1
00:00:01,110 --> 00:00:02,280
- Hello, everyone.

2
00:00:02,280 --> 00:00:03,720
We would love your feedback

3
00:00:03,720 --> 00:00:05,820
on Conversations at the Perimeter.

4
00:00:05,820 --> 00:00:06,990
Let us know what you like

5
00:00:06,990 --> 00:00:08,416
and what you'd like to hear more of.

6
00:00:08,416 --> 00:00:12,690
Go to perimeterinstitute.ca/podcastsurvey

7
00:00:12,690 --> 00:00:14,040
to share your thoughts.

8
00:00:14,040 --> 00:00:15,568
Thanks so much.

9
00:00:15,568 --> 00:00:18,068
(light music)

10
00:00:24,090 --> 00:00:25,800
Hi everyone, and welcome back

11
00:00:25,800 --> 00:00:27,840
to Conversations at the Perimeter.

12
00:00:27,840 --> 00:00:30,000
I'm Lauren and I'm joined by Colin.

13
00:00:30,000 --> 00:00:30,833

- Hey.

14
00:00:30,833 --> 00:00:32,460
- And we are so thrilled to bring you

15
00:00:32,460 --> 00:00:34,740
this conversation today
with Nobel Laureate,

16
00:00:34,740 --> 00:00:36,630
Sir Anthony Leggett.

17
00:00:36,630 --> 00:00:38,160
Sir Anthony works in the fields

18
00:00:38,160 --> 00:00:40,530
of condensed matter physics
and quantum mechanics,

19
00:00:40,530 --> 00:00:42,982
and he won the 2003 Nobel Prize

20
00:00:42,982 --> 00:00:45,780
for his groundbreaking
work on superfluidity,

21
00:00:45,780 --> 00:00:47,900
which he tells us about
in this conversation.

22
00:00:47,900 --> 00:00:52,320
- Sir Anthony, who honestly
prefers to just be called Tony,

23
00:00:52,320 --> 00:00:54,051
Tony tells us about his
lifetime in science,

24
00:00:54,051 --> 00:00:57,174

his formative experiences
in the developing world,

25
00:00:57,174 --> 00:01:02,010
and the pros and occasional
cons of winning a Nobel Prize.

26
00:01:02,010 --> 00:01:03,653
And using some very helpful metaphors,

27
00:01:03,653 --> 00:01:04,760
he helped me understand

28
00:01:04,760 --> 00:01:07,065
why high temperature superconductivity

29
00:01:07,065 --> 00:01:10,680
is such a sought after goal
in fundamental physics.

30
00:01:10,680 --> 00:01:12,870
- I was so excited to talk to Tony

31
00:01:12,870 --> 00:01:15,857
because he truly is a legend
in the field of quantum matter,

32
00:01:15,857 --> 00:01:18,420
which is my field of research as well.

33
00:01:18,420 --> 00:01:19,616
And during my graduate studies,

34
00:01:19,616 --> 00:01:22,112
I studied superconductivity and I remember

35
00:01:22,112 --> 00:01:24,210
how much I struggled to form

36
00:01:24,210 --> 00:01:26,152
a simple picture in my
head of what electrons

37
00:01:26,152 --> 00:01:28,470
are doing within a superconductor.

38
00:01:28,470 --> 00:01:29,880
So during this conversation,

39
00:01:29,880 --> 00:01:32,130
I just kept wishing I
could have talked to Tony

40
00:01:32,130 --> 00:01:34,858
back then because I know his
metaphors would've helped me.

41
00:01:34,858 --> 00:01:36,538
- (chuckles) Yeah, I first met Tony

42
00:01:36,538 --> 00:01:39,903
about 12 years ago when he
was a regular summer lecturer

43
00:01:39,903 --> 00:01:42,626
at the nearby Institute
for Quantum Computing,

44
00:01:42,626 --> 00:01:45,016
and I was immediately
struck by his kindness

45
00:01:45,016 --> 00:01:47,232
and his brilliance and his real ability

46
00:01:47,232 --> 00:01:50,630
to help other people understand
really complicated subjects.

47
00:01:50,630 --> 00:01:53,100
And this conversation only reinforced

48
00:01:53,100 --> 00:01:54,210
those first impressions.

49
00:01:54,210 --> 00:01:57,270
So I'm really excited for our
listeners to get to know him.

50
00:01:57,270 --> 00:01:59,220
So, let's step inside the perimeter

51
00:01:59,220 --> 00:02:00,897
with Sir Anthony Leggett.

52
00:02:00,897 --> 00:02:04,170
(upbeat music fades)

53
00:02:04,170 --> 00:02:05,280
- Sir Anthony Leggett,

54
00:02:05,280 --> 00:02:06,861
we are so happy to have you visiting us

55
00:02:06,861 --> 00:02:09,330
here at Perimeter Institute today,

56
00:02:09,330 --> 00:02:10,542
and we're so thrilled that we get

57
00:02:10,542 --> 00:02:13,170
to chat with you for
Conversations at the Perimeter.

58
00:02:13,170 --> 00:02:14,910
Thank you so much for joining us.

59
00:02:14,910 --> 00:02:15,743
- Pleasure.

60
00:02:15,743 --> 00:02:18,510
- I know that you've
visited Waterloo many times,

61
00:02:18,510 --> 00:02:19,620
but it's been a few years,

62
00:02:19,620 --> 00:02:22,650
so can you just tell us
what it's like to be back?

63
00:02:22,650 --> 00:02:26,220
- Oh, it's a very pleasant feeling.

64
00:02:26,220 --> 00:02:31,220
I really enjoyed my time
working here in Waterloo,

65
00:02:31,770 --> 00:02:35,340
and I'm just sorry that I couldn't visit

66
00:02:35,340 --> 00:02:39,193
more often over the last five
years for various reasons.

67
00:02:39,193 --> 00:02:44,040
But it's interesting to see how the town,

68
00:02:45,120 --> 00:02:48,060
particularly in this area has changed.

69
00:02:48,060 --> 00:02:50,130
I'm just very, very glad to be back.

70

00:02:50,130 --> 00:02:52,590
- What are the biggest
changes that you've noticed?

71
00:02:52,590 --> 00:02:54,125
- I think probably the railway.

72
00:02:54,125 --> 00:02:59,125
When I was last here, the
railway was under construction.

73
00:03:00,790 --> 00:03:03,441
It wasn't running, but it nevertheless

74
00:03:03,441 --> 00:03:06,684
made a huge nuisance
to getting around town.

75
00:03:06,684 --> 00:03:11,057
And that now seems to have been completed,

76
00:03:11,057 --> 00:03:16,057
and so everything's seems
much more normal and pleasant

77
00:03:17,150 --> 00:03:19,110
in this particular area.

78
00:03:19,110 --> 00:03:21,255
- Well, I remember for years,

79
00:03:21,255 --> 00:03:23,280
many years in a row you came

80
00:03:23,280 --> 00:03:24,990
to the Institute for Quantum Computing

81
00:03:24,990 --> 00:03:26,247
to teach the summer talk,

- Yes.

82
00:03:26,247 --> 00:03:27,180
- and I would see you,

83
00:03:27,180 --> 00:03:29,370
I worked there for a
number of years myself,

84
00:03:29,370 --> 00:03:31,213
and I would see you
arrive on your bicycle.

85
00:03:31,213 --> 00:03:32,046
- Yes.

86
00:03:32,046 --> 00:03:32,910
- And go home on your bicycle

87
00:03:32,910 --> 00:03:35,730
and I remember the chaos
that the construction caused.

88
00:03:35,730 --> 00:03:36,979
So I'm glad
- Yes (chuckles).

89
00:03:36,979 --> 00:03:39,210
- the construction is behind us.

90
00:03:39,210 --> 00:03:40,043
- Yes, indeed.

91
00:03:40,043 --> 00:03:41,250
- Can you tell us what it was

92
00:03:41,250 --> 00:03:43,515
you were doing at the Institute
for Quantum Computing?

93
00:03:43,515 --> 00:03:47,370
- That's actually a good
question and really,

94
00:03:47,370 --> 00:03:50,371
I think the most accurate statement

95
00:03:50,371 --> 00:03:52,582
is that I was trying to learn

96
00:03:52,582 --> 00:03:56,191
about the current developments
in quantum information.

97
00:03:56,191 --> 00:04:01,191
Because while I have a certain history

98
00:04:01,440 --> 00:04:04,620
in the area of quantum foundations,

99
00:04:04,620 --> 00:04:07,620
I missed out on the early developments

100
00:04:07,620 --> 00:04:09,573
in the quantum information revolution

101
00:04:09,573 --> 00:04:14,573
and was only two anxious to pick them up

102
00:04:16,007 --> 00:04:17,918
from what was obviously

103
00:04:17,918 --> 00:04:20,924
the world's leading place in this area.

104
00:04:20,924 --> 00:04:22,479
- That's funny that you came to learn

105
00:04:22,479 --> 00:04:26,280
and every summer students
would come to learn from you.

106
00:04:26,280 --> 00:04:27,332
You hosted a series of talks

107
00:04:27,332 --> 00:04:30,060
and I remember they were highly
popular and sought after.

108
00:04:30,060 --> 00:04:30,893
- Yeah.

109
00:04:30,893 --> 00:04:31,860
- So I guess it was a two-way street.

110
00:04:31,860 --> 00:04:36,545
- Yes, well, I think I tried to put across

111
00:04:36,545 --> 00:04:41,545
some of the things I'd picked
up in condense matter physics,

112
00:04:42,090 --> 00:04:44,514
which was not something
at that time at least,

113
00:04:44,514 --> 00:04:48,810
in which the IQC was
primarily specialized.

114
00:04:48,810 --> 00:04:52,687
And on the other hand,
I was trying to gain

115
00:04:52,687 --> 00:04:56,040
the latest developments

in quantum information.

116
00:04:56,040 --> 00:04:57,720
- Now, in preparing for today,

117
00:04:57,720 --> 00:04:59,880
I was trying to think
what kind of questions

118
00:04:59,880 --> 00:05:01,980
can I ask you that
really kind of encompass

119
00:05:01,980 --> 00:05:04,560
a lot of the different types
of work that you have done?

120
00:05:04,560 --> 00:05:06,510
And one thing I thought about is that

121
00:05:06,510 --> 00:05:08,387
a lot of your work really relies

122
00:05:08,387 --> 00:05:10,920
on systems being at very low temperatures.

123
00:05:10,920 --> 00:05:12,240
- Yes.
- So, could you tell

124
00:05:12,240 --> 00:05:15,510
us what is so special
about low temperatures?

125
00:05:15,510 --> 00:05:17,070
- Yes.

126
00:05:17,070 --> 00:05:22,049
Well, basically I think

it was put rather well

127
00:05:22,049 --> 00:05:23,716
by Kamerlingh Onnes,

128
00:05:24,665 --> 00:05:29,370
who's in some sense the father
of low temperature physics

129
00:05:29,370 --> 00:05:31,172
as we know it today.

130
00:05:31,172 --> 00:05:35,670
When he got the Nobel Prize,

131
00:05:35,670 --> 00:05:40,670
and I think it was
probably 1914 thereabouts,

132
00:05:41,250 --> 00:05:42,810
but anyway, sometime around then,

133
00:05:42,810 --> 00:05:47,580
he said among other things that by going

134
00:05:47,580 --> 00:05:51,450
to low temperatures,
we draw away the veil,

135
00:05:51,450 --> 00:05:56,130
I think he called it, that
at ordinary temperatures

136
00:05:56,130 --> 00:06:01,130
noise draws over the phenomena predicted,

137
00:06:01,770 --> 00:06:03,480
I don't think he actually said predicted

138
00:06:03,480 --> 00:06:05,965
by quantum mechanics
because the whole idea

139
00:06:05,965 --> 00:06:09,309
of quantum mechanics are only
just being born at that time,

140
00:06:09,309 --> 00:06:14,309
but by microscopic physics
or something of that kind.

141
00:06:15,690 --> 00:06:20,057
So, so basically we're
going to low temperatures.

142
00:06:20,057 --> 00:06:24,240
You get rid of a lot of the noise,

143
00:06:24,240 --> 00:06:25,980
which is irrelevant to the real phenomenon

144
00:06:25,980 --> 00:06:26,940
you're trying to study,

145
00:06:26,940 --> 00:06:30,630
in this case, particularly
quantum mechanical phenomenon.

146
00:06:30,630 --> 00:06:33,870
- When you say noise, I think
a lot of us think of a sound,

147
00:06:33,870 --> 00:06:34,860
a very loud sound,
- Yes.

148
00:06:34,860 --> 00:06:35,833
- but that's not what we're

talking about necessarily.

149
00:06:35,833 --> 00:06:37,960
- It's a more general concept.

150
00:06:37,960 --> 00:06:40,956
- Can, you explain what noise
is and why low temperatures

151
00:06:40,956 --> 00:06:42,840
eliminate it?
- Yes.

152
00:06:42,840 --> 00:06:43,673
Yeah.

153
00:06:43,673 --> 00:06:48,673
Noise is, well, basically
anything you're not interested in.

154
00:06:48,944 --> 00:06:50,013
- (laughs) Sounds right.

155
00:06:50,013 --> 00:06:53,250
- And generally speaking
that if you're studying

156
00:06:53,250 --> 00:06:55,695
a particular system, say a set of atoms,

157
00:06:55,695 --> 00:06:57,870
what you're not interested in is going

158
00:06:57,870 --> 00:07:02,378
to be random effects coming
from the environment.

159
00:07:02,378 --> 00:07:07,378
Crudely speaking, the magnitude

of these random effects

160
00:07:07,442 --> 00:07:09,540
is proportional to the temperature.

161
00:07:09,540 --> 00:07:11,670
So, if you go to low enough temperatures,

162
00:07:11,670 --> 00:07:14,760
you get rid of most of it.

163
00:07:14,760 --> 00:07:18,745
And people nowadays
have got extremely good

164
00:07:18,745 --> 00:07:23,745
at devising means, first of all
getting to low temperatures.

165
00:07:23,790 --> 00:07:26,517
But when you're at low
temperatures shielding

166
00:07:26,517 --> 00:07:28,203
out anything that's left.

167
00:07:29,333 --> 00:07:31,260
- And you've already
sort of alluded to this,

168
00:07:31,260 --> 00:07:34,782
but I think in the past, and
maybe still sometimes today,

169
00:07:34,782 --> 00:07:37,238
people tend to associate quantum physics

170
00:07:37,238 --> 00:07:40,050
with effects at the microscopic level.

171
00:07:40,050 --> 00:07:41,640
But a lot of your work has shown

172
00:07:41,640 --> 00:07:44,640
that we can see quantum effects
at the macroscopic level

173
00:07:44,640 --> 00:07:46,500
- Yes.
- and with our own eyes.

174
00:07:46,500 --> 00:07:47,640
- Yes.
- Can you tell us

175
00:07:47,640 --> 00:07:50,100
about some of those
effects that you've studied

176
00:07:50,100 --> 00:07:51,985
and what makes them quantum?

177
00:07:51,985 --> 00:07:52,818
- Sure.

178
00:07:52,818 --> 00:07:54,900
I think one only has to distinguish

179
00:07:54,900 --> 00:07:57,482
between two different meanings

180
00:07:57,482 --> 00:07:59,894
of the words quantum mechanical effects

181
00:07:59,894 --> 00:08:02,420
at the macroscopic level.

182

00:08:02,420 --> 00:08:03,941
One kind of effect,

183
00:08:03,941 --> 00:08:07,185
which we've actually known
about for a long time,

184
00:08:07,185 --> 00:08:12,185
is when you have a large
number of microscopic entities,

185
00:08:15,120 --> 00:08:19,045
let us say atoms or
helium atoms for example,

186
00:08:19,045 --> 00:08:21,494
and for one reason or another,

187
00:08:21,494 --> 00:08:26,130
they're all constrained,
especially in low temperatures,

188
00:08:26,130 --> 00:08:27,980
they're all constrained to be behaving

189
00:08:27,980 --> 00:08:31,800
in exactly the same way at the same time.

190
00:08:31,800 --> 00:08:36,800
And you see what this means by an analogy.

191
00:08:37,470 --> 00:08:39,944
Suppose that I'm on a mountain top

192
00:08:39,944 --> 00:08:43,688
and looking down at the main square

193
00:08:43,688 --> 00:08:45,497
of a city below the mountain,

194
00:08:45,497 --> 00:08:50,370
and first of all,
suppose it's a market day

195
00:08:50,370 --> 00:08:54,058
when all the citizens are just
going about their business,

196
00:08:54,058 --> 00:08:56,871
and their business of course
is different in each case.

197
00:08:56,871 --> 00:08:59,711
And so looking down
from this great height,

198
00:08:59,711 --> 00:09:01,180
it's very difficult for me to see

199
00:09:01,180 --> 00:09:04,380
what any particular one of them's doing.

200
00:09:04,380 --> 00:09:06,000
But now suppose it's not the market day,

201
00:09:06,000 --> 00:09:08,730
but it's the day of a military parade.

202
00:09:08,730 --> 00:09:11,310
Now then you have a whole squad

203
00:09:11,310 --> 00:09:15,180
of soldiers marching exactly in lockstep,

204
00:09:15,180 --> 00:09:18,660
all doing exactly the same
thing at the same time.

205
00:09:18,660 --> 00:09:20,293
Much easier to determine

206
00:09:20,293 --> 00:09:24,210
what it is they're coming on and doing.

207
00:09:24,210 --> 00:09:25,950
And it's pretty much like that

208
00:09:25,950 --> 00:09:30,120
with the atoms or electrons
or pairs of electrons.

209
00:09:30,120 --> 00:09:34,365
The most spectacular
effects of this nature

210
00:09:34,365 --> 00:09:36,930
are probably those associated

211
00:09:36,930 --> 00:09:40,260
with superfluidity or superconductivity.

212
00:09:40,260 --> 00:09:44,458
In the case of
superconductivity for example,

213
00:09:44,458 --> 00:09:46,190
it means something like the following.

214
00:09:46,190 --> 00:09:48,381
Suppose that I take...

215
00:09:48,381 --> 00:09:50,730
And this is actually a demonstration,

216
00:09:50,730 --> 00:09:54,923
which I do quite frequently

at the father's market

217
00:09:54,923 --> 00:09:59,610
in about for school children and so forth.

218
00:09:59,610 --> 00:10:04,080
What you do is you take
a simple copper tube,

219
00:10:04,080 --> 00:10:07,530
maybe this is kind of
radius, and first of all,

220
00:10:07,530 --> 00:10:09,667
just to show the kids that there's nothing

221
00:10:09,667 --> 00:10:12,900
at all suspicious or weird about the tube,

222
00:10:12,900 --> 00:10:14,477
we just take a pebble and drop it down

223
00:10:14,477 --> 00:10:16,020
and it just goes down, right?

224
00:10:16,020 --> 00:10:20,130
Then next you take a little magnet

225
00:10:20,130 --> 00:10:22,530
and you try to drop it down

226
00:10:22,530 --> 00:10:25,650
and because it does not
drop instantaneously,

227
00:10:25,650 --> 00:10:28,140
it just takes a few seconds to do it,

228

00:10:28,140 --> 00:10:31,050
and you explain to the kids that this

229
00:10:31,050 --> 00:10:34,899
is because the magnet, as it falls,

230
00:10:34,899 --> 00:10:38,070
it's inducing an electric
current circulating

231
00:10:38,070 --> 00:10:40,230
around the tube.

232
00:10:40,230 --> 00:10:43,740
This in turn is producing
a magnetic field,

233
00:10:43,740 --> 00:10:46,020
which tends to sustain the magnet.

234
00:10:46,020 --> 00:10:48,303
So it does fall down but the currents,

235
00:10:48,303 --> 00:10:51,750
although they're generated
by the falling magnet,

236
00:10:51,750 --> 00:10:53,760
they tend to die away.

237
00:10:53,760 --> 00:10:55,140
And as they die away,

238
00:10:55,140 --> 00:10:57,993
the magnet falls further
and so on and so forth.

239
00:10:59,340 --> 00:11:02,536
And then you ask the kids

what they expect to happen

240
00:11:02,536 --> 00:11:06,360
if for some reason the
currents never did die away,

241
00:11:06,360 --> 00:11:08,038
but just kept on circulating.

242
00:11:08,038 --> 00:11:10,530
And some of them may
come up with the answer,

243
00:11:10,530 --> 00:11:12,171
well then the magnet is never going

244
00:11:12,171 --> 00:11:13,980
to come outta the bottom of the tube.

245
00:11:13,980 --> 00:11:15,000
It's just gonna hang there forever.

246
00:11:15,000 --> 00:11:17,850
And then you show them that if I take

247
00:11:17,850 --> 00:11:21,930
a pellet of yttrium barium copper oxide,

248
00:11:21,930 --> 00:11:24,243
one of the so-called high
temperature superconductors,

249
00:11:24,243 --> 00:11:27,682
I dunk it in liquid nitrogen

250
00:11:27,682 --> 00:11:30,365
and then I take a little magnet,

251

00:11:30,365 --> 00:11:34,950
and try to lower it onto the
pellet, then it will not fall.

252
00:11:34,950 --> 00:11:38,340
It'll just stay there
suspended until eventually,

253
00:11:38,340 --> 00:11:42,030
of course, if I don't
keep pouring nitrogen,

254
00:11:42,030 --> 00:11:44,408
the nitrogen will boil away.

255
00:11:44,408 --> 00:11:49,140
The YBCO compound just revert

256
00:11:49,140 --> 00:11:50,687
to its normal state and then indeed,

257
00:11:50,687 --> 00:11:52,054
the magnet will fall down.

