
Space
matched to ISS)

1
00:00:01,200 --> 00:00:05,200
[musical tones]
[electronic sounds of data]

2
00:00:16,966 --> 00:00:21,900
So welcome to the 2015
NASA Ames Summer Series.

3
00:00:23,333 --> 00:00:26,400
Space exploration allows us
to investigate

4
00:00:26,400 --> 00:00:30,133
the frontiers of space,
our future.

5
00:00:30,133 --> 00:00:34,466
It also allows us to make
science fiction a reality,

6
00:00:34,466 --> 00:00:37,400
and in the process,
we learn about ourselves,

7
00:00:37,400 --> 00:00:39,900
and our home planet, Earth.

8
00:00:41,600 --> 00:00:46,566
One of the ways that we study
and investigate space

9
00:00:46,566 --> 00:00:50,233
and make sure that we survive
that environment

10
00:00:50,233 --> 00:00:52,900
is to use model organisms.

11
00:00:54,266 --> 00:00:57,066

NASA Ames is
the lead research center

12
00:00:57,066 --> 00:01:01,833
for conducting, managing,
and building hardware

13
00:01:01,833 --> 00:01:05,933
to conduct rodent research
in space.

14
00:01:05,933 --> 00:01:09,000
Today's seminar, entitled
"Flying Through the Ages:

15
00:01:09,000 --> 00:01:11,700
Rodent Research
for Human Health,"

16
00:01:11,700 --> 00:01:14,933
will be given
by Dr. Ruth Globus.

17
00:01:16,766 --> 00:01:21,833
Ruth earned a BA degree
in sociology in 1979

18
00:01:21,833 --> 00:01:25,100
from the University
of California at Santa Cruz,

19
00:01:25,100 --> 00:01:28,566
followed by another
BA degree in 1981 in biology

20
00:01:28,566 --> 00:01:31,833
from the same university.

21
00:01:31,833 --> 00:01:36,400
After that, she worked

at the lab of Emily Holton

22
00:01:36,400 --> 00:01:39,100
here at NASA Ames,
where she got introduced

23
00:01:39,100 --> 00:01:43,566
and got the bug of being
at Ames Research Center.

24
00:01:43,566 --> 00:01:45,766
She worked for two years,
and then she realized

25
00:01:45,766 --> 00:01:49,000
that her future lies
in being a PI

26
00:01:49,000 --> 00:01:53,400
and doing space research and
ground research with rodents.

27
00:01:53,400 --> 00:01:58,100
So she went on to get a Ph.D.
degree in endocrinology

28
00:01:58,100 --> 00:02:01,233
from the University
of California at San Francisco,

29
00:02:01,233 --> 00:02:05,400
followed by a postdoc
in cell biology.

30
00:02:05,400 --> 00:02:07,266
She became
a principal investigator

31
00:02:07,266 --> 00:02:10,400
at NASA Ames in 1993

32
00:02:10,400 --> 00:02:16,500
and then joined
the civil-servant staff in 1997.

33
00:02:16,500 --> 00:02:19,800
She has numerous awards
and publications,

34
00:02:19,800 --> 00:02:24,533
too many to go here
at this moment.

35
00:02:24,533 --> 00:02:28,033
Please join me in welcoming
Dr. Ruth Globus.

36
00:02:28,033 --> 00:02:31,033
[applause]

37
00:02:39,433 --> 00:02:41,266
Thank you very much, Jacob.

38
00:02:41,266 --> 00:02:42,766
Thank you, Ames,

39
00:02:42,766 --> 00:02:47,466
for giving me the opportunity
to share our work.

40
00:02:47,466 --> 00:02:48,700
I won't say "my work."

41
00:02:48,700 --> 00:02:50,033
I'll say "our work,"

42
00:02:50,033 --> 00:02:52,900
and I think, as I proceed
through this talk,

43
00:02:52,900 --> 00:02:55,800
you'll see why.

44
00:02:55,800 --> 00:02:58,900
We have been actively engaged

45
00:02:58,900 --> 00:03:01,500
in developing capability

46
00:03:01,500 --> 00:03:05,900
to conduct long-duration rodent
research on the Space Station.

47
00:03:05,900 --> 00:03:08,433
And it makes sense.
Why do we want to do that?

48
00:03:08,433 --> 00:03:12,000
What's our big goal?
Where are we going?

49
00:03:12,000 --> 00:03:14,266
So, if we accept
as our big goal

50
00:03:14,266 --> 00:03:19,533
we want to have long-duration
human habitation in space,

51
00:03:19,533 --> 00:03:23,233
then let's set as a goal to stay
healthy while we do that,

52
00:03:23,233 --> 00:03:27,400
both during and after we come
home to Earth.

53
00:03:27,400 --> 00:03:29,900

So ambitious goals

54
00:03:29,900 --> 00:03:32,466
call for ambitious questions,

55
00:03:32,466 --> 00:03:35,200
and here are some of
the questions that came to mind

56
00:03:35,200 --> 00:03:37,300
as I thought about it.

57
00:03:37,300 --> 00:03:39,000
What are the biological changes

58
00:03:39,000 --> 00:03:41,300
that are relevant
to human health?

59
00:03:41,300 --> 00:03:45,466
What changes occur,
and when do they occur?

60
00:03:45,466 --> 00:03:49,400
How far do the adverse changes
progress?

61
00:03:49,400 --> 00:03:52,966
Some changes may or may not have
an adverse effect.

62
00:03:52,966 --> 00:03:54,400
So, what, if anything,

63
00:03:54,400 --> 00:03:58,100
do we need to do
about those responses?

64
00:03:58,100 --> 00:04:01,933

Second big question that you'll
see emerging during this talk

65
00:04:01,933 --> 00:04:04,466
is really "How do these changes
come about?"

66
00:04:04,466 --> 00:04:06,333
What are
the fundamental mechanisms

67
00:04:06,333 --> 00:04:10,600
at the molecular, cellular,
and physiological levels

68
00:04:10,600 --> 00:04:13,733
that lead to observed responses?

69
00:04:13,733 --> 00:04:16,133
We want to do this
both to better understand

70
00:04:16,133 --> 00:04:18,700
human biology and disease
on Earth,

71
00:04:18,700 --> 00:04:23,433
and also we hope that will
lead to a better ability

72
00:04:23,433 --> 00:04:26,433
to predict changes that occur

73
00:04:26,433 --> 00:04:29,766
and to identify interventions
that may be needed.

74
00:04:29,766 --> 00:04:32,700
In short, these type
of mechanistic studies

75
00:04:32,700 --> 00:04:33,866
that animal research

76
00:04:33,866 --> 00:04:37,766
and other analog research
makes possible

77
00:04:37,766 --> 00:04:41,033
is to take some of the guesswork
out of making decisions

78
00:04:41,033 --> 00:04:43,900
for our future in space.

79
00:04:43,900 --> 00:04:45,066
So general outline

80
00:04:45,066 --> 00:04:47,066
of what I want to talk to you
about today is,

81
00:04:47,066 --> 00:04:49,966
first, to provide
a background.

82
00:04:49,966 --> 00:04:52,566
What are some of the challenges
of the space environment?

83
00:04:52,566 --> 00:04:54,666
Why do we study rodents?

84
00:04:54,666 --> 00:04:56,966
I'll touch briefly
on some of the past,

85
00:04:56,966 --> 00:04:59,400
some of what we've learned,

86
00:04:59,400 --> 00:05:01,900
and then I'm going to go
into some detail

87
00:05:01,900 --> 00:05:03,900
into what we're doing now

88
00:05:03,900 --> 00:05:05,633
with the rodent research
project,

89
00:05:05,633 --> 00:05:09,633
the challenges we face
in accomplishing our objectives,

90
00:05:09,633 --> 00:05:11,900
what the capabilities are,

91
00:05:11,900 --> 00:05:15,266
and some of our new
and surprising findings

92
00:05:15,266 --> 00:05:18,333
that we've obtained.

93
00:05:18,333 --> 00:05:20,733
So, first, what are
the challenges that are posed

94
00:05:20,733 --> 00:05:23,033
by going into
a space environment?

95
00:05:23,033 --> 00:05:28,333
This should pose no surprise
to people in this audience

96
00:05:28,333 --> 00:05:30,500

and thinking about the problem.

97
00:05:30,500 --> 00:05:35,066
We've all evolved on Earth
in 1g, all species.

98
00:05:35,066 --> 00:05:36,566
This is continuous,

99
00:05:36,566 --> 00:05:40,800
except for very transient and
short periods of acceleration,

100
00:05:40,800 --> 00:05:44,733
so our cells,
our living systems,

101
00:05:44,733 --> 00:05:46,400
the intact organism

102
00:05:46,400 --> 00:05:48,066
has evolved
under that influence,

103
00:05:48,066 --> 00:05:51,266
and, in fact,
we already know quite well

104
00:05:51,266 --> 00:05:54,033
that we can adapt
to changes in that.

105
00:05:54,033 --> 00:05:56,466
We haven't been
in that environment

106
00:05:56,466 --> 00:05:58,800
for much more than two years
at the most,

107
00:05:58,800 --> 00:06:01,800
so there are still
many unanswered questions.

108
00:06:01,800 --> 00:06:05,733
The second important aspect
of the space environment

109
00:06:05,733 --> 00:06:08,766
that most are aware of
is space radiation.

110
00:06:08,766 --> 00:06:11,666
Space radiation is unique,

111
00:06:11,666 --> 00:06:15,633
both in type
and in exposure rates,

112
00:06:15,633 --> 00:06:19,400
and so it poses
unique challenges potentially,

113
00:06:19,400 --> 00:06:21,833
both short-term and long-term,

114
00:06:21,833 --> 00:06:24,733
to the health of astronaut crew.

115
00:06:24,733 --> 00:06:26,100
But that's not all.

116
00:06:26,100 --> 00:06:28,800
Those aren't
the only challenges we face

117
00:06:28,800 --> 00:06:32,033
when we go into space.

118
00:06:32,033 --> 00:06:33,400
Here are some of the others.

119
00:06:33,400 --> 00:06:36,800
Now, these might look
somewhat familiar to you,

120
00:06:36,800 --> 00:06:38,433
because these are challenges

121
00:06:38,433 --> 00:06:41,266
that we certainly face
on Earth as well,

122
00:06:41,266 --> 00:06:43,966
and, in fact,
things like nutrition

123
00:06:43,966 --> 00:06:46,133
or demanding workload,

124
00:06:46,133 --> 00:06:48,566
we have a great deal
of understanding of.

