic chn fragments

1266
00:49:26,009 --> 00:49:23,140
if there's a sugar on the surface you'll

1267
00:49:27,990 --> 00:49:26,019
see characteristic CH o fragments and so

1268
00:49:30,450 --> 00:49:28,000
forth and you can look at look for those

1269
00:49:32,819 --> 00:49:30,460
and basically analyze what molecules may

1270
00:49:36,599 --> 00:49:32,829
or may not have stuck to a surface here

1271
00:49:39,299 --> 00:49:36,609
for example our top Sims results on a

1272
00:49:42,839 --> 00:49:39,309
single hundred 50 micron diameter spot

1273
00:49:44,880 --> 00:49:42,849
of lysine LIC on a calcite 214 surface

1274
00:49:47,759 --> 00:49:44,890
that's that chiral surface now what you

1275
00:49:50,519 --> 00:49:47,769
see here are various fragments most of

1276
00:49:54,569 --> 00:49:50,529
them that are showing as bright spots

1277
00:49:57,900 --> 00:49:54,579
our chn fragments of various sorts you

1278
00:50:00,150 --> 00:49:57,910
also see mask this is a calcium spot so

1279
00:50:04,589 --> 00:50:00,160
the spot masks

1280
00:50:06,240 --> 00:50:04,599
the calcite and so here's a very simple

1281
00:50:08,819 --> 00:50:06,250
way of telling whether something has

1282
00:50:11,730 --> 00:50:08,829
stuck are not stuck to the surface you

1283
00:50:13,859 --> 00:50:11,740
basically do a spectrum on the spot you

1284
00:50:16,200 --> 00:50:13,869
do a spectrum off the spot you do a

1285
00:50:18,930 --> 00:50:16,210
difference and basically by looking here

1286
00:50:21,720 --> 00:50:18,940
in red is just the health site will see

1287
00:50:25,289 --> 00:50:21,730
very strong mass fragments related to

1288
00:50:27,630 --> 00:50:25,299

the calcite you also see very strong

1289
00:50:28,950 --> 00:50:27,640
pregnancy related to the amino acid and

1290
00:50:30,569 --> 00:50:28,960
you can do a difference and therefore

1291
00:50:33,089 --> 00:50:30,579
come up with a quantitative measure of

1292
00:50:37,260 --> 00:50:33,099
how much lysine has stuck to that

1293
00:50:39,450 --> 00:50:37,270
surface so this is a nice technique we

1294
00:50:41,579 --> 00:50:39,460
still have some problems here we have a

1295
00:50:43,170 --> 00:50:41,589
very dirty surfaces but we've finally

1296
00:50:44,910 --> 00:50:43,180
figured out how to take care of that

1297
00:50:48,599 --> 00:50:44,920
with plasma cleaning in these surfaces

1298
00:50:50,490 --> 00:50:48,609
we use this high-resolution detail and

1299
00:50:52,410 --> 00:50:50,500
we have some additional problems which

1300
00:50:55,650 --> 00:50:52,420
you basically resolve now by cutting

1301
00:50:59,700 --> 00:50:55,660
very precise one centimeter square point

1302
00:51:01,289 --> 00:50:59,710
three centimeters thick slices in the

1303
00:51:02,700 --> 00:51:01,299
minerals right off crystal like the ones

1304
00:51:04,230 --> 00:51:02,710
that I've been handing around just just

1305
00:51:06,089 --> 00:51:04,240
cut them out very carefully and a gem

1306
00:51:07,859 --> 00:51:06,099
cutter does this you give us the best

1307
00:51:10,319 --> 00:51:07,869
possible structures and then we can

1308
00:51:12,480 --> 00:51:10,329
create an array so here's a map for an

1309
00:51:15,150 --> 00:51:12,490
array this particular one we have four

1310
00:51:16,829 --> 00:51:15,160
different pento sugars including ribose

1311
00:51:20,700 --> 00:51:16,839
and the three other pento sugars and

1312
00:51:23,279 --> 00:51:20,710
also dicl lycaenidae lyc so this was a

1313
00:51:25,859 --> 00:51:23,289

another sort of test to trial run to see

1314
00:51:27,599 --> 00:51:25,869
if we could both print the array there's

1315
00:51:30,450 --> 00:51:27,609
the array looks like in reflected light

1316
00:51:32,760 --> 00:51:30,460
before the crystals washed so you print

1317
00:51:36,480 --> 00:51:32,770
the array you then wash the crystal you

1318
00:51:38,760 --> 00:51:36,490
see what sticks and here's that prepare

1319
00:51:40,440 --> 00:51:38,770
feldspar crystal it's in a new special

1320
00:51:42,900 --> 00:51:40,450
holder we've made because you have very

1321
00:51:45,210 --> 00:51:42,910
precise leveling and also allows you to

1322
00:51:47,279 --> 00:51:45,220
get back through XY coordinates exactly

1323
00:51:48,720 --> 00:51:47,289
and refined your spots because if you

1324
00:51:51,000 --> 00:51:48,730
wash it off a spot it's hard to know

