

1

00:00:00,000 --> 00:00:16,285

This series presents information based in part on theory and conjecture.

2

00:00:16,285 --> 00:00:20,806

The producer's purpose is to suggest some possible explanations, but not necessarily

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00:00:20,806 --> 00:00:29,768

the only ones to the mysteries we will examine.

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00:00:29,768 --> 00:00:40,490

Frozen alive to 100 degrees below zero, a three-day old embryo is held in suspended animation.

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00:00:40,490 --> 00:00:46,291

As temperatures approach absolute zero, all chemical and biological activity ceases.

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00:00:46,291 --> 00:01:00,253

In this state, frozen life might be preserved forever.

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00:01:00,253 --> 00:01:06,254

Since the dawn of man, cold has been our cruelest enemy.

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00:01:06,254 --> 00:01:11,735

Even today, blizzards claim a yearly toll of the unprepared.

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00:01:11,735 --> 00:01:23,698

During winter, death by freezing remains a constant threat.

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00:01:23,698 --> 00:01:31,579

Below the freezing point of water, zero degrees Celsius, human flesh can freeze solid.

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00:01:31,579 --> 00:01:37,060

Hands and feet are especially vulnerable to frostbite.

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00:01:37,060 --> 00:01:40,861

In severe cases, the damage is irreversible.

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00:01:40,861 --> 00:01:50,382

When flesh freezes, cells are usually disrupted beyond repair.

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00:01:50,382 --> 00:01:56,704

Research has led to advances in design of protective clothing.

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00:01:56,704 --> 00:02:01,785

Along the Alaskan pipeline, properly dressed workers are safe down to minus 60 degrees

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00:02:01,785 --> 00:02:03,985

Celsius.

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00:02:03,985 --> 00:02:12,107

No such temperatures, however, cold becomes increasingly lethal.

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00:02:12,107 --> 00:02:16,747

For most of us, once temperatures drop into the subzero range, we've reached the limit

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00:02:16,747 --> 00:02:18,948

of our knowledge about cold.

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00:02:18,948 --> 00:02:23,309

We all know that food keeps better in the refrigerator, but it lasts even longer in

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00:02:23,309 --> 00:02:24,709

a freezer.

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00:02:24,709 --> 00:02:30,790

But beyond freezer temperatures, we enter the realm of cryogenics, the realm of the

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00:02:30,790 --> 00:02:37,951

very cold.

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00:02:37,951 --> 00:02:47,993

At 196 degrees below zero, nitrogen, the main ingredient of air, becomes liquid.

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00:02:47,993 --> 00:02:57,155

73 degrees further down, helium, the gas most resistant to cold, also becomes liquid.

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00:02:57,155 --> 00:03:04,196

As temperatures drop still further, we approach the ultimate limit of minus 273 degrees, or

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00:03:04,196 --> 00:03:09,997

absolute zero.

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00:03:09,997 --> 00:03:15,798

To understand how freezing damage occurs, MIT scientists freeze cells under controlled

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00:03:15,798 --> 00:03:18,039

thermal conditions.

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00:03:18,039 --> 00:03:23,560

Using a special cryo microscope, they have made films and videotapes of blood cells,

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00:03:23,560 --> 00:03:28,921

embryos, and human tissue cells.

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00:03:28,921 --> 00:03:36,322

Red blood cells are relatively easy to freeze safely.

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00:03:36,322 --> 00:03:44,044

With the aid of protective chemicals and moderate cooling speeds, most cells survive.

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00:03:44,044 --> 00:03:46,524

They're chill at the correct rate.

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00:03:46,524 --> 00:03:53,045

Even human tissue cells sometimes survive freezing.

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00:03:53,045 --> 00:04:05,848

But when the freezing is too fast, ice forms within the cells, causing them to flash black

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00:04:05,848 --> 00:04:12,489

and die.

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00:04:12,489 --> 00:04:16,930

In nature, not all living things die when they are frozen.