125
00:06:48,566 --> 00:06:50,766
Others, somewhat less.

126
00:06:50,766 --> 00:06:53,833
For example,
in the ISS environment,

127
00:06:53,833 --> 00:06:58,600
there is a low but elevated
level of carbon dioxide

128
00:06:58,600 --> 00:07:00,566
that the crew breathes in,

129
00:07:00,566 --> 00:07:02,566
and that has
a biological effect.

130
00:07:02,566 --> 00:07:05,366
We know some--
something about that

131
00:07:05,366 --> 00:07:10,033
from studies
on long-duration submariners.

132
00:07:10,033 --> 00:07:12,300
But when you combine
all these challenges

133
00:07:12,300 --> 00:07:13,800
and these factors together,

134
00:07:13,800 --> 00:07:18,566
you end up with a realization
that the--

135
00:07:18,566 --> 00:07:22,233
that it is not possible
with reliability

136
00:07:22,233 --> 00:07:25,566
to predict
the long-term consequences

137
00:07:25,566 --> 00:07:28,900
of these environments,

138
00:07:28,900 --> 00:07:33,500
especially as we seek to live
in space.

139
00:07:33,500 --> 00:07:36,566

So what are those changes
that occur?

140
00:07:36,566 --> 00:07:40,766
Now, in microgravity,
we have widespread unloading,

141
00:07:40,766 --> 00:07:43,300
or muscular skeletal disuse.

142
00:07:43,300 --> 00:07:47,500
Also, because our circulatory
system has evolved in 1g,

143
00:07:47,500 --> 00:07:51,433
the entire system is tuned
to that,

144
00:07:51,433 --> 00:07:54,866
and when we go into space,
there's a fluid shift,

145
00:07:54,866 --> 00:07:58,333
an equalization
and distribution of that fluid,

146
00:07:58,333 --> 00:08:02,566
and many different organ systems
in the body are affected

147
00:08:02,566 --> 00:08:05,866
and yield adaptations,

148
00:08:05,866 --> 00:08:10,800
some successful,
some somewhat less successful.

149
00:08:10,800 --> 00:08:12,900
And, in fact,
as I've already mentioned,

150
00:08:12,900 --> 00:08:14,566
we understand a lot.

151
00:08:14,566 --> 00:08:16,533
We've been going
to space for a while now.

152
00:08:16,533 --> 00:08:18,333
We know that there's
muscle atrophy.

153
00:08:18,333 --> 00:08:21,466
We know that there's
cardiovascular deconditioning

154
00:08:21,466 --> 00:08:25,266
and that there's very rapid
vestibular responses.

155
00:08:25,266 --> 00:08:28,833
I'm heightening
bone decrements here,

156
00:08:28,833 --> 00:08:30,766
because this is my area
of research

157
00:08:30,766 --> 00:08:32,666
and something
I feel a lot of passion about,

158
00:08:32,666 --> 00:08:35,766
so we will talk in
a little more depth about that

159
00:08:35,766 --> 00:08:38,500
to illustrate some of the points
I'd like to make,

160
00:08:38,500 --> 00:08:41,500
but these points
equally pertain,

161
00:08:41,500 --> 00:08:43,900
differing in detail,
to some of the other systems

162
00:08:43,900 --> 00:08:46,233
that are affected
by space flight.

163
00:08:46,233 --> 00:08:47,933
And in bone decrements,
what do we know

164
00:08:47,933 --> 00:08:51,233
about fracture repair in space
in humans?

165
00:08:51,233 --> 00:08:54,066
Nothing.
It hasn't happened yet.

166
00:08:54,066 --> 00:08:57,066
What do we know
about mechanisms?

167
00:08:57,066 --> 00:09:01,233
We know something,
but very little.

168
00:09:01,233 --> 00:09:03,733
We've also flown rodents,
and I'll talk a little bit

169
00:09:03,733 --> 00:09:06,500
about some of that history
in a moment.

170
00:09:06,500 --> 00:09:09,066
We know things
from rodent research as well,

171
00:09:09,066 --> 00:09:12,633
and we're making progress
in getting answers

172
00:09:12,633 --> 00:09:14,866
to some of these really
important questions

173
00:09:14,866 --> 00:09:17,566
from that research already.

174
00:09:19,100 --> 00:09:23,266
Pointing to my example here,
in terms of the bone decrements,

175
00:09:23,266 --> 00:09:26,400
already two space flight
experiments have looked

176
00:09:26,400 --> 00:09:29,400
at the ability of bone
to repair from a fracture

177
00:09:29,400 --> 00:09:33,233
and, in fact, have found
that deficits do occur.

178
00:09:33,233 --> 00:09:36,233
We also have more detailed
understanding of mechanisms

179
00:09:36,233 --> 00:09:40,066
than we've been able to obtain
from human flights.

180

00:09:40,066 --> 00:09:42,233
So, when I talk
about mechanisms,

181
00:09:42,233 --> 00:09:44,333
what do I mean here?

182
00:09:44,333 --> 00:09:46,766
In fact, there are
a hierarchy of mechanisms

183
00:09:46,766 --> 00:09:50,700
that we can think about when
we're trying to solve a problem,

184
00:09:50,700 --> 00:09:52,233
and typically in biology,

185
00:09:52,233 --> 00:09:55,266
we can start
at the smaller level,

186
00:09:55,266 --> 00:09:57,533
from the molecular
understanding,

187
00:09:57,533 --> 00:10:02,133
which specific molecules are
responsible for a given outcome.

188
00:10:02,133 --> 00:10:05,233
The molecules organize
into cells,

189
00:10:05,233 --> 00:10:08,866
into communities of cells,
into tissues,

190
00:10:08,866 --> 00:10:12,566
into organs,

and into organ systems,

191
00:10:12,566 --> 00:10:15,400
and I'd like to pause here
for a moment to point out--

192
00:10:15,400 --> 00:10:19,466
As we all know, one organ system
or one tissue in our body

193
00:10:19,466 --> 00:10:21,466
communicates with many others.

194
00:10:21,466 --> 00:10:24,200
They don't exist
in and of themselves

195
00:10:24,200 --> 00:10:26,100
to yield a healthy organism.

196
00:10:26,100 --> 00:10:27,833
They work together.

197
00:10:27,833 --> 00:10:32,533
So, in the end,
these together combine

198
00:10:32,533 --> 00:10:36,100
to result
in the observed behavior

199
00:10:36,100 --> 00:10:40,533
and biological function
of the organism--

200
00:10:40,533 --> 00:10:44,500
in this case, the mammal rodent.

201
00:10:44,500 --> 00:10:46,766

Now, you might ask me,
why rodents?

202
00:10:46,766 --> 00:10:49,166
Why do we study rodents?

203
00:10:49,166 --> 00:10:51,766
The simplest answer
is because of the benefits

204
00:10:51,766 --> 00:10:53,200
that can be accrued

205
00:10:53,200 --> 00:10:57,733
and have already been shown
to be accrued using those--

206
00:10:57,733 --> 00:11:02,166
using rats and mice primarily.

207
00:11:02,166 --> 00:11:06,300
71 of the past Nobel Prizes
in medicine have been awarded

208
00:11:06,300 --> 00:11:10,200
to people who have used
animals in their research,

209
00:11:10,200 --> 00:11:12,033
and it's made
possible discoveries

210
00:11:12,033 --> 00:11:14,266
that simply wouldn't have been
possible otherwise,

211
00:11:14,266 --> 00:11:16,833
such as
the fracture-healing studies

212
00:11:16,833 --> 00:11:19,100
that have been conducted.

213
00:11:19,100 --> 00:11:23,400
We don't embark lightly
on a plan

214
00:11:23,400 --> 00:11:24,900
to study rodents

215
00:11:24,900 --> 00:11:28,066
in long-duration habitation
in space

216
00:11:28,066 --> 00:11:31,733
and develop the hardware
and the plan

217
00:11:31,733 --> 00:11:34,300
and conduct the experiments.

218
00:11:34,300 --> 00:11:37,366
We do that
under the advice of experts,

219
00:11:37,366 --> 00:11:40,433
who review what's needed,

220
00:11:40,433 --> 00:11:46,166
and the National Research
Council in 2011

221
00:11:46,166 --> 00:11:49,266
produced a report
on really looking carefully

222
00:11:49,266 --> 00:11:54,333
at what's needed in both
the life and physical sciences

223
00:11:54,333 --> 00:11:57,366
for space exploration

224
00:11:57,366 --> 00:12:01,566
and point out that the lack
of a facility

225
00:12:01,566 --> 00:12:05,200
for conducting long-term
rodent research on the station

226
00:12:05,200 --> 00:12:09,733
is a major impediment
for important--

227
00:12:09,733 --> 00:12:13,233
to achieve important goals

228
00:12:13,233 --> 00:12:15,466
for astronaut health,

229
00:12:15,466 --> 00:12:18,433
and it's important to note
here also,

230
00:12:18,433 --> 00:12:20,900
that we observe carefully

231
00:12:20,900 --> 00:12:23,200
the federal regulations
and requirements

232
00:12:23,200 --> 00:12:27,066
to ensure the well-being
of the animals.

233
00:12:27,066 --> 00:12:30,266
So here's another interesting

scientific reason why rodents,

234
00:12:30,266 --> 00:12:34,733
and we can think
about this together--aging.

235
00:12:34,733 --> 00:12:38,333
The typical life span
of a human,

236
00:12:38,333 --> 00:12:43,433
depending on many variables,
can be 70 to 90 years.

237
00:12:43,433 --> 00:12:47,366
Typical life span of a mouse
is two years.

238
00:12:47,366 --> 00:12:51,433
Now, despite this enormous
difference in life span,

239
00:12:51,433 --> 00:12:54,466
rodents acquire
age-related diseases

240
00:12:54,466 --> 00:12:58,533
that very closely resemble
those of humans.

241
00:12:58,533 --> 00:13:01,366
Osteoporosis, the loss of bone,

242
00:13:01,366 --> 00:13:06,233
cardiovascular deconditioning,
muscle wasting--

243
00:13:06,233 --> 00:13:10,733
these are
just several examples.

244
00:13:10,733 --> 00:13:12,166
So what that means is

245
00:13:12,166 --> 00:13:15,566
if you look
at various stages during aging,

246
00:13:15,566 --> 00:13:18,633
you have
a compressed timeline.