1325
00:51:52,349 --> 00:51:51,010
where it is so you want to find out if

1326
00:51:54,690 --> 00:51:52,359
there's anything preserved there and

1327
00:51:58,980 --> 00:51:54,700
then you can do this kind of mapping so

1328
00:52:02,549 --> 00:51:58,990
here's box of the lyceum feldspar in

1329
00:52:05,400 --> 00:52:02,559
this particular surface here's a mixture

1330
00:52:05,900 --> 00:52:05,410
of D and L xylose on feldspar that's one

1331
00:52:08,029 --> 00:52:05,910
of the pen

1332
00:52:10,220 --> 00:52:08,039
sugars and again you can do differents

1333
00:52:13,579 --> 00:52:10,230
maps you can map the spectrum here's the

1334
00:52:15,380 --> 00:52:13,589
mass fragment right around 40 mass 43

1335
00:52:19,520 --> 00:52:15,390
but you'll notice is that there is a

1336
00:52:21,470 --> 00:52:19,530
characteristic CHMP care of amino acid

1337
00:52:23,839 --> 00:52:21,480
which is not present in the sugar very

1338
00:52:25,609 --> 00:52:23,849

strong peak for the sugars which is not

1339
00:52:27,890 --> 00:52:25,619
nearly as strong in the amino acid and

1340
00:52:30,230 --> 00:52:27,900
you can do again ratios and differences

1341
00:52:33,349 --> 00:52:30,240
you can see what sticks in what does it

1342
00:52:36,710 --> 00:52:33,359
bypasses so this is an ongoing project

1343
00:52:38,630 --> 00:52:36,720
we are now sort of eagerly anticipating

1344
00:52:40,609 --> 00:52:38,640
results in a whole variety of mineral

1345
00:52:43,910 --> 00:52:40,619
surfaces and preparing essentially a

1346
00:52:46,760 --> 00:52:43,920
library of mineral surfaces and and to

1347
00:52:48,980 --> 00:52:46,770
do this with toph Sims our conclusions

1348
00:52:50,630 --> 00:52:48,990
first I really want to just take home

1349
00:52:53,150 --> 00:52:50,640
message many many different mineral

1350
00:52:58,010 --> 00:52:53,160
surfaces any geochemical environment has

1351
00:52:59,750 --> 00:52:58,020
the potential for chiro selection and it

1352
00:53:01,130 --> 00:52:59,760
selects these plausible prebiotic

1353
00:53:02,809 --> 00:53:01,140
molecules this may have been a

1354
00:53:04,730 --> 00:53:02,819
contributing factor in creating local

1355
00:53:07,339 --> 00:53:04,740
chiral micro environments with

1356
00:53:10,549 --> 00:53:07,349
concentrations of one chiral molecule or

1357
00:53:12,490 --> 00:53:10,559
another and I think the second idea is

1358
00:53:14,930 --> 00:53:12,500
that using a microarray technology

1359
00:53:17,000 --> 00:53:14,940
merging ideas from geology and biology

1360
00:53:19,130 --> 00:53:17,010
bringing them together we have the

1361
00:53:21,160 --> 00:53:19,140
possibility of that approaching this in

1362
00:53:23,359 --> 00:53:21,170
a combinatorics a where we can study

1363
00:53:25,579 --> 00:53:23,369

potentially thousands of different

1364
00:53:29,420 --> 00:53:25,589
mineral molecule pairs in a single

1365
00:53:31,069 --> 00:53:29,430
experiment and therefore understand in

1366
00:53:34,940 --> 00:53:31,079
much greater detail why certain

1367
00:53:36,200 --> 00:53:34,950
molecules stick to certain minerals so

1368
00:53:37,970 --> 00:53:36,210
with that I want to thank the Carnegie

1369
00:53:40,670 --> 00:53:37,980
Institution national science foundation

1370
00:53:42,620 --> 00:53:40,680
especially NASA for funding in this

1371
00:53:52,410 --> 00:53:42,630
research project and I will really look

1372
00:54:00,220 --> 00:53:56,470
yes sir um so you've shown that

1373
00:54:03,250 --> 00:54:00,230
chirality can be produced by reagents at

1374
00:54:07,330 --> 00:54:03,260
select rows I'm enough for others but in

1375
00:54:09,970 --> 00:54:07,340
extent life is produced by synthetic

1376
00:54:12,520 --> 00:54:09,980
action and so I was wondering how you

1377
00:54:18,370 --> 00:54:12,530
reconcile the two and what that implies

1378
00:54:20,410 --> 00:54:18,380
something about the origin of play it's

1379
00:54:23,020 --> 00:54:20,420
intriguing yes and in life now basically

1380
00:54:25,570 --> 00:54:23,030
uses pro chiral reactants increased

1381
00:54:27,099 --> 00:54:25,580
tyrolia pure products which is what the

1382
00:54:28,870 --> 00:54:27,109
chemical engineers would love to do in

1383
00:54:30,430 --> 00:54:28,880
every case because it's a much simpler

1384
00:54:32,410 --> 00:54:30,440