258
00:11:52,054 --> 00:11:55,223
But then I tell them one further subtlety.

259
00:11:55,223 --> 00:11:56,918
Okay, let's imagine I don't do

260
00:11:56,918 --> 00:11:59,010
the experiment that way round as it were.

261
00:11:59,010 --> 00:12:00,568
What I'm going to do this time

262
00:12:00,568 --> 00:12:04,860
is to first take the little pellet,

263
00:12:04,860 --> 00:12:08,750
metal pellet in the normal phase,

264
00:12:08,750 --> 00:12:10,620
so at room temperature,

265
00:12:10,620 --> 00:12:12,096
I'll place the magnet on top of it

266
00:12:12,096 --> 00:12:15,264
and now I'm gonna pour
liquid nitrogen on it

267
00:12:15,264 --> 00:12:19,530
so that it will cool down into
the superconducting phase.

268
00:12:19,530 --> 00:12:21,480
Then what do you expect to happen?

269
00:12:21,480 --> 00:12:22,323
It's pretty difficult, actually.

270
00:12:22,323 --> 00:12:25,170
I don't think people
usually guess this right.

271
00:12:25,170 --> 00:12:26,902
What if I do the experiment right

272
00:12:26,902 --> 00:12:28,918
and it does take a little manipulation,

273
00:12:28,918 --> 00:12:31,350
but if I do it correctly,

274
00:12:31,350 --> 00:12:32,480
that what'll happen is that

275
00:12:32,480 --> 00:12:34,567
as the pellet goes superconducting,

276
00:12:34,567 --> 00:12:38,461
the magnet will actually
lift off spontaneously

277
00:12:38,461 --> 00:12:41,280
and just sort of hang there in mid air.

278
00:12:41,280 --> 00:12:43,648
I mean, unfortunately it's not too easy

279
00:12:43,648 --> 00:12:47,580
to do that experiment with large magnets.

280
00:12:47,580 --> 00:12:48,451
They're usually pretty tiny

281
00:12:48,451 --> 00:12:51,270
so you have to squint fairly
hard to see what's going on,

282
00:12:51,270 --> 00:12:52,969
but nevertheless is quite spectacular

283
00:12:52,969 --> 00:12:56,010
to see this thing lifting
off spontaneously.

284
00:12:56,010 --> 00:12:59,002
- How do children tend to react
to seeing this experiment?

285
00:12:59,002 --> 00:13:01,440
- They're fascinated, usually.

286

00:13:01,440 --> 00:13:02,823
- You must get all kinds of reactions.

287
00:13:02,823 --> 00:13:03,896
- Yes, yes.

288
00:13:03,896 --> 00:13:06,060
- And this is something you say

289
00:13:06,060 --> 00:13:07,350
you do fairly often to-

290
00:13:07,350 --> 00:13:10,349
- Well, before the pandemic, yes.

291
00:13:10,349 --> 00:13:13,026
for the Physics Department's slot

292
00:13:13,026 --> 00:13:15,602
at the farmer's market a couple

293
00:13:15,602 --> 00:13:17,880
of times every fall semester, really.

294
00:13:17,880 --> 00:13:18,713
- Mm hm.

295
00:13:18,713 --> 00:13:20,499
Why is it that you like
to do those demonstrations

296
00:13:20,499 --> 00:13:21,814
for young people?

297
00:13:21,814 --> 00:13:25,350
As a professor, you're
probably typically speaking

298

00:13:25,350 --> 00:13:27,450
to university aged people.
- Yeah,

299
00:13:27,450 --> 00:13:31,730
but it gets them fascinated with physics

300
00:13:31,730 --> 00:13:34,227
and I think that's always worthwhile.

301
00:13:34,227 --> 00:13:36,810
- Do you think that those
kind of demonstrations

302
00:13:36,810 --> 00:13:38,749
are able to convey an understanding

303
00:13:38,749 --> 00:13:41,150
of superconductivity
even to young children?

304
00:13:41,150 --> 00:13:43,328
- (laughs) Well, probably
not to be honest.

305
00:13:43,328 --> 00:13:47,800
In fact I say probably
not because I've actually,

306
00:13:48,810 --> 00:13:51,570
for the last few years I've been teaching

307
00:13:51,570 --> 00:13:54,630
a course at Shanghai Jiao
Tong University in China

308
00:13:54,630 --> 00:13:56,460
where I have a visiting appointment,

309

00:13:56,460 --> 00:13:58,845
and this course is to third year,

310
00:13:58,845 --> 00:14:02,771
fourth year undergraduates,
physics majors.

311
00:14:02,771 --> 00:14:06,690
And I've done everything
that I can possibly think of

312
00:14:06,690 --> 00:14:09,279
to really convey an understanding

313
00:14:09,279 --> 00:14:13,414
of superconductivity in what I think

314
00:14:13,414 --> 00:14:15,724
is relatively simple language.

315
00:14:15,724 --> 00:14:16,999
It never works.

316
00:14:16,999 --> 00:14:19,507
They always complain it's much too hard

317
00:14:19,507 --> 00:14:21,123
and advanced for them.

318
00:14:22,498 --> 00:14:24,544
And these are not dumb students.

319
00:14:24,544 --> 00:14:27,416
I mean, they're pretty
smart and, but nevertheless,

320
00:14:27,416 --> 00:14:32,416
it does seem rather hard to
get across the true essentials.

321
00:14:33,930 --> 00:14:36,607
I think it's rather easy to give,

322
00:14:36,607 --> 00:14:38,131
as it were a slick

323
00:14:38,131 --> 00:14:42,120
and rather misleading
picture of superconductivity,

324
00:14:42,120 --> 00:14:44,777
but to actually convey
what I think is the essence

325
00:14:44,777 --> 00:14:46,500
is pretty tricky.

326
00:14:46,500 --> 00:14:47,426
- Mm hm.
- Mm hm.

327
00:14:47,426 --> 00:14:50,370
Speaking of explaining
superconductivity to children,

328
00:14:50,370 --> 00:14:51,784
we were going to wait until a little later

329
00:14:51,784 --> 00:14:53,430
to ask children's questions,

330
00:14:53,430 --> 00:14:55,676
but there's one specifically
that we received

331
00:14:55,676 --> 00:14:58,377
from a young student named Damir,

332
00:14:58,377 --> 00:15:00,000
and I'm wondering if we could play that

333
00:15:00,000 --> 00:15:01,950
because it's very much on this subject.

334
00:15:02,850 --> 00:15:05,280
- Hi, my name is Damir
and I'm in grade eight.

335
00:15:05,280 --> 00:15:06,825
Why is superconductivity important

336
00:15:06,825 --> 00:15:10,080
in our lives today
other than MRI machines?

337
00:15:10,080 --> 00:15:11,880
Do you think they have a hidden use?

338
00:15:13,085 --> 00:15:18,085
- Already superconductors
are being used for,

339
00:15:18,987 --> 00:15:21,570
I don't know what the right word is,

340
00:15:21,570 --> 00:15:26,570
but in the United States there
are three major power grids

341
00:15:27,720 --> 00:15:30,416
and it's very important to be able

342
00:15:30,416 --> 00:15:35,040
to switch power from one grid,

343
00:15:35,040 --> 00:15:37,530

which may be overloaded to another one,

344
00:15:37,530 --> 00:15:40,470
which has sufficient
current carrying ability.

345
00:15:40,470 --> 00:15:43,194
I'm told there is a particular place

346
00:15:43,194 --> 00:15:44,951
somewhere down in Texas,

347
00:15:44,951 --> 00:15:48,648
which brings the three grids together

348
00:15:48,648 --> 00:15:52,500
and therefore is able to
switch current between them.

349
00:15:52,500 --> 00:15:55,710
Now if you do this with a,

350
00:15:55,710 --> 00:15:59,850
just using ordinary metals,
which are not superconducting,

351
00:15:59,850 --> 00:16:03,570
then one problem is that I think

352
00:16:03,570 --> 00:16:05,795
the device itself may overload

353
00:16:05,795 --> 00:16:10,795
and cause a catastrophic
failure in the grid.

354
00:16:11,400 --> 00:16:13,736
However, if you have a superconductor,

355
00:16:13,736 --> 00:16:17,220
it has the interesting property,

356
00:16:17,220 --> 00:16:21,180
if you try to drive to
higher current through it,

357
00:16:21,180 --> 00:16:24,081
it will just revert to its normal phase

358
00:16:24,081 --> 00:16:26,700
and therefore no longer
be superconducting.

359
00:16:26,700 --> 00:16:28,779
So, as automatic limiting feature,

360
00:16:28,779 --> 00:16:31,641
and as I say this right
now it's being used

361
00:16:31,641 --> 00:16:33,990
in the technical device in Texas,

362
00:16:33,990 --> 00:16:36,827
but in future I think
there's every prospect

363
00:16:36,827 --> 00:16:40,596
it may be used for long
distance current carrying,

364
00:16:40,596 --> 00:16:44,520
and that'll have the additional

365
00:16:44,520 --> 00:16:46,246
and very important benefit

366

00:16:46,246 --> 00:16:49,984
that as long as the metal
stays super conducting,

367
00:16:49,984 --> 00:16:53,625
no power is gonna be dissipated
in the transmission itself.

368
00:16:53,625 --> 00:16:57,600
Today, something like
10% of all the power,

369
00:16:57,600 --> 00:16:59,824
electrical power, which is produced,

370
00:16:59,824 --> 00:17:02,460
let us say in a coal fired power station

371
00:17:02,460 --> 00:17:04,649
or a nuclear power station or whatever,

372
00:17:04,649 --> 00:17:09,649
10% of it gets lost on
transmission to the place of use,

373
00:17:09,720 --> 00:17:13,440
which might be on
ordinary domestic housing.

374
00:17:13,440 --> 00:17:17,155
If we can in fact find
superconductors which are,

375
00:17:17,155 --> 00:17:19,073
remain superconducting at reasonable

376
00:17:19,073 --> 00:17:21,903
and also room temperature
and are sufficient,

377
00:17:21,903 --> 00:17:24,360
importantly are
sufficiently cheap to make,

378
00:17:24,360 --> 00:17:26,310
then they will dissipate no power,

379
00:17:26,310 --> 00:17:28,620
we will have saved 10%
all the power produced,

380
00:17:28,620 --> 00:17:31,200
and that's not by any
means a trivial thing.

381
00:17:31,200 --> 00:17:33,382
- Yeah, especially at times
when there are energy crises

382
00:17:33,382 --> 00:17:36,506
and growing populations.
- Yeah.

383
00:17:36,506 --> 00:17:40,080
- Can you tell us what is
the hurdle to attaining that?

384
00:17:40,080 --> 00:17:42,150
Why don't we have that already?

385
00:17:42,150 --> 00:17:43,320
Why is it so difficult.
- Yeah.

386
00:17:43,320 --> 00:17:48,090
For many years, let us
say certainly until 1986,

387
00:17:48,090 --> 00:17:50,460

there was a general belief

388
00:17:50,460 --> 00:17:54,100
that superconductivity could only occur

389
00:17:54,100 --> 00:17:58,620
at temperatures below about
sur 10th of room temperature.

390
00:17:58,620 --> 00:18:02,610
The reason for that is
somewhat complicated,

391
00:18:02,610 --> 00:18:05,505
but typically one factor which comes

392
00:18:05,505 --> 00:18:09,650
into the expression for
the maximum temperature

393
00:18:09,650 --> 00:18:12,531
of superconductivity is the characteristic

394
00:18:12,531 --> 00:18:15,187
so-called Dubai temperature associated

395
00:18:15,187 --> 00:18:19,800
with the lattice vibrations in a metal.

396
00:18:19,800 --> 00:18:21,817
Typically, that will itself be something

397
00:18:21,817 --> 00:18:23,970
of the order of room temperature.

398
00:18:23,970 --> 00:18:26,276
And then you find that
there's another factor

399
00:18:26,276 --> 00:18:31,276
which annoyingly never seems
to be quite equal to one.

400
00:18:31,330 --> 00:18:34,650
You can be able to say a 10th or 20th,

401
00:18:34,650 --> 00:18:37,200
but it's never really quite equal to one.

402
00:18:37,200 --> 00:18:39,780
So when you take those two
together, multiply 'em together,

403
00:18:39,780 --> 00:18:41,280
you'll get something like about
a 10th of room temperature.

404
00:18:41,280 --> 00:18:42,270
And as I say,

405
00:18:42,270 --> 00:18:45,840
this is the general
belief in the community

406
00:18:45,840 --> 00:18:47,193
for many, many years.

407
00:18:48,420 --> 00:18:49,998
However, in 1986,

408
00:18:49,998 --> 00:18:52,582
the high temperature, cuprate,

409
00:18:52,582 --> 00:18:55,645
superconductors were
discovered they are class,

410

00:18:55,645 --> 00:18:59,580
a rather special class of metals where,

411
00:18:59,580 --> 00:19:00,413
well, first of all,

412
00:19:00,413 --> 00:19:02,190
the mechanism of superconductivity appears

413
00:19:02,190 --> 00:19:03,433
to be quite different from what it is

414
00:19:03,433 --> 00:19:06,350
in the more traditional superconductors.

415
00:19:06,350 --> 00:19:09,480
And so, these factors
really becoming relevant

416
00:19:09,480 --> 00:19:12,500
and what governs the
transition temperature

417
00:19:12,500 --> 00:19:14,970
at the highest temperature,
which you get superconductivity,

418
00:19:14,970 --> 00:19:16,393
is something different.

419
00:19:16,393 --> 00:19:19,500
So initially these were discovered

420
00:19:19,500 --> 00:19:20,730
to be superconducting at something

421
00:19:20,730 --> 00:19:22,830
like 90 or 100 degrees absolute.

422
00:19:22,830 --> 00:19:24,780
So, about a third of room temperature

423
00:19:24,780 --> 00:19:27,570
and that was already a
big, big leap forward.

424
00:19:27,570 --> 00:19:30,243
But people were very
optimistic in the early days.

425
00:19:30,243 --> 00:19:31,620
They thought, okay,

426
00:19:31,620 --> 00:19:33,359
well, if we make it a
third of room temperature,

427
00:19:33,359 --> 00:19:35,321
then why not room temperature itself?

428
00:19:35,321 --> 00:19:38,670
Unfortunately, turned out
to be not quite that simple.

429
00:19:38,670 --> 00:19:42,151
They got up to about half a
room temperature and then stuck,

430
00:19:42,151 --> 00:19:45,060
and it's been stuck there for oh,

431
00:19:45,060 --> 00:19:46,713
30 years now I think, probably.

432
00:19:48,060 --> 00:19:52,000
In the meantime, something
else exciting has happened.

433
00:19:52,000 --> 00:19:57,000
People indeed do now have
essentially superconductivity

434
00:19:57,720 --> 00:19:59,790
at room temperature where they've actually

435
00:19:59,790 --> 00:20:02,615
got up to 273 degrees.

436
00:20:02,615 --> 00:20:07,615
Absolute is 300 and is
absolute, I'm not sure,

437
00:20:07,620 --> 00:20:08,840
it's probably 295 or something.

438
00:20:08,840 --> 00:20:11,753
But anyway, it's essentially
room temperature.

439
00:20:11,753 --> 00:20:15,510
However, since it's a rather a major snag,

440
00:20:15,510 --> 00:20:19,020
you can only do this under
really, really huge pressures,

441
00:20:19,020 --> 00:20:20,126
the kind of thing you can only get

442
00:20:20,126 --> 00:20:22,303
in a diamond anvil press for example.

443
00:20:22,303 --> 00:20:23,713
Not the sort of thing you just turn

444
00:20:23,713 --> 00:20:25,156

a knob and get it room temp,

445
00:20:25,156 --> 00:20:26,404
at room pressure.
- Right.

446
00:20:26,404 --> 00:20:31,267
- And so, people have all sorts of ideas

447
00:20:31,267 --> 00:20:34,050
about how you might get
around this problem.

448
00:20:34,050 --> 00:20:36,233
For example, you might try to produce

449
00:20:36,233 --> 00:20:40,110
the superconductivity under
these very high pressures

450
00:20:40,110 --> 00:20:43,020
and then gradually relax
the pressure and so forth.

451
00:20:43,020 --> 00:20:44,580
And some of those might work,

452
00:20:44,580 --> 00:20:46,654
but so far we don't actually

453
00:20:46,654 --> 00:20:50,585
have the robust superconductivity

454
00:20:50,585 --> 00:20:52,950
at under ambient conditions,

455
00:20:52,950 --> 00:20:56,514
meaning at normal
temperatures and pressures

456
00:20:56,514 --> 00:20:58,170
like in this room now.

457
00:20:58,170 --> 00:21:00,816
So, I think we'll get them but I mean,

458
00:21:00,816 --> 00:21:02,506
I'm an optimist in that respect.

459
00:21:02,506 --> 00:21:03,789
- (chuckles) That was my next question.

460
00:21:03,789 --> 00:21:06,000
Are you an optimist that we'll get there,

461
00:21:06,000 --> 00:21:07,050
but you just said so.

462
00:21:07,050 --> 00:21:08,424
- Yeah, I think I am.

463
00:21:08,424 --> 00:21:12,570
In fact, when I talk to a
audience of school kids,

464
00:21:12,570 --> 00:21:15,810
I often predict that if
not in my time, lifetime,

465
00:21:15,810 --> 00:21:17,040
at least in there's we will

466
00:21:17,040 --> 00:21:18,855
have room temperature superconductivity

467
00:21:18,855 --> 00:21:22,790
and then we'll have all these

marvelous science fiction

468
00:21:22,790 --> 00:21:26,764
like scenarios of people being conveyed

469
00:21:26,764 --> 00:21:28,170
from one place to another

470
00:21:28,170 --> 00:21:31,162
on these floating superconducting magnets

471
00:21:31,162 --> 00:21:32,649
and so on and so forth.

472
00:21:32,649 --> 00:21:35,370
- And earlier when we were asking

473
00:21:35,370 --> 00:21:38,430
you about these macroscopic
quantum effects in general,

474
00:21:38,430 --> 00:21:39,295
you made this nice analogy
- Oh.

475
00:21:39,295 --> 00:21:41,356
- to this military parade.
- Yes.

476
00:21:41,356 --> 00:21:43,731
- How do I think of that military parade

477
00:21:43,731 --> 00:21:46,680
in the context of superconductivity?

478
00:21:46,680 --> 00:21:49,722
- The really two, well, I would say,

479

00:21:49,722 --> 00:21:51,370
other people might disagree,

480
00:21:51,370 --> 00:21:54,480
but I would say that there
are two major phenomena,

481
00:21:54,480 --> 00:21:56,459
which in some sense for me at least define

482
00:21:56,459 --> 00:21:59,128
what I mean by superconductivity.

483
00:21:59,128 --> 00:22:03,390
One of them is the sort
of floating magnet effect,

484
00:22:03,390 --> 00:22:05,640
which is very spectacular,

485
00:22:05,640 --> 00:22:08,289
very characteristic of superconductors.

486
00:22:08,289 --> 00:22:12,810
The other is in some
sense less spectacular.

487
00:22:12,810 --> 00:22:16,170
It's simply that if I take a ring say of,

488
00:22:16,170 --> 00:22:18,480
first I take an ordinary copper ring

489
00:22:18,480 --> 00:22:21,351
and I generate what we call an EMF,

490
00:22:21,351 --> 00:22:25,920
a voltage around the
ring or electric field,

491
00:22:25,920 --> 00:22:27,150
if you like, around the ring.

492
00:22:27,150 --> 00:22:28,200
I can do that for example,

493
00:22:28,200 --> 00:22:31,560
by waving a little magnet in the vicinity.

494
00:22:31,560 --> 00:22:35,009
Then that will generate
an electric current.

495
00:22:35,009 --> 00:22:38,280
But if I'm talking about
just something like copper,

496
00:22:38,280 --> 00:22:42,345
an ordinary metal, once I've
stopped waving the magnet,

497
00:22:42,345 --> 00:22:43,748
the current will just die away

498
00:22:43,748 --> 00:22:46,080
and it'll die away on a
very short time scale,

499
00:22:46,080 --> 00:22:49,260
maybe a billionth of a second
or something like that.

500
00:22:49,260 --> 00:22:50,430
Very, very fast.

501
00:22:50,430 --> 00:22:53,880
If on the other hand I take
a superconducting ring,

502
00:22:53,880 --> 00:22:56,544
I do the same thing, I
wave the magnet around,

503
00:22:56,544 --> 00:22:59,289
generate current, start circulating,

504
00:22:59,289 --> 00:23:02,880
but now I take the magnet
away, nothing happens.

505
00:23:02,880 --> 00:23:05,320
The current continues to circulate.

506
00:23:05,320 --> 00:23:10,320
Okay, so now in terms of the
platoon of soldiers analogy,

507
00:23:11,190 --> 00:23:13,890
think first about the
normal metal and say,

508
00:23:13,890 --> 00:23:15,180
rather than the marketplace now,

509
00:23:15,180 --> 00:23:17,165
think about a forest,

510
00:23:17,165 --> 00:23:19,530
a natural forest, not a plantation.

511
00:23:19,530 --> 00:23:22,457
So, the trees are just arranged at random.

512
00:23:22,457 --> 00:23:25,816
And imagine I take a group of school kids

513

00:23:25,816 --> 00:23:29,077
and I simply tell them to run

514
00:23:29,077 --> 00:23:32,276
into the forest and I
start 'em running off

515
00:23:32,276 --> 00:23:34,468
in a particular direction,

516
00:23:34,468 --> 00:23:37,830
but I don't give them any
further instructions than that.

517
00:23:37,830 --> 00:23:42,030
Well fine, they start running
all in the same direction,

518
00:23:42,030 --> 00:23:46,435
but eventually one kid is
going to run up against a tree.