247
00:13:18,633 --> 00:13:21,333
Here you see in humans--

248
00:13:21,333 --> 00:13:25,500
age of 20- to 30-year-old
human, in years,

249
00:13:25,500 --> 00:13:32,200
corresponds to a 3-
to 6-month-old animal in mice

250
00:13:32,200 --> 00:13:34,966
and also approximately rats

251
00:13:34,966 --> 00:13:38,966
going on
to older and older ages.

252
00:13:38,966 --> 00:13:41,500
So what's the consequence
of this for us,

253
00:13:41,500 --> 00:13:44,700
when we're trying to solve
the problem

254
00:13:44,700 --> 00:13:48,033

of influence of long-duration
habitation in space

255
00:13:48,033 --> 00:13:49,633
on human health?

256
00:13:49,633 --> 00:13:54,266
Well, let's grab a hypothesis.

257
00:13:54,266 --> 00:13:56,066
We'll look at the hypothesis

258
00:13:56,066 --> 00:13:58,833
that's really been long-standing
for many years,

259
00:13:58,833 --> 00:14:01,900
that's been based
on the observation

260
00:14:01,900 --> 00:14:06,233
that age-related disease,

261
00:14:06,233 --> 00:14:09,166
such as bone loss
and muscle loss,

262
00:14:09,166 --> 00:14:13,966
is observed and is very similar
in the space-flight environment,

263
00:14:13,966 --> 00:14:15,633
as I just mentioned.

264
00:14:15,633 --> 00:14:20,400
The hypothesis is that living
in space accelerates aging.

265
00:14:20,400 --> 00:14:22,700

Let me emphasize--
this is a hypothesis.

266
00:14:22,700 --> 00:14:24,233
This is not a fact.

267
00:14:24,233 --> 00:14:27,700
What's it gonna take for us
to test this hypothesis?

268
00:14:27,700 --> 00:14:31,133
The age of our astronauts
are 38--

269
00:14:31,133 --> 00:14:34,300
in the approximately
38- to 47-year range.

270
00:14:34,300 --> 00:14:36,133
This is a one-year-old animal.

271
00:14:36,133 --> 00:14:39,566
If you want to do
a life-span experiment--

272
00:14:39,566 --> 00:14:42,533
let's just say,
design that experiment--

273
00:14:42,533 --> 00:14:47,266
that would require
roughly 40 years for humans--

274
00:14:47,266 --> 00:14:49,800
not very practical right now.

275
00:14:49,800 --> 00:14:53,666
That same experiment
could take about a year--

276
00:14:53,666 --> 00:14:56,733
much more doable.

277
00:14:56,733 --> 00:15:00,500
So now I'd like to describe
to you in a little more detail

278
00:15:00,500 --> 00:15:04,266
the biology of the changes
that occur

279
00:15:04,266 --> 00:15:06,333
in the microgravity environment.

280
00:15:06,333 --> 00:15:10,900
I just spoke to you about aging,
but very similar changes

281
00:15:10,900 --> 00:15:13,100
can occur
and have been shown to occur

282
00:15:13,100 --> 00:15:16,566
in various experiments
with aging,

283
00:15:16,566 --> 00:15:19,400
with radiation exposures,

284
00:15:19,400 --> 00:15:23,033
disuse on Earth,
and hormonal changes.

285
00:15:23,033 --> 00:15:25,600
In humans,
it takes months to decades

286
00:15:25,600 --> 00:15:29,233
to go from a bone

that looks like this

287
00:15:29,233 --> 00:15:33,300
to a bone that looks like this
in response to these factors.

288
00:15:33,300 --> 00:15:36,666
This is a micro-CT--
these are both micro-CT images,

289
00:15:36,666 --> 00:15:39,100
micro-computed tomography
images,

290
00:15:39,100 --> 00:15:43,900
that show the three-dimensional
structure of cancellous bone,

291
00:15:43,900 --> 00:15:47,566
which is the highly
metabolically active bone

292
00:15:47,566 --> 00:15:52,266
that's inside the outside shell.

293
00:15:52,266 --> 00:15:54,700
This looks like this
in humans.

294
00:15:54,700 --> 00:15:56,966
It also looks like this
in rodents,

295
00:15:56,966 --> 00:15:59,733
but we can see this,
depending on the stimulus,

296
00:15:59,733 --> 00:16:02,800
even in a matter of days.

297
00:16:02,800 --> 00:16:05,400
Now, how do we get
to a structure

298
00:16:05,400 --> 00:16:09,366
that looks like this
to one that looks like this?

299
00:16:09,366 --> 00:16:11,166
It's a product of cells.

300
00:16:11,166 --> 00:16:13,666
We don't think about this
in the context of bone,

301
00:16:13,666 --> 00:16:17,100
but just like the other tissues,
cells contribute

302
00:16:17,100 --> 00:16:21,366
to the growth and maintenance
of tissue function,

303
00:16:21,366 --> 00:16:23,966
and I'm going to talk more
about that now,

304
00:16:23,966 --> 00:16:27,266
in the context of what we've
learned from space flight.

305
00:16:27,266 --> 00:16:31,933
We would like to understand
at the cellular level,

306
00:16:31,933 --> 00:16:35,100
as well as molecular level,
which cells are responsible--

307

00:16:35,100 --> 00:16:38,700
responsible for the changes
in bone structure that occur

308
00:16:38,700 --> 00:16:41,666
in the space environment.

309
00:16:41,666 --> 00:16:44,700
Two different lineages
or derivations of cells

310
00:16:44,700 --> 00:16:47,400
are found in the bone marrow
that give rise to--

311
00:16:47,400 --> 00:16:48,766
Excuse me--

312
00:16:48,766 --> 00:16:52,933
That give rise to the most
differentiated or mature cells.

313
00:16:52,933 --> 00:16:55,533
The osteoclasts,
which break down bone,

314
00:16:55,533 --> 00:16:59,166
and the osteoblasts,
which build or form bone.

315
00:16:59,166 --> 00:17:01,333
Together, these cells define

316
00:17:01,333 --> 00:17:06,000
whether bone looks like this
or this.

317
00:17:06,000 --> 00:17:09,100
These cells derive originally
from stem cells,

318
00:17:09,100 --> 00:17:11,700
two separate lineages,

319
00:17:11,700 --> 00:17:17,166
which divide
and mature sequentially

320
00:17:17,166 --> 00:17:19,366
to become the mature cells.

321
00:17:19,366 --> 00:17:23,600
Where in this process
do we see defects?

322
00:17:23,600 --> 00:17:27,833
And we've acquired information
from rodent experiments

323
00:17:27,833 --> 00:17:30,933
that the defect
is not found only

324
00:17:30,933 --> 00:17:34,000
in the mature cells
that are responsible

325
00:17:34,000 --> 00:17:37,733
for breaking down and forming
new bone,

326
00:17:37,733 --> 00:17:42,666
but also in the earlier
progenitors and precursors

327
00:17:42,666 --> 00:17:48,700
that supply a continuous source

328
00:17:48,700 --> 00:17:51,566

of cells throughout life.

329
00:17:54,366 --> 00:17:55,866
So now that I've introduced you

330
00:17:55,866 --> 00:17:58,133
to some of the concepts
that we'll be talking about,

331
00:17:58,133 --> 00:18:02,000
let's get into some details
about what we've learned

332
00:18:02,000 --> 00:18:05,166
from space-flight experiments
and the platforms,

333
00:18:05,166 --> 00:18:08,800
and I'll only have time
to touch on those briefly,

334
00:18:08,800 --> 00:18:11,966
but there have been
three different space platforms

335
00:18:11,966 --> 00:18:16,500
that have been used to date.

336
00:18:16,500 --> 00:18:20,466
The Cosmos missions, which
have grown until recently into--

337
00:18:20,466 --> 00:18:22,900
continued into
the Bion missions,

338
00:18:22,900 --> 00:18:25,200
are unmanned missions
by the Russians,

339
00:18:25,200 --> 00:18:31,133
and really, in these missions,
performed groundbreaking work

340
00:18:31,133 --> 00:18:33,733
in the midst of the Cold War

341
00:18:33,733 --> 00:18:37,400
to determine what are the basic
physiological responses

342
00:18:37,400 --> 00:18:41,466
of rodents and mammals
to the space-flight environment.

343
00:18:41,466 --> 00:18:45,033
Many more experiments were
conducted in the shuttle era,

344
00:18:45,033 --> 00:18:50,733
and we're coming
to the present in the ISS.

345
00:18:50,733 --> 00:18:54,500
So, to summarize some
of the most important features--

346
00:18:54,500 --> 00:18:58,666
take-home features--from this
shuttle era of experimentation,

347
00:18:58,666 --> 00:19:00,400
we really--

348
00:19:00,400 --> 00:19:04,433
one of the key aspects
of the shuttle program

349
00:19:04,433 --> 00:19:09,166

was it provided the opportunity
to do multiple experiments

350
00:19:09,166 --> 00:19:13,433
gathering new information and
taking the next logical step,

351
00:19:13,433 --> 00:19:15,133
which really formulates
the basis

352
00:19:15,133 --> 00:19:18,166
of making progress in research,

353
00:19:18,166 --> 00:19:20,333
and in that,
that frequent access

354
00:19:20,333 --> 00:19:22,566
that was made possible
in that program

355
00:19:22,566 --> 00:19:27,433
allowed us to both define
responses and test treatments.

356
00:19:27,433 --> 00:19:29,933
Now, what are some
of the gaps in knowledge

357
00:19:29,933 --> 00:19:31,933
that came as a consequence

358
00:19:31,933 --> 00:19:34,633
of this structure
of the shuttle program?

359
00:19:34,633 --> 00:19:36,566
One was the duration.

360
00:19:36,566 --> 00:19:39,966
We never learned what happens
after three weeks.

361
00:19:39,966 --> 00:19:42,500
That was the longest flight.

362
00:19:42,500 --> 00:19:45,333
In that period, we mostly--
not exclusively,

363
00:19:45,333 --> 00:19:49,700
but mostly studied growing rats,
not adult animals.

364
00:19:49,700 --> 00:19:51,966
We know--basic biology--

365
00:19:51,966 --> 00:19:54,833
that the processes that control
growth are very different

366
00:19:54,833 --> 00:19:58,733
than the processes
that control maintenance

367
00:19:58,733 --> 00:20:00,633
or aging.

368
00:20:00,633 --> 00:20:02,833
So what about adults?