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00:04:16,930 --> 00:04:25,451

Some trees and plants have adapted to the bitter arctic winter.

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00:04:25,451 --> 00:04:31,212

Certain insects, like the tardigrade, survive below minus 50 degrees.

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00:04:31,212 --> 00:04:37,933

The tardigrade and other arctic insects freeze in winter and thaw without ill effect in summer.

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00:04:37,933 --> 00:04:43,615

Is it conceivable that larger animals, perhaps even people, could survive freezing?

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00:04:43,615 --> 00:04:48,735

To answer this provocative question, we must first examine the state of the art of freezing

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00:04:48,735 --> 00:04:52,776

the separate elements of life.

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00:04:52,776 --> 00:04:58,177

At the Carnation Genetics Company in California, workers get a sample of sperm from a prized

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00:04:58,177 --> 00:05:03,778

bull.

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00:05:03,778 --> 00:05:09,219

They add the sperm to a solution of glycerol, the same chemical arctic insects produce to

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00:05:09,219 --> 00:05:14,540

prevent freezing damage.

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00:05:14,540 --> 00:05:21,221

The sperm is frozen in liquid nitrogen at 196 degrees below zero Celsius.

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00:05:21,221 --> 00:05:29,063

At this low temperature, it remains in a state of suspended animation.

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00:05:29,063 --> 00:05:33,904

Years or even years later, the sperm will be shipped to cattle breeders.

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00:05:33,904 --> 00:05:39,185

They thaw the sperm, bringing it back to life, and use it to artificially inseminate their

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00:05:39,185 --> 00:05:41,065

cows.

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00:05:41,065 --> 00:05:46,746

By carefully matching bulls and cows, farmers have vastly improved production of milk and

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00:05:46,746 --> 00:05:49,107

beef.

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00:05:49,107 --> 00:05:54,788

At the Tyler Clinic in Los Angeles, human sperm is preserved for many years.

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00:05:55,188 --> 00:06:00,309

Reportedly, there have been human births from sperm kept in frozen suspended animation

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00:06:00,309 --> 00:06:02,709

for over 10 years.

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00:06:02,709 --> 00:06:09,510

No one knows how long it keeps its potency.

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00:06:09,510 --> 00:06:15,351

Human sperm frozen today could possibly sire a child hundreds or even thousands of years

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00:06:15,351 --> 00:06:18,512

from now.

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00:06:18,512 --> 00:06:21,273

Blood is the very symbol of life.

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00:06:21,273 --> 00:06:29,514

It carries warmth and oxygen to all parts of the body.

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00:06:29,514 --> 00:06:36,555

Today however, blood freezing is routine.

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00:06:36,555 --> 00:06:48,718

The red cells are protected by adding glycerol.

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00:06:48,718 --> 00:06:53,479

If frozen blood cells stay alive for many years, their use has greatly increased the

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00:06:53,479 --> 00:06:58,439

available supply of this precious substance.

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00:06:58,439 --> 00:07:08,161

The frozen blood can be thawed, and the glycerol washed out in less than an hour.

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00:07:08,161 --> 00:07:16,923

Dr. Charles Huggins directs the blood bank at Massachusetts General Hospital.

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00:07:16,923 --> 00:07:22,724

He is also a pioneer on the next frontier of cryogenics, the preservation of whole organs

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00:07:22,724 --> 00:07:24,484

by freezing.

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00:07:24,484 --> 00:07:30,245

By freezing the organ, you would make it much easier to coordinate the donor organs and

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00:07:30,245 --> 00:07:34,086

the potential recipient in a much higher percentage of people could be.

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00:07:34,086 --> 00:07:38,207

It could have successful transplants with good genetic matching, and I don't think there's

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00:07:38,207 --> 00:07:43,688

any fundamentally unsolvable problem, but it's not going to come in the next day or

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00:07:43,688 --> 00:07:48,449

two, and in fact, I think it will be quite a number of years before we have clinical

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00:07:48,449 --> 00:07:53,090

banks of kidneys and hearts and that sort of thing.