519
00:23:46,435 --> 00:23:48,810
So having no special instructions,

520
00:23:48,810 --> 00:23:50,773
he will swerve to avoid it

521
00:23:50,773 --> 00:23:53,880
and end up running in
a different direction.

522
00:23:53,880 --> 00:23:55,950
And after a few minutes you can see

523
00:23:55,950 --> 00:23:57,360
that all the kids are
gonna be running around

524

00:23:57,360 --> 00:23:59,100
in completely random directions.

525
00:23:59,100 --> 00:24:02,194
So that's the analog of
what happens in a normal,

526
00:24:02,194 --> 00:24:04,080
in the normal metal like copper,

527
00:24:04,080 --> 00:24:06,964
you start the electrons off all
going in the same direction.

528
00:24:06,964 --> 00:24:11,781
Then they bump into, in this
case, impurities in the metal,

529
00:24:11,781 --> 00:24:14,640
be scattered in random
directions as it were,

530
00:24:14,640 --> 00:24:16,140
no special instructions.

531
00:24:16,140 --> 00:24:19,770
So they stay in the new
direction and after a short time,

532
00:24:19,770 --> 00:24:21,450
they're all running around at random.

533
00:24:21,450 --> 00:24:22,608
So, no total current.

534
00:24:22,608 --> 00:24:24,456
The currents just canceled.

535
00:24:24,456 --> 00:24:27,703

Now, okay, let's think
about the superconductor

536
00:24:27,703 --> 00:24:29,060
and let's think about the,

537
00:24:29,060 --> 00:24:31,650
in this case, actually,
it's not single electrons,

538
00:24:31,650 --> 00:24:32,760
it's pairs of electrons,

539
00:24:32,760 --> 00:24:34,628
which makes it a little more complicated.

540
00:24:34,628 --> 00:24:36,999
So, you have these pairs of electrons,

541
00:24:36,999 --> 00:24:39,180
which I send off.

542
00:24:39,180 --> 00:24:43,140
Again, I send them off all
running in the same direction.

543
00:24:43,140 --> 00:24:45,120
Well, again, one of the electrons

544
00:24:45,120 --> 00:24:49,250
in the pair or maybe the two
run up against an impurity,

545
00:24:49,250 --> 00:24:51,030
so they swerve to avoid it.

546
00:24:51,030 --> 00:24:52,980
But the crucial difference

547
00:24:52,980 --> 00:24:55,590
is that they now have instructions.

548
00:24:55,590 --> 00:24:56,940
They've all got to keep in step,

549
00:24:56,940 --> 00:24:59,250
at least as far as this is possible.

550
00:24:59,250 --> 00:25:02,311
So having swerved to avoid the impurity,

551
00:25:02,311 --> 00:25:04,976
they all drop back and get in in step

552
00:25:04,976 --> 00:25:08,670
with all the rest.

553
00:25:08,670 --> 00:25:10,740
So they'll be like the platoon

554
00:25:10,740 --> 00:25:13,291
of soldiers rather than the kids.

555
00:25:13,291 --> 00:25:15,900
And so, the current will
continue essentially

556
00:25:15,900 --> 00:25:18,619
to flow for as long as
I want to look at it.

557
00:25:18,619 --> 00:25:22,501
- And that's due to the
makeup of the metal itself?

558
00:25:22,501 --> 00:25:24,140
It's internal structure?

559
00:25:24,140 --> 00:25:26,489
- That's a very complicated
question actually.

560
00:25:26,489 --> 00:25:27,428
(Colin chuckles)

561
00:25:27,428 --> 00:25:29,790
In other words, what
exactly is it that makes

562
00:25:29,790 --> 00:25:31,540
some metal superconducting and others not?

563
00:25:31,540 --> 00:25:33,150
- Mm hm.
- In the old days,

564
00:25:33,150 --> 00:25:34,314
it used to be thought the answer

565
00:25:34,314 --> 00:25:37,925
was at least somewhat straightforward.

566
00:25:37,925 --> 00:25:42,925
You've gotta be able to form
these pairs of electrons,

567
00:25:43,055 --> 00:25:44,490
but in order to do that,

568
00:25:44,490 --> 00:25:48,273
you need some kind of effective
attraction between them.

569
00:25:49,290 --> 00:25:50,992
Now, the problem is that if you just think

570
00:25:50,992 --> 00:25:55,287
about the direct coulomb
interaction between electrons,

571
00:25:55,287 --> 00:25:57,015
it actually is repulsive.

572
00:25:57,015 --> 00:25:59,850
So it's not going to
help you to form pairs,

573
00:25:59,850 --> 00:26:01,007
or at least not obviously.

574
00:26:01,007 --> 00:26:03,660
However, it turns out that the subtlety,

575
00:26:03,660 --> 00:26:08,100
and this is the work of my
former colleague John Bardeen,

576
00:26:08,100 --> 00:26:11,580
and by colleagues plural, John Bardeen,

577
00:26:11,580 --> 00:26:13,590
and David Pines at the
University of Illinois

578
00:26:13,590 --> 00:26:15,480
way back in the '50s,

579
00:26:15,480 --> 00:26:19,020
they realized that if what could happen

580
00:26:19,020 --> 00:26:20,976
is something like this,

581
00:26:20,976 --> 00:26:25,770

one of the electrons is
coming through the lattice,

582
00:26:25,770 --> 00:26:28,256
and it's coming in sometimes quite fast,

583
00:26:28,256 --> 00:26:31,284
and as it comes through,

584
00:26:31,284 --> 00:26:35,344
it will tend to attract the ions

585
00:26:35,344 --> 00:26:38,760
of the metal which are positively charged.

586
00:26:38,760 --> 00:26:42,428
So the ions will tend to congregate

587
00:26:42,428 --> 00:26:44,673
towards the path of the electron,

588
00:26:45,638 --> 00:26:49,491
but the electron's rather fast
and the ions are rather slow.

589
00:26:49,491 --> 00:26:54,491
So, long after the electron
has gone away again,

590
00:26:54,930 --> 00:26:58,110
the ions will still be left
there sort of hanging around

591
00:26:58,110 --> 00:27:01,590
in around the path where the electron was.

592
00:27:01,590 --> 00:27:04,680
That of course forms a positive charge,

593
00:27:04,680 --> 00:27:07,080
and our second electron
is now attracted to that.

594
00:27:07,080 --> 00:27:09,690
And so, the second electron is attracted

595
00:27:09,690 --> 00:27:12,720
not to where the first one now is,

596
00:27:12,720 --> 00:27:15,120
but where it was in the recent past.

597
00:27:15,120 --> 00:27:20,040
And it turns out that
is a very effective way

598
00:27:20,040 --> 00:27:21,840
of forming these pairs,

599
00:27:21,840 --> 00:27:25,140
so called Cooper pairs of electrons.

600
00:27:25,140 --> 00:27:27,762
And then that is thought
to be the mechanism

601
00:27:27,762 --> 00:27:31,899
of superconductivity in the
old-fashioned superconductors.

602
00:27:31,899 --> 00:27:35,790
So, the metals which don't
become superconducting

603
00:27:35,790 --> 00:27:36,623
are simply those which,

604

00:27:36,623 --> 00:27:39,456
of which this effect is not strong enough

605
00:27:39,456 --> 00:27:42,630
to outweigh the original
coulomb repulsion.

606
00:27:42,630 --> 00:27:43,775
And that's a very detailed matter

607
00:27:43,775 --> 00:27:46,920
which is difficult to get
right from those principles,

608
00:27:46,920 --> 00:27:48,990
but people are getting
better at it these days.

609
00:27:48,990 --> 00:27:53,250
But now in more recent superconductors

610
00:27:53,250 --> 00:27:55,170
like the so-called high temperature ones,

611
00:27:55,170 --> 00:27:57,360
the cuprate superconductors,

612
00:27:57,360 --> 00:27:59,850
almost certainly that's
not what's happening.

613
00:27:59,850 --> 00:28:01,458
Something different is happening,

614
00:28:01,458 --> 00:28:05,175
and although one doesn't know
in detail what's going on,

615
00:28:05,175 --> 00:28:09,223

what seems to be likely is that already

616
00:28:09,223 --> 00:28:13,110
in the normal phase at say
room temperature or whatever,

617
00:28:13,110 --> 00:28:14,339
these metals are what

618
00:28:14,339 --> 00:28:17,509
are called strongly correlated systems,

619
00:28:17,509 --> 00:28:20,610
which means that the coulomb interaction

620
00:28:20,610 --> 00:28:22,223
already has had a large effect

621
00:28:22,223 --> 00:28:25,770
and governs the relative behavior

622
00:28:25,770 --> 00:28:27,785
of the electrons and so forth.

623
00:28:27,785 --> 00:28:30,941
What happens when the Cooper
pairs form in this case

624
00:28:30,941 --> 00:28:33,840
is not that you've produced, as it were,

625
00:28:33,840 --> 00:28:36,990
a new attraction between the electrons,

626
00:28:36,990 --> 00:28:39,636
rather you've reduced
the original repulsion

627

00:28:39,636 --> 00:28:42,270
and that makes it advantageous to do it.

628
00:28:42,270 --> 00:28:43,440
I think most people would agree

629
00:28:43,440 --> 00:28:46,410
that that's the sort of
very general scenario,

630
00:28:46,410 --> 00:28:49,573
but to actually dot the
Is and cross the Ts exists

631
00:28:49,573 --> 00:28:51,600
by no means trivial.
- Much more complicated.

632
00:28:51,600 --> 00:28:55,620
- No, so there really is
no universal agreed theory

633
00:28:55,620 --> 00:28:57,960
of the cuprate superconductors

634
00:28:57,960 --> 00:29:00,600
in the sense that it was
of the old-fashioned ones.

635
00:29:00,600 --> 00:29:05,130
What I talked about was
explicitly superconductivity.

636
00:29:05,130 --> 00:29:08,010
Superfluidity is a very similar phenomenon

637
00:29:08,010 --> 00:29:12,300
but occurring in a
electrically neutral system,

638
00:29:12,300 --> 00:29:13,560
like say, liquid helium.

639
00:29:13,560 --> 00:29:17,001
It's basically the same
conjunction of effects,

640
00:29:17,001 --> 00:29:19,590
but in slightly different disguise

641
00:29:19,590 --> 00:29:21,900
because you are talking
about a neutral system.

642
00:29:21,900 --> 00:29:25,062
So for example, in the case
of the persistent currents,

643
00:29:25,062 --> 00:29:27,817
it's basically the same
as in superconductors.

644
00:29:27,817 --> 00:29:32,141
If I take a ring, annular
flower ball kind of geometry,

645
00:29:32,141 --> 00:29:33,984
I put liquid helium in it

646
00:29:33,984 --> 00:29:38,448
and I somehow manage
to get in circulating,

647
00:29:38,448 --> 00:29:40,560
if it's in all phase again,

648
00:29:40,560 --> 00:29:42,694
it'll just stop after a minute or two.

649
00:29:42,694 --> 00:29:44,949
If it's in the superfluid phase,

650
00:29:44,949 --> 00:29:47,257
it'll basically continue
to circulate forever

651
00:29:47,257 --> 00:29:49,800
just as the electrons did
in the superconductor.

652
00:29:49,800 --> 00:29:51,750
So that's straightforward analogy.

653
00:29:51,750 --> 00:29:55,863
But in the case of the levitated magnet,

654
00:29:55,863 --> 00:29:57,440
it's a little more complicated.

655
00:29:57,440 --> 00:30:00,780
In this case what happens is that

656
00:30:00,780 --> 00:30:02,575
if I again take an annular ring,

657
00:30:02,575 --> 00:30:06,750
put it to say on a old-fashioned
grammophone turntable

658
00:30:06,750 --> 00:30:08,706
and start the turntable rotating,

659
00:30:08,706 --> 00:30:11,250
again, if it's in the normal
phase, it just like water,

660
00:30:11,250 --> 00:30:13,868

it'll eventually come into
retraction with the turntable.

661
00:30:13,868 --> 00:30:18,683
If I do this with helium at not
sufficient low temperatures,

662
00:30:18,683 --> 00:30:22,973
it will refuse to rotate
with the container

663
00:30:22,973 --> 00:30:26,310
and it'll stay, well,
at the site at least,

664
00:30:26,310 --> 00:30:31,310
it'll stay stationary in the
laboratory frame of reference.

665
00:30:31,681 --> 00:30:35,377
Now, if you think about
it, you might think,

666
00:30:35,377 --> 00:30:36,450
"Well, wait a minute.

667
00:30:36,450 --> 00:30:38,850
That's a bit suspicious,"
because after all

668
00:30:38,850 --> 00:30:40,673
the laboratories itself rotating

669
00:30:40,673 --> 00:30:42,897
was the rotation of the earth, et cetera.

670
00:30:42,897 --> 00:30:45,720
Is it really stationary in the laboratory

671

00:30:45,720 --> 00:30:48,390
or is it really stationary in
the frame of the fixed stars?

672
00:30:48,390 --> 00:30:51,840
And the theoretical
prediction rather confidently

673
00:30:51,840 --> 00:30:54,124
is it's stationary in
the frame of fixed stars.

674
00:30:54,124 --> 00:30:57,570
Experimentally it's a little less clear,

675
00:30:57,570 --> 00:30:58,403
but it's consistent.

676
00:30:58,403 --> 00:30:59,745
I should say the
experiments are consistent,

677
00:30:59,745 --> 00:31:02,580
at least from that big rod, right answer.

678
00:31:02,580 --> 00:31:03,900
So superfluids then

679
00:31:03,900 --> 00:31:06,434
are rather closely analogous
to superconductors.

680
00:31:06,434 --> 00:31:08,550
On the other hand, again,

681
00:31:08,550 --> 00:31:10,835
a consequence of a very large number

682
00:31:10,835 --> 00:31:12,443

of microscopic objects,

683
00:31:12,443 --> 00:31:15,390
in this case the atoms being constrained

684
00:31:15,390 --> 00:31:16,980
to do the same thing at the same time.

685
00:31:16,980 --> 00:31:19,750
The other kind of
macroscopic quantum effect,

686
00:31:19,750 --> 00:31:23,141
which is what I've been
more specifically interested

687
00:31:23,141 --> 00:31:26,946
in over the last 30, 40 odd years

688
00:31:26,946 --> 00:31:31,110
is that in microscopic physics

689
00:31:31,110 --> 00:31:34,800
you very often get the situation

690
00:31:34,800 --> 00:31:39,079
that a microscopic
object, let's say an atom,

691
00:31:39,079 --> 00:31:44,079
it appears to behave in
a different way depending

692
00:31:44,430 --> 00:31:46,980
on whether or not you're looking at it.

693
00:31:46,980 --> 00:31:49,115
The standard example of this

694
00:31:49,115 --> 00:31:52,187
is a so-called Young slits
interference experiment,

695
00:31:52,187 --> 00:31:57,180
which was originally done
by Young himself with light.

696
00:31:57,180 --> 00:31:58,800
Nowadays it's done with electrons

697
00:31:58,800 --> 00:32:01,950
and the late Akira Tonomura in Japan

698
00:32:01,950 --> 00:32:05,490
did a whole series of very
convincing experiments on this.

699
00:32:05,490 --> 00:32:07,170
And so at least in principle,

700
00:32:07,170 --> 00:32:08,825
you can do the experiment this way.

701
00:32:08,825 --> 00:32:12,178
You take a source of of electrons.

702
00:32:12,178 --> 00:32:15,216
Well, you have to sort of tune

703
00:32:15,216 --> 00:32:17,019
the knobs on the black
box rather carefully

704
00:32:17,019 --> 00:32:19,350
to make sure they're the right electrons.

705
00:32:19,350 --> 00:32:20,734

But you know.

706
00:32:20,734 --> 00:32:23,281
And you allow them to go
through one of two paths

707
00:32:23,281 --> 00:32:26,380
and eventually arrive at a final screen.

708
00:32:26,380 --> 00:32:29,173
And if you just set it up that way

709
00:32:29,173 --> 00:32:31,890
and you don't look at
what's going on as it were,

710
00:32:31,890 --> 00:32:35,130
then you find you get a standard pattern

711
00:32:35,130 --> 00:32:39,570
of bright and dark lines
on your final screen.

712
00:32:39,570 --> 00:32:40,890
The way that Tonomura does it,

713
00:32:40,890 --> 00:32:43,200
you can actually see, as it were,

714
00:32:43,200 --> 00:32:46,050
the individual electrons
coming through one by one

715
00:32:46,050 --> 00:32:47,719
and gradually building up this pattern.

716
00:32:47,719 --> 00:32:49,890
So, it's clear that
that's what they're doing

717
00:32:49,890 --> 00:32:50,723
when you don't look at them.

718
00:32:50,723 --> 00:32:52,170
On the other hand,

719
00:32:52,170 --> 00:32:54,719
if you try to detect
which of these two paths

720
00:32:54,719 --> 00:32:57,401
the given an electron took,

721
00:32:57,401 --> 00:33:01,175
you always see it took
one path or the other,

722
00:33:01,175 --> 00:33:04,699
then you destroy the
interference pattern, okay?

723
00:33:04,699 --> 00:33:07,170
So you have the choice between observing

724
00:33:07,170 --> 00:33:09,510
which path it took or observing
the interference pattern.

725
00:33:09,510 --> 00:33:10,410
This is an example

726
00:33:10,410 --> 00:33:13,020
of what Niels Bohr called
complementarity, basically.

727
00:33:13,020 --> 00:33:14,733
In the early days of quantum mechanics,

728
00:33:14,733 --> 00:33:19,304
it used to be thought that
somehow this phenomenon,

729
00:33:19,304 --> 00:33:22,350
so called interference or phenomenon,

730
00:33:22,350 --> 00:33:24,120
or quantum superposition,

731
00:33:24,120 --> 00:33:27,299
this was limited to the microscopic world,

732
00:33:27,299 --> 00:33:29,761
atoms, electrons, and so forth.

733
00:33:29,761 --> 00:33:32,250
Then Schrodinger through,

734
00:33:32,250 --> 00:33:37,250
well, let's say make a pun,
a cat among pigeons (laughs)

735
00:33:37,260 --> 00:33:39,660
by his famous cat for the experiment,

736
00:33:39,660 --> 00:33:41,597
he envisaged a situation

737
00:33:41,597 --> 00:33:45,480
in which if the electron in question,

738
00:33:45,480 --> 00:33:46,950
I actually had a slightly different setup,

739
00:33:46,950 --> 00:33:49,667
but let's say the electron in
question, if it went one way,

740
00:33:49,667 --> 00:33:54,667
then it would trigger some
kind of encounter or whatever.

741
00:33:55,770 --> 00:33:58,160
And as a result, various
things would happen

742
00:33:58,160 --> 00:33:59,130
at the everyday level.

743
00:33:59,130 --> 00:34:02,400
In his case he had a
cat inside a closed box

744
00:34:02,400 --> 00:34:06,210
and the cat would die.

745
00:34:06,210 --> 00:34:10,440
It would actually not be as
many people erroneously think,

746
00:34:10,440 --> 00:34:13,020
it would not be shot or electrocuted.

747
00:34:13,020 --> 00:34:16,890
It would actually be poisoned
with cyanide as a detail.

748
00:34:16,890 --> 00:34:18,560
Anyway, the cat would end up dead.

749
00:34:18,560 --> 00:34:21,993
If the electron went in the opposite path,

750
00:34:21,993 --> 00:34:23,040
nothing would happen.

751
00:34:23,040 --> 00:34:24,570
The cat will stay alive.

752
00:34:24,570 --> 00:34:28,560
Now, the thing is that
it's not an experimental,

753
00:34:28,560 --> 00:34:31,200
it's not a directly observed
experimental result,

754
00:34:31,200 --> 00:34:33,570
but it's a very firm prediction

755
00:34:33,570 --> 00:34:36,029
of the formalism of quantum mechanics

756
00:34:36,029 --> 00:34:40,230
that if you're not looking
at the experiment as it were,

757
00:34:40,230 --> 00:34:43,039
the correct description of the electron

758
00:34:43,039 --> 00:34:44,431
at the intermediate stage

759
00:34:44,431 --> 00:34:47,291
is that it is neither doing
one thing nor the other.

760
00:34:47,291 --> 00:34:49,272
It's in a so-called quantum superposition

761
00:34:49,272 --> 00:34:52,230
and it's only because it's
in this quantum superposition

762

00:34:52,230 --> 00:34:54,630
that it can later cause
the interference phenomenon

763
00:34:54,630 --> 00:34:55,740
on the screen.

764
00:34:55,740 --> 00:34:57,660
On the other hand, if you look at it,

765
00:34:57,660 --> 00:35:01,104
then it appears to choose
one alternative or the other.

766
00:35:01,104 --> 00:35:03,990
Well, what Schrodinger
was pointing out basically

767
00:35:03,990 --> 00:35:08,070
was that if you believe as here most

768
00:35:08,070 --> 00:35:09,108
of his contemporaries believed

769
00:35:09,108 --> 00:35:12,090
that quantum mechanics is the whole story,

770
00:35:12,090 --> 00:35:14,850
then you observe that the formalism

771
00:35:14,850 --> 00:35:18,319
of quantum mechanics has a
very characteristic property.

772
00:35:18,319 --> 00:35:21,908
However complicated the
system you're talking about,

773
00:35:21,908 --> 00:35:24,854

if you start off with two possibilities,

774
00:35:24,854 --> 00:35:29,854
A and B say, if alternative
A initially leads

775
00:35:29,957 --> 00:35:32,564
to alternative A prime,
at the end of the day,

776
00:35:32,564 --> 00:35:34,794
alternative B leads to alternative B prime

777
00:35:34,794 --> 00:35:36,510
at the end of the day,

778
00:35:36,510 --> 00:35:39,574
then the quantum
superposition of A + B leads

779
00:35:39,574 --> 00:35:41,250
to the quantum superposition

780
00:35:41,250 --> 00:35:42,500
of A prime + B prime.