369
00:20:02,833 --> 00:20:05,533
All but two
of the 27 rodent experiments

370
00:20:05,533 --> 00:20:09,233
that were conducted
using the shuttle platform

371
00:20:09,233 --> 00:20:11,566
entailed returning
the animals to Earth

372
00:20:11,566 --> 00:20:15,033
and recovering tissues
and studying them.

373
00:20:15,033 --> 00:20:18,833
Now this introduces
an additional variable

374
00:20:18,833 --> 00:20:21,733
of reentry, landing,
and a time delay,

375
00:20:21,733 --> 00:20:24,200
which in the shuttle era
was relatively brief,

376
00:20:24,200 --> 00:20:25,233
only a few hours,

377
00:20:25,233 --> 00:20:27,900
but we know even
that brief period

378
00:20:27,900 --> 00:20:32,333
can result in a change
in outcome,

379
00:20:32,333 --> 00:20:35,833
depending on what variable
is being analyzed.

380
00:20:35,833 --> 00:20:40,400
So these findings really point
to the science value

381
00:20:40,400 --> 00:20:44,733
for doing on-orbit
sample recovery.

382
00:20:44,733 --> 00:20:48,566
Now, moving beyond the shuttle
into long-duration missions,

383
00:20:48,566 --> 00:20:54,966
the first one was performed
on the ISS,

384
00:20:54,966 --> 00:20:59,366
using a mouse drawer system
developed by the Italians.

385
00:20:59,366 --> 00:21:03,600
They achieved 91 days
on station,

386
00:21:03,600 --> 00:21:07,966
launched in 2009,
via the shuttle.

387
00:21:07,966 --> 00:21:09,666
Male mice were flown,

388
00:21:09,666 --> 00:21:15,066
and samples were analyzed
after returned.

389
00:21:15,066 --> 00:21:16,766
Now this flight resulted

390
00:21:16,766 --> 00:21:20,166
in a limited number
of animals recovered.

391
00:21:20,166 --> 00:21:23,400

Nonetheless, there are some
interesting new findings

392
00:21:23,400 --> 00:21:25,466
that invite further study,

393
00:21:25,466 --> 00:21:28,566
and citations mentioned here--

394
00:21:28,566 --> 00:21:30,500
and as of today,

395
00:21:30,500 --> 00:21:36,600
we see more than five index
papers describing this study.

396
00:21:36,600 --> 00:21:41,266
More recently, we've had
an unmanned Bion-M1 mission,

397
00:21:41,266 --> 00:21:43,300
which is a Russian mission.

398
00:21:43,300 --> 00:21:48,033
U.S. investigators work closely
with them in tissue sharing.

399
00:21:48,033 --> 00:21:52,733
This is a 30-day mission
that flew older male animals.

400
00:21:52,733 --> 00:21:55,366
Again, this is a sample recovery
after landing,

401
00:21:55,366 --> 00:21:59,833
in this case, 13 hours,
a fairly long period of time.

402

00:21:59,833 --> 00:22:03,666
And new results are still
emerging from these studies.

403
00:22:03,666 --> 00:22:08,400
More than 13 papers
have been published to date.

404
00:22:09,766 --> 00:22:12,033
So learning
from these examples,

405
00:22:12,033 --> 00:22:13,500
what are our main objectives

406
00:22:13,500 --> 00:22:16,866
going into the rodent research
project here at Ames?

407
00:22:16,866 --> 00:22:19,333
What kind of gaps in knowledge
do we want to fill

408
00:22:19,333 --> 00:22:24,233
and what do we need to do
to fill those?

409
00:22:24,233 --> 00:22:25,233
First--

410
00:22:25,233 --> 00:22:27,000
Excuse me.

411
00:22:27,000 --> 00:22:31,300
We knew we wanted to provide
reliable, long-duration habitat

412
00:22:31,300 --> 00:22:33,566
for rodents on the ISS.

413
00:22:35,666 --> 00:22:38,300
We wanted a habitat
that could support the animals

414
00:22:38,300 --> 00:22:41,733
in groups or individually.

415
00:22:41,733 --> 00:22:45,033
Rodents are social animals.
They like to live together.

416
00:22:45,033 --> 00:22:47,366
It's important to have
that capability.

417
00:22:47,366 --> 00:22:49,833
We also wanted the hardware
to have the potential

418
00:22:49,833 --> 00:22:52,966
for future modification so that
we can support, eventually,

419
00:22:52,966 --> 00:22:55,700
multiple generations in space.

420
00:22:55,700 --> 00:22:58,233
It also needed to have
relatively low maintenance,

421
00:22:58,233 --> 00:23:02,100
to minimize crew time,
which is at a premium...

422
00:23:02,100 --> 00:23:05,566
so we could conduct
daily health checks,

423
00:23:05,566 --> 00:23:07,833

to monitor animal welfare

424
00:23:07,833 --> 00:23:11,533
without taking up
extra crew time.

425
00:23:11,533 --> 00:23:14,366
We wanted to perform
multiple missions,

426
00:23:14,366 --> 00:23:15,800
capture some of what the shuttle

427
00:23:15,800 --> 00:23:18,400
was able to do for us
in that era.

428
00:23:18,400 --> 00:23:20,400
The current plan
for flying these

429
00:23:20,400 --> 00:23:24,866
is to conduct two flights
per year.

430
00:23:24,866 --> 00:23:27,266
And finally, we wanted
to make sure

431
00:23:27,266 --> 00:23:29,266
we had the science capability

432
00:23:29,266 --> 00:23:31,533
to apply
cutting-edge technologies

433
00:23:31,533 --> 00:23:35,200
to any samples that we recover
on orbit or after return,

434
00:23:35,200 --> 00:23:37,533
should those experiments
be conducted.

435
00:23:37,533 --> 00:23:39,700
What do I mean
by technical advances?

436
00:23:39,700 --> 00:23:42,766
Well, here are a couple
of examples.

437
00:23:42,766 --> 00:23:45,433
One is genetically modified
animals.

438
00:23:45,433 --> 00:23:47,966
These have already been applied
to previous platforms,

439
00:23:47,966 --> 00:23:50,566
but there's a lot more work
that needs to be done.

440
00:23:50,566 --> 00:23:52,800
What do I mean
by genetically modified?

441
00:23:52,800 --> 00:23:57,400
Mice can be--the gene sequence
can be modified

442
00:23:57,400 --> 00:23:59,400
so that a particular gene
of interest

443
00:23:59,400 --> 00:24:03,600
is over-expressed or
under-expressed or knocked out,

444
00:24:03,600 --> 00:24:07,200
and that allows us to determine

445
00:24:07,200 --> 00:24:08,733
what the mechanism--

446
00:24:08,733 --> 00:24:10,700
how important
that particular gene

447
00:24:10,700 --> 00:24:14,000
and gene product is
for a given response.

448
00:24:14,000 --> 00:24:17,100
And a good example of that
for a flight experiment,

449
00:24:17,100 --> 00:24:22,333
is the Rodent Research-1
CASIS Novartis experiment.

450
00:24:22,333 --> 00:24:25,033
which I'll talk about
in a moment.

451
00:24:25,033 --> 00:24:28,033
Second new technology
that we wanted to make sure

452
00:24:28,033 --> 00:24:30,266
our samples were good for,

453
00:24:30,266 --> 00:24:34,366
was to be able to apply really
cutting-edge technologies

454
00:24:34,366 --> 00:24:40,100
that have expanded so greatly

in the last 10 to 15 years,

455
00:24:40,100 --> 00:24:42,466
and those are loosely referred
to as omics.

456
00:24:42,466 --> 00:24:46,566
That is a characterization
of a large pool

457
00:24:46,566 --> 00:24:49,666
of molecules--

458
00:24:49,666 --> 00:24:53,533
they may be genes,

459
00:24:53,533 --> 00:24:56,966
RNA transcripts, metabolites--

460
00:24:56,966 --> 00:24:58,933
that allows us
to have greater insight

461
00:24:58,933 --> 00:25:01,066
into structure and function,

462
00:25:01,066 --> 00:25:04,266
and an example here from
a previous flight experiment

463
00:25:04,266 --> 00:25:07,866
where this technology
was applied

464
00:25:07,866 --> 00:25:10,066
to learn something new
and important

465
00:25:10,066 --> 00:25:12,533

is shown here.

466
00:25:12,533 --> 00:25:14,833
So talking about challenges.

467
00:25:14,833 --> 00:25:17,733
What were our challenges in
getting something to work here

468
00:25:17,733 --> 00:25:20,500
and getting it up and running?

469
00:25:20,500 --> 00:25:23,466
So we decided to adapt
legacy hardware,

470
00:25:23,466 --> 00:25:27,966
taking advantage of the fact
that we had 27 prior flights

471
00:25:27,966 --> 00:25:31,100
that successfully flew.

472
00:25:31,100 --> 00:25:35,600
We needed to interface
that hardware with new vehicles.

473
00:25:35,600 --> 00:25:38,466
We don't have the shuttle
to take anymore,

474
00:25:38,466 --> 00:25:41,233
so we worked with SpaceX

475
00:25:41,233 --> 00:25:44,066
and developed the capability

476
00:25:44,066 --> 00:25:48,233
to use the unmanned

"Dragon" capsule

477
00:25:48,233 --> 00:25:51,166
to deliver the hardware.

478
00:25:51,166 --> 00:25:54,033
Finally, we needed
to take care of the animals,

479
00:25:54,033 --> 00:25:55,166
provide husbandry.

480
00:25:55,166 --> 00:25:56,800
That entails training of crew

481
00:25:56,800 --> 00:25:59,066
and monitoring
the animal welfare every day,

482
00:25:59,066 --> 00:26:01,366
which I already alluded to.

483
00:26:01,366 --> 00:26:05,433
This all seems pretty
straightforward, doesn't it?

484
00:26:05,433 --> 00:26:07,566
I'm going to delve into that
for just a moment.

485
00:26:07,566 --> 00:26:09,633
This is the basic equipment
that you need

486
00:26:09,633 --> 00:26:12,366
to conduct a rodent experiment
on Earth.

487
00:26:12,366 --> 00:26:16,800

This is a standard mouse cage,
blown up here.

488
00:26:16,800 --> 00:26:20,966
The scientist can sit in the
chair and observe the animals.

489
00:26:20,966 --> 00:26:22,500
And one thing,
if you look at this,

490
00:26:22,500 --> 00:26:25,066
you can see, in fact,
that, you know,

491
00:26:25,066 --> 00:26:28,100
this is pretty straightforward,
with gravity, how this works.