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00:07:53,090 --> 00:07:58,611

Attempting to solve the organ freezing problem, biologists chill living tissue below the ice

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00:07:58,611 --> 00:08:00,171

point.

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00:08:00,171 --> 00:08:06,012

They observe how blood vessels are damaged when the tissues freeze.

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00:08:06,012 --> 00:08:11,493

Such difficulties limit the size of organs which can be frozen.

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00:08:11,493 --> 00:08:18,534

The UCLA, Dr. Josiah Brown has frozen the tiny pancreas gland of fetal rats and successfully

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00:08:18,534 --> 00:08:21,695

transplanted it into adult rats.

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00:08:21,695 --> 00:08:27,056

We're trying to work out in the rat pancreas the technique for freezing the pancreas so

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00:08:27,056 --> 00:08:32,737

that it can be frozen permanently and implanted into a diabetic animal in order to reverse

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00:08:32,737 --> 00:08:34,457

the diabetes.

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00:08:34,457 --> 00:08:41,338

Our vision, our dream is to have a laboratory with large banks of frozen pancreas and then

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00:08:41,338 --> 00:08:48,980

implant the donor organ into the diabetic human and have it function.

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00:08:48,980 --> 00:08:55,301

Of all life processes, none is more awesome than the growth of a tiny embryo into a complete

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00:08:55,301 --> 00:09:02,182

animal.

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00:09:02,182 --> 00:09:07,463

If human embryos could be frozen successfully, we could send our children on journeys into

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00:09:07,463 --> 00:09:15,025

the distant future.

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00:09:15,025 --> 00:09:23,586

Protected by a chemical called DMSO, a mouse embryo is carefully frozen.

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00:09:23,586 --> 00:09:34,108

Icy fingers hold it hostage down to 100 degrees below zero, suspending all growth or change.

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00:09:34,108 --> 00:09:42,790

With thawing, the embryo swells back to normal size, ready to continue its development.

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00:09:42,790 --> 00:09:49,991

At the Oak Ridge National Laboratory, scientists have frozen mouse embryos in liquid nitrogen.

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00:09:49,991 --> 00:09:56,472

They take embryos from the uterus of a pregnant mouse.

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00:09:56,472 --> 00:10:03,634

The embryos are gently put in DMSO.

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00:10:03,634 --> 00:10:09,795

Then the scientists freeze the living embryos and store them in liquid nitrogen.

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00:10:09,795 --> 00:10:16,396

Days later, the embryos will be thawed and re-implanted in the wombs of other mice.

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00:10:16,396 --> 00:10:24,077

Remarkably, they develop into normal, healthy mice.

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00:10:24,077 --> 00:10:29,638

Soon after the mouse experiments, cattle breeders also began freezing embryos.

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00:10:29,638 --> 00:10:35,079

They flush weak old embryos out of cows known to have superior calves.

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00:10:35,079 --> 00:10:42,481

By super-ovulating with fertility drugs, they can get as many as 15 embryos per cow.

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00:10:42,481 --> 00:10:49,402

The embryos are cooled slowly in DMSO, then plunged into liquid nitrogen and held in cold

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00:10:49,402 --> 00:10:50,402

storage.

107

00:10:50,402 --> 00:10:56,804

When it is time to bring them to life, the breeders thaw the embryos, remove the chemical

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00:10:56,804 --> 00:11:01,004

antifreeze, and prepare cows for implantation.

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00:11:01,004 --> 00:11:05,205

They inject an embryo into the cow's womb and sew her up.

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00:11:05,205 --> 00:11:08,926

The embryo will grow naturally to term.

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00:11:08,926 --> 00:11:15,127

This calf is the first frozen embryo calf ever born in the United States.

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00:11:15,127 --> 00:11:20,128

Such use of suspended animation could revolutionize the cattle industry.