781
00:35:42,500 --> 00:35:45,690
It's a very, very fundamental feature

782
00:35:45,690 --> 00:35:47,220
of the quantum formulism.

783
00:35:47,220 --> 00:35:51,180
And if you deny that, you're
no longer really believing

784
00:35:51,180 --> 00:35:53,460
in quantum mechanics, you're
believing in something else.

785
00:35:53,460 --> 00:35:56,330
So in his case, in the
case of the cat experiment,

786
00:35:56,330 --> 00:35:58,907
since the electron started off

787
00:35:58,907 --> 00:36:02,370
in the linear quantum superposition

788
00:36:02,370 --> 00:36:04,195
of these two possibilities,

789
00:36:04,195 --> 00:36:08,700
then finally the cat or more accurately,

790
00:36:08,700 --> 00:36:10,436
the universe containing the cat,

791
00:36:10,436 --> 00:36:13,268
must end up in a quantum superposition

792
00:36:13,268 --> 00:36:15,539
of these two possibilities.

793
00:36:15,539 --> 00:36:17,708
And yet, I don't think anyone doubts

794
00:36:17,708 --> 00:36:19,589
that if we were to do this experiment

795
00:36:19,589 --> 00:36:23,106
and fortunately animal
protection societies

796
00:36:23,106 --> 00:36:26,760
have prevented us doing it in

statistically significant way,

797
00:36:26,760 --> 00:36:29,553
but if we did, then in
each individual case

798
00:36:29,553 --> 00:36:30,857
when we open the box,

799
00:36:30,857 --> 00:36:33,960
we would definitely find the
cat to be either alive or dead.

800
00:36:33,960 --> 00:36:35,190
And that's basically the,

801
00:36:35,190 --> 00:36:37,230
people usually call it the
quantum measurement paradox.

802
00:36:37,230 --> 00:36:40,173
I prefer to call quantum
realization paradox.

803
00:36:40,173 --> 00:36:43,275
The fact that at the microscopic level,

804
00:36:43,275 --> 00:36:48,275
no alternative is definitely realized.

805
00:36:48,644 --> 00:36:52,353
At the microscopic level
it fairly obviously is.

806
00:36:52,353 --> 00:36:57,353
When Schrodinger first
put up this paradox,

807
00:36:57,480 --> 00:36:59,730

it isn't clear whether how seriously

808
00:36:59,730 --> 00:37:01,440
he himself took it, really.

809
00:37:01,440 --> 00:37:03,930
People shrugged it off, basically.

810
00:37:03,930 --> 00:37:07,427
And the reason that most
people shrugged it off

811
00:37:07,427 --> 00:37:12,300
was the phenomenon was
called de-coherence.

812
00:37:12,300 --> 00:37:13,590
Which means that, okay,

813
00:37:13,590 --> 00:37:18,590
so long as I have a system
which is sufficiently isolated

814
00:37:18,944 --> 00:37:22,507
that I can try to describe it entirely

815
00:37:22,507 --> 00:37:24,106
in its own right as it were,

816
00:37:24,106 --> 00:37:26,550
for example a beam of atoms in vacuum,

817
00:37:26,550 --> 00:37:27,599
something like that,

818
00:37:27,599 --> 00:37:30,150
then I can simply write down

819

00:37:30,150 --> 00:37:32,460
the textbook quantum mechanical formula.

820
00:37:32,460 --> 00:37:34,350
But the moment that system starts

821
00:37:34,350 --> 00:37:37,584
to interact with any kind of environment,

822
00:37:37,584 --> 00:37:40,732
that means anything I'm
not interested in really,

823
00:37:40,732 --> 00:37:43,650
the environment will come in
and try to screw things up.

824
00:37:43,650 --> 00:37:45,004
And in particular what it'll try to do

825
00:37:45,004 --> 00:37:47,778
is to randomize the relative phase

826
00:37:47,778 --> 00:37:49,710
of the different components

827
00:37:49,710 --> 00:37:51,330
of the quantum mechanical wave function.

828
00:37:51,330 --> 00:37:53,139
A slight over simplification,

829
00:37:53,139 --> 00:37:54,697
but it basically conveys the essence.

830
00:37:54,697 --> 00:37:57,057
Since the interference pattern depends

831

00:37:57,057 --> 00:37:59,230
very crucially on the relative phase,

832
00:37:59,230 --> 00:38:02,339
this means that the moment the
environment screws things up,

833
00:38:02,339 --> 00:38:05,117
you no longer get the
interference effect and so forth.

834
00:38:05,117 --> 00:38:07,852
So all your predictions
are just as if the electron

835
00:38:07,852 --> 00:38:09,544
had gone through one slit or the other,

836
00:38:09,544 --> 00:38:10,817
but you just don't know which.

837
00:38:10,817 --> 00:38:11,790
In technical language,

838
00:38:11,790 --> 00:38:13,710
it means that the off
diagonal one elements

839
00:38:13,710 --> 00:38:15,714
of the density matrix go away.

840
00:38:15,714 --> 00:38:19,198
Anyway, so a lot of people
just basically shrugged

841
00:38:19,198 --> 00:38:21,630
this off and this is an argument

842
00:38:21,630 --> 00:38:23,984

which occurred and recurred and oh,

843
00:38:23,984 --> 00:38:26,280
even through the '70s and '80s

844
00:38:26,280 --> 00:38:28,679
you were still finding people
publishing papers claiming

845
00:38:28,679 --> 00:38:32,640
to resolve the cat paradox this way.

846
00:38:32,640 --> 00:38:33,817
So, I started to ask myself,

847
00:38:33,817 --> 00:38:34,650
"Well, wait a moment.

848
00:38:34,650 --> 00:38:35,956
Is that really true?"

849
00:38:35,956 --> 00:38:39,057
The further you go from
the microscopic level,

850
00:38:39,057 --> 00:38:40,890
the level of the electron

851
00:38:40,890 --> 00:38:42,957
and the atom to the macroscopic level,

852
00:38:42,957 --> 00:38:46,500
the level of the cat or the
guider counter or whatever,

853
00:38:46,500 --> 00:38:48,390
the more important

854

00:38:48,390 --> 00:38:50,020
these interference
effects generally become

855
00:38:50,020 --> 00:38:54,018
so that most people agree
that under most circumstances,

856
00:38:54,018 --> 00:38:55,160
by the time you've got up

857
00:38:55,160 --> 00:38:57,426
to the level of cats and
counters and whatever,

858
00:38:57,426 --> 00:39:00,510
none of these interference
effects really are left at all.

859
00:39:00,510 --> 00:39:02,035
A lot of people were happy with that.

860
00:39:02,035 --> 00:39:03,277
- 'Bout you?

861
00:39:03,277 --> 00:39:04,233
- Not me.

862
00:39:04,233 --> 00:39:08,229
And actually I say not some rather

863
00:39:08,229 --> 00:39:10,260
well known other people like John Bell,

864
00:39:10,260 --> 00:39:13,140
but that was a minority point of view.

865
00:39:13,140 --> 00:39:14,760
So, somehow around the late '70s

866
00:39:14,760 --> 00:39:15,960
I started asking myself,

867
00:39:15,960 --> 00:39:18,360
well, can't we somehow get around

868
00:39:18,360 --> 00:39:20,310
the de-coherence objection?

869
00:39:20,310 --> 00:39:24,236
That is can't we devise a situation

870
00:39:24,236 --> 00:39:26,890
in which quantum mechanics,
if you do take it seriously

871
00:39:26,890 --> 00:39:28,980
as Schrodinger had done,

872
00:39:28,980 --> 00:39:30,122
quantum mechanics really predicts

873
00:39:30,122 --> 00:39:32,704
that genuinely macroscopic object

874
00:39:32,704 --> 00:39:35,082
is in a quantum superposition

875
00:39:35,082 --> 00:39:38,910
of macroscopically distinct sites.

876
00:39:38,910 --> 00:39:40,830
And can we then now try to indicate

877
00:39:40,830 --> 00:39:43,110
that it's in that superposition

878
00:39:43,110 --> 00:39:46,380
by getting it to display
interference effects

879
00:39:46,380 --> 00:39:47,700
the same way as the electron did?

880
00:39:47,700 --> 00:39:50,784
My shorthand for this program of research,

881
00:39:50,784 --> 00:39:52,195
which I was not gonna do myself

882
00:39:52,195 --> 00:39:53,543
'cause I'm not an experimentalist

883
00:39:53,543 --> 00:39:55,223
but I was gonna try to persuade

884
00:39:55,223 --> 00:39:57,483
some of my experimental
colleagues to do it.

885
00:39:58,885 --> 00:40:01,622
My shorthand for it was
building Schrodinger's cat

886
00:40:01,622 --> 00:40:03,523
in the laboratory.

887
00:40:03,523 --> 00:40:07,050
Incidentally, I was not the
only person to think of this,

888
00:40:07,050 --> 00:40:09,750
but I think that the
one or two other people

889

00:40:09,750 --> 00:40:11,687
who did propose things along these lines

890
00:40:11,687 --> 00:40:16,590
had really not taken the
de-coherence objection seriously.

891
00:40:16,590 --> 00:40:20,126
And I thought it was really
necessary to do that.

892
00:40:20,126 --> 00:40:22,770
And anyway, there's a
huge cry of objection

893
00:40:22,770 --> 00:40:27,570
from the whole professional
quantum measurement community.

894
00:40:27,570 --> 00:40:28,920
I mean, there's this
whole group of people,

895
00:40:28,920 --> 00:40:31,800
usually sometimes in
departments of physics,

896
00:40:31,800 --> 00:40:33,780
more often in departments of philosophy

897
00:40:33,780 --> 00:40:35,371
or mathematics or whatever,

898
00:40:35,371 --> 00:40:40,371
who'd basically made it their
life's work to implement

899
00:40:40,444 --> 00:40:43,440
the de-coherence argument in more detail

900
00:40:43,440 --> 00:40:45,720
and to show that you could
never see interference

901
00:40:45,720 --> 00:40:47,130
at the macroscopic level.

902
00:40:47,130 --> 00:40:48,990
So, of course all these
people are up in arms

903
00:40:48,990 --> 00:40:51,497
and very indigent that I'd
suggested any such thing.

904
00:40:51,497 --> 00:40:53,730
And so, with the whole series of exchanges

905
00:40:53,730 --> 00:40:54,840
over the next 20 years or so

906
00:40:54,840 --> 00:40:57,603
in the pages of physical review letters.

907
00:40:58,800 --> 00:41:00,990
Luckily, very luckily,

908
00:41:00,990 --> 00:41:01,823
my experimental colleagues

909
00:41:01,823 --> 00:41:04,680
are much more open-minded (chuckles) and,

910
00:41:04,680 --> 00:41:06,000
which is something I found actually

911
00:41:06,000 --> 00:41:08,191
much more generally in fact.

912
00:41:08,191 --> 00:41:10,740
And so, several experimental groups

913
00:41:10,740 --> 00:41:12,826
did start off in the early and mid '80s

914
00:41:12,826 --> 00:41:15,173
to begin implementing this program

915
00:41:15,173 --> 00:41:18,180
and it had to go at a
sort of measured pace,

916
00:41:18,180 --> 00:41:21,669
but by around 2000 they
had got to the point

917
00:41:21,669 --> 00:41:24,374
where they could show that at least

918
00:41:24,374 --> 00:41:27,240
in a certain kind of
superconducting device,

919
00:41:27,240 --> 00:41:32,240
technically called a, well, it
used to be called a rf SQUID,

920
00:41:32,610 --> 00:41:34,197
but nowadays it goes by a more fancy name,

921
00:41:34,197 --> 00:41:36,000
the name of flux qubit

922
00:41:36,000 --> 00:41:37,530
'cause it's used in quantum computing.

923

00:41:37,530 --> 00:41:39,720
Anyway, in this kind of device,

924
00:41:39,720 --> 00:41:42,905
you got a situation where
quantum mechanics appeared

925
00:41:42,905 --> 00:41:46,162
to predict that you would get
these interference effects

926
00:41:46,162 --> 00:41:49,282
and experiments seemed
consistent at least with it.

927
00:41:49,282 --> 00:41:53,010
However, now it was not
the end of the story

928
00:41:53,010 --> 00:41:54,643
because I mean, the mere fact

929
00:41:54,643 --> 00:41:57,865
that quantum mechanics
predicts a certain kind

930
00:41:57,865 --> 00:42:00,442
of effect and you see
this effect experimentally

931
00:42:00,442 --> 00:42:02,982
doesn't prove that quantum
mechanics is right.

932
00:42:02,982 --> 00:42:04,530
What you would rather do is to prove

933
00:42:04,530 --> 00:42:06,720
that some alternative
class of theories is wrong.

934
00:42:06,720 --> 00:42:09,000
That's logically much
more sound an argument.

935
00:42:09,000 --> 00:42:12,252
And so, I and others did
some analysis for this

936
00:42:12,252 --> 00:42:15,996
and eventually we did get
around to an experiment.

937
00:42:15,996 --> 00:42:18,891
This experiment was done by a group

938
00:42:18,891 --> 00:42:23,891
in identity in Japan in 2016.

939
00:42:24,540 --> 00:42:27,519
And I'm a sort of incidental
co-author on the paper,

940
00:42:27,519 --> 00:42:29,673
sort of rather (indistinct).

941
00:42:29,673 --> 00:42:32,009
Sure enough that experiment did seem

942
00:42:32,009 --> 00:42:34,740
to show not only that
quantum mechanics is working,

943
00:42:34,740 --> 00:42:36,601
but that a whole class of other theories

944
00:42:36,601 --> 00:42:39,780
in which things are at
the macroscopic level,

945
00:42:39,780 --> 00:42:42,990
things do one thing or
the other was not working.

946
00:42:42,990 --> 00:42:46,110
And so I think that's been
at least somewhat satisfying.

947
00:42:46,110 --> 00:42:47,280
It's got that far.

948
00:42:47,280 --> 00:42:49,315
Where we go from here of
course is anyone's guess.

949
00:42:49,315 --> 00:42:52,106
My own feeling is that we're
not at the end of the road

950
00:42:52,106 --> 00:42:54,070
and that if we push things far enough,

951
00:42:54,070 --> 00:42:56,430
and particularly if we
push them far enough

952
00:42:56,430 --> 00:43:00,390
in the direction of
direct human perception,

953
00:43:00,390 --> 00:43:02,364
that we will get a surprise at some point

954
00:43:02,364 --> 00:43:05,490
that something will go wrong.

955
00:43:05,490 --> 00:43:07,620
We don't know what,

but we don't know when,

956
00:43:07,620 --> 00:43:09,366
but we do know it could go wrong.

957
00:43:09,366 --> 00:43:10,230
(Colin chuckles)
(Lauren chuckles)

958
00:43:10,230 --> 00:43:12,255
- You seem excited about the
prospect of things going wrong,

959
00:43:12,255 --> 00:43:14,280
which isn't always the case.
- I do (chuckles).

960
00:43:14,280 --> 00:43:15,240
It's much more interesting.

961
00:43:15,240 --> 00:43:16,073
Yes.
- Yeah.

962
00:43:16,073 --> 00:43:16,906
- Yeah.

963
00:43:16,906 --> 00:43:17,739
- You've mentioned a couple

964
00:43:17,739 --> 00:43:19,382
of times collaborators around the world,

965
00:43:19,382 --> 00:43:21,870
places like China and Japan,
- Yeah.

966
00:43:21,870 --> 00:43:24,124
- and when we were chatting

with you the other day,

967
00:43:24,124 --> 00:43:25,589
you mentioned how important

968
00:43:25,589 --> 00:43:27,900
your travels to other countries have been.

969
00:43:27,900 --> 00:43:29,700
And we actually have a
question that we'd like

970
00:43:29,700 --> 00:43:30,918
to play for you on that subject.

971
00:43:30,918 --> 00:43:31,786
- Okay.

972
00:43:31,786 --> 00:43:33,175
- I'm David Pomeranski

973
00:43:33,175 --> 00:43:35,590
and I'm currently a researcher in Japan

974
00:43:35,590 --> 00:43:38,561
at the Institute of Physical
and Chemical Research.

975
00:43:38,561 --> 00:43:40,140
I've noticed that you've lived

976
00:43:40,140 --> 00:43:42,840
in several distinct places
throughout your career.

977
00:43:42,840 --> 00:43:44,700
I think this is one of
the great opportunities

978
00:43:44,700 --> 00:43:45,990
of being a researcher.

979
00:43:45,990 --> 00:43:48,150
Can you comment on the
factors that drove you?

980
00:43:48,150 --> 00:43:49,530
What were the pros and cons

981
00:43:49,530 --> 00:43:51,776
of these experiences
in shaping your career?

982
00:43:51,776 --> 00:43:53,130
- Yeah, thank you.

983
00:43:53,130 --> 00:43:55,057
That's very interesting question.

984
00:43:55,057 --> 00:43:58,262
I think my original motivation

985
00:43:58,262 --> 00:44:03,262
for spending a postdoctoral year in Japan,

986
00:44:04,530 --> 00:44:07,310
which is my first major foreign excursion

987
00:44:07,310 --> 00:44:10,597
was simply curiosity.

988
00:44:10,597 --> 00:44:13,017
I'd always been curious,

989
00:44:13,017 --> 00:44:17,640
but to try to learn about
the culture, history,

990
00:44:17,640 --> 00:44:22,318
and to some extent the
languages of Northeast Asia,

991
00:44:22,318 --> 00:44:24,200
both Japan and China,

992
00:44:24,200 --> 00:44:27,195
at the point where I had the opportunity

993
00:44:27,195 --> 00:44:30,870
of possibly taking a year,
but I should say incidentally,

994
00:44:30,870 --> 00:44:33,958
this was by the kindness
of my Oxford College

995
00:44:33,958 --> 00:44:36,687
who interpreted the terms of my fellowship

996
00:44:36,687 --> 00:44:39,630
very liberally trying to allow me

997
00:44:39,630 --> 00:44:41,858
to spend a year as a fellowship in Japan.

998
00:44:41,858 --> 00:44:43,267
At that particular point,

999
00:44:43,267 --> 00:44:46,110
there was no realistic
opportunity of going to China.

1000
00:44:46,110 --> 00:44:49,282
It was in the last days of
the agricultural revolution.

1001
00:44:49,282 --> 00:44:52,350
But Japan seemed also very attractive.

1002
00:44:52,350 --> 00:44:56,040
And so I was able to
get a position in the,

1003
00:44:56,040 --> 00:45:00,030
or get at least a disk in the group

1004
00:45:00,030 --> 00:45:02,953
of Professor Takamitsu
Matsubara and Kyoto.

1005
00:45:04,405 --> 00:45:09,351
And so the prospect of living
a new society and culture,

1006
00:45:09,351 --> 00:45:11,760
learning a new language and trying

1007
00:45:11,760 --> 00:45:13,290
to operate in it were a challenge,

1008
00:45:13,290 --> 00:45:15,000
which I rather looked forward to.

1009
00:45:15,000 --> 00:45:17,850
And indeed, I think
that's how it worked out.

1010
00:45:17,850 --> 00:45:22,350
I made many, many, many friends in Japan

1011
00:45:22,350 --> 00:45:23,610
and many of them I've kept in touch

1012
00:45:23,610 --> 00:45:25,083

with throughout my career.

1013
00:45:25,920 --> 00:45:28,950
I think by living in a
culture where the things

1014
00:45:28,950 --> 00:45:32,490
which are obviously taken for
granted in one's own culture,

1015
00:45:32,490 --> 00:45:35,728
and for example, in the
degree to which certain kinds

1016
00:45:35,728 --> 00:45:40,728
of human relationship
impose privileges at one,

1017
00:45:40,860 --> 00:45:43,170
on the other hand, responsibilities,

1018
00:45:43,170 --> 00:45:46,467
these are really quite
different between say,

1019
00:45:46,467 --> 00:45:50,581
Europe and North America on one
hand and Japan on the other.

1020
00:45:50,581 --> 00:45:54,450
And so, I find it very
mentally stimulating

1021
00:45:54,450 --> 00:45:57,330
to experience this and
to think about and try

1022
00:45:57,330 --> 00:45:59,190
to operate according to a set

1023
00:45:59,190 --> 00:46:02,700
of slightly different rules and so forth.

1024
00:46:02,700 --> 00:46:06,013
I find learning a very, a new language,

1025
00:46:06,013 --> 00:46:07,470
not just a new language,

1026
00:46:07,470 --> 00:46:10,478
but a language that is a
very, very different structure

1027
00:46:10,478 --> 00:46:13,950
from most Indo-European languages,

1028
00:46:13,950 --> 00:46:17,490
it's almost like learning
to use a new muscle

1029
00:46:17,490 --> 00:46:19,193
which you didn't know you had.

1030
00:46:19,193 --> 00:46:23,730
So again, very, very stimulating,
very exciting, I think.

1031
00:46:23,730 --> 00:46:26,070
- You're making me nostalgic
because in my early 20s

1032
00:46:26,070 --> 00:46:27,203
I spent two years in Japan.

1033
00:46:27,203 --> 00:46:28,036
- Oh, really?
- So,

1034

00:46:28,036 --> 00:46:29,550
all of these experiences of learning

1035
00:46:29,550 --> 00:46:31,470
a new language and learning a new culture.