492
00:26:28,100 --> 00:26:31,733
The animal's in the cage, and,
you know, the water comes down,

493
00:26:31,733 --> 00:26:34,300
and the waste falls
into the bottom of the cage,

494
00:26:34,300 --> 00:26:36,266
and you provide--
this orange thing,

495
00:26:36,266 --> 00:26:38,500
in case you're curious,
is enrichment.

496
00:26:38,500 --> 00:26:43,366
The animal plays and nests
in this type of material.

497
00:26:43,366 --> 00:26:47,500

This is what you need to conduct
an experiment on orbit.

498
00:26:49,500 --> 00:26:52,000
Not scaled to size.

499
00:26:52,000 --> 00:26:56,533
You need habitats that will
manage the waste

500
00:26:56,533 --> 00:26:58,133
and provide the food and water

501
00:26:58,133 --> 00:27:01,366
in a way that is
not gravity-dependent.

502
00:27:01,366 --> 00:27:04,700
You need to protect
the cabin environment,

503
00:27:04,700 --> 00:27:08,733
and so you need systems
in which you handle the animals

504
00:27:08,733 --> 00:27:12,366
and transfer the animals
in a controlled way.

505
00:27:12,366 --> 00:27:14,733
And you need a variety
of kits and things

506
00:27:14,733 --> 00:27:17,700
to do all that

507
00:27:17,700 --> 00:27:21,200
in a safe and productive way.

508

00:27:21,200 --> 00:27:24,233
So let's talk about
the system that was developed

509
00:27:24,233 --> 00:27:25,800
to accomplish that.

510
00:27:25,800 --> 00:27:28,933
There are two hardwares
that the animals live in--

511
00:27:28,933 --> 00:27:30,433
the transport and the habitat.

512
00:27:30,433 --> 00:27:32,866
They look pretty similar
on the outside,

513
00:27:32,866 --> 00:27:34,933
so I'm showing you this
in a cutaway mode.

514
00:27:34,933 --> 00:27:38,400
The animals live inside here,
and this is a port

515
00:27:38,400 --> 00:27:42,233
that allows you
to access two chambers,

516
00:27:42,233 --> 00:27:44,733
both sides.

517
00:27:44,733 --> 00:27:47,200
There's an air-flow system
through here

518
00:27:47,200 --> 00:27:50,533
that captures the waste.

519
00:27:50,533 --> 00:27:53,033
There's also
an animal-access unit,

520
00:27:53,033 --> 00:27:57,766
which is a simple glove-box
type of arrangement

521
00:27:57,766 --> 00:28:02,033
that mates with either
the transporter or the habitat

522
00:28:02,033 --> 00:28:05,033
so that the crew can go in,
reach in,

523
00:28:05,033 --> 00:28:09,500
and recover the animals, placing
them in a mouse-transfer box,

524
00:28:09,500 --> 00:28:11,533
because you can't take an animal
and walk acr--

525
00:28:11,533 --> 00:28:14,066
you know, walk across--
whoops, sorry--

526
00:28:14,066 --> 00:28:15,966
Walk across the room with it.

527
00:28:15,966 --> 00:28:18,200
It needs always to be contained,

528
00:28:18,200 --> 00:28:21,400
and it can be transferred
in the mouse transfer box.

529
00:28:21,400 --> 00:28:25,800

And then we have too many kits
to mention.

530
00:28:25,800 --> 00:28:28,900
This shows a view
from the inside,

531
00:28:28,900 --> 00:28:31,733
where the animals live.

532
00:28:31,733 --> 00:28:33,500
The Rodent Research-1--

533
00:28:33,500 --> 00:28:35,633
there were five animals
per compartment,

534
00:28:35,633 --> 00:28:38,600
two compartments
per hardware system.

535
00:28:38,600 --> 00:28:42,100
You'll see grating
on all sides

536
00:28:42,100 --> 00:28:44,333
that allows the animals
to ambulate,

537
00:28:44,333 --> 00:28:49,000
air flow to be collected
in filters,

538
00:28:49,000 --> 00:28:51,433
Food--these are food bars

539
00:28:51,433 --> 00:28:53,766
that are supplied continuously
to the animal.

540
00:28:53,766 --> 00:28:54,966
There's a water supply

541
00:28:54,966 --> 00:28:57,633
that is not gravity-dependent
for delivery,

542
00:28:57,633 --> 00:29:00,633
which you can't see
from this picture.

543
00:29:00,633 --> 00:29:05,866
Lighting--we supply
a "lights on, lights off" cycle.

544
00:29:05,866 --> 00:29:09,466
The animals are most active
in the dark cycle,

545
00:29:09,466 --> 00:29:12,600
as you may already know.

546
00:29:12,600 --> 00:29:16,866
And video cameras
with infrared capability

547
00:29:16,866 --> 00:29:19,200
that allow us
to monitor and observe

548
00:29:19,200 --> 00:29:22,766
the behavior of the animals.

549
00:29:22,766 --> 00:29:26,833
So let's develop our concept
of operations here.

550
00:29:26,833 --> 00:29:31,766
How are we going to get them

up there and get our samples?

551
00:29:31,766 --> 00:29:35,233
The animals are put
in a transporter

552
00:29:35,233 --> 00:29:38,900
and delivered to "Dragon"
or mounted in "Dragon"

553
00:29:38,900 --> 00:29:42,333
as a late load,
as a late payload.

554
00:29:42,333 --> 00:29:45,600
Undergoes launch, can be--

555
00:29:45,600 --> 00:29:48,800
In the case Rodent Research-1,
it was four days in transit

556
00:29:48,800 --> 00:29:52,900
before docking and the crew

557
00:29:52,900 --> 00:29:56,500
was scheduled and conducted
the transfer operation.

558
00:29:56,500 --> 00:30:00,233
The animal access unit was
attached, the animals recovered,

559
00:30:00,233 --> 00:30:04,066
and placed into habitats,
where they lived

560
00:30:04,066 --> 00:30:07,833
for as long as 33 days,

561

00:30:07,833 --> 00:30:12,300
making the longest stay
in microgravity 37 days.

562
00:30:12,300 --> 00:30:14,666
At the termination
of the experiment,

563
00:30:14,666 --> 00:30:17,066
the animals were then
transferred

564
00:30:17,066 --> 00:30:19,333
into the microgravity science
glove box,

565
00:30:19,333 --> 00:30:21,300
which had been prepared,

566
00:30:21,300 --> 00:30:24,566
and the animals
were humanely euthanized,

567
00:30:24,566 --> 00:30:26,866
and then tissues were retrieved

568
00:30:26,866 --> 00:30:30,233
and recovered
under specific conditions

569
00:30:30,233 --> 00:30:34,900
that made sample analysis
optimal.

570
00:30:34,900 --> 00:30:39,833
The samples were stowed
and returned to Earth.

571
00:30:39,833 --> 00:30:43,000
So that's the plan,

but we don't get to start yet,

572
00:30:43,000 --> 00:30:45,666
because we have to make sure
it all works before we go.

573
00:30:45,666 --> 00:30:49,500
So we conducted extensive
preflight testing

574
00:30:49,500 --> 00:30:52,433
to show that the animals thrive
in the hardware,

575
00:30:52,433 --> 00:30:55,433
the operations work,
and that samples recovered,

576
00:30:55,433 --> 00:30:58,900
as the crew would eventually do,
would be done so

577
00:30:58,900 --> 00:31:02,700
in a way that got
the expected science outcome.

578
00:31:02,700 --> 00:31:07,233
So now all systems go--
Rodent Research-1.

579
00:31:07,233 --> 00:31:09,233
There were two main aspects,

580
00:31:09,233 --> 00:31:13,533
main objectives
of Rodent Research-1.

581
00:31:13,533 --> 00:31:15,066
One was a validation.

582
00:31:15,066 --> 00:31:18,133
The goal of this was
to demonstrate the capability

583
00:31:18,133 --> 00:31:19,900
to support the health
of the animals

584
00:31:19,900 --> 00:31:22,366
in long-duration experiments.

585
00:31:22,366 --> 00:31:26,200
This was achieved by evaluating
all the key factors,

586
00:31:26,200 --> 00:31:29,333
including animal health,
behavior, and tissue results,

587
00:31:29,333 --> 00:31:32,766
which I'll be talking about
in a moment.

588
00:31:32,766 --> 00:31:35,533
In addition, there were mice

589
00:31:35,533 --> 00:31:39,333
flown for the national lab,
which CASIS--

590
00:31:39,333 --> 00:31:41,733
the Center for the Advancement
of Science and Space--

591
00:31:41,733 --> 00:31:43,666
manages.

592
00:31:43,666 --> 00:31:48,066
And a Novartis scientist

593
00:31:48,066 --> 00:31:51,366
planned this experiment,
where MuRF-1 Knockout mice--

594
00:31:51,366 --> 00:31:56,833
These, again, are mice that have
a key gene knocked out

595
00:31:56,833 --> 00:32:00,500
and are resistant
to muscle wasting--

596
00:32:00,500 --> 00:32:04,400
As well as control mice
were flown.

597
00:32:07,200 --> 00:32:10,900
Here was our plan
for sample retrieval.

598
00:32:10,900 --> 00:32:13,866
For validation,
we were able to--

599
00:32:13,866 --> 00:32:16,900
CASIS kindly shared samples
with us

600
00:32:16,900 --> 00:32:20,100
so we could work together
to achieve our objectives.

601
00:32:20,100 --> 00:32:24,766
We recovered spleen, liver,
also preserved animals

602
00:32:24,766 --> 00:32:28,100
for measuring body weight
after return to Earth

603
00:32:28,100 --> 00:32:33,800
and also for conducting
postflight tissue retrieval.

604
00:32:33,800 --> 00:32:36,400
So let me take
a few minutes first now,

605
00:32:36,400 --> 00:32:40,033
as we start talking
about how the experiment went,

606
00:32:40,033 --> 00:32:43,300
to talk about behavioral
observations.

607
00:32:43,300 --> 00:32:46,366
Here are some qualitative
observations that were made.

608
00:32:46,366 --> 00:32:49,000
When animals first entered
the habitat,

609
00:32:49,000 --> 00:32:51,900
they very actively explored
the compartments,

610
00:32:51,900 --> 00:32:55,366
much like they do routinely
on Earth

611
00:32:55,366 --> 00:32:59,133
when you transfer them
from one cage to a novel cage.