more streamlined matter start with

1385
00:54:34,540 --> 00:54:32,420
something simple end up with a complex

1386
00:54:37,030 --> 00:54:34,550
product in one step that's a great way

1387
00:54:38,890 --> 00:54:37,040
to do it the wife does that a lot life

1388
00:54:40,960 --> 00:54:38,900

has lots of interesting enzymes and

1389
00:54:45,040 --> 00:54:40,970
chemical reaction pathways that have

1390
00:54:47,470 --> 00:54:45,050
evolved over time to what extent is that

1391
00:54:50,080 --> 00:54:47,480
pointing us to prebiotic sort of

1392
00:54:51,820 --> 00:54:50,090
geochemical mechanisms I'm not sure I

1393
00:54:54,910 --> 00:54:51,830
think that life keeps adding on

1394
00:54:58,089 --> 00:54:54,920
complexity through selective processes

1395
00:54:59,859 --> 00:54:58,099
the natural selection derives to these

1396
00:55:02,530 --> 00:54:59,869
more and more efficient mechanisms in

1397
00:55:05,170 --> 00:55:02,540
the beginning it was not a selective

1398
00:55:07,470 --> 00:55:05,180
process in the sense of competition that

1399
00:55:09,160 --> 00:55:07,480
just was some environments that

1400
00:55:10,780 --> 00:55:09,170
concentrated this form in some

1401
00:55:12,910 --> 00:55:10,790
environments concentrated that form and

1402
00:55:15,900 --> 00:55:12,920
it's from that milieu that you had to

1403
00:55:20,710 --> 00:55:15,910
develop the first Homo chiral

1404
00:55:22,150 --> 00:55:20,720
crystalline like your systems and what

1405
00:55:23,620 --> 00:55:22,160
many people think is life arose from

1406
00:55:25,450 --> 00:55:23,630
those systems so there really is the

1407
00:55:28,060 --> 00:55:25,460
different there's a difference between

1408
00:55:31,420 --> 00:55:28,070
the competitive natural selective

1409
00:55:34,180 --> 00:55:31,430
environment and just the selective

1410
00:55:37,690 --> 00:55:34,190
environment that reflects local

1411
00:55:42,920 --> 00:55:40,279
at one point you specified room

1412
00:55:44,870 --> 00:55:42,930
temperature for seeing a chiral effect

1413
00:55:46,640 --> 00:55:44,880

would you comment on the impacts of

1414
00:55:49,069 --> 00:55:46,650
changing the temperature either warmer

1415
00:55:51,500 --> 00:55:49,079
or cooler or having the mineral surface

1416
00:55:54,620 --> 00:55:51,510
exposed to a temperature gradient yes

1417
00:55:56,240 --> 00:55:54,630
there are situations where at cooler

1418
00:55:59,150 --> 00:55:56,250
temperatures you get a much stronger

1419
00:56:01,099 --> 00:55:59,160
selective effect and indeed the way the

1420
00:56:03,200 --> 00:56:01,109
chemical engineers study these effects

1421
00:56:04,940 --> 00:56:03,210
on metal surfaces because they do it in

1422
00:56:07,880 --> 00:56:04,950
a vacuum chamber where they can vary the

1423
00:56:11,000 --> 00:56:07,890
temperature but you will find is that as

1424
00:56:12,380 --> 00:56:11,010
you raise the temperature first of all

1425
00:56:13,730 --> 00:56:12,390
there are always a few molecules they're

1426
00:56:16,849 --> 00:56:13,740
sticking there with just one point of

1427
00:56:19,670 --> 00:56:16,859
interaction and it say a hundred degrees

1428
00:56:22,700 --> 00:56:19,680
centigrade 150 degrees centigrade they

1429
00:56:25,099 --> 00:56:22,710
fly off you get a little higher

1430
00:56:26,569 --> 00:56:25,109
temperature and there are always some

1431
00:56:28,789 --> 00:56:26,579
molecules are sticking on the surface

1432
00:56:30,980 --> 00:56:28,799
with two points of interaction so maybe

1433
00:56:35,359 --> 00:56:30,990
you hit 200 or 225 degrees centigrade

1434
00:56:37,009 --> 00:56:35,369
and those molecules fly off you hit 300

1435
00:56:38,390 --> 00:56:37,019
degrees centigrade before the things

1436
00:56:40,940 --> 00:56:38,400
that are bonded with three points of

1437
00:56:43,700 --> 00:56:40,950
interaction go flying off and so this is

1438
00:56:45,890 --> 00:56:43,710

a way of cairo purification in in

1439
00:56:47,420 --> 00:56:45,900
chemical engineering is you basically

1440
00:56:49,640 --> 00:56:47,430
bond a whole bunch of things to a

1441
00:56:52,549 --> 00:56:49,650
surface heat up the surface to a point

1442
00:56:55,220 --> 00:56:52,559
where only the things the three that's

1443
00:56:57,589 --> 00:56:55,230
the chiral interaction remains so

1444
00:56:59,809 --> 00:56:57,599
temperature is very important and the