1036
00:46:31,470 --> 00:46:32,650
- Yeah, yeah, wow.
- I didn't know that, so.

1037
00:46:32,650 --> 00:46:33,870
- Yeah, yeah.

1038
00:46:33,870 --> 00:46:34,837
So, it was a wonderful place.

1039
00:46:34,837 --> 00:46:36,906
What years were you in Japan?

1040
00:46:36,906 --> 00:46:41,460
- The first year was 1965 to six.

1041
00:46:41,460 --> 00:46:44,280
The second year was after I got married.

1042
00:46:44,280 --> 00:46:46,080
My wife is Japanese and we spent

1043
00:46:46,080 --> 00:46:50,760
the year 1973 or most of the
year, 1973 to four there.

1044
00:46:50,760 --> 00:46:53,075
- And you've told us about
other travels as well.

1045
00:46:53,075 --> 00:46:54,150
- Yes.

1046
00:46:54,150 --> 00:46:56,280
- I remember you mentioned some work

1047
00:46:56,280 --> 00:46:57,510
that you did in Ghana in Africa.

1048
00:46:57,510 --> 00:46:58,631
- Yes, that's right. Yes.

1049
00:46:58,631 --> 00:46:59,470
- Could you tell us what motivated that

1050
00:46:59,470 --> 00:47:01,717
and what you got out of it?
- Oh, yes.

1051
00:47:01,717 --> 00:47:03,153
That was, well, I mean,

1052
00:47:03,153 --> 00:47:06,090
it's possible I would've gone anyway,

1053
00:47:06,090 --> 00:47:09,300
but had I found different
means of doing so.

1054
00:47:09,300 --> 00:47:10,712
But in that case,

1055
00:47:10,712 --> 00:47:14,070
there were no, obviously
set up arrangements.

1056
00:47:14,070 --> 00:47:16,217
I mean, there were no
major university groups

1057
00:47:16,217 --> 00:47:18,690

say in my subject working in Ghana.

1058
00:47:18,690 --> 00:47:21,510
And so the way that that worked out

1059
00:47:21,510 --> 00:47:26,070
was that when I and the
person, Douglas Brewer,

1060
00:47:26,070 --> 00:47:27,805
who eventually became Professor

1061
00:47:27,805 --> 00:47:29,820
of Experimental Physics at Sussex,

1062
00:47:29,820 --> 00:47:31,630
which is where I ended up in the UK,

1063
00:47:31,630 --> 00:47:34,672
he had been a student in Oxford as I had,

1064
00:47:34,672 --> 00:47:39,672
and he had met a doctoral
student from Ghana at that time.

1065
00:47:40,957 --> 00:47:43,595
And a few years later they met up

1066
00:47:43,595 --> 00:47:46,050
at some international
conference or whatever,

1067
00:47:46,050 --> 00:47:49,530
and the Ghanaian, who's by that
time was not only back home,

1068
00:47:49,530 --> 00:47:50,480
but was head of department

1069
00:47:50,480 --> 00:47:52,601
in the Physics Department

1070
00:47:52,601 --> 00:47:55,255
at the University of
Science and Technology

1071
00:47:55,255 --> 00:47:57,510
in Kumasi in Ghana.

1072
00:47:57,510 --> 00:47:58,679
This head of department suggested

1073
00:47:58,679 --> 00:48:01,320
that we set up an exchange arrangement

1074
00:48:01,320 --> 00:48:03,540
between the University of Sussex

1075
00:48:03,540 --> 00:48:05,391
where Douglas Brewer and I were working

1076
00:48:05,391 --> 00:48:09,780
and the University of
Science and Technology.

1077
00:48:09,780 --> 00:48:11,579
The arrangement was that
they would send across

1078
00:48:11,579 --> 00:48:14,197
one of their junior faculty members

1079
00:48:14,197 --> 00:48:16,410
to try to finish off a PhD

1080
00:48:16,410 --> 00:48:18,383
in a better environment as it were.

1081
00:48:18,383 --> 00:48:20,855
And we would send off a faculty member

1082
00:48:20,855 --> 00:48:22,920
for their heaviest teaching semester,

1083
00:48:22,920 --> 00:48:25,620
which was the fourth semester each year.

1084
00:48:25,620 --> 00:48:27,450
Well, the first year one
of my colleagues went

1085
00:48:27,450 --> 00:48:30,935
and had a good time and
nothing went wrong much.

1086
00:48:30,935 --> 00:48:35,130
The second year I volunteered to go.

1087
00:48:35,130 --> 00:48:38,781
And so I went for the fall
semester of I think '76.

1088
00:48:38,781 --> 00:48:43,770
The third year I wasn't
particularly anxious to go again,

1089
00:48:43,770 --> 00:48:45,750
but none of my colleagues
seemed anxious either,

1090
00:48:45,750 --> 00:48:48,757
so I felt I should
volunteer again and I did.

1091
00:48:50,222 --> 00:48:52,425
I was somewhat dismayed at the prospect

1092
00:48:52,425 --> 00:48:55,860
of having to do a third
year, but I was actually,

1093
00:48:55,860 --> 00:48:57,030
well, somewhat
unfortunately, to be honest,

1094
00:48:57,030 --> 00:48:59,411
I was somewhat, I was saved by that

1095
00:48:59,411 --> 00:49:02,602
from the fact that one of the phenomena,

1096
00:49:02,602 --> 00:49:05,340
sort of recurring phenomena in Ghana,

1097
00:49:05,340 --> 00:49:06,180
at least in those days,

1098
00:49:06,180 --> 00:49:08,790
we're talking about the
mid '70s was the coups.

1099
00:49:08,790 --> 00:49:10,358
So they used to have a
coup every two years or so.

1100
00:49:10,358 --> 00:49:11,386
It didn't mean much.

1101
00:49:11,386 --> 00:49:13,590
Generally speaking, what it meant was that

1102
00:49:13,590 --> 00:49:15,903
they just renamed a couple
of the major streets downtown

1103
00:49:15,903 --> 00:49:18,540
and so forth in honor of the new regime,

1104
00:49:18,540 --> 00:49:20,428
but things went up pretty much let's say,

1105
00:49:20,428 --> 00:49:21,750
they had previous,

1106
00:49:21,750 --> 00:49:23,940
and no one took all
that much notice of it.

1107
00:49:23,940 --> 00:49:27,060
Unfortunately, in I think 1977,

1108
00:49:27,060 --> 00:49:29,430
they had a rather more serious coup

1109
00:49:29,430 --> 00:49:31,200
when people did actually get killed.

1110
00:49:31,200 --> 00:49:32,460
I mean, the previous coups,

1111
00:49:32,460 --> 00:49:34,800
they're pretty bloodless, really.

1112
00:49:34,800 --> 00:49:36,203
But this time people really did get killed

1113
00:49:36,203 --> 00:49:39,930
and the university got
involved and as a result,

1114
00:49:39,930 --> 00:49:43,770
the authorities shut down the
university for a semester,

1115
00:49:43,770 --> 00:49:46,857
which totally put their
timetable out of kilter.

1116
00:49:46,857 --> 00:49:49,410
And so, in fact, the
arrangement was discontinued.

1117
00:49:49,410 --> 00:49:53,580
So I went for those two years
in the fall of '76 and '77.

1118
00:49:53,580 --> 00:49:55,140
Again, I found it very interesting

1119
00:49:55,140 --> 00:49:57,470
in perhaps a rather different kind of way.

1120
00:49:57,470 --> 00:50:00,257
In this case, I didn't really make a,

1121
00:50:00,257 --> 00:50:03,090
I made some attempt to learn
the basics of the language,

1122
00:50:03,090 --> 00:50:04,416
but I didn't have a lot of opportunity.

1123
00:50:04,416 --> 00:50:06,798
I mean, there was no systematic teaching,

1124
00:50:06,798 --> 00:50:09,540
a language teacher or anything like that.

1125
00:50:09,540 --> 00:50:13,170
So my knowledge of Akan is
very, very basic indeed.

1126
00:50:13,170 --> 00:50:16,290
And again, it wasn't too easy

1127
00:50:16,290 --> 00:50:20,040
to mingle in most of the
society because of course,

1128
00:50:20,040 --> 00:50:22,380
most of society as it was
located in the villages

1129
00:50:22,380 --> 00:50:24,592
around outside the main town

1130
00:50:24,592 --> 00:50:27,030
where the university campus was.

1131
00:50:27,030 --> 00:50:29,330
But it is nevertheless very
interesting, for example,

1132
00:50:29,330 --> 00:50:34,330
to see the difference that
their childhood experiences

1133
00:50:35,700 --> 00:50:39,575
of technology or lack of
experience made to my students.

1134
00:50:39,575 --> 00:50:42,292
As you actually volunteered in second year

1135
00:50:42,292 --> 00:50:45,420
that I was there to the
horror I should say initially

1136
00:50:45,420 --> 00:50:48,660
of my colleagues to supervise
the first year labs.

1137
00:50:48,660 --> 00:50:49,530
They said, "You can't do that.

1138
00:50:49,530 --> 00:50:50,445
You're serious?"

1139
00:50:50,445 --> 00:50:51,753
(all laughing)

1140
00:50:51,753 --> 00:50:53,379
- You more than qualified.
- They have a point.

1141
00:50:53,379 --> 00:50:58,379
- No, I was all qualified
but I took the point of view,

1142
00:50:58,530 --> 00:51:00,402
which unfortunately
turned out to be correct,

1143
00:51:00,402 --> 00:51:04,710
that the sort of unconscious common sense,

1144
00:51:04,710 --> 00:51:06,477
well, most people I
think would think of it

1145
00:51:06,477 --> 00:51:08,760
as physical common sense,

1146
00:51:08,760 --> 00:51:10,770
which I'd picked up in childhood

1147
00:51:10,770 --> 00:51:13,122
and adolescences simply by messing

1148

00:51:13,122 --> 00:51:17,280
around with odd bits of
equipment and so forth.

1149
00:51:17,280 --> 00:51:18,570
I mean, not at all complicated.

1150
00:51:18,570 --> 00:51:20,090
I mean, it wasn't a matter of taking

1151
00:51:20,090 --> 00:51:22,434
the radio apart to see how it worked,

1152
00:51:22,434 --> 00:51:24,076
something much simpler than that.

1153
00:51:24,076 --> 00:51:27,292
It nevertheless gave you a
sort of physical common sense

1154
00:51:27,292 --> 00:51:30,663
that many of these kids who
came directly from the villages,

1155
00:51:30,663 --> 00:51:32,370
they just didn't have.

1156
00:51:32,370 --> 00:51:34,275
I mean, in the villages,

1157
00:51:34,275 --> 00:51:36,674
if you grew up in a Ghanaian village,

1158
00:51:36,674 --> 00:51:40,299
the odds are that the
most sophisticated product

1159
00:51:40,299 --> 00:51:44,102
of traditional technology

that you would've seen

1160
00:51:44,102 --> 00:51:47,520
is just a simple hand loom.

1161
00:51:47,520 --> 00:51:49,620
And by Northeast Asian standards,

1162
00:51:49,620 --> 00:51:51,570
the Ghanaian hand looms are really,

1163
00:51:51,570 --> 00:51:53,340
very, very straightforward.

1164
00:51:53,340 --> 00:51:55,260
And I wouldn't say primitive,

1165
00:51:55,260 --> 00:51:59,688
but they're certainly not at
all elaborate or sophisticated.

1166
00:51:59,688 --> 00:52:01,497
And you go, I mean,

1167
00:52:01,497 --> 00:52:03,955
you go from there
directly to the motor car.

1168
00:52:03,955 --> 00:52:06,030
And so, of course then the motor car

1169
00:52:06,030 --> 00:52:07,932
is just a black box really to you,

1170
00:52:07,932 --> 00:52:10,440
even more so than it was to me.

1171
00:52:10,440 --> 00:52:14,158

So I did find, so in some sense
it was a bit embarrassing,

1172
00:52:14,158 --> 00:52:16,865
but I did find that in many cases

1173
00:52:16,865 --> 00:52:18,393
these people just didn't have

1174
00:52:18,393 --> 00:52:19,997
the kind of common sense...

1175
00:52:19,997 --> 00:52:22,170
That wasn't universally true.

1176
00:52:22,170 --> 00:52:24,312
Some of them were really
very much on the job

1177
00:52:24,312 --> 00:52:26,320
and they really figured out

1178
00:52:26,320 --> 00:52:29,550
how quite complicated bits
of electrical equipment

1179
00:52:29,550 --> 00:52:30,510
and so forth worked.

1180
00:52:30,510 --> 00:52:32,100
But by and large,

1181
00:52:32,100 --> 00:52:33,930
they didn't really have that background.

1182
00:52:33,930 --> 00:52:36,813
- Did this experience
make you a better teacher?

1183
00:52:36,813 --> 00:52:37,966
- (chuckles) Who knows?

1184
00:52:37,966 --> 00:52:39,993
I never asked the students.

1185
00:52:42,030 --> 00:52:46,020
What I can say is that
many, many years later,

1186
00:52:46,020 --> 00:52:48,209
this maybe only 10 years,
something like 10 years ago,

1187
00:52:48,209 --> 00:52:51,540
I was at a conference somewhere

1188
00:52:51,540 --> 00:52:54,440
in the American south and ran into

1189
00:52:54,440 --> 00:52:59,440
a guy who was teaching there
who remarked he's from Ghana.

1190
00:52:59,550 --> 00:53:04,350
And I said, "Oh, I spent a
semester at UST," and whatever.

1191
00:53:04,350 --> 00:53:05,666
And he said, "You taught me,"

1192
00:53:05,666 --> 00:53:08,626
and he seemed very happy
about it, so (laughs).

1193
00:53:08,626 --> 00:53:09,740
- Oh, that's good feedback

1194

00:53:09,740 --> 00:53:12,150
that a former student came to see you

1195
00:53:12,150 --> 00:53:12,983
and spoke highly of it.

1196
00:53:12,983 --> 00:53:14,359
- Yeah, yeah, yeah, sure.

1197
00:53:14,359 --> 00:53:15,723
But I'd have to say

1198
00:53:15,723 --> 00:53:17,910
that I didn't really like the way

1199
00:53:17,910 --> 00:53:22,910
the courses were organized or
the kind of syllabus they had,

1200
00:53:23,700 --> 00:53:26,250
because this is based almost entirely

1201
00:53:26,250 --> 00:53:28,111
on the British system since Ghana

1202
00:53:28,111 --> 00:53:30,520
had been a British continent in the past.

1203
00:53:30,520 --> 00:53:34,941
So they're just really teaching
standard electromagnetism

1204
00:53:34,941 --> 00:53:38,970
to standard stagnant,
et cetera, et cetera.

1205
00:53:38,970 --> 00:53:41,790
It's not really I think,
what these guys could use.

1206
00:53:41,790 --> 00:53:44,211
The thing is in a country like Ghana,

1207
00:53:44,211 --> 00:53:46,684
and I have to remember that really,

1208
00:53:46,684 --> 00:53:51,033
if you look at Africa
or sub-Saharan Africa,

1209
00:53:51,033 --> 00:53:56,033
excluding say South Africa
and Zimbabwe and so forth,

1210
00:53:56,198 --> 00:54:00,259
but if you look at most
sub-Saharan Africa,

1211
00:54:00,259 --> 00:54:04,536
Ghana is relatively ahead
of the flock in most things,

1212
00:54:04,536 --> 00:54:08,340
but nevertheless they have a huge shortage

1213
00:54:08,340 --> 00:54:11,190
of just basic everyday
mechanical skills there.

1214
00:54:11,190 --> 00:54:15,971
And so, all sorts of things,
which in Europe or America,

1215
00:54:15,971 --> 00:54:19,590
you'd assume you just farm out
to some kind of specialist.

1216
00:54:19,590 --> 00:54:21,301

In Ghana, those have to
be done by the university

1217
00:54:21,301 --> 00:54:22,470
because the university's

1218
00:54:22,470 --> 00:54:24,726
the only place you can do them, basically.

1219
00:54:24,726 --> 00:54:29,060
One example of this was that when the UST,

1220
00:54:29,060 --> 00:54:30,545
the place I was working,

1221
00:54:30,545 --> 00:54:33,150
they had some kind of anniversary

1222
00:54:33,150 --> 00:54:35,712
they wanted to celebrate
and in connection with that

1223
00:54:35,712 --> 00:54:37,594
they wanted to have a university flag

1224
00:54:37,594 --> 00:54:40,351
and erect it on a flag pole.

1225
00:54:40,351 --> 00:54:42,270
Well, I mean, I think probably

1226
00:54:42,270 --> 00:54:44,220
if something like the
University of Waterloo

1227
00:54:44,220 --> 00:54:45,977
for example was doing the same thing,

1228

00:54:45,977 --> 00:54:48,367
they routinely just sent off an order

1229
00:54:48,367 --> 00:54:49,806
to the local engineering firm

1230
00:54:49,806 --> 00:54:52,927
with the flagpole and they
sent off an order to the,

1231
00:54:52,927 --> 00:54:53,959
what's the word?

1232
00:54:53,959 --> 00:54:57,615
Seamstress specialist to
sew an appropriate flag

1233
00:54:57,615 --> 00:54:59,460
and so on and so forth.

1234
00:54:59,460 --> 00:55:01,374
And this is all just be
done as a routine part

1235
00:55:01,374 --> 00:55:02,741
of everyday business.

1236
00:55:02,741 --> 00:55:04,979
Well, you can't do that in Ghana.

1237
00:55:04,979 --> 00:55:07,080
These such places don't exist.

1238
00:55:07,080 --> 00:55:09,900
It had to be the engineering department

1239
00:55:09,900 --> 00:55:12,270
of the university which
directed the flag pole,

1240
00:55:12,270 --> 00:55:15,240
and it had to be the finance
department of the university

1241
00:55:15,240 --> 00:55:17,031
which sold the flag and a lot

1242
00:55:17,031 --> 00:55:18,780
of things go like that.
- Yeah.

1243
00:55:18,780 --> 00:55:21,729
- So, really I think what's needed

1244
00:55:21,729 --> 00:55:25,214
was to train a lot more people at a level,

1245
00:55:25,214 --> 00:55:28,470
which in Europe or
America would not usually

1246
00:55:28,470 --> 00:55:30,480
be regarded as the
province of the university.

1247
00:55:30,480 --> 00:55:32,370
Something much more basic as it were.

1248
00:55:32,370 --> 00:55:33,780
But nevertheless very essential

1249
00:55:33,780 --> 00:55:35,070
to the function of the country.

1250
00:55:35,070 --> 00:55:36,370
One of the big problems with,

1251

00:55:36,370 --> 00:55:37,942
which I certainly experienced

1252
00:55:37,942 --> 00:55:40,647
when I was in Ghana was that you had

1253
00:55:40,647 --> 00:55:42,210
all these aid organizations

1254
00:55:42,210 --> 00:55:43,765
in Britain and Germany and whatever,

1255
00:55:43,765 --> 00:55:48,181
which were sending out these nice fleets

1256
00:55:48,181 --> 00:55:50,110
of shiny buses and so forth,

1257
00:55:50,110 --> 00:55:51,793
which were intended to revolutionize

1258
00:55:51,793 --> 00:55:54,825
the transport network
of a particular region.

1259
00:55:54,825 --> 00:55:57,677
Well, they got there and after
a few weeks or a few months,

1260
00:55:57,677 --> 00:56:01,024
they broke down and no one was
around to fix it, basically.

1261
00:56:01,024 --> 00:56:03,913
And so, the whole aid program really

1262
00:56:03,913 --> 00:56:05,579
rather went into the ground and-

1263
00:56:05,579 --> 00:56:06,774
- It's sort of a presumption

1264
00:56:06,774 --> 00:56:08,913
that what works in the places

1265
00:56:08,913 --> 00:56:10,890
that we're from will work somewhere else,

1266
00:56:10,890 --> 00:56:11,915
but that's not the case.
- That's right, yeah.

1267
00:56:11,915 --> 00:56:13,717
It doesn't.

1268
00:56:13,717 --> 00:56:16,890
I think I was not the only one of the,

1269
00:56:16,890 --> 00:56:19,680
among the expatriate teachers in Ghana.

1270
00:56:19,680 --> 00:56:20,822
There were quite a few,

1271
00:56:20,822 --> 00:56:23,113
and many of them have been
there a lot longer than I had,

1272
00:56:23,113 --> 00:56:26,430
but I think most of them
would agree with us.

1273
00:56:26,430 --> 00:56:28,170
- So, I'm sure a lot of our listeners

1274
00:56:28,170 --> 00:56:29,850
are just waiting patiently for us

1275
00:56:29,850 --> 00:56:31,860
to ask you a bit about the Nobel Prize

1276
00:56:31,860 --> 00:56:33,270
and you've shown us already

1277
00:56:33,270 --> 00:56:34,800
that you're such a great storyteller,

1278
00:56:34,800 --> 00:56:36,810
so would you mind telling us the story

1279
00:56:36,810 --> 00:56:39,120
of how you found out
you won a Nobel Prize?

1280
00:56:39,120 --> 00:56:40,073
- Oh (chuckles).

1281
00:56:40,073 --> 00:56:41,281
Yeah, well that's a fairly easy one.

1282
00:56:41,281 --> 00:56:43,695
It had occurred to me vaguely.