612
00:32:59,133 --> 00:33:01,800
They're also observed eating,
drinking, and grooming.

613
00:33:01,800 --> 00:33:05,233
They groom both themselves and
others while in the habitats.

614
00:33:05,233 --> 00:33:06,466
and these are all, again,

615
00:33:06,466 --> 00:33:09,900
considered normal behaviors
of healthy mice.

616
00:33:09,900 --> 00:33:11,233
They were interesting to watch.

617
00:33:11,233 --> 00:33:13,633
Mice propelled themselves
around the compartment

618
00:33:13,633 --> 00:33:15,400
in more than one way,

619
00:33:15,400 --> 00:33:18,466
mostly by pulling along the cage
with their forelimbs,

620
00:33:18,466 --> 00:33:22,133
although their hind limbs were
used to a more limited extent,

621
00:33:22,133 --> 00:33:26,033
also by floating from
one location to another

622
00:33:26,033 --> 00:33:28,233
and remarkably resembling

623
00:33:28,233 --> 00:33:31,633
how crew ambulate

around the cabin.

624
00:33:31,633 --> 00:33:34,166
As time went on,
the mice moved

625
00:33:34,166 --> 00:33:36,300
more and more quickly
around the compartment.

626
00:33:36,300 --> 00:33:39,400
They translated with ease
through the open spaces,

627
00:33:39,400 --> 00:33:42,933
but they also most often
anchored themselves,

628
00:33:42,933 --> 00:33:45,166
using their tails and paws.

629
00:33:45,166 --> 00:33:50,233
A detailed behavioral analysis
is now in progress.

630
00:33:52,133 --> 00:33:53,333
So I'm going to talk to you

631
00:33:53,333 --> 00:33:55,633
about our initial results
with the tissues.

632
00:33:55,633 --> 00:33:59,933
First, I want to take
a moment to explain the groups.

633
00:33:59,933 --> 00:34:02,000
There were, in fact,
four different groups

634
00:34:02,000 --> 00:34:04,733
to evaluate the responses

635
00:34:04,733 --> 00:34:08,400
from the validation aspect
of this flight.

636
00:34:08,400 --> 00:34:10,000
There was
the space-flight group,

637
00:34:10,000 --> 00:34:12,066
and there were three controls.

638
00:34:12,066 --> 00:34:15,533
So, as I pointed out to you,

639
00:34:15,533 --> 00:34:18,533
changes occur rapidly over time
with these animals,

640
00:34:18,533 --> 00:34:20,733
because their life span
is relatively short.

641
00:34:20,733 --> 00:34:24,066
So one independent variable
in this design

642
00:34:24,066 --> 00:34:27,500
of a long-duration experiment
is time.

643
00:34:27,500 --> 00:34:30,600
What are the changes
that take place over time

644
00:34:30,600 --> 00:34:32,333
just due to aging?

645
00:34:32,333 --> 00:34:35,033
And, so, for that, we have
what we call a basal group.

646
00:34:35,033 --> 00:34:36,400
These animals were euthanized,

647
00:34:36,400 --> 00:34:38,566
and tissues recovered
at the time of launch

648
00:34:38,566 --> 00:34:39,800
from the same group of animals

649
00:34:39,800 --> 00:34:42,300
that the flight animals
came from.

650
00:34:42,300 --> 00:34:45,366
They were compared--
you can compare those results

651
00:34:45,366 --> 00:34:48,833
to those of animals
that were maintained

652
00:34:48,833 --> 00:34:51,533
in standard cages
the way we normally do

653
00:34:51,533 --> 00:34:53,233
and where an investigator

654
00:34:53,233 --> 00:34:56,866
in a lab anywhere would do

655
00:34:56,866 --> 00:34:58,733
and answer the question,

656
00:34:58,733 --> 00:35:00,533
"What is the effect of time

657
00:35:00,533 --> 00:35:05,400
as an independent variable
on a given outcome?"

658
00:35:05,400 --> 00:35:06,733
What's the other variable here?

659
00:35:06,733 --> 00:35:08,500
The other variable is cage.

660
00:35:08,500 --> 00:35:10,066
So the habitat--

661
00:35:10,066 --> 00:35:11,866
As you can imagine,

662
00:35:11,866 --> 00:35:14,400
nobody does experiments
in those habitats

663
00:35:14,400 --> 00:35:16,833
unless you're planning
to go to space,

664
00:35:16,833 --> 00:35:20,366
and, in fact, changes in
the environment of the animals

665
00:35:20,366 --> 00:35:23,433
can have
very profound consequences

666
00:35:23,433 --> 00:35:29,700
for basic physiological
and cellular responses.

667
00:35:29,700 --> 00:35:31,733
And so...

668
00:35:31,733 --> 00:35:35,400
to facilitate
future investigators' ability

669
00:35:35,400 --> 00:35:40,066
to evaluate whether the changes
in their control groups...

670
00:35:42,066 --> 00:35:44,900
Are due to the cage,

671
00:35:44,900 --> 00:35:48,533
we evaluate and compare
this vivarium group

672
00:35:48,533 --> 00:35:52,400
in standard cages
to the ground controls.

673
00:35:52,400 --> 00:35:54,733
And the ground controls
of the group of mice

674
00:35:54,733 --> 00:35:59,066
that are housed in
identical cages to the flight,

675
00:35:59,066 --> 00:36:01,933
they're also kept
in an environmental chamber

676
00:36:01,933 --> 00:36:03,900
at Kennedy Space Center

677
00:36:03,900 --> 00:36:07,566

that has the environment
of carbon dioxide,

678
00:36:07,566 --> 00:36:09,133
temperature, and humidity

679
00:36:09,133 --> 00:36:11,400
matched to ambient conditions

680
00:36:11,400 --> 00:36:13,466
in the cabin
on the Space Station,

681
00:36:13,466 --> 00:36:17,566
because we want
the main variable

682
00:36:17,566 --> 00:36:19,000
making the comparison

683
00:36:19,000 --> 00:36:21,766
between space-flight
and ground-control animals

684
00:36:21,766 --> 00:36:24,300
to be space.

685
00:36:24,300 --> 00:36:26,900
And that is the final

686
00:36:26,900 --> 00:36:30,566
and key comparison.

687
00:36:30,566 --> 00:36:34,333
So this summarizes the results
we've obtained to date.

688
00:36:34,333 --> 00:36:37,233
We have body weight

and tissue weights

689
00:36:37,233 --> 00:36:40,933
from the validation mice.

690
00:36:40,933 --> 00:36:43,900
I'm not going to talk
about the variable

691
00:36:43,900 --> 00:36:45,933
of time and cage in detail,

692
00:36:45,933 --> 00:36:49,766
but, fortunately, there were not
huge differences,

693
00:36:49,766 --> 00:36:53,600
which yields
a simpler analysis.

694
00:36:53,600 --> 00:36:57,133
Now we can--In the case of
the space flight environment,

695
00:36:57,133 --> 00:37:01,166
we can simply compare the ground
controls to the flight group

696
00:37:01,166 --> 00:37:03,900
and ask "What were the direction
of changes?"

697
00:37:03,900 --> 00:37:07,733
Now, one thing I've done here
is I've put in green...

698
00:37:09,100 --> 00:37:12,833
The changes or lack of changes
that is new information.

699
00:37:12,833 --> 00:37:14,966
These are not changes
that we observed

700
00:37:14,966 --> 00:37:18,000
in shorter-duration
shuttle missions.

701
00:37:18,000 --> 00:37:21,966
They are different in direction
from some of those experiments,

702
00:37:21,966 --> 00:37:26,466
and so going through them
sequentially,

703
00:37:26,466 --> 00:37:29,433
we saw no difference
in body weights,

704
00:37:29,433 --> 00:37:31,833
between the ground control
and the flight,

705
00:37:31,833 --> 00:37:35,366
nor compared to any
of the other groups.

706
00:37:35,366 --> 00:37:38,200
There was an increase
in liver mass.

707
00:37:38,200 --> 00:37:41,666
There was no effect
on adrenal gland.

708
00:37:41,666 --> 00:37:43,733
Now, the adrenal gland
is responsible

709
00:37:43,733 --> 00:37:46,766
for producing a principal
stress hormone in the body.

710
00:37:46,766 --> 00:37:48,500
In humans, it's cortisol.

711
00:37:48,500 --> 00:37:51,133
In mice, it's corticosterone.

712
00:37:51,133 --> 00:37:53,600
And previous
short-duration experiments

713
00:37:53,600 --> 00:37:57,866
on occasion observed hypertrophy
or growth of the adrenal gland,

714
00:37:57,866 --> 00:38:02,000
which can occur in response
to a chronic stressor.

715
00:38:02,000 --> 00:38:04,400
So there was no effect
of the space environment

716
00:38:04,400 --> 00:38:07,433
on the gland size.

717
00:38:07,433 --> 00:38:09,866
The thymus and the spleen
are two glands

718
00:38:09,866 --> 00:38:12,533
that are involved
in the immune response.

719
00:38:12,533 --> 00:38:16,300
We saw an increase in mass--

720
00:38:16,300 --> 00:38:19,733
Shuttle missions in mice
have shown a decrease,

721
00:38:19,733 --> 00:38:22,000
in short duration--

722
00:38:22,000 --> 00:38:25,233
And a decrease in spleen mass.

723
00:38:25,233 --> 00:38:27,733
Now, what we did see
that was consistent

724
00:38:27,733 --> 00:38:29,600
with previous missions

725
00:38:29,600 --> 00:38:32,333
is a decline
in the soleus muscle mass,

726
00:38:32,333 --> 00:38:35,000
and the soleus muscle
is an antigravity

727
00:38:35,000 --> 00:38:37,400
or postural muscle in the leg

728
00:38:37,400 --> 00:38:39,566
that atrophies in response

729
00:38:39,566 --> 00:38:42,433
to disuse or microgravity,

730
00:38:42,433 --> 00:38:45,833
and that was
a very consistent finding.

731
00:38:45,833 --> 00:38:49,133
What about the quality
of our sample retrieved?

732
00:38:49,133 --> 00:38:50,400
So...

733
00:38:52,500 --> 00:38:55,900
We evaluated RNA quality

734
00:38:55,900 --> 00:38:59,866
recovered from the liver
and the spleen

735
00:38:59,866 --> 00:39:04,566
and looked
at the quantitative value

736
00:39:04,566 --> 00:39:06,966
of quality,

737
00:39:06,966 --> 00:39:08,233
and we found,

738
00:39:08,233 --> 00:39:11,466
from the flight animals
as well as the ground controls,

739
00:39:11,466 --> 00:39:13,600
that the quality was acceptable

740
00:39:13,600 --> 00:39:16,200
for even the most demanding
of analyses.