1445
00:57:02,150 --> 00:56:59,819
higher you go in temperature you can

1446
00:57:03,769 --> 00:57:02,160
certainly select things in a new way but

1447
00:57:05,210 --> 00:57:03,779
also you get stronger bonding at lower

1448
00:57:07,099 --> 00:57:05,220
temperatures so there's a there's a

1449
00:57:09,980 --> 00:57:07,109
trade-off I think this is another case

1450
00:57:12,529 --> 00:57:09,990
I've made this comment repeatedly like

1451
00:57:15,319 --> 00:57:12,539
yesterday in in the lecture that's

1452
00:57:17,059 --> 00:57:15,329
cycling cycling of conditions is

1453
00:57:18,769 --> 00:57:17,069
critically important in the origin of

1454
00:57:20,960 --> 00:57:18,779
life if you're going to try to do

1455
00:57:23,630 --> 00:57:20,970
chemical experiments that mimic origin

1456
00:57:25,490 --> 00:57:23,640
processes think always about how you can

1457
00:57:27,109 --> 00:57:25,500
bring cycling into it raising and

1458
00:57:29,839 --> 00:57:27,119
lowering the temperatures drying and

1459
00:57:31,910 --> 00:57:29,849
wedding cycles cycles of light and

1460
00:57:33,470 --> 00:57:31,920
darkness to all these different cycles

1461
00:57:37,069 --> 00:57:33,480
were very prevalent in the early Earth

1462
00:57:38,400 --> 00:57:37,079
and each cycle adds it windows out the

1463
00:57:39,539 --> 00:57:38,410

possibility in fact

1464
00:57:42,059 --> 00:57:39,549
think about each cycle is adding

1465
00:57:44,730 --> 00:57:42,069
information to the system and therefore

1466
00:57:46,200 --> 00:57:44,740
making the system more selective so so I

1467
00:57:47,730 --> 00:57:46,210
think that it's not not only the

1468
00:57:49,319 --> 00:57:47,740
temperature but it's the cycling of

1469
00:57:52,470 --> 00:57:49,329
temperatures it can be really important

1470
00:57:54,930 --> 00:57:52,480
in enhancing his effects I've not used

1471
00:57:56,450 --> 00:57:54,940
cycling in my experiments yet but that

1472
00:58:08,130 --> 00:57:56,460
certainly is a very interesting

1473
00:58:12,089 --> 00:58:08,140
possibility for soon oh wow yes ice does

1474
00:58:16,109 --> 00:58:12,099
have chiral faces absolutely and I've

1475
00:58:19,559 --> 00:58:16,119
not studied ice in detail but but

1476
00:58:20,940 --> 00:58:19,569
certainly if you fracture hice you're

1477
00:58:22,859 --> 00:58:20,950
going to have a whole range of

1478
00:58:24,359 --> 00:58:22,869
interesting chiral surfaces and

1479
00:58:26,760 --> 00:58:24,369
furthermore I suspect that they will

1480
00:58:28,799 --> 00:58:26,770
have both positive and negative charge

1481
00:58:32,789 --> 00:58:28,809
centres and furthermore those charged

1482
00:58:34,680 --> 00:58:32,799
centers what is the H 0 distance in ice

1483
00:58:36,450 --> 00:58:34,690
you know it's mean I know that if zips

1484
00:58:38,970 --> 00:58:36,460
up it's a hydrogen bond of thing so it's

1485
00:58:41,069 --> 00:58:38,980
like there's two distances I wanted to 1

1486
00:58:43,109 --> 00:58:41,079
and 2 on strim so you could have some

1487
00:58:45,269 --> 00:58:43,119
very interesting geometries that match

1488
00:58:48,059 --> 00:58:45,279

up with some molecules so that's a very

1489
00:58:49,609 --> 00:58:48,069
interesting possibility and obviously I

1490
00:58:51,809 --> 00:58:49,619
should have thought about that but but I

1491
00:58:53,339 --> 00:58:51,819
haven't but there yeah that's a very

1492
00:58:56,599 --> 00:58:53,349
interesting possibility of icing else

1493
00:58:59,519 --> 00:58:56,609
can she do that for her dissertation oh

1494
00:59:02,039 --> 00:58:59,529
no no one is no one has discussed chiral

1495
00:59:03,539 --> 00:59:02,049
surfaces of Isis absolutely not I'm

1496
00:59:05,940 --> 00:59:03,549
there's no literature there that's a

1497
00:59:07,230 --> 00:59:05,950
very very interesting ability and

1498
00:59:10,230 --> 00:59:07,240
another thing that's really interesting

1499
00:59:12,000 --> 00:59:10,240
and no one's studied is the microbial

1500
00:59:13,589 --> 00:59:12,010
interactions with these different chiral

1501
00:59:15,150 --> 00:59:13,599
services and i'm not sure if there isn't

1502
00:59:17,460 --> 00:59:15,160
it ramin microbes are much much larger

1503
00:59:19,170 --> 00:59:17,470
than the molecular scale features we're

1504
00:59:22,500 --> 00:59:19,180