1283
00:56:43,695 --> 00:56:46,161
I mean, I'd be dishonest
I think to say it hadn't,

1284
00:56:46,161 --> 00:56:50,614
that I might possibly get
the Nobel Prize someday,

1285
00:56:50,614 --> 00:56:53,403
or I mean, this does sound a bit arrogant,

1286
00:56:53,403 --> 00:56:55,978

but I'd actually, when I entered prize

1287
00:56:55,978 --> 00:56:57,710
I'd thought about it at all,

1288
00:56:57,710 --> 00:57:01,548
I thought it was more probable
that I'd get the prize

1289
00:57:01,548 --> 00:57:05,102
for the work I'd done
on quantum foundations

1290
00:57:05,102 --> 00:57:08,038
because I thought that
in the case of helium-3,

1291
00:57:08,038 --> 00:57:09,570
superfluid helium-3,

1292
00:57:09,570 --> 00:57:11,940
they'd already given a prize
to the three experimentalists.

1293
00:57:11,940 --> 00:57:12,773
And I thought that was probably

1294
00:57:12,773 --> 00:57:14,067
the lot that they were
gonna give for that.

1295
00:57:14,067 --> 00:57:15,960
And so I hadn't particularly
worried about it.

1296
00:57:15,960 --> 00:57:17,220
In particular I hadn't,

1297
00:57:17,220 --> 00:57:19,800

I don't think I'd made a note of October,

1298
00:57:19,800 --> 00:57:21,262
whatever it is on my calendar.

1299
00:57:21,262 --> 00:57:22,701
(all chuckling)

1300
00:57:22,701 --> 00:57:24,957
A lot of people I hear do (chuckles).

1301
00:57:24,957 --> 00:57:25,790
- I hadn't.

1302
00:57:25,790 --> 00:57:27,134
- I was up at 5:30 in the morning watching

1303
00:57:27,134 --> 00:57:29,280
the recent Nobel announcements.

1304
00:57:29,280 --> 00:57:31,080
I'm one of those people (laughs).

1305
00:57:31,080 --> 00:57:32,280
- Well, congratulations.

1306
00:57:33,663 --> 00:57:34,496
Well, let us-

1307
00:57:34,496 --> 00:57:36,093
- And I'm not even in the running for one.

1308
00:57:36,093 --> 00:57:37,170
- Yeah.

1309
00:57:37,170 --> 00:57:38,430
- But you have to write about it, I guess.

1310
00:57:38,430 --> 00:57:39,344
- Yes, I do have to write about it.

1311
00:57:39,344 --> 00:57:42,841
- Anyway, so here was I
sleeping soundly in my bed

1312
00:57:42,841 --> 00:57:44,850
at something like 4:30 in the morning

1313
00:57:44,850 --> 00:57:47,007
and then the phone starts to ring

1314
00:57:47,007 --> 00:57:49,980
and my first thought is that this is one

1315
00:57:49,980 --> 00:57:53,399
of my in-laws in Japan who's
got the time difference

1316
00:57:53,399 --> 00:57:54,232
the wrong way around,

1317
00:57:54,232 --> 00:57:56,910
which they're always doing
and calling in the middle

1318
00:57:56,910 --> 00:57:58,878
of the night at some
totally inappropriate hour.

1319
00:57:58,878 --> 00:58:01,453
So I stop and get stumble
out of bed bleary eyed

1320
00:58:01,453 --> 00:58:04,830
and go to the phone
and I pick up the phone

1321
00:58:04,830 --> 00:58:06,582
and there's a voice on
the other end which says,

1322
00:58:06,582 --> 00:58:11,582
"Am I speaking to Professor
Anthony James Leggett?"

1323
00:58:11,927 --> 00:58:14,807
Rather formally and I say,
"Well, yes, that's me."

1324
00:58:14,807 --> 00:58:16,160
"This is so and so

1325
00:58:16,160 --> 00:58:21,160
of the Swedish Academy of
Sciences in Stockholm," wherever.

1326
00:58:22,590 --> 00:58:24,824
And he says, "The Physics Committee

1327
00:58:24,824 --> 00:58:27,659
of the Swedish Academy of Sciences

1328
00:58:27,659 --> 00:58:32,659
has debated concerning
the Nobel Prize of 2003.

1329
00:58:34,616 --> 00:58:39,185
And they have decided to award the prize

1330
00:58:39,185 --> 00:58:43,050
to Professor Vitaly Ginzburg

1331
00:58:43,050 --> 00:58:48,050
of the Lebedev Academy
of Sciences in Moscow,"

1332
00:58:49,051 --> 00:58:50,368
and dot, dot, dot, dot, dot,

1333
00:58:50,368 --> 00:58:52,546
various qualifications,

1334
00:58:52,546 --> 00:58:57,546
"And to Professor Alexi
Alexeyevich Abrikosov"

1335
00:58:57,608 --> 00:58:59,129
I was thinking by that time,

1336
00:58:59,129 --> 00:59:01,343
"What's this got do with me?"

1337
00:59:01,343 --> 00:59:02,610
- Why are you telling me
- Yeah, right.

1338
00:59:02,610 --> 00:59:04,490
- this at 4:30 in the morning?

1339
00:59:04,490 --> 00:59:08,992
- And finally, "And Professor
Anthony James Leggett

1340
00:59:08,992 --> 00:59:11,577
of the University of Illinois

1341
00:59:11,577 --> 00:59:14,000
at Urbana-Champagne (chuckles)."

1342
00:59:15,210 --> 00:59:17,120
So I think my first thought,

1343
00:59:17,120 --> 00:59:18,907
as I suspect is a lot of people is,

1344
00:59:18,907 --> 00:59:20,154
"This has to be a hoax."

1345
00:59:20,154 --> 00:59:22,504
(all laughing)

1346
00:59:22,504 --> 00:59:26,610
And but I decided, I would
just put the phone down

1347
00:59:26,610 --> 00:59:28,290
and at least I'd go on listening.

1348
00:59:28,290 --> 00:59:30,510
And so he went on about various things,

1349
00:59:30,510 --> 00:59:32,193
but the thing which I
think really convinced me

1350
00:59:32,193 --> 00:59:34,594
that it was probably for
real was that he said,

1351
00:59:34,594 --> 00:59:36,599
"Look, I have to warn you one thing.

1352
00:59:36,599 --> 00:59:40,140
We're going to announce this
prize at such and such a time."

1353
00:59:40,140 --> 00:59:42,540
I think it was 12 o'clock in Stockholm,

1354
00:59:42,540 --> 00:59:44,850
so five o'clock a.m. in a few minutes

1355

00:59:44,850 --> 00:59:47,287
in central daylight time.

1356
00:59:47,287 --> 00:59:49,120
- You only found out a few minutes before?

1357
00:59:49,120 --> 00:59:50,275
- Yeah, yeah.

1358
00:59:50,275 --> 00:59:51,157
(Colin chuckles)

1359
00:59:51,157 --> 00:59:52,860
"And once this happens,

1360
00:59:52,860 --> 00:59:54,030
you're gonna get a lot of calls

1361
00:59:54,030 --> 00:59:55,386
from journalists and so forth,

1362
00:59:55,386 --> 00:59:58,560
and so you should make
some, as best you can,

1363
00:59:58,560 --> 01:00:01,530
some kind of arrangement
to handle these calls."

1364
01:00:01,530 --> 01:00:02,363
And I thought,

1365
01:00:02,363 --> 01:00:03,196
"That's not something a hoaxer

1366
01:00:03,196 --> 01:00:05,353
would think of somehow (chuckles)."

1367

01:00:05,353 --> 01:00:08,547
So, I finally got convinced
that that was right.

1368
01:00:08,547 --> 01:00:10,140
- And I think your case is kind

1369
01:00:10,140 --> 01:00:13,050
of particularly unique
because as you said,

1370
01:00:13,050 --> 01:00:15,660
you shared this prize with
two other researchers,

1371
01:00:15,660 --> 01:00:18,281
Alexei Abrikosov and Vitaly Ginzburg.

1372
01:00:18,281 --> 01:00:20,813
And of course, I know that
you've referred to them

1373
01:00:20,813 --> 01:00:23,220
as giants in the field and
many people would have,

1374
01:00:23,220 --> 01:00:24,606
but their work was done

1375
01:00:24,606 --> 01:00:25,920
quite awhile
- Oh, yeah.

1376
01:00:25,920 --> 01:00:27,984
- before your contributions to the prize.

1377
01:00:27,984 --> 01:00:29,880
How did you react to finding out

1378

01:00:29,880 --> 01:00:30,754
that you were sharing the prize

1379
01:00:30,754 --> 01:00:32,580
with these other researchers?

1380
01:00:32,580 --> 01:00:35,367
- Well, to be honest,
I was slightly puzzled.

1381
01:00:35,367 --> 01:00:40,347
And I mean, look, I know,

1382
01:00:40,347 --> 01:00:43,253
although obviously this
is not the sort of thing,

1383
01:00:43,253 --> 01:00:44,490
this is public knowledge,

1384
01:00:44,490 --> 01:00:47,888
but I'm pretty sure that
the experimentalists,

1385
01:00:47,888 --> 01:00:50,370
in particular the Cornell experimentalists

1386
01:00:50,370 --> 01:00:52,713
lobbied hard for me.

1387
01:00:52,713 --> 01:00:56,475
And I'm sure they're very
effective in doing so.

1388
01:00:56,475 --> 01:00:59,502
But yeah, I mean, my feeling, frankly,

1389
01:00:59,502 --> 01:01:03,039
if I think about it

seriously then logically,

1390
01:01:03,039 --> 01:01:08,039
if they were going to give
a prize mostly for pre BCS,

1391
01:01:08,360 --> 01:01:11,122
superconductivity, I mean,
no reason they shouldn't.

1392
01:01:11,122 --> 01:01:12,536
But if they're going to do that,

1393
01:01:12,536 --> 01:01:14,970
I really think that was another person

1394
01:01:14,970 --> 01:01:16,836
besides Ginzburg and Abrikosov

1395
01:01:16,836 --> 01:01:19,290
who had a very good claim for that,

1396
01:01:19,290 --> 01:01:20,327
and that was Brian Pippard.

1397
01:01:22,170 --> 01:01:23,640
Well, but I'm not complaining

1398
01:01:23,640 --> 01:01:27,083
that they chose me
(chuckles), but in some sense,

1399
01:01:27,083 --> 01:01:29,188
I think it was a bit
outta the, as you say,

1400
01:01:29,188 --> 01:01:31,913
a bit outta the ordinary
logical structure of the prize.

1401
01:01:31,913 --> 01:01:32,746
- Yeah.

1402
01:01:32,746 --> 01:01:33,579
- This is a question of course,

1403
01:01:33,579 --> 01:01:36,270
I used to get I at press
conferences and so forth,

1404
01:01:36,270 --> 01:01:39,570
people would ask, "Did you
collaborate with Abrikosov,

1405
01:01:39,570 --> 01:01:40,860
with Ginzburg and Abrikosov?"

1406
01:01:40,860 --> 01:01:43,327
And I'd have to say,

1407
01:01:43,327 --> 01:01:45,990
"Well, when Ginzburg and Landau

1408
01:01:45,990 --> 01:01:47,130
actually were doing the work,

1409
01:01:47,130 --> 01:01:50,010
which eventually qualified
them for the prize,

1410
01:01:50,010 --> 01:01:52,050
I was 12 years old and living

1411
01:01:52,050 --> 01:01:55,220
on the wrong side of the iron
curtains, so no (chuckles)."

1412

01:01:56,970 --> 01:01:59,850
- How does winning a
Nobel change your life?

1413
01:01:59,850 --> 01:02:01,376
- One thing that's certainly changed

1414
01:02:01,376 --> 01:02:06,180
is that I tend far more
than I did previously

1415
01:02:06,180 --> 01:02:11,180
to get asked for my
opinion on matters often

1416
01:02:11,580 --> 01:02:15,889
of concerning world politics
or sociology or whatever,

1417
01:02:15,889 --> 01:02:19,181
on which I really don't feel
I have sufficient information

1418
01:02:19,181 --> 01:02:22,095
to give a sensible answer.

1419
01:02:22,095 --> 01:02:25,293
So, I usually try to dodge
those questions as best I can,

1420
01:02:25,293 --> 01:02:27,990
but in some cases I feel that the cause

1421
01:02:27,990 --> 01:02:28,937
is sufficiently worthwhile

1422
01:02:28,937 --> 01:02:32,370
that I do try to find out
enough having been asked

1423
01:02:32,370 --> 01:02:34,201
the question or asked to sign

1424
01:02:34,201 --> 01:02:36,138
a petition usually or whatever,

1425
01:02:36,138 --> 01:02:39,993
I try to find out enough
about the assumed question

1426
01:02:39,993 --> 01:02:42,286
and the pros and cons and to decide

1427
01:02:42,286 --> 01:02:46,023
whether I can honestly
sign the petition or not.

1428
01:02:46,860 --> 01:02:48,900
- You're giving a talk here tomorrow,

1429
01:02:48,900 --> 01:02:50,439
and I've noticed the title of the talk is,

1430
01:02:50,439 --> 01:02:53,880
"The Serendipitous Road to a Nobel Prize."

1431
01:02:53,880 --> 01:02:54,713
- Yes, right.

1432
01:02:54,713 --> 01:02:55,546
- Can you speak to the idea

1433
01:02:55,546 --> 01:02:58,578
of serendipity and what role that plays?

1434
01:02:58,578 --> 01:03:00,293
- The most serendipitous event,

1435
01:03:00,293 --> 01:03:02,144
I think in my whole career really,

1436
01:03:02,144 --> 01:03:07,144
was the elevation of
Sputnik in the fall of 1957.

1437
01:03:07,623 --> 01:03:11,689
That was what basically enabled me

1438
01:03:11,689 --> 01:03:16,530
to switch from my original
course of study in Oxford,

1439
01:03:16,530 --> 01:03:19,754
which was on the humanity side
of the Oxford Greats degree,

1440
01:03:19,754 --> 01:03:22,620
to switch from that to physics.

1441
01:03:22,620 --> 01:03:26,139
Had it not been for that, I think the,

1442
01:03:26,139 --> 01:03:29,332
as a whole idea of someone
who had no experience,

1443
01:03:29,332 --> 01:03:32,040
well, it's not quite literally true

1444
01:03:32,040 --> 01:03:35,010
that I had zero experience
of physics at high school.

1445
01:03:35,010 --> 01:03:38,970
But to intents and purposes,
I had no experience of it.

1446
01:03:38,970 --> 01:03:41,709
Someone had no meaningful experience

1447
01:03:41,709 --> 01:03:43,508
of physics at high school

1448
01:03:43,508 --> 01:03:48,029
and had not taken any
undergraduate course in physics,

1449
01:03:48,029 --> 01:03:50,199
whatever, suddenly to start

1450
01:03:50,199 --> 01:03:53,757
a second undergraduate degree

1451
01:03:53,757 --> 01:03:56,337
after finishing the
first one in humanities,

1452
01:03:56,337 --> 01:03:59,340
but luckily the Sputnik

1453
01:03:59,340 --> 01:04:03,810
changed popular attitudes quite a lot.

1454
01:04:03,810 --> 01:04:05,670
And one of the things it did

1455
01:04:05,670 --> 01:04:08,940
was to make a lot of
people question their idea,

1456
01:04:08,940 --> 01:04:10,704
which in some sense of
being a sort of given

1457
01:04:10,704 --> 01:04:13,371

in British society up to that point,

1458
01:04:13,371 --> 01:04:17,726
that the natural thing for people

1459
01:04:17,726 --> 01:04:21,703
who were intellectually
talented and anyway,

1460
01:04:21,703 --> 01:04:26,703
was to study things like the
classics or perhaps politics,

1461
01:04:28,886 --> 01:04:31,740
philosophy and economics
in the Oxford degree.

1462
01:04:31,740 --> 01:04:35,430
And then to go into some
kind of governmental role

1463
01:04:35,430 --> 01:04:37,169
in the civil service or whatever.

1464
01:04:37,169 --> 01:04:39,864
Not a great deal of
attention had been paid

1465
01:04:39,864 --> 01:04:42,478
to the education of scientists

1466
01:04:42,478 --> 01:04:45,454
and in particular to making sure

1467
01:04:45,454 --> 01:04:49,696
that people who really had an aptitude

1468
01:04:49,696 --> 01:04:53,675
and certainly a zeal for science

1469
01:04:53,675 --> 01:04:55,170
could actually go into it.

1470
01:04:55,170 --> 01:04:57,810
I mean, I never really
had that opportunity.

1471
01:04:57,810 --> 01:04:59,820
Rather surprisingly,
actually because my father

1472
01:04:59,820 --> 01:05:02,340
was in fact a school
teacher of mathematics,

1473
01:05:02,340 --> 01:05:04,920
physics and chemistry,
but he never, never really

1474
01:05:04,920 --> 01:05:08,160
put any kind of pressure on
me to study in that area.

1475
01:05:08,160 --> 01:05:09,240
In fact, rather the opposite.

1476
01:05:09,240 --> 01:05:10,860
He encouraged me to go into the classics.

1477
01:05:10,860 --> 01:05:13,530
So again, I think he was a sort of victim

1478
01:05:13,530 --> 01:05:15,292
of his time (chuckles) in that respect.

1479
01:05:15,292 --> 01:05:16,125
- Yeah.

1480
01:05:16,125 --> 01:05:17,554
So, the launch of Sputnik just put

1481
01:05:17,554 --> 01:05:19,530
in the public consciousness

1482
01:05:19,530 --> 01:05:21,660
this idea that studying science could have

1483
01:05:21,660 --> 01:05:24,450
a real important practical outcome.

1484
01:05:24,450 --> 01:05:25,283
Is that-
- Well, yeah.

1485
01:05:25,283 --> 01:05:26,183
I mean, basically.

1486
01:05:26,183 --> 01:05:27,831
I mean, the cry went up how come

1487
01:05:27,831 --> 01:05:30,489
that the Soviets have got ahead of us

1488
01:05:30,489 --> 01:05:33,390
in this incredibly important
technological field?

1489
01:05:33,390 --> 01:05:34,987
And because the answer
was what we've encouraged

1490
01:05:34,987 --> 01:05:38,553
all our best people to
go into useless things

1491
01:05:38,553 --> 01:05:42,105

like classics and not into
useful things like physics.

1492
01:05:42,105 --> 01:05:43,759
So I was not by means the only person

1493
01:05:43,759 --> 01:05:46,560
who tried to make the switch at that time.

1494
01:05:46,560 --> 01:05:49,339
In particular, I remember
maybe half a dozen people

1495
01:05:49,339 --> 01:05:53,890
in my year at Oxford who had done

1496
01:05:53,890 --> 01:05:56,389
the first degree in
history and then decided

1497
01:05:56,389 --> 01:05:58,950
to switch into chemistry.

1498
01:05:58,950 --> 01:06:01,110
And I don't think that
never really worked out

1499
01:06:01,110 --> 01:06:01,943
for any of those people.

1500
01:06:01,943 --> 01:06:04,790
And I mean, I think I can sort of see why

1501
01:06:04,790 --> 01:06:06,678
because really chemistry and physics

1502
01:06:06,678 --> 01:06:11,561
are somewhat different in
the fact that this far,

1503
01:06:11,561 --> 01:06:13,578
I suspect at least, I
mean, I've never really

1504
01:06:13,578 --> 01:06:17,406
had any proper course in
chemistry so I can't really tell.

1505
01:06:17,406 --> 01:06:21,178
But I suspect that much more
of undergraduate education

1506
01:06:21,178 --> 01:06:23,807
in chemistry consists
of just learning facts

1507
01:06:23,807 --> 01:06:26,253
and reactions and so on and so forth.

1508
01:06:26,253 --> 01:06:28,620
Whereas physics is,

1509
01:06:28,620 --> 01:06:30,600
at least is a great deal
more organized as it were

1510
01:06:30,600 --> 01:06:33,870
'cause you have a much
clearer intellectual pattern.

1511
01:06:33,870 --> 01:06:37,229
- Is that organization part
of what drew you to physics?

1512
01:06:37,229 --> 01:06:41,319
- Okay, what drew me to
physics specifically?

1513

01:06:41,319 --> 01:06:42,152
Yeah, okay.

1514
01:06:42,152 --> 01:06:43,413
That was sort of indirect process

1515
01:06:43,413 --> 01:06:45,457
of argumentation with myself.

1516
01:06:45,457 --> 01:06:48,340
The first step along
was all negative really

1517
01:06:48,340 --> 01:06:51,660
in the sense that I was very immature.

1518
01:06:51,660 --> 01:06:53,259
I mean, in retrospect.

1519
01:06:53,259 --> 01:06:55,646
I first started thinking
about my future career

1520
01:06:55,646 --> 01:06:58,900
at let's say sometime in
the end of my third year

1521
01:06:58,900 --> 01:07:01,320
of my four year degree in Oxford.

1522
01:07:01,320 --> 01:07:02,640
Suddenly realized that I was gonna

1523
01:07:02,640 --> 01:07:04,320
have to do something in life,

1524
01:07:04,320 --> 01:07:05,657
which someone else is gonna pay me.

1525
01:07:05,657 --> 01:07:08,914
I couldn't go on being a student forever.

1526
01:07:08,914 --> 01:07:09,815
So at that point,

1527
01:07:09,815 --> 01:07:13,183
I really had no experience
outside of high school

1528
01:07:13,183 --> 01:07:16,506
or university under graduate work.

1529
01:07:16,506 --> 01:07:18,829
I mean, there was no peace corps

1530
01:07:18,829 --> 01:07:21,390
or anything equivalent in those days.

1531
01:07:21,390 --> 01:07:26,390
I tried rather a (indistinct)
way to find a short-term job

1532
01:07:26,795 --> 01:07:29,010
for the last two semesters of my,

1533
01:07:29,010 --> 01:07:32,700
what would've been my high
school career, didn't work out.

1534
01:07:32,700 --> 01:07:34,715
So, I had to stay at school.