741
00:39:16,200 --> 00:39:20,333
RNA-Seq is a method
that allows it to sequence

742
00:39:20,333 --> 00:39:24,733
all of the RNA transcripts
in a sample

743
00:39:24,733 --> 00:39:27,133
and is demanding
for high RNA quality.

744
00:39:27,133 --> 00:39:29,133
In fact, we've achieved that.

745
00:39:29,133 --> 00:39:31,100
The analysis
hasn't been complete,

746
00:39:31,100 --> 00:39:34,933
nor has the
liver-enzyme-activity analyses

747
00:39:34,933 --> 00:39:36,966
that are still in progress,

748
00:39:36,966 --> 00:39:40,066
but we achieved our goal

749
00:39:40,066 --> 00:39:44,166
of obtaining samples
of adequate quality,

750
00:39:44,166 --> 00:39:49,400
for applying these
very demanding techniques.

751
00:39:49,400 --> 00:39:53,133
Now, how can we expand
our science outcome

752
00:39:53,133 --> 00:39:55,833
from our original goals?

753
00:39:55,833 --> 00:39:59,833
One way we do that is through
biospecimen sharing.

754
00:39:59,833 --> 00:40:03,400
So, when we got the samples

755
00:40:03,400 --> 00:40:06,000
back from the Station,

756
00:40:06,000 --> 00:40:09,600
the project recovered
32 tissues

757
00:40:09,600 --> 00:40:11,233
from 40 validation mice,

758
00:40:11,233 --> 00:40:14,333
which yielded
more than 3,000 vials of tissues

759
00:40:14,333 --> 00:40:18,166
that are now being stored in
the Life Sciences Data Archive.

760
00:40:18,166 --> 00:40:20,900
These are destined
for distribution

761
00:40:20,900 --> 00:40:23,166
through
the Biospecimen Sharing Program

762
00:40:23,166 --> 00:40:24,866
of Space Biology,

763
00:40:24,866 --> 00:40:29,733
which includes our Russian

colleagues at IMBP,

764
00:40:29,733 --> 00:40:31,866
who've requested tissues.

765
00:40:31,866 --> 00:40:33,000
In addition,
some of the tissues

766
00:40:33,000 --> 00:40:36,866
will go to
the NASA Genelab Project,

767
00:40:36,866 --> 00:40:39,166
which I'll talk about
in a moment.

768
00:40:39,166 --> 00:40:40,633
I just want to take one moment

769
00:40:40,633 --> 00:40:44,600
to describe
the Biospecimen Sharing

770
00:40:44,600 --> 00:40:47,900
because it's been so successful
in the past.

771
00:40:47,900 --> 00:40:51,633
The images show a team
that traveled to Russia

772
00:40:51,633 --> 00:40:55,466
to recover samples
from the Bion-M1 mission,

773
00:40:55,466 --> 00:41:00,700
and you can see from the outcome
from previous flights--

774
00:41:00,700 --> 00:41:04,400
This is only a select group
of scientific manuscripts

775
00:41:04,400 --> 00:41:08,300
that came out of a single
shuttle experiment--

776
00:41:08,300 --> 00:41:12,233
How insight
into multiple systems

777
00:41:12,233 --> 00:41:14,533
can be derived
from this type of approach.

778
00:41:14,533 --> 00:41:18,800
So I'm very excited
about the future

779
00:41:18,800 --> 00:41:21,933
for the samples coming
out of Rodent Research-1.

780
00:41:21,933 --> 00:41:24,400
In addition,
we provided liver samples

781
00:41:24,400 --> 00:41:26,233
to the Genelab Project,

782
00:41:26,233 --> 00:41:29,733
who are processing these samples

783
00:41:29,733 --> 00:41:34,633
to analyze the RNA transcripts,

784
00:41:34,633 --> 00:41:39,533
DNA modifications,

and protein profile

785
00:41:39,533 --> 00:41:41,733
in the samples in some detail,

786
00:41:41,733 --> 00:41:44,700
and these samples and data sets

787
00:41:44,700 --> 00:41:48,066
will be made available
to the scientific community.

788
00:41:48,066 --> 00:41:50,200
So I'm going to take a moment
to summarize now

789
00:41:50,200 --> 00:41:53,133
where we are so far
with rodent research.

790
00:41:53,133 --> 00:41:57,766
The hardware and operations were
performed successfully on orbit.

791
00:41:57,766 --> 00:42:01,200
We got it all the way through
to sample return.

792
00:42:01,200 --> 00:42:04,600
The mice thrived through
37 days in microgravity.

793
00:42:04,600 --> 00:42:08,566
Some important analyses
are still in progress.

794
00:42:08,566 --> 00:42:11,833
It's important to note
the common indicators of stress

795
00:42:11,833 --> 00:42:13,666
were not observed in
the animals,

796
00:42:13,666 --> 00:42:16,600
such as a loss of body weight,

797
00:42:16,600 --> 00:42:18,533
an increase
in adrenal gland weight.

798
00:42:18,533 --> 00:42:21,233
They were the same
in all the groups.

799
00:42:22,566 --> 00:42:27,133
Also, the preliminary findings
on wet tissue masses

800
00:42:27,133 --> 00:42:30,400
contrasted sharply to findings
from shuttle experiments,

801
00:42:30,400 --> 00:42:34,366
which were shorter in duration,
also had other variables,

802
00:42:34,366 --> 00:42:38,100
but duration may be one
of the key variables

803
00:42:38,100 --> 00:42:40,700
in defining those differences.

804
00:42:40,700 --> 00:42:44,833
And with biospecimen sharing,
much more to come.

805
00:42:44,833 --> 00:42:49,033

So I would suggest,
from these findings--

806
00:42:49,033 --> 00:42:52,100
and this is a hypothesis,
not a conclusion--

807
00:42:52,100 --> 00:42:54,166
that there are
at least two phases

808
00:42:54,166 --> 00:42:56,766
of physiological changes
that occur after entry

809
00:42:56,766 --> 00:42:59,000
into the space-flight
environment.

810
00:42:59,000 --> 00:43:02,933
Of course, we don't know yet
how far they will progress.

811
00:43:02,933 --> 00:43:05,066
So I'm addressing the audience

812
00:43:05,066 --> 00:43:08,866
to think about and invite you
to pose your own hypotheses

813
00:43:08,866 --> 00:43:11,633
that might explain
such a thing.

814
00:43:11,633 --> 00:43:13,533
But one thing I'd like you
to keep in mind,

815
00:43:13,533 --> 00:43:16,566
as you think about this

in the future--

816
00:43:16,566 --> 00:43:21,033
This sort of diagrammatically
represents

817
00:43:21,033 --> 00:43:23,300
the problem that's being posed

818
00:43:23,300 --> 00:43:26,200
with the magnitude
of the response on the Y axis

819
00:43:26,200 --> 00:43:29,000
and time and space
on the X axis.

820
00:43:29,000 --> 00:43:30,466
Each of the colors represents

821
00:43:30,466 --> 00:43:33,233
a different
organ-system response.

822
00:43:33,233 --> 00:43:34,800
So the green may represent

823
00:43:34,800 --> 00:43:38,200
the vestibular response
to microgravity,

824
00:43:38,200 --> 00:43:40,166
which occurs very rapidly.

825
00:43:40,166 --> 00:43:43,566
The red may be
cardiovascular adaptations,

826
00:43:43,566 --> 00:43:46,000

which improve over time,

827
00:43:46,000 --> 00:43:50,066
and the blue may be another
system that takes a longer time.

828
00:43:50,066 --> 00:43:52,733
So these various
time dependencies

829
00:43:52,733 --> 00:43:54,900
need to be taken into account

830
00:43:54,900 --> 00:43:57,900
as you think about whether
or not duration and space

831
00:43:57,900 --> 00:44:01,700
is a key variable
and might explain our results

832
00:44:01,700 --> 00:44:06,366
and help us design
new space-flight experiments.

833
00:44:06,366 --> 00:44:08,833
Maybe we'll get some insight
from Rodent Research-2.

834
00:44:08,833 --> 00:44:12,000
That mission,
all the on-orbit activities

835
00:44:12,000 --> 00:44:14,900
have been completed
for Rodent Research-2.

836
00:44:14,900 --> 00:44:18,166
That's a CASIS mission
that lasted 60 days.

837
00:44:18,166 --> 00:44:22,333
So perhaps we'll get insight
into that.

838
00:44:22,333 --> 00:44:25,066
So I'd like to wrap up now

839
00:44:25,066 --> 00:44:28,666
with a couple
concluding comments.

840
00:44:28,666 --> 00:44:31,333
To live in space--

841
00:44:31,333 --> 00:44:33,933
Hopefully I've effectively
shared with you

842
00:44:33,933 --> 00:44:37,566
that there are multiple
challenges to the human body

843
00:44:37,566 --> 00:44:39,500
that are posed
by that environment

844
00:44:39,500 --> 00:44:41,900
and that many different
physiological systems

845
00:44:41,900 --> 00:44:44,233
can be affected.

846
00:44:44,233 --> 00:44:47,133
And I believe the resulting
complexity is such

847
00:44:47,133 --> 00:44:50,633

that the consequences
of these challenges

848
00:44:50,633 --> 00:44:52,866
and these responses are such

849
00:44:52,866 --> 00:44:57,433
that it's virtually impossible
to predict with certainty

850
00:44:57,433 --> 00:45:00,266
what those consequences will be
for human health,

851
00:45:00,266 --> 00:45:05,266
for human reproduction,
over very long periods of time.

852
00:45:05,266 --> 00:45:10,400
We believe that insight into
those responses and mechanisms

853
00:45:10,400 --> 00:45:12,700
will improve our ability
to predict

854
00:45:12,700 --> 00:45:13,900
and potentially mitigate,

855
00:45:13,900 --> 00:45:15,900
make decisions
about what we need to do

856
00:45:15,900 --> 00:45:17,866
to protect humans in space--

857
00:45:17,866 --> 00:45:23,466
living in space, and also that
rodent research on the ISS

858
00:45:23,466 --> 00:45:26,000
will help us get there.

859
00:45:26,000 --> 00:45:29,366
I'll finish up
with some acknowledgements.