talking about but it's conceivable that

1505
00:59:26,609 --> 00:59:22,510
there is some different sorption you may

1506
00:59:29,579 --> 00:59:26,619
have who's a fellow who is it Virginia

1507
00:59:31,650 --> 00:59:29,589
Tech and and Maryland who did biological

1508
00:59:34,380 --> 00:59:31,660
force microscopy putting microbes on the

1509
00:59:36,299 --> 00:59:34,390
end of an AFM and having them touch

1510
00:59:39,120 --> 00:59:36,309
mineral surfaces to see whether they

1511
00:59:40,650 --> 00:59:39,130
like to eat them or not good measure the

1512
00:59:42,420 --> 00:59:40,660
force way you could do this on a roll

1513
00:59:44,309 --> 00:59:42,430

surfaces as well I mean so that there

1514
00:59:45,250 --> 00:59:44,319
are a lot of intriguing ways you could

1515
00:59:48,940 --> 00:59:45,260
study the center

1516
01:00:00,250 --> 00:59:48,950
shins and I encourage you to think you

1517
01:00:02,800 --> 01:00:00,260
know out of the box on this stuff how

1518
01:00:04,570 --> 01:00:02,810
are you here T especially with the two

1519
01:00:09,340 --> 01:00:04,580
methods that you described they do

1520
01:00:12,150 --> 01:00:09,350
splint them I guess especially not

1521
01:00:15,160 --> 01:00:12,160
thinking of medicinal uses and abuses

1522
01:00:20,830 --> 01:00:15,170
how are you guaranteed that I'm only

1523
01:00:22,440 --> 01:00:20,840
getting the lmd asked the FDA I don't

1524
01:00:25,660 --> 01:00:22,450
know this is really an important

1525
01:00:27,940 --> 01:00:25,670
important question many many drugs that

1526
01:00:30,130 --> 01:00:27,950
we take I mean you and your family and

1527
01:00:32,320 --> 01:00:30,140
your friends take I would say the

1528
01:00:34,720 --> 01:00:32,330
majority of the really expensive drugs

1529
01:00:37,180 --> 01:00:34,730
that are out there are have to be chiral

1530
01:00:39,220 --> 01:00:37,190
epure and and how do they how do they

1531
01:00:40,780 --> 01:00:39,230
test it how they appear and you have to

1532
01:00:43,360 --> 01:00:40,790
basically good quality controls with

1533
01:00:45,310 --> 01:00:43,370
chiral columns that there are ways of

1534
01:00:46,690 --> 01:00:45,320
passing these molecules through columns

1535
01:00:49,510 --> 01:00:46,700
and separating out the left or right

1536
01:00:52,810 --> 01:00:49,520
hand and seeing if you get one peak or

1537
01:00:55,360 --> 01:00:52,820
two but it's not an easy job to test

1538
01:00:57,400 --> 01:00:55,370

them and purify them and I think when I

1539
01:01:03,040 --> 01:00:57,410
buy drugs they just sort of trust that

1540
01:01:04,870 --> 01:01:03,050
they're okay I also don't know of any

1541
01:01:06,490 --> 01:01:04,880
case other than thalidomide it's so

1542
01:01:08,710 --> 01:01:06,500
dramatic so they're probably a lot of

1543
01:01:10,510 --> 01:01:08,720
chiral epure drugs where there wouldn't

1544
01:01:19,330 --> 01:01:10,520
be a huge difference if you took left

1545
01:01:21,250 --> 01:01:19,340
and right-handed molecules well okay

1546
01:01:22,510 --> 01:01:21,260
first of all let me let me just I'll

1547
01:01:24,880 --> 01:01:22,520
come back to your question the

1548
01:01:27,370 --> 01:01:24,890
definition of left and right-handed is a

1549
01:01:29,050 --> 01:01:27,380
completely arbitrary historical

1550
01:01:31,870 --> 01:01:29,060
definition based on going clockwise

1551
01:01:34,090 --> 01:01:31,880
around the carbon atom from the least to

1552
01:01:36,250 --> 01:01:34,100
the greatest mass and you go clockwise

1553
01:01:38,170 --> 01:01:36,260
or counterclockwise in that because you

1554
01:01:41,170 --> 01:01:38,180
left to right hand is so so the whole

1555
01:01:43,270 --> 01:01:41,180
question of left Iranian most of the

1556
01:01:45,130 --> 01:01:43,280
amino acids that our body according to

1557
01:01:46,810 --> 01:01:45,140
that definition are the left-handed

1558
01:01:49,630 --> 01:01:46,820
variety although it turns out that in

1559
01:01:51,580 --> 01:01:49,640
your gut there are microbes to coat

1560
01:01:54,940 --> 01:01:51,590
themselves with right-handed amino acids

1561
01:01:56,140 --> 01:01:54,950
so they don't get eaten by your

1562
01:01:58,450 --> 01:01:56,150
digestive system

1563
01:02:00,099 --> 01:01:58,460

but you know so there's always some

1564
01:02:01,990 --> 01:02:00,109
exceptions yeah most of your body is