1535
01:07:34,715 --> 01:07:38,400
Then three years of undergraduate study,

1536
01:07:38,400 --> 01:07:40,434
so no experience really of life outside

1537
01:07:40,434 --> 01:07:43,140
some kind in academia.

1538
01:07:43,140 --> 01:07:45,150
So, I was just pretty, and
I'll mentioned too, frankly,

1539
01:07:45,150 --> 01:07:47,783
I just thought, "Well, what
am I going to do in life?"

1540
01:07:47,783 --> 01:07:50,812
Well, I look around, I
see one of my classmates

1541
01:07:50,812 --> 01:07:54,058
of the earlier years.

1542
01:07:54,058 --> 01:07:56,516
What have they done in people

1543
01:07:56,516 --> 01:07:59,520
who've graduated in
this particular course?

1544
01:07:59,520 --> 01:08:00,420
Greats course.

1545
01:08:00,420 --> 01:08:03,270
Well, the answer is mostly either

1546
01:08:03,270 --> 01:08:05,416
they had gone into the
British Civil Service

1547
01:08:05,416 --> 01:08:08,271
or they had become teachers of one

1548
01:08:08,271 --> 01:08:10,500
of the subjects they'd studied.

1549
01:08:10,500 --> 01:08:12,921
These were classical
languages and literature,

1550
01:08:12,921 --> 01:08:16,602
ancient history, ancient
Greek and Roman philosophy.

1551
01:08:16,602 --> 01:08:20,107
And I took one look at the
civil service and I thought,

1552
01:08:20,107 --> 01:08:22,287
"Really, this is not
my cup of tea at all."

1553
01:08:22,287 --> 01:08:23,700
I'm not gonna be good at it.

1554
01:08:23,700 --> 01:08:26,010
I'd probably even fail
the civil service exam,

1555
01:08:26,010 --> 01:08:27,501
I imagine had I taken it
cause I just don't have

1556
01:08:27,501 --> 01:08:28,862
the right kind of skills.

1557
01:08:28,862 --> 01:08:31,126
So that was not an option really for me.

1558
01:08:31,126 --> 01:08:33,354
Well, so had to be teaching basically.

1559
01:08:33,354 --> 01:08:35,820
So, which of the three subjects?

1560
01:08:35,820 --> 01:08:37,455
Well, I'd enjoyed all three,

1561
01:08:37,455 --> 01:08:40,008
but the one I really enjoyed most of all

1562
01:08:40,008 --> 01:08:43,140
probably done best at what was philosophy.

1563
01:08:43,140 --> 01:08:45,660
So, I started thinking a
little more concretely about,

1564
01:08:45,660 --> 01:08:47,220
so what I'm going to do.

1565
01:08:47,220 --> 01:08:49,876
I'm going to get my
final degree in Greats.

1566
01:08:49,876 --> 01:08:54,876
I will apply for a postgraduate
degree in philosophy.

1567
01:08:55,790 --> 01:08:58,590
Eventually I'll get there
after three years or so.

1568
01:08:58,590 --> 01:09:00,330
I will then, in those days,

1569
01:09:00,330 --> 01:09:01,440
probably I would've gone straight on

1570
01:09:01,440 --> 01:09:04,080

to a junior faculty position.

1571
01:09:04,080 --> 01:09:05,460
I'll end up in a...

1572
01:09:05,460 --> 01:09:07,710
Incidentally school teaching

1573
01:09:07,710 --> 01:09:09,660
was not an option because philosophy

1574
01:09:09,660 --> 01:09:12,180
just isn't taught high
school level in the UK.

1575
01:09:12,180 --> 01:09:14,070
At least it wasn't in those days.

1576
01:09:14,070 --> 01:09:16,110
So, it had to be university.

1577
01:09:16,110 --> 01:09:19,398
So I ran up as a faculty member

1578
01:09:19,398 --> 01:09:21,625
in the department of
philosophy at the university.

1579
01:09:21,625 --> 01:09:22,540
End of story.

1580
01:09:22,540 --> 01:09:23,497
That's my career.

1581
01:09:23,497 --> 01:09:24,403
- Mm hm.

1582
01:09:24,403 --> 01:09:26,498

- The more I thought about this,

1583
01:09:26,498 --> 01:09:30,707
more I realized I somehow
just didn't want to do this.

1584
01:09:30,707 --> 01:09:34,773
And so I started thinking,

1585
01:09:34,773 --> 01:09:39,773
"What is it exactly that I
don't like about this prospect?"

1586
01:09:40,770 --> 01:09:42,510
Well, I mean, I think had I been,

1587
01:09:42,510 --> 01:09:43,680
had a little more experience in life,

1588
01:09:43,680 --> 01:09:45,947
I would've thought maybe I'm not really,

1589
01:09:45,947 --> 01:09:47,280
should not really be thinking

1590
01:09:47,280 --> 01:09:48,420
about going into academia at all.

1591
01:09:48,420 --> 01:09:50,880
Maybe I should go and become
a rock climbing instructor

1592
01:09:50,880 --> 01:09:54,979
or something where I'd
be terrible incidentally.

1593
01:09:54,979 --> 01:09:59,250
And but that didn't occur to me.

1594
01:09:59,250 --> 01:10:00,930
So it had to be something
about philosophy,

1595
01:10:00,930 --> 01:10:02,230
specifically as a subject.

1596
01:10:03,240 --> 01:10:06,120
I started asking myself,
"What exactly is it?

1597
01:10:06,120 --> 01:10:07,320
Why is it that I don't want

1598
01:10:07,320 --> 01:10:10,440
to spend my whole life
doing, not just teaching,

1599
01:10:10,440 --> 01:10:14,107
but presumably also research
in academic philosophy?"

1600
01:10:14,107 --> 01:10:16,080
And the more I thought about it,

1601
01:10:16,080 --> 01:10:18,945
and the more it seemed
that it was because,

1602
01:10:18,945 --> 01:10:23,070
at least as it was practiced
in Oxford in those days,

1603
01:10:23,070 --> 01:10:25,350
but what counted as good or bad work

1604
01:10:25,350 --> 01:10:29,270
in philosophy seemed to be so
much a matter first of all,

1605
01:10:29,270 --> 01:10:32,910
of how exactly you
phrased your conclusions,

1606
01:10:32,910 --> 01:10:34,670
the exact nuances in terms of phrase

1607
01:10:34,670 --> 01:10:37,968
and secondly of your colleague's opinions

1608
01:10:37,968 --> 01:10:40,410
of what you've done.

1609
01:10:40,410 --> 01:10:42,330
It really didn't seem to be any kind

1610
01:10:42,330 --> 01:10:44,040
of hard touchstone of whether

1611
01:10:44,040 --> 01:10:46,560
what you are doing was good or bad work,

1612
01:10:46,560 --> 01:10:47,970
whether it's correct or not.

1613
01:10:47,970 --> 01:10:49,805
And so I started thinking,

1614
01:10:49,805 --> 01:10:53,617
I really want to go into some area

1615
01:10:53,617 --> 01:10:58,617
of academia where there will
be an external touchstone

1616
01:10:59,668 --> 01:11:02,640
of whether what I'm doing

is good work or not.

1617
01:11:02,640 --> 01:11:07,640
And I had had, by a
series of coincidences,

1618
01:11:08,456 --> 01:11:12,796
I'd had a very little
exposure at high school level

1619
01:11:12,796 --> 01:11:14,698
to modern mathematics.

1620
01:11:14,698 --> 01:11:16,357
And so my first thought was,

1621
01:11:16,357 --> 01:11:17,550
"Well, perhaps I should become

1622
01:11:17,550 --> 01:11:19,290
a mathematician or try to become

1623
01:11:19,290 --> 01:11:20,843
a professional mathematician."

1624
01:11:20,843 --> 01:11:24,067
Then I remember very
clearly saying to myself,

1625
01:11:24,067 --> 01:11:28,320
"No, I don't want to become a
professional mathematician."

1626
01:11:28,320 --> 01:11:29,153
Why not?

1627
01:11:29,153 --> 01:11:30,775
Because in mathematics,

1628
01:11:30,775 --> 01:11:34,440
by the very nature of the
subject, if you are wrong,

1629
01:11:34,440 --> 01:11:35,626
it means you're stupid.

1630
01:11:35,626 --> 01:11:38,695
I would like to be able to be
wrong without being stupid.

1631
01:11:38,695 --> 01:11:40,501
(Colin laughs)
(Lauren laughs)

1632
01:11:40,501 --> 01:11:42,206
And so I started in some sense,

1633
01:11:42,206 --> 01:11:43,686
at least subconsciously looking

1634
01:11:43,686 --> 01:11:47,610
for a subject where I could be wrong.

1635
01:11:47,610 --> 01:11:50,998
That is I could make some
conjectures about the world,

1636
01:11:50,998 --> 01:11:53,001
which were not trivial,

1637
01:11:53,001 --> 01:11:55,500
but which nevertheless
might be right or wrong.

1638
01:11:55,500 --> 01:11:57,750
And then I thought, "All
my colleagues could go out

1639
01:11:57,750 --> 01:12:00,210
and find out whether they
were right or wrong."

1640
01:12:00,210 --> 01:12:03,120
And that's how eventually
I came to physics.

1641
01:12:03,120 --> 01:12:07,706
I think frankly had I were
able to make the choice again,

1642
01:12:07,706 --> 01:12:10,230
I could easily have
applied for engineering

1643
01:12:10,230 --> 01:12:11,250
rather than physics.

1644
01:12:11,250 --> 01:12:12,930
But that was a period,

1645
01:12:12,930 --> 01:12:14,910
and I was at a state of my career

1646
01:12:14,910 --> 01:12:17,280
where it seemed that to be an engineer,

1647
01:12:17,280 --> 01:12:18,537
you had to be good with your hands.

1648
01:12:18,537 --> 01:12:20,207
And I was terrible with my hands.

1649
01:12:20,207 --> 01:12:22,440
I mean, I didn't realize the aspects

1650
01:12:22,440 --> 01:12:24,540

of engineering with it
didn't really apply.

1651
01:12:24,540 --> 01:12:27,360
But anyway, I didn't really
consider that seriously.

1652
01:12:27,360 --> 01:12:29,490
So, physics it had to be.

1653
01:12:29,490 --> 01:12:32,320
And then of course, then
all the fun started.

1654
01:12:32,320 --> 01:12:34,386
I had to actually start making

1655
01:12:34,386 --> 01:12:38,372
this a reality and that
was highly non trivial.

1656
01:12:38,372 --> 01:12:40,512
There were lots of aspects to that.

1657
01:12:40,512 --> 01:12:42,941
I had to get a university to accept me.

1658
01:12:42,941 --> 01:12:45,450
Actually more than one
Oxford College did accept me.

1659
01:12:45,450 --> 01:12:47,280
And I ended up at a different one

1660
01:12:47,280 --> 01:12:48,480
where they would not only accept me,

1661
01:12:48,480 --> 01:12:50,379
but give me some financial support.

1662
01:12:50,379 --> 01:12:54,841
But the major obstacle was
the draft, the military draft.

1663
01:12:54,841 --> 01:12:59,841
We're talking about my
graduation in the summer of 1959.

1664
01:13:03,150 --> 01:13:04,431
Some, a couple of years before that,

1665
01:13:04,431 --> 01:13:06,595
the British government had decided

1666
01:13:06,595 --> 01:13:10,262
that the draft would
end and the last intake

1667
01:13:10,262 --> 01:13:12,660
would be the summer of '59.

1668
01:13:12,660 --> 01:13:15,120
Now, I'd already got four years deferment

1669
01:13:15,120 --> 01:13:18,660
from the draft to do my
first undergraduate degree.

1670
01:13:18,660 --> 01:13:21,837
I go to my draft board and say to them,

1671
01:13:21,837 --> 01:13:26,400
"Look, you guys, I know
you've been very generous

1672
01:13:26,400 --> 01:13:29,430
and given me four years,
do a degree in Greats.

1673
01:13:29,430 --> 01:13:30,720
Well, I would actually rather like

1674
01:13:30,720 --> 01:13:33,893
to do a second undergraduate
degree in physics.

1675
01:13:33,893 --> 01:13:37,350
So, would you like to give me
another two years for that?"

1676
01:13:37,350 --> 01:13:38,737
And they of course would
look at me and say,

1677
01:13:38,737 --> 01:13:40,020
"Well, we've got your number,

1678
01:13:40,020 --> 01:13:42,300
you're just trying to get
out of it all together."

1679
01:13:42,300 --> 01:13:44,910
Which of course is what
happened eventually.

1680
01:13:44,910 --> 01:13:47,232
But anyway, that did
not seem likely to fly.

1681
01:13:47,232 --> 01:13:49,642
And that of course, is
where Sputnik came in.

1682
01:13:49,642 --> 01:13:52,440
Because finally, my tutors, again,

1683
01:13:52,440 --> 01:13:55,020

I think sure, my tutors argued very, very,

1684
01:13:55,020 --> 01:13:56,490
very hard and eloquently in my favor,

1685
01:13:56,490 --> 01:13:58,140
but as they were able to convince

1686
01:13:58,140 --> 01:14:00,181
the draft board that I'd be more used

1687
01:14:00,181 --> 01:14:02,820
to a country doing a second degree

1688
01:14:02,820 --> 01:14:07,180
in science rather than
on the parade ground.

1689
01:14:07,180 --> 01:14:09,180
- Well, there's actually another question

1690
01:14:09,180 --> 01:14:10,400
from a student that touches

1691
01:14:10,400 --> 01:14:13,800
on this idea from a
student named Felicity.

1692
01:14:13,800 --> 01:14:14,790
So, let's play

1693
01:14:14,790 --> 01:14:15,690
that one for you.
- Okay.

1694
01:14:15,690 --> 01:14:17,280
Let's listen to her.

1695

01:14:17,280 --> 01:14:18,660
- Hi, Sir Anthony.

1696
01:14:18,660 --> 01:14:20,790
I'm Felicity in grade eight.

1697
01:14:20,790 --> 01:14:24,592
Can you imagine yourself
in any other profession?

1698
01:14:24,592 --> 01:14:28,092
- (laughs) Well, I did in the past.

1699
01:14:28,092 --> 01:14:29,988
When I was five years old,

1700
01:14:29,988 --> 01:14:32,550
my ambition, believe it or not,

1701
01:14:32,550 --> 01:14:35,100
was to become a railway signaler.

1702
01:14:35,100 --> 01:14:36,145
- Hm.

1703
01:14:36,145 --> 01:14:36,978
- I was very fascinated

1704
01:14:36,978 --> 01:14:39,030
by the way the signals worked, et cetera.

1705
01:14:39,030 --> 01:14:42,180
A bit later than that my ambition

1706
01:14:42,180 --> 01:14:43,202
was to become an explorer.

1707
01:14:43,202 --> 01:14:45,783

In those days there was no
GPS or anything like that.

1708
01:14:45,783 --> 01:14:49,230
And there was still fairly
large tracks of the planet,

1709
01:14:49,230 --> 01:14:51,248
which had at least not,

1710
01:14:51,248 --> 01:14:52,966
I mean, they may have
been inhabited or not,

1711
01:14:52,966 --> 01:14:55,306
but they're certainly not
systematically mapped or whatever.

1712
01:14:55,306 --> 01:14:58,830
So, that was not totally unrealistic.

1713
01:14:58,830 --> 01:15:01,648
But nowadays, yes, I think I could,

1714
01:15:01,648 --> 01:15:04,791
and had I got to start my career again,

1715
01:15:04,791 --> 01:15:07,110
then I think I'd probably plumb

1716
01:15:07,110 --> 01:15:10,050
for something like
experimental neuropsychology.

1717
01:15:10,050 --> 01:15:11,310
- Hm.

1718
01:15:11,310 --> 01:15:13,781
- And the reason for that is partly that

1719
01:15:13,781 --> 01:15:18,180
I think it's has full of
very fascinating questions,

1720
01:15:18,180 --> 01:15:19,830
but secondly that,

1721
01:15:19,830 --> 01:15:23,280
well, it really is much
more direct practical use

1722
01:15:23,280 --> 01:15:25,650
to humanities than doing research

1723
01:15:25,650 --> 01:15:26,951
in the foundation of quantum mechanics

1724
01:15:26,951 --> 01:15:30,970
or in the superfluid helium-3 or whatever.

1725
01:15:30,970 --> 01:15:34,800
So, I think I probably
would go in that direction.

1726
01:15:34,800 --> 01:15:37,143
Whether I'd be successful or
happy or not in that career,

1727
01:15:37,143 --> 01:15:39,700
I don't know, but I think
that's what I would do.

1728
01:15:39,700 --> 01:15:41,700
- There's actually a related question.

1729
01:15:41,700 --> 01:15:43,807
I put up on an internet forum, I said,

1730
01:15:43,807 --> 01:15:45,420
"I'm gonna speak to Sir Anthony Leggett,

1731
01:15:45,420 --> 01:15:46,860
would you have any questions for him?"

1732
01:15:46,860 --> 01:15:48,993
And we received a question
from someone named Douglas

1733
01:15:48,993 --> 01:15:52,050
that is related to this topic as well.

1734
01:15:52,050 --> 01:15:53,669
- Hi Anthony, my name is Douglas

1735
01:15:53,669 --> 01:15:58,080
and I'm a student of physics
in the University of Maryland.

1736
01:15:58,080 --> 01:16:01,650
And as someone who's about
to go to a physics PhD,

1737
01:16:01,650 --> 01:16:03,356
I'm very curious to hear from you,

1738
01:16:03,356 --> 01:16:05,480
what do you think are the most promising

1739
01:16:05,480 --> 01:16:07,827
and exciting fields of physics right now?

1740
01:16:07,827 --> 01:16:10,164
And if you were to choose your field

1741
01:16:10,164 --> 01:16:13,377
and your career path right

now, would you choose say,

1742
01:16:13,377 --> 01:16:15,925
low temperature physics again

1743
01:16:15,925 --> 01:16:18,180
and condensed matter of theory,

1744
01:16:18,180 --> 01:16:20,017
or would you go for something else?

1745
01:16:20,017 --> 01:16:21,729
- Okay, thank you Douglas.

1746
01:16:21,729 --> 01:16:23,219
That's a good question.

1747
01:16:23,219 --> 01:16:25,440
I don't know if you're familiar.

1748
01:16:25,440 --> 01:16:26,307
I'm addressing Douglas now.

1749
01:16:26,307 --> 01:16:28,080
I don't know if you're familiar

1750
01:16:28,080 --> 01:16:31,350
with the late Thomas Coons distinction

1751
01:16:31,350 --> 01:16:35,670
between so-called revolutionary
and normal science.

1752
01:16:35,670 --> 01:16:38,823
The idea is that for most
of the history of science,

1753
01:16:38,823 --> 01:16:40,290

things are done according

1754
01:16:40,290 --> 01:16:42,420
to what he calls a particular paradigm,

1755
01:16:42,420 --> 01:16:44,670
which basically sets the kind
of questions you can ask,

1756
01:16:44,670 --> 01:16:46,010
the kind of answers you
are allowed to give,

1757
01:16:46,010 --> 01:16:47,670
et cetera, et cetera.

1758
01:16:47,670 --> 01:16:52,358
And then very occasionally, so
these revolutionary periods,

1759
01:16:52,358 --> 01:16:55,650
when all the rules change,

1760
01:16:55,650 --> 01:16:57,088
in some sense the subject comes

1761
01:16:57,088 --> 01:16:59,517
out of that revolutionary
period looking quite different

1762
01:16:59,517 --> 01:17:01,617
from what it was when it went in.

1763
01:17:01,617 --> 01:17:02,940
And he cites, for example,

1764
01:17:02,940 --> 01:17:04,680
the Copernican revolution.

1765
01:17:04,680 --> 01:17:06,120
In the history of physics,

1766
01:17:06,120 --> 01:17:07,860
the quantum mechanical revolution,

1767
01:17:07,860 --> 01:17:09,755
special relativity, et cetera, et cetera.

1768
01:17:09,755 --> 01:17:11,234
Addressing again, Douglas,

1769
01:17:11,234 --> 01:17:12,932
I think you should ask yourself,

1770
01:17:12,932 --> 01:17:14,909
would I rather work in a normal

1771
01:17:14,909 --> 01:17:17,683
or a revolutionary period of science?

1772
01:17:17,683 --> 01:17:22,393
And at first sight, you might
think it's much more exciting

1773
01:17:22,393 --> 01:17:24,828
to work in a revolutionary period.

1774
01:17:24,828 --> 01:17:28,140
On the other hand, if
you want to, as it were,

1775
01:17:28,140 --> 01:17:30,600
get a certain minimum
achievement in your career,

1776
01:17:30,600 --> 01:17:32,160
and that may not be the answer,

1777
01:17:32,160 --> 01:17:34,584
it may be better to
work in a normal period

1778
01:17:34,584 --> 01:17:37,770
when you have well defined rules according

1779
01:17:37,770 --> 01:17:38,899
to which you can operate,

1780
01:17:38,899 --> 01:17:43,044
if you work hard and are
conscientious and so forth,

1781
01:17:43,044 --> 01:17:45,588
the odds are high that you will make

1782
01:17:45,588 --> 01:17:47,100
a successful career,

1783
01:17:47,100 --> 01:17:48,840
publish a appropriate number of papers,

1784
01:17:48,840 --> 01:17:50,220
et cetera, et cetera.

1785
01:17:50,220 --> 01:17:52,320
So that's one choice you have to make.

1786
01:17:52,320 --> 01:17:53,160
But then of course,

1787
01:17:53,160 --> 01:17:56,280
suppose you do come out with
the revolutionary answer,

1788
01:17:56,280 --> 01:17:58,447

then in which area of physics

1789
01:17:58,447 --> 01:18:02,934
is a revolution most likely to occur?