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00:11:20,128 --> 00:11:25,609

By selecting genetically superior-parent cows and bulls, a farmer could quickly build up

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00:11:25,609 --> 00:11:31,770

a champion herd.

115

00:11:31,770 --> 00:11:40,652

Blood cells and embryos have survived cooling to within a few degrees of absolute zero.

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00:11:40,652 --> 00:11:47,373

As the temperature drops toward its theoretical limit, molecular motion virtually ceases.

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00:11:47,373 --> 00:11:50,653

Processes of growth and deterioration stop.

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00:11:50,653 --> 00:11:55,334

In this state, the essence of life could be preserved forever.

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00:11:55,334 --> 00:12:09,977

Here are those who would like to imagine that freezing could make man immortal.

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00:12:09,977 --> 00:12:14,378

The balance of temperature within a human body is incredibly delicate.

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00:12:14,378 --> 00:12:20,219

A drop of only five degrees in body temperature brings on the potentially lethal state called

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00:12:20,219 --> 00:12:34,302

hypothermia.

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00:12:34,302 --> 00:12:41,223

Without adequate clothing, an injured skier is potentially in danger of losing her life.

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00:12:41,223 --> 00:12:46,344

In direct contact with snow, her body will cool rapidly toward the point where no amount

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00:12:46,344 --> 00:12:54,825

of exercise or clothing could restore adequate warmth.

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00:12:54,825 --> 00:13:09,828

Unless she is rescued, death would then be inevitable.

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00:13:09,828 --> 00:13:16,389

Dr. Paul Siegel is conducting experiments on hypothermia in rats.

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00:13:16,389 --> 00:13:18,990

We're taking the rat down to zero degrees centigrade.

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00:13:18,990 --> 00:13:26,311

We're taking it down to the ice point and seeing how long we can stay at the ice point

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00:13:26,311 --> 00:13:29,952

without breathing, without respiration.

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00:13:29,952 --> 00:13:32,232

The rat's heart has stopped.

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00:13:32,232 --> 00:13:34,273

Its vital signs gone.

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00:13:34,273 --> 00:13:46,435

The rat is clinically dead.

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00:13:46,435 --> 00:13:50,756

Dr. Siegel's assistant uses a desk lamp to warm the rat.

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00:13:50,756 --> 00:13:54,636

She gives it artificial respiration.

136

00:13:54,636 --> 00:14:00,998

Usually between 15 and 18 degrees we reestablish heartbeat sometimes before, so in the next

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00:14:00,998 --> 00:14:08,079

couple of minutes, since the temperature is rising rapidly, we should begin to see a heartbeat.

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00:14:08,079 --> 00:14:09,079

That's it.

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00:14:09,079 --> 00:14:10,079

We've got a beat.

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00:14:10,079 --> 00:14:11,079

That is a heartbeat.

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00:14:11,079 --> 00:14:12,080

There's another one, yeah.

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00:14:12,080 --> 00:14:13,080

Keep going, Judy.

143

00:14:13,080 --> 00:14:14,080

Beautiful.

144

00:14:14,080 --> 00:14:15,080

Beautiful.

145

00:14:15,080 --> 00:14:22,482

All right, heartbeat established at 13.5 degrees centigrade.

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00:14:22,482 --> 00:14:29,803

During long, cold winter months, when food is scarce, some animals are able to hibernate.

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00:14:29,803 --> 00:14:36,924

This suggests another approach to suspended animation.

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00:14:36,924 --> 00:14:42,285

During hibernation, the ground squirrel drastically reduces its metabolic rate.

149

00:14:42,285 --> 00:14:45,646

To the touch, it is icy cold.

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00:14:45,646 --> 00:14:50,567

Although heartbeat and breathing do not stop, they are greatly slowed.

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00:14:50,567 --> 00:14:56,888

As the squirrel warms to room temperature, it gradually regains consciousness.

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00:14:56,888 --> 00:15:01,449

They're only beginning to understand how some animals hibernate.