1565
01:02:03,789 --> 01:02:02,000
forced and amino acids and by this

1566
01:02:05,710 --> 01:02:03,799
definition if you have a left-hand amino

1567
01:02:09,190 --> 01:02:05,720
acids it turns out that the sugars are

1568
01:02:10,599 --> 01:02:09,200
right-handed sugar so in DNA and RNA and

1569
01:02:12,760 --> 01:02:10,609
the other sugars you've taken and

1570
01:02:14,289 --> 01:02:12,770
there's now a dietary supplement that's

1571
01:02:16,480 --> 01:02:14,299
available which is left-handed sugar

1572
01:02:18,760 --> 01:02:16,490
which tastes like sugar but turns out

1573
01:02:20,829 --> 01:02:18,770
isn't digestible because it's the wrong

1574
01:02:23,049 --> 01:02:20,839
handedness so so that mean there's all

1575
01:02:25,059 --> 01:02:23,059
kinds of weirdnesses in terms of talking

1576
01:02:35,039 --> 01:02:25,069
about left or right yeah but your body

1577
01:02:42,490 --> 01:02:39,430
especially medicinal testing how we do

1578
01:02:48,460 --> 01:02:42,500
know how your body reacts to it whether

1579
01:02:50,920 --> 01:02:48,470
it's left I don't know I know it well

1580
01:02:57,099 --> 01:02:50,930
it's a very important question um I just

1581
01:02:58,720 --> 01:02:57,109
use mice first profession it's a very

1582
01:03:01,750 --> 01:02:58,730
important question maybe we should all

1583
01:03:04,210 --> 01:03:01,760
be a little more skeptical about but

1584
01:03:06,250 --> 01:03:04,220
that's why we have you know FDA and all

1585
01:03:07,779 --> 01:03:06,260
sorts of drug testing procedures and why

1586
01:03:11,579 --> 01:03:07,789
they reject a lot of drugs that might

1587
01:03:13,839 --> 01:03:11,589
otherwise be important it's not my

1588
01:03:15,279 --> 01:03:13,849

expertise but it's a fascinating area

1589
01:03:17,920 --> 01:03:15,289
I'd like to bring up an issue that was

1590
01:03:20,019 --> 01:03:17,930
briefly mentioned last night namely with

1591
01:03:22,420 --> 01:03:20,029
the origin of life succeed so we get we

1592
01:03:24,789 --> 01:03:22,430
get some separate separation on these

1593
01:03:28,359 --> 01:03:24,799
different surfaces but it's a relatively

1594
01:03:30,880 --> 01:03:28,369
small-scale kind of you're not talking

1595
01:03:33,789 --> 01:03:30,890
about you know this 100 kilometer area

1596
01:03:37,900 --> 01:03:33,799
or even meters Yeah right I mean is this

1597
01:03:41,130 --> 01:03:37,910
summary millimeters or microns so how

1598
01:03:45,819 --> 01:03:41,140
does one get life going with such small

1599
01:03:47,109 --> 01:03:45,829
regions of interest how else would you

1600
01:03:49,420 --> 01:03:47,119
get it going though that's the real

1601
01:03:51,519 --> 01:03:49,430
question I mean it's a juxtaposition of

1602
01:03:53,470 --> 01:03:51,529
molecules in a micro environment is

1603
01:03:57,190 --> 01:03:53,480
those molecules creating a

1604
01:03:59,680 --> 01:03:57,200
self-replicating system that then takes

1605
01:04:01,180 --> 01:03:59,690
over with it but the quality over

1606
01:04:02,620 --> 01:04:01,190
definitely another surface right next

1607
01:04:03,170 --> 01:04:02,630
door that they're incompatible and

1608
01:04:05,299 --> 01:04:03,180
that's not

1609
01:04:06,980 --> 01:04:05,309
experiment and that's one of the amazing

1610
01:04:08,780 --> 01:04:06,990
things about the early Earth you see

1611
01:04:10,790 --> 01:04:08,790
they were just trillions upon trillions

1612
01:04:12,380 --> 01:04:10,800
upon trillions of micro environment that

1613
01:04:14,540 --> 01:04:12,390

were chiral some of the more Tyrell

1614
01:04:16,520 --> 01:04:14,550
different molecular selection on this

1615
01:04:19,160 --> 01:04:16,530
face and on that face and in this pH

1616
01:04:20,510 --> 01:04:19,170
range and it in that salinity range you

1617
01:04:21,470 --> 01:04:20,520
had all these different experiments

1618
01:04:23,510 --> 01:04:21,480
going on and one of those

1619
01:04:24,620 --> 01:04:23,520
microenvironments the juxtaposition

1620
01:04:27,170 --> 01:04:24,630
molecules was such that a

1621
01:04:28,579 --> 01:04:27,180
self-replicating system began spreading

1622
01:04:30,440 --> 01:04:28,589
out and once that self-replicating

1623
01:04:33,109 --> 01:04:30,450
system got going and eat everything else

1624
01:04:35,630 --> 01:04:33,119
very quickly so that's that sort of the