1790
01:18:02,934 --> 01:18:05,040
I think I would have to say that probably

1791
01:18:05,040 --> 01:18:07,446
not very likely in most current areas.

1792
01:18:07,446 --> 01:18:10,800
The only one in which I do see
a possibility is cosmology.

1793
01:18:10,800 --> 01:18:13,307
I'm a total outsider in this,

1794
01:18:13,307 --> 01:18:14,910
so I'm speaking from ignorance,

1795
01:18:14,910 --> 01:18:17,795
but my impression at
least for what it's worth

1796
01:18:17,795 --> 01:18:21,870
is that many of the
ideas which are floating

1797
01:18:21,870 --> 01:18:24,926
around in cosmology,
dark matter, dark energy,

1798
01:18:24,926 --> 01:18:27,900
these are to some extent really BAND-AIDS.

1799
01:18:27,900 --> 01:18:30,030
And that there are,
there's something much,

1800
01:18:30,030 --> 01:18:32,784
much deeper that that may
be wrong and may have to be,

1801
01:18:32,784 --> 01:18:35,100
may eventually be overthrown.

1802
01:18:35,100 --> 01:18:38,280
So, if I had to bet on where
the next major revolution

1803
01:18:38,280 --> 01:18:40,395
in physics is going to come,
it would be in that area.

1804
01:18:40,395 --> 01:18:44,523
Other than that, would I go
for low temperature physics?

1805
01:18:44,523 --> 01:18:48,180
I might, I think because
low temperature physics

1806
01:18:48,180 --> 01:18:51,275
is one area in which you see

1807
01:18:51,275 --> 01:18:55,421
how the interaction of many particles,

1808
01:18:55,421 --> 01:18:58,678
which individually may be rather boring,

1809
01:18:58,678 --> 01:19:03,030
how the interaction and collaboration

1810
01:19:03,030 --> 01:19:06,112
of those particles may produce effects

1811
01:19:06,112 --> 01:19:09,660
which are qualitatively
quite unexpected and novel.

1812
01:19:09,660 --> 01:19:10,822
You'll notice I've not used

1813
01:19:10,822 --> 01:19:14,640
in that sentence the word emergence.

1814
01:19:14,640 --> 01:19:15,473
I hate it.

1815
01:19:15,473 --> 01:19:16,523
I hate the word emergence.

1816
01:19:16,523 --> 01:19:17,502
- Oh no, I was about to use it.

1817
01:19:17,502 --> 01:19:18,533
Why do you hate it?

1818
01:19:18,533 --> 01:19:20,700
- Why do I hate the word emergence?

1819
01:19:20,700 --> 01:19:22,644
Well, I'm sorry, I shouldn't
say I hate it, too.

1820
01:19:22,644 --> 01:19:23,477
That would be too strong.

1821
01:19:23,477 --> 01:19:27,351
I mean, I think there are valid
uses of the word emergence.

1822
01:19:27,351 --> 01:19:30,299
For example, if someone says that space

1823
01:19:30,299 --> 01:19:34,586
and time are emergent from
a deeper level of reality,

1824
01:19:34,586 --> 01:19:37,050
which is based on quite
different kinds of concept,

1825
01:19:37,050 --> 01:19:39,390
I think that's probably
a valid use of the term.

1826
01:19:39,390 --> 01:19:42,870
What I hate is when people talk about,

1827
01:19:42,870 --> 01:19:45,099
say emergent superconductivity

1828
01:19:45,099 --> 01:19:48,360
as is actually the title on an institution

1829
01:19:48,360 --> 01:19:49,830
I worked in a few years ago.

1830
01:19:49,830 --> 01:19:50,663
I hated it.

1831
01:19:50,663 --> 01:19:53,028
Because, and the reason I hate it there

1832
01:19:53,028 --> 01:19:57,330
is that essentially there is no topic in,

1833
01:19:57,330 --> 01:19:58,832
no, certainly no interesting topic

1834
01:19:58,832 --> 01:20:01,080

in the whole of condensed matter physics,

1835
01:20:01,080 --> 01:20:03,589
which is not quote, "Emergent," unquote.

1836
01:20:03,589 --> 01:20:06,540
So saying that something is
emergent in that context,

1837
01:20:06,540 --> 01:20:07,710
there's nothing to it.

1838
01:20:07,710 --> 01:20:08,700
It's just a buzzword.

1839
01:20:08,700 --> 01:20:09,533
Nothing more.

1840
01:20:09,533 --> 01:20:13,380
But anyway, getting back to
the low temperature physics.

1841
01:20:13,380 --> 01:20:15,780
Yeah, so that's what I like
about low temperature physics.

1842
01:20:15,780 --> 01:20:18,813
And moreover, unlike
say, high energy physics,

1843
01:20:18,813 --> 01:20:21,574
it is a tabletop kind of area.

1844
01:20:21,574 --> 01:20:24,362
You can not only make conjectures,

1845
01:20:24,362 --> 01:20:26,640
you can actually do experiments

1846
01:20:26,640 --> 01:20:27,690
or at least get your colleagues

1847
01:20:27,690 --> 01:20:30,600
to do experiments often
within a time scale

1848
01:20:30,600 --> 01:20:32,843
of a year or two on these ideas.

1849
01:20:32,843 --> 01:20:35,214
For example, I did this
in on one occasion,

1850
01:20:35,214 --> 01:20:39,180
I had an idea concerning
superconductivity,

1851
01:20:39,180 --> 01:20:41,250
and sure enough within a few months

1852
01:20:41,250 --> 01:20:43,514
my colleague (indistinct)
and his collaborators

1853
01:20:43,514 --> 01:20:45,726
had actually done it, an experiment.

1854
01:20:45,726 --> 01:20:48,030
So that's what what I like
about the temperatures.

1855
01:20:48,030 --> 01:20:51,224
But I think I might
again be somewhat drawn

1856
01:20:51,224 --> 01:20:53,385
by the fact that there are areas

1857
01:20:53,385 --> 01:20:57,390
of physics which are both
intellectually exciting

1858
01:20:57,390 --> 01:21:00,450
and have much more direct human relevance.

1859
01:21:00,450 --> 01:21:02,564
And one of those would
obviously be neuro physics

1860
01:21:02,564 --> 01:21:04,170
or more generally biophysics,

1861
01:21:04,170 --> 01:21:06,600
but neuro physics in particular.

1862
01:21:06,600 --> 01:21:08,985
So, I think I might well make that choice

1863
01:21:08,985 --> 01:21:11,339
had I got to do it again from scratch.

1864
01:21:11,339 --> 01:21:13,620
- You've already given
some specific advice

1865
01:21:13,620 --> 01:21:16,980
to someone who's deciding
to pursue a PhD in physics,

1866
01:21:16,980 --> 01:21:18,360
but do you have other advice

1867
01:21:18,360 --> 01:21:20,399
for students that might be earlier

1868
01:21:20,399 --> 01:21:23,055

in deciding that they like science,

1869
01:21:23,055 --> 01:21:25,020
but they're maybe still deciding

1870
01:21:25,020 --> 01:21:26,364
what they wanna do from there?

1871
01:21:26,364 --> 01:21:28,256
- I think my first piece

1872
01:21:28,256 --> 01:21:32,972
of advice would be do
follow your own curiosity.

1873
01:21:32,972 --> 01:21:37,281
If there's a question which
you feel you don't understand,

1874
01:21:37,281 --> 01:21:39,174
and you have a suspicion

1875
01:21:39,174 --> 01:21:41,820
that no other people aren't understanding

1876
01:21:41,820 --> 01:21:42,768
it too well either,

1877
01:21:42,768 --> 01:21:45,840
well, really beaver away at it.

1878
01:21:45,840 --> 01:21:46,770
Follow it up.

1879
01:21:46,770 --> 01:21:51,088
Don't worry if other people
shrug their shoulders and say,

1880

01:21:51,088 --> 01:21:52,690
"Ah, that's a silly question.

1881
01:21:52,690 --> 01:21:55,229
Everyone knows how that works."

1882
01:21:55,229 --> 01:21:57,660
I will say, remember Einstein.

1883
01:21:57,660 --> 01:21:59,490
For 250 years,

1884
01:21:59,490 --> 01:22:01,800
people have been sort of
taking it for granted,

1885
01:22:01,800 --> 01:22:03,625
or most people at least have
been taking it for granted

1886
01:22:03,625 --> 01:22:07,470
that if an object is dropped in vacuum,

1887
01:22:07,470 --> 01:22:11,340
whether it's a feather, a
stone, a pencil or whatever,

1888
01:22:11,340 --> 01:22:14,370
it will fall with exactly
the same acceleration.

1889
01:22:14,370 --> 01:22:15,570
They're sort of taken it for granted

1890
01:22:15,570 --> 01:22:17,194
ever since Galileo basically.

1891
01:22:17,194 --> 01:22:18,830
Einstein asked, why?

1892
01:22:18,830 --> 01:22:20,411
Why, why does this happen?

1893
01:22:20,411 --> 01:22:22,650
Now I'm sure that when
he asked that question,

1894
01:22:22,650 --> 01:22:24,800
a whole lot of his colleagues said,

1895
01:22:24,800 --> 01:22:26,400
"Ah, that's a stupid question.

1896
01:22:26,400 --> 01:22:27,233
They just do.

1897
01:22:27,233 --> 01:22:28,260
Everyone knows that."

1898
01:22:28,260 --> 01:22:30,928
So don't take that as an answer.

1899
01:22:30,928 --> 01:22:33,900
Just fall away at it and wait,

1900
01:22:33,900 --> 01:22:37,260
work away at it until you find an answer,

1901
01:22:37,260 --> 01:22:38,932
which at least is satisfying to you,

1902
01:22:38,932 --> 01:22:43,233
whether or not other people
agree with it or not.

1903
01:22:44,160 --> 01:22:46,305
And in the process of doing that,

1904
01:22:46,305 --> 01:22:48,113
the second point I'd say,

1905
01:22:48,113 --> 01:22:53,113
don't worry too much about
the existing literature.

1906
01:22:53,190 --> 01:22:55,260
I mean, well, if you're
at undergraduate stage,

1907
01:22:55,260 --> 01:22:56,430
perhaps you're not reading

1908
01:22:56,430 --> 01:22:58,419
the physical review or
physical letters, I don't know,

1909
01:22:58,419 --> 01:23:01,508
but you will certainly
at a graduate level.

1910
01:23:01,508 --> 01:23:05,291
I'll say don't go away and
find every single paper

1911
01:23:05,291 --> 01:23:07,020
that's been written on the question

1912
01:23:07,020 --> 01:23:09,390
you're interested in in the last 50 years.

1913
01:23:09,390 --> 01:23:11,460
That's usually a disaster
because these papers

1914
01:23:11,460 --> 01:23:15,570
will give contradictory

ideas and so on and so forth.

1915
01:23:15,570 --> 01:23:16,860
No clear picture will come out of it.

1916
01:23:16,860 --> 01:23:18,827
Try as much as you can and try

1917
01:23:18,827 --> 01:23:20,790
and do it yourself from scratch,

1918
01:23:20,790 --> 01:23:24,240
from really rather basic principles.

1919
01:23:24,240 --> 01:23:26,064
I was very lucky to be able to do that,

1920
01:23:26,064 --> 01:23:28,770
pretty much by accident,
not more than by design,

1921
01:23:28,770 --> 01:23:31,104
but when the experiments

1922
01:23:31,104 --> 01:23:36,104
on superfluid helium-3 came up in 1972,

1923
01:23:37,325 --> 01:23:39,821
these were all nuclear magnetic resonance.

1924
01:23:39,821 --> 01:23:43,530
There are lots of textbooks
on nuclear magnetic resonance,

1925
01:23:43,530 --> 01:23:46,230
including a very nice one by
my colleague Charlie Slickter,

1926

01:23:46,230 --> 01:23:48,834
my late colleague at
Illinois and so forth.

1927
01:23:48,834 --> 01:23:52,350
I hadn't read those textbooks.

1928
01:23:52,350 --> 01:23:54,210
And I made a quite conscious decision

1929
01:23:54,210 --> 01:23:55,850
not to read them because it seemed to me

1930
01:23:55,850 --> 01:23:58,230
that what was going on in this experiment

1931
01:23:58,230 --> 01:24:01,610
was so anonymous and
so out of the ordinary

1932
01:24:01,610 --> 01:24:04,410
that it couldn't be any of the things

1933
01:24:04,410 --> 01:24:06,733
which were handled in these tapes.

1934
01:24:06,733 --> 01:24:09,104
So I decided just to try to
do it for first principles

1935
01:24:09,104 --> 01:24:11,866
and was lucky eventually
that it worked out.

1936
01:24:11,866 --> 01:24:15,102
Of course, once you've got your solution,

1937
01:24:15,102 --> 01:24:17,220
then of course you don't want to rush off

1938
01:24:17,220 --> 01:24:18,127
and publish it without checking

1939
01:24:18,127 --> 01:24:21,030
that it hasn't been done for 100 years.

1940
01:24:21,030 --> 01:24:23,089
And sometimes you'll find it
has, but it doesn't matter.

1941
01:24:23,089 --> 01:24:24,180
It doesn't matter.

1942
01:24:24,180 --> 01:24:25,560
It's been known for 100 years.

1943
01:24:25,560 --> 01:24:26,757
You did it yourself.

1944
01:24:26,757 --> 01:24:28,450
Almost certainly, you
would've learned something

1945
01:24:28,450 --> 01:24:30,448
that you would not have learned

1946
01:24:30,448 --> 01:24:33,554
had you just read the existing literature.

1947
01:24:33,554 --> 01:24:36,926
Now, point three is don't feel

1948
01:24:36,926 --> 01:24:41,880
that any honestly
conducted piece of research

1949
01:24:41,880 --> 01:24:42,883

is gonna be wasted.

1950
01:24:42,883 --> 01:24:45,030
You may feel that you've got,

1951
01:24:45,030 --> 01:24:47,580
had this research project
and it's just sort

1952
01:24:47,580 --> 01:24:48,985
of run into the ground.

1953
01:24:48,985 --> 01:24:50,493
The experiment just didn't work

1954
01:24:50,493 --> 01:24:54,118
or the theory didn't give
the result, which it sort of,

1955
01:24:54,118 --> 01:24:56,040
you thought it'd ought
to give or whatever.

1956
01:24:56,040 --> 01:24:58,829
But anyway, you had to
basically abandon it.

1957
01:24:58,829 --> 01:25:00,426
Well, don't just leave it there.

1958
01:25:00,426 --> 01:25:01,277
Write it up.

1959
01:25:01,277 --> 01:25:03,719
Write it up carefully,
put it away in a drawer.

1960
01:25:03,719 --> 01:25:06,059
I will bet that 10, 15 years down the road

1961
01:25:06,059 --> 01:25:08,949
it will come back and
help you out in some,

1962
01:25:08,949 --> 01:25:11,222
perhaps apparently
totally different problem.

1963
01:25:11,222 --> 01:25:14,001
That happened to me when I worked

1964
01:25:14,001 --> 01:25:17,160
on two band superconductors during

1965
01:25:17,160 --> 01:25:18,578
my post doc year in Japan.

1966
01:25:18,578 --> 01:25:21,075
It turned out that I was working,

1967
01:25:21,075 --> 01:25:23,202
and that what had triggered my interest

1968
01:25:23,202 --> 01:25:25,590
in this subject was a
particular experiment,

1969
01:25:25,590 --> 01:25:28,920
which seemed to show that
particular metal niobium

1970
01:25:28,920 --> 01:25:31,138
was the two band superconductor.

1971
01:25:31,138 --> 01:25:33,960
So I went away and did the
theory concerning that.

1972
01:25:33,960 --> 01:25:36,840
A few months later, second
experiment came along,

1973
01:25:36,840 --> 01:25:39,541
said it wasn't really a two
band superconductor after all.

1974
01:25:39,541 --> 01:25:42,696
So at first sight my work
was totally wasted, but no.

1975
01:25:42,696 --> 01:25:46,023
I did write it up, I put
it away and remembered it.

1976
01:25:47,700 --> 01:25:51,210
And eight years later when
the helium-3 problem came up,

1977
01:25:51,210 --> 01:25:54,180
that was sometimes the
key to solving that.

1978
01:25:54,180 --> 01:25:57,210
Fourth piece of advice, make things simple

1979
01:25:57,210 --> 01:25:58,920
if you possibly can.

1980
01:25:58,920 --> 01:26:00,843
Don't look for the most elegant

1981
01:26:00,843 --> 01:26:05,843
or the most sophisticated way
of describing a phenomenon.

1982
01:26:07,620 --> 01:26:08,492
This is really for the theorists.

1983
01:26:08,492 --> 01:26:10,260
People are gonna be theorists, I guess.

1984
01:26:10,260 --> 01:26:14,510
But try to find some simple
idea which is equivalent,

1985
01:26:15,392 --> 01:26:17,280
even though it may not look

1986
01:26:17,280 --> 01:26:20,373
as elegant as the more
sophisticated formalisms.

1987
01:26:21,210 --> 01:26:23,190
Again, helped in my own work.

1988
01:26:23,190 --> 01:26:26,040
My first work on, or my
first non-trivial work

1989
01:26:26,040 --> 01:26:26,977
on superfluid helium-3

1990
01:26:26,977 --> 01:26:29,850
before it was experimentally discovered,

1991
01:26:29,850 --> 01:26:30,960
I started off doing it

1992
01:26:30,960 --> 01:26:34,050
with very highly sophisticated
Green's function,

1993
01:26:34,050 --> 01:26:36,130
field theoretic formalisms.

1994

01:26:36,130 --> 01:26:38,637
And I got a particular result,
which I didn't understand,

1995
01:26:38,637 --> 01:26:41,834
and I mean, I could have just rushed off

1996
01:26:41,834 --> 01:26:43,830
and published that result.

1997
01:26:43,830 --> 01:26:46,813
I thought, "No, I don't,
not understanding it.

1998
01:26:46,813 --> 01:26:48,997
I have to find something simpler."

1999
01:26:48,997 --> 01:26:52,470
And so I worked at it a bit and eventually

2000
01:26:52,470 --> 01:26:54,827
I did find a way of putting it,

2001
01:26:54,827 --> 01:26:58,279
which was much, much more
straightforward and simple.

2002
01:26:58,279 --> 01:27:02,194
In the meanwhile, my Russian
colleagues were typically,

2003
01:27:02,194 --> 01:27:03,646
were working away

2004
01:27:03,646 --> 01:27:06,417
with these high powered
Green's functional formalisms.

2005
01:27:06,417 --> 01:27:08,910

And they basically
discovered the same result,

2006
01:27:08,910 --> 01:27:12,183
but they didn't realize
they discovered it 'cause...

2007
01:27:13,126 --> 01:27:15,660
So anyway, so that's that.

2008
01:27:15,660 --> 01:27:17,024
And finally, I think and in some ways

2009
01:27:17,024 --> 01:27:18,709
the most important piece of advice,

2010
01:27:18,709 --> 01:27:21,809
I mean, assuming that you're thinking

2011
01:27:21,809 --> 01:27:25,020
of going into academia

2012
01:27:25,020 --> 01:27:26,460
or possibly into high school teaching,

2013
01:27:26,460 --> 01:27:29,610
rather than say industry,
and if that's the case,

2014
01:27:29,610 --> 01:27:31,080
then whatever else you do,

2015
01:27:31,080 --> 01:27:33,390
then take your teaching at least

2016
01:27:33,390 --> 01:27:35,621
as seriously as you take your research.

2017

01:27:35,621 --> 01:27:39,765
That's going to be not just
good for your students,

2018
01:27:39,765 --> 01:27:42,149
it's gonna be good for your research also,

2019
01:27:42,149 --> 01:27:46,039
I find that many of my most fruitful ideas

2020
01:27:46,039 --> 01:27:48,660
have at least indirectly come out

2021
01:27:48,660 --> 01:27:49,710
of courses I've taught,

2022
01:27:49,710 --> 01:27:53,880
both at the undergraduate
and postgraduate levels.

2023
01:27:53,880 --> 01:27:56,910
So remember, whatever else you remember,

2024
01:27:56,910 --> 01:27:58,955
you are not just a
researcher, you are a teacher.

2025
01:27:58,955 --> 01:28:01,614
- Well, Tony, thank you
so much for sitting down

2026
01:28:01,614 --> 01:28:02,447
with us today.
- No problem.

2027
01:28:02,447 --> 01:28:05,100
- This has been an absolutely
fascinating conversation

2028

01:28:05,100 --> 01:28:07,020
and I'm so thankful that
you joined us today.

2029
01:28:07,020 --> 01:28:07,955
- Well, it's been a pleasure for me too.

2030
01:28:07,955 --> 01:28:09,437
Thank you.
- Thank you.

2031
01:28:09,437 --> 01:28:11,700
(upbeat music)

2032
01:28:11,700 --> 01:28:13,059
Thanks so much for listening.

2033
01:28:13,059 --> 01:28:14,136
Perimeter Institute

2034
01:28:14,136 --> 01:28:16,763
is a not-for-profit
charitable organization

2035
01:28:16,763 --> 01:28:18,282
that shares cutting edge ideas

2036
01:28:18,282 --> 01:28:20,619
with the world thanks
to the ongoing support

2037
01:28:20,619 --> 01:28:23,280
of the governments of Ontario and Canada,

2038
01:28:23,280 --> 01:28:24,798
and thanks to donors like you.

2039
01:28:24,798 --> 01:28:27,275
Thanks for being part of the equation.

2040
01:28:27,275 --> 01:28:30,154
(inspirational music)

2041
01:28:30,154 --> 01:28:31,406
(music fades)