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00:15:01,449 --> 00:15:08,730

As yet, we know of no fundamental barrier to human hibernation.

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00:15:08,730 --> 00:15:18,412

A freeze-dried animal retains its external form years after its contemporaries have decomposed.

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00:15:18,412 --> 00:15:24,573

Mammoths frozen for 10,000 years have been found in Siberia, their meat so fresh that

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00:15:24,573 --> 00:15:26,873

it can be eaten.

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00:15:26,873 --> 00:15:41,156

Some people have concluded that freezing and reviving whole animals might be possible.

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00:15:41,156 --> 00:15:45,477

The finality of death is hard to accept.

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00:15:45,477 --> 00:15:51,198

The lure of finding a window to the future is strong.

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00:15:51,198 --> 00:15:55,919

In California, Art Quafe operates a cryonic suspension facility.

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00:15:55,919 --> 00:16:01,120

Displacing patients into low-temperature suspension after they've been pronounced legally dead

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00:16:01,120 --> 00:16:05,641

in the hope that at some future date medical science may be able to cure whatever they

163

00:16:05,641 --> 00:16:14,042

died of, repair any damage caused by the freezing procedure, and restore them to life.

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00:16:14,042 --> 00:16:18,963

In this capsule, we have the head of a 79-year-old man who was a retired Army colonel.

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00:16:18,963 --> 00:16:23,724

He died about two years ago of respiratory ailments and was placed in suspension by a

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00:16:23,724 --> 00:16:27,085

team in Los Angeles.

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00:16:27,085 --> 00:16:29,845

This capsule contains two whole-body patients.

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00:16:29,845 --> 00:16:35,086

One is a 65-year-old Maryland man, other was a 75-year-old Midwestern woman.

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00:16:35,086 --> 00:16:38,127

Both of them died four years ago of cerebral strokes.

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00:16:38,127 --> 00:16:46,848

It also contains the brain of a 15-year-old girl who was murdered in Berkeley in 1976.

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00:16:46,848 --> 00:16:54,970

Over eight films and videotapes by amateur cameramen document the original encapsulation.

172

00:16:54,970 --> 00:17:05,732

One of the patients arrives already frozen to dry ice temperature.

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00:17:05,732 --> 00:17:09,812

His body is placed in a plastic bag.

174

00:17:09,812 --> 00:17:16,134

It is wrapped in alternating layers of foil and fiberglass.

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00:17:16,134 --> 00:17:21,335

The insulation will reduce the risk of thawing in case the liquid nitrogen in his capsule

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00:17:21,335 --> 00:17:26,536

temporarily boils away.

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00:17:26,536 --> 00:17:35,897

Carefully, the patient is eased into the steel capsule where he will remain until someone

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00:17:35,897 --> 00:17:43,019

tries to revive him.

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00:17:43,019 --> 00:17:46,619

After encapsulation, liquid nitrogen was added.

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00:17:46,619 --> 00:17:51,180

It has been replenished ever since.

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00:17:51,180 --> 00:17:57,141

Has any person or animal ever been brought back, revived after having been frozen such

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00:17:57,141 --> 00:17:58,862

a long time?

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00:17:58,862 --> 00:18:02,022

No human has ever been revived from the temperature of liquid nitrogen.

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00:18:02,022 --> 00:18:03,902

We wouldn't know how to do that today.

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00:18:03,902 --> 00:18:07,903

But there have been many successes with lower forms of life and less complicated organisms.

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00:18:07,903 --> 00:18:14,784

If I were interested in cryonic suspension, what would it cost me to enroll in your program?

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00:18:14,784 --> 00:18:17,825

First you would become a suspension member of the Bay Area Cryonic Society and that

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00:18:17,825 --> 00:18:19,905

would cost you a thousand dollars.

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00:18:19,905 --> 00:18:22,026

Beyond that you would have to provide funding for your suspension.