1625
01:04:37,400 --> 01:04:35,640
in a very simplistic idea but I think it

1626
01:04:38,540 --> 01:04:37,410
has to start out in a microbe army

1627
01:04:40,730 --> 01:04:38,550
because there has to be molecules

1628
01:04:43,609 --> 01:04:40,740
interacting with molecules it can't be

1629
01:04:46,180 --> 01:04:43,619
molecule over here and a molecule over

1630
01:04:48,559 --> 01:04:46,190
here sort of thinking about each other I

1631
01:04:50,839 --> 01:04:48,569
mean it really is a chemical process

1632
01:04:53,620 --> 01:04:50,849
right so that's one of the reasons why

1633
01:04:57,890 --> 01:04:53,630
the prebiotic soup is so problematic a

1634
01:04:59,780 --> 01:04:57,900
soup is to dilute a suit the chances of

1635
01:05:01,400 --> 01:04:59,790
just the right molecules contacting each

1636
01:05:03,020 --> 01:05:01,410
other in an aqueous oh so you need to

1637
01:05:05,030 --> 01:05:03,030
have a surface and whether it's an oil

1638
01:05:07,339 --> 01:05:05,040

slick or whether it's a mineral surface

1639
01:05:09,650 --> 01:05:07,349
or whether it's an aerosol or a dried-up

1640
01:05:11,109 --> 01:05:09,660
pond and a tidal flat it's got to be a

1641
01:05:13,520 --> 01:05:11,119
surface because you have to concentrate

1642
01:05:15,410 --> 01:05:13,530
your molecules and you have to bring

1643
01:05:18,289 --> 01:05:15,420
them together in environment and that

1644
01:05:19,819 --> 01:05:18,299
micro environment is chiral although is

1645
01:05:22,280 --> 01:05:19,829
the idea that you start off with this

1646
01:05:26,930 --> 01:05:22,290
speckled nature so to speak but that the

1647
01:05:29,839 --> 01:05:26,940
the facets that are similar eventually

1648
01:05:31,549 --> 01:05:29,849
combined together into it well take over

1649
01:05:33,680 --> 01:05:31,559
I mean isn't it as the chemistry is

1650
01:05:35,539 --> 01:05:33,690
produced by those facets it isn't

1651
01:05:37,789 --> 01:05:35,549
necessarily even the chemistry of all

1652
01:05:40,270 --> 01:05:37,799
the different facets combines and takes

1653
01:05:43,010 --> 01:05:40,280
over it's just that some place an

1654
01:05:46,640 --> 01:05:43,020
efficient self-replicating molecular

1655
01:05:49,000 --> 01:05:46,650
system begins and when an efficient

1656
01:05:51,170 --> 01:05:49,010
self-replicating molecular system begins

1657
01:05:54,740 --> 01:05:51,180
it's so much more efficient than

1658
01:05:57,140 --> 01:05:54,750
anything else than it just and but that

1659
01:06:00,230 --> 01:05:57,150
could just be a hundred square

1660
01:06:02,000 --> 01:06:00,240
centimeters it could be that uh what was

1661
01:06:04,309 --> 01:06:02,010
the initial kernel is where micron it

1662
01:06:05,900 --> 01:06:04,319
could be a few thousand square an enemy

1663
01:06:07,339 --> 01:06:05,910

this one I'm committing I know you're

1664
01:06:09,559 --> 01:06:07,349
talking about the origin of life as

1665
01:06:12,590 --> 01:06:09,569
being on 100 square centimeters yes

1666
01:06:14,810 --> 01:06:12,600
rather than is pond yes

1667
01:06:16,280 --> 01:06:14,820
yes it's going to be in a pond or in a

1668
01:06:18,680 --> 01:06:16,290
title fight or something what is right

1669
01:06:20,420 --> 01:06:18,690
the actual origin of light is a group of

1670
01:06:24,050 --> 01:06:20,430
Molitor the starts do we might call it

1671
01:06:26,900 --> 01:06:24,060
the pointing and so that it wants he go

1672
01:06:28,250 --> 01:06:26,910
and then it and then it goes ok and it

1673
01:06:32,060 --> 01:06:28,260
may have happened a thousand different

1674
01:06:33,890 --> 01:06:32,070
places in the sense that this locality

1675
01:06:35,330 --> 01:06:33,900
is okay and these experiments started

1676
01:06:39,050 --> 01:06:35,340
and maybe they weren't very efficient

1677
01:06:41,420 --> 01:06:39,060
and they failed or or the Jason one

1678
01:06:45,110 --> 01:06:41,430
Hayden because it was just so much

1679
01:06:46,340 --> 01:06:45,120
better so I'm not opposed to multiple

1680
01:06:49,490 --> 01:06:46,350
origins but I think each of those

1681
01:06:51,520 --> 01:06:49,500
origins is a local time in place highly

1682
01:06:52,940 --> 01:06:51,530
localized and you're looking at

1683
01:06:55,400 --> 01:06:52,950
microenvironments that's what we're

1684
01:06:57,230 --> 01:06:55,410