860
00:45:29,366 --> 00:45:32,133
This shows
a very happy group of people,

861
00:45:32,133 --> 00:45:33,733
after staying up all night,

862
00:45:33,733 --> 00:45:36,133
talking the astronaut crew

863
00:45:36,133 --> 00:45:40,066
through some difficult
on-orbit operations

864
00:45:40,066 --> 00:45:41,600
in Rodent Research-1,

865
00:45:41,600 --> 00:45:45,833
but, of course,
they are a very small sample

866
00:45:45,833 --> 00:45:49,900
of the number of people who
actually had a hand in making--

867
00:45:49,900 --> 00:45:54,000
have a hand in making
rodent research work on Station.

868
00:45:54,000 --> 00:45:56,733
It would vie with the number
of people that showed up

869
00:45:56,733 --> 00:45:58,733
to break the "Guinness Book
of World Records"

870
00:45:58,733 --> 00:46:01,400
for dancing at the same place
at the same time

871
00:46:01,400 --> 00:46:04,233
in Mexico City,

872
00:46:04,233 --> 00:46:07,700
but still, there are
many important people

873
00:46:07,700 --> 00:46:10,033
who can't be named here.

874
00:46:10,033 --> 00:46:12,233
And also I want to mention
the inspiration

875
00:46:12,233 --> 00:46:15,566
that comes from
the research lab that I work in,

876
00:46:15,566 --> 00:46:17,866
the Bone and Signaling Lab.

877
00:46:17,866 --> 00:46:19,966
And I'm going to finish up here

878
00:46:19,966 --> 00:46:22,900
and leave up
during the Q&A period--

879
00:46:22,900 --> 00:46:27,100
First, thank you very, very much

for listening so patiently.

880
00:46:27,100 --> 00:46:28,900
And also,
I'm going to leave this up

881
00:46:28,900 --> 00:46:30,166
in case you have interest

882
00:46:30,166 --> 00:46:33,900
in following up
with some of these links

883
00:46:33,900 --> 00:46:37,633
and some aspects
of what I've talked about today.

884
00:46:37,633 --> 00:46:40,633
[applause]

885
00:46:45,600 --> 00:46:47,033
So, thank you, Ruth.

886
00:46:47,033 --> 00:46:49,433
We have a few minutes
for questions.

887
00:46:49,433 --> 00:46:52,666
If you have a question,
please line up on the microphone

888
00:46:52,666 --> 00:46:55,100
in the center of the aisle.

889
00:46:55,100 --> 00:46:58,600
Please be brief,
and no follow-up questions.

890
00:46:58,600 --> 00:47:00,666

Thank you.

891
00:47:08,366 --> 00:47:10,366
Ruth, is this the first time

892
00:47:10,366 --> 00:47:14,966
that mice have been in space
for that 30-day duration?

893
00:47:14,966 --> 00:47:17,566
Is that the longest--
one of the longest periods?

894
00:47:17,566 --> 00:47:21,066
(Ruth)
So...

895
00:47:21,066 --> 00:47:22,966
And my follow-on question--
Sorry, I'll ask--

896
00:47:22,966 --> 00:47:24,266
Is, you know, what--

897
00:47:24,266 --> 00:47:25,900
You know, basically,
I'm just really fascinated

898
00:47:25,900 --> 00:47:29,033
about what would happen with
adaptation of those animals

899
00:47:29,033 --> 00:47:30,433
over that long period of time,

900
00:47:30,433 --> 00:47:33,733
in terms of behavior,
interacting with feed systems,

901

00:47:33,733 --> 00:47:36,433
interacting with each other,
that kind of thing.

902
00:47:36,433 --> 00:47:39,966
Right, well, so...

903
00:47:39,966 --> 00:47:43,466
there were two other
flight experiments that--

904
00:47:43,466 --> 00:47:46,466
one, 30 days, the Bion mission
was a 30-day mission,

905
00:47:46,466 --> 00:47:48,233
and the "mouse drawer system"
experiment

906
00:47:48,233 --> 00:47:51,566
was a 90-day mission
that was flown once.

907
00:47:54,933 --> 00:47:58,033
You pose a good question
about interacting over time,

908
00:47:58,033 --> 00:47:59,766
and that is one
of the reasons why

909
00:47:59,766 --> 00:48:03,233
we are performing
a very careful and quantitative

910
00:48:03,233 --> 00:48:08,833
behavioral analysis of the video
collected from that mission.

911
00:48:08,833 --> 00:48:12,433

But I think we need
more longer-duration missions,

912
00:48:12,433 --> 00:48:16,366
so we can capture
a larger fraction

913
00:48:16,366 --> 00:48:19,366
of that total time in space.

914
00:48:21,400 --> 00:48:23,233
Hi.

915
00:48:23,233 --> 00:48:25,166
I was wondering
if there were any plans

916
00:48:25,166 --> 00:48:27,233
to do partial-gravity
assimilations

917
00:48:27,233 --> 00:48:28,966
in space or on the ground?

918
00:48:28,966 --> 00:48:31,466
Like one third?

919
00:48:31,466 --> 00:48:35,633
So JAXA,
the Japanese Space Agency,

920
00:48:35,633 --> 00:48:37,600
is going to be--

921
00:48:37,600 --> 00:48:40,833
is working on flying
a rodent experiment now

922
00:48:40,833 --> 00:48:42,800

where I do believe

923
00:48:42,800 --> 00:48:46,700
the plan is to completely
replace the gravity vector,

924
00:48:46,700 --> 00:48:49,400
but once the capability

925
00:48:49,400 --> 00:48:53,366
is developed
for centrifugation,

926
00:48:53,366 --> 00:48:56,066
then it's possible to do
partial-gravity experiments,

927
00:48:56,066 --> 00:48:59,633
and there's a lot of interest
in doing that,

928
00:48:59,633 --> 00:49:03,066
in thinking
about going to other planets.

929
00:49:03,066 --> 00:49:06,900
Would it be helpful
to have a centrifuge

930
00:49:06,900 --> 00:49:08,166
so you could tease out

931
00:49:08,166 --> 00:49:11,300
the effects of weightlessness
versus radiation?

932
00:49:11,300 --> 00:49:12,366
(Ruth)
Absolutely.

933
00:49:12,366 --> 00:49:15,066
It would be great.

934
00:49:16,366 --> 00:49:19,100
Ruth, there's more data
on humans in space

935
00:49:19,100 --> 00:49:20,900
in terms of duration
than there are on mice.

936
00:49:20,900 --> 00:49:24,566
Have you done anything
to compare the mice results

937
00:49:24,566 --> 00:49:27,400
to data that you've gotten
from humans?

938
00:49:27,400 --> 00:49:30,266
That's a really good question,
because, fundamentally,

939
00:49:30,266 --> 00:49:32,400
if we want to extrapolate
from the result--

940
00:49:32,400 --> 00:49:34,000
The assumption of these studies

941
00:49:34,000 --> 00:49:37,566
is that they will yield insight
into humans.

942
00:49:37,566 --> 00:49:40,233
So, as you can imagine,

943
00:49:40,233 --> 00:49:43,066
the answer to that question

is a work in progress.

944
00:49:44,733 --> 00:49:47,400
There are limits
to every model system,

945
00:49:47,400 --> 00:49:53,066
and in terms of going forward
with the new capability we have,

946
00:49:53,066 --> 00:49:56,600
that's going to be
an important aspect to look at.

947
00:49:56,600 --> 00:50:00,333
So a work in progress.

948
00:50:00,333 --> 00:50:02,400
One follow-on question,
and that is,

949
00:50:02,400 --> 00:50:05,866
do you have data that suggests
where an end point would be?

950
00:50:05,866 --> 00:50:08,166
I mean, we know
the endocrine system is damaged,

951
00:50:08,166 --> 00:50:12,133
the muscles are problematic,
the skeleton has issues.

952
00:50:12,133 --> 00:50:16,200
At what point would we decide,
"Well, gee, we can't do space.

953
00:50:16,200 --> 00:50:17,500
It's gonna be too difficult.

954
00:50:17,500 --> 00:50:19,466
We're never gonna be able
to colonize space."

955
00:50:19,466 --> 00:50:21,066
Do you have a feeling

956
00:50:21,066 --> 00:50:24,966
after 40 years
of data collection?

957
00:50:24,966 --> 00:50:28,200
Well, I'm not sure
that I would answer that ques--

958
00:50:28,200 --> 00:50:29,700
That is a question

959
00:50:29,700 --> 00:50:32,566
that's gonna take more than
rodent experiments to answer.

960
00:50:32,566 --> 00:50:36,133
It's an excellent question
without a single end point,

961
00:50:36,133 --> 00:50:38,566
and I'm sorry I don't have
a better answer for you,

962
00:50:38,566 --> 00:50:40,666
but I think the answer
to that question

963
00:50:40,666 --> 00:50:43,500
needs to take
into consideration

964
00:50:43,500 --> 00:50:47,033

both our ability to extrapolate
from the rodent experiments,

965
00:50:47,033 --> 00:50:50,566
also an understanding
of when the changes

966
00:50:50,566 --> 00:50:53,566
that we observe pass the bar

967
00:50:53,566 --> 00:50:56,566
from subclinical
into clinical significance,

968
00:50:56,566 --> 00:50:57,933
and that's very important.

969
00:50:57,933 --> 00:51:02,933
The Human Research Program
at NASA spends a lot of time

970
00:51:02,933 --> 00:51:05,066
reviewing that,

971
00:51:05,066 --> 00:51:10,233
and they've compiled
evidence books

972
00:51:10,233 --> 00:51:15,066
related to all
of the major identified risks

973
00:51:15,066 --> 00:51:16,766
to human health,

974
00:51:16,766 --> 00:51:19,633
and part of that process--

975
00:51:19,633 --> 00:51:22,633

the goal of that process
is really to identify

976
00:51:22,633 --> 00:51:25,966
when do you see a change
that's acceptable,

977
00:51:25,966 --> 00:51:28,400
and when do you pass

978
00:51:28,400 --> 00:51:32,933
into significant
versus very severe risk.

979
00:51:32,933 --> 00:51:35,600
And so I would say
there's a whole program

980
00:51:35,600 --> 00:51:38,733
devoted to answering
that question.

981
00:51:44,300 --> 00:51:45,666
All right, please join me

982
00:51:45,666 --> 00:51:48,900
in thanking Dr. Ruth Globus
for an excellent seminar.

983
00:51:48,900 --> 00:51:51,900
[applause]