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00:18:22,026 --> 00:18:25,586

We recommend a minimum of fifty thousand dollars worth of funding.

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00:18:25,586 --> 00:18:31,067

If I were to decide to find out for the program, what assurance do I have that you would keep

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00:18:31,067 --> 00:18:35,668

the temperature even, that you would keep me in suspension, that you would bring me

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00:18:35,668 --> 00:18:36,669

back?

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00:18:36,669 --> 00:18:38,269

That's basically an act of faith.

195

00:18:38,269 --> 00:18:40,869

Well the procedure isn't perfected so no, we can't give any guarantee.

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00:18:40,869 --> 00:18:43,590

The only guarantee we can give you is that if you're put in a grave you have virtually

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00:18:43,590 --> 00:18:45,190

no chance of coming back.

198

00:18:45,190 --> 00:18:47,110

If you're frozen you have some chance.

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00:18:47,110 --> 00:18:52,151

It seems very dubious to me that we'll ever be able to successfully freeze all humans.

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00:18:52,151 --> 00:18:56,312

You have all the problems of preserving each of the separate organs of the person and the

201

00:18:56,312 --> 00:19:01,193

thousands of problems of that multiplied by the thousands of different organs that are

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00:19:01,193 --> 00:19:02,193

in the body.

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00:19:02,753 --> 00:19:07,634

I personally don't feel that this will ever come before seven hundred or a thousand years

204

00:19:07,634 --> 00:19:08,794

from now.

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00:19:11,475 --> 00:19:17,276

There is no exact count but in the world today there are about twenty frozen bodies waiting

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00:19:17,276 --> 00:19:20,477

with a bare wisp of hope for the future.

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00:19:24,157 --> 00:19:27,878

Most advocates of cryonic suspension are immortalists.

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00:19:27,878 --> 00:19:33,359

They believe that medical science will eventually find a way to reverse the process of aging

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00:19:33,359 --> 00:19:35,879

and extend our lives indefinitely.

210

00:19:39,960 --> 00:19:46,161

The more realistic chance of immortality however, exists for the frozen embryo.

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00:19:46,161 --> 00:19:50,362

For mice and calves the technology already exists.

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00:19:50,362 --> 00:19:53,603

The process will surely work for humans as well.

213

00:19:54,603 --> 00:20:01,604

It is believed that embryos could be kept frozen in suspended animation for generations.

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00:20:02,604 --> 00:20:08,606

A woman of the future could choose her child from a frozen embryo bank.

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00:20:09,606 --> 00:20:15,607

If whole body suspended animation is ultimately achieved, citizens of tomorrow could practice

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00:20:15,607 --> 00:20:17,607

an intriguing new lifestyle.

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00:20:18,607 --> 00:20:24,608

They would have themselves suspended before they grow old.

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00:20:26,609 --> 00:20:32,610

Intending to sample life in centuries to come, they would launch themselves into the unknown.

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00:20:33,610 --> 00:20:39,611

Millennial later they would be revived, take part in life for a decade or so in a fantastic

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00:20:39,611 --> 00:20:43,612

new world and then continue their voyage into the future.

221

00:20:48,613 --> 00:20:51,613

In Search of

222

00:20:52,614 --> 00:20:57,615

The use of cold storage to preserve human sperm, embryos and even whole people

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00:20:57,615 --> 00:21:00,615

raises many ethical and social questions.

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00:21:00,615 --> 00:21:03,616

Whose sperm and embryos should be saved?

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00:21:03,616 --> 00:21:07,616

Could everyone afford to be frozen or only the rich?

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00:21:07,616 --> 00:21:12,617

The research in cryobiology will surely lead to life-saving medical advances.

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00:21:12,617 --> 00:21:17,618

But even if we achieve suspended animation, we may not be able to deal with the unknown

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00:21:17,618 --> 00:21:20,619

consequences of frozen immortality.

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00:21:42,623 --> 00:21:47,624

Thank you for watching!