thinking about no the other thing I have

1685
01:06:58,820 --> 01:06:57,240
to say is that those microenvironments

1686
01:07:00,560 --> 01:06:58,830
may have been influenced by many other

1687
01:07:02,600 --> 01:07:00,570
environments hydrothermal vents and

1688
01:07:06,610 --> 01:07:02,610

comets and asteroids coming in and

1689
01:07:09,680 --> 01:07:06,620
miliary processes and different kinds of

1690
01:07:13,250 --> 01:07:09,690
chemical processes that that will cause

1691
01:07:16,250 --> 01:07:13,260
the juxtaposition of these molecules in

1692
01:07:17,750 --> 01:07:16,260
that particular micro environment so it

1693
01:07:20,720 --> 01:07:17,760
could be that all of those environments

1694
01:07:23,840 --> 01:07:20,730
are important but ultimately life began

1695
01:07:28,610 --> 01:07:23,850
as a molecular process in a micro time

1696
01:07:32,480 --> 01:07:28,620
and place there in the am at the same

1697
01:07:35,240 --> 01:07:32,490
vein so there seems to be a spatial

1698
01:07:39,550 --> 01:07:35,250
bottleneck at some point as wondering

1699
01:07:44,810 --> 01:07:39,560
what in the sequence of the origin play

1700
01:07:48,050 --> 01:07:44,820
specifically what was at what stage

1701
01:07:52,910 --> 01:07:48,060
in the emergence of life is that okay

1702
01:07:54,530 --> 01:07:52,920
and that's the big question in fact I'm

1703
01:07:56,600 --> 01:07:54,540
going to devote most of the next origin

1704
01:07:58,820 --> 01:07:56,610
of life Gordon conference to that is a

1705
01:08:01,100 --> 01:07:58,830
question is a metabolism first that is

1706
01:08:03,470 --> 01:08:01,110
was that was that bottleneck was at

1707
01:08:06,320 --> 01:08:03,480
first being just a group of molecules

1708
01:08:09,230 --> 01:08:06,330
that created a metabolic cycle or

1709
01:08:11,480 --> 01:08:09,240
network in that local environment or was

1710
01:08:13,370 --> 01:08:11,490
it an information-rich molecule that

1711
01:08:15,099 --> 01:08:13,380
somehow was first able to pass on

1712
01:08:19,790 --> 01:08:15,109
information to make copies of itself

1713
01:08:21,380 --> 01:08:19,800

that's the genetics first so that's a

1714
01:08:23,510 --> 01:08:21,390
big debate there's there many people

1715
01:08:26,060 --> 01:08:23,520
think it had to be that that genetic

1716
01:08:29,570 --> 01:08:26,070
molecule that somehow then used its

1717
01:08:30,440 --> 01:08:29,580
environment to promote making copies and

1718
01:08:32,420 --> 01:08:30,450
some people think you had to be

1719
01:08:34,250 --> 01:08:32,430
metabolism that just remind lessly make

1720
01:08:37,700 --> 01:08:34,260
copies of molecules without any sort of

1721
01:08:41,090 --> 01:08:37,710
information context at all and just in

1722
01:08:43,160 --> 01:08:41,100
and this debate is is I think at this

1723
01:08:45,320 --> 01:08:43,170
point unresolvable but i think you know

1724
01:08:48,290 --> 01:08:45,330
experiments there are key experiments on

1725
01:08:50,030 --> 01:08:48,300
both sides of the issue that might at

1726
01:08:52,070 --> 01:08:50,040
least persuade people one side or

1727
01:08:53,900 --> 01:08:52,080
another and maybe somehow you had to

1728
01:08:55,730 --> 01:08:53,910
have both you had to in one environment

1729
01:08:57,200 --> 01:08:55,740
you had an information-rich molecule

1730
01:08:59,720 --> 01:08:57,210
that learn to make copies of itself but

1731
01:09:02,210 --> 01:08:59,730
really because it didn't have metabolism

1732
01:09:03,680 --> 01:09:02,220
built into it was very much limited in

1733
01:09:05,570 --> 01:09:03,690
time and space but then you had these

1734
01:09:07,670 --> 01:09:05,580
self-replicating networks of molecules

1735
01:09:09,260 --> 01:09:07,680
that kind of boozed around but really

1736
01:09:12,460 --> 01:09:09,270
we're not able to do and then they came

1737
01:09:15,829 --> 01:09:12,470
together and bingo you had a merging of

1738
01:09:18,320 --> 01:09:15,839

genetics and metabolism and that's where

1739
01:09:21,140 --> 01:09:18,330
things just took off so we don't know

1740
01:09:23,750 --> 01:09:21,150
it's it's a very I can wave my hands all

1741
01:09:25,490 --> 01:09:23,760
day about I don't have any idea at this

1742
01:09:28,310 --> 01:09:25,500
point it's just a lot of fun to think

1743
01:09:32,599 --> 01:09:28,320
about well I think we better and here