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Dr. Gamme

TV program series
Rice U.

DOCTORS IN SPACE

Film No. 3:

THE SEA OF AIR

DR. RIDER

Life on Earth appeared first in the sea, and it still shows many signs of its maritime origin. As everyone knows, about 80 per cent of the human body is fluid, bathing and permeating the tissues under the skin. The chemical processes that characterize life all take place in water. The blood coursing through the arteries is a salty solution, closely resembling in temperature and content the warm ocean that once was our home.

Indeed, you might say that the human body is a kind of space ship, maintaining inside it the liquid environment from which we came, millions of years ago, while we explore a foreign medium, a chill, dry world, composed largely of gas.

But the atmospheric region that we inhabit today is, in fact, another kind of sea — a sea of air, rather than of water. Reaching far above us, it provides the elements that we require to live, and at the same time shields us from the hazards of space.

Air is intangible, invisible, and seemingly as immaterial as thought. Yet it protects us from hurtling missiles of solid iron and rock, from speeding particles that penetrate a wall of lead, from deadly rays that burn the exposed body to a crisp. If we were to fall from a great height above this airy ocean, as meteors do, we would hit it with the force of an express train crashing into a concrete embankment.

The Earth's atmosphere maintains a constant pressure on the body, so that its fluids will not evaporate from their own heat. It scatters the blazing light that emanates from the Sun, giving us the gentle illumination of the blue sky overhead. It furnishes the lifting power that enables heavy aircraft like the B-36 to fly.

All these benefits begin to vanish as we go up. For the sea of air, unlike the ocean where life was born, dwindles rapidly in both pressure and density, as we approach its upper limits. Most of it is concentrated on the bottom, where we make our home. Long before we reach a height of 600 miles, defined by astronomers as the physical border of the atmosphere, its usefulness to living things is gone. For all the good it does us, we are in space.

On our last program, Brigadier General Otis O. Benson Jr., Commandant of the Air Force School of Aviation Medicine, told us about a classic research report, published in 1951 by the School's Department of Space Medicine. Called "Where Does Space Begin?," it gave us an entirely new concept of the relationship between our atmosphere and space.

Today we have with us the principal author of the report. He is Dr.

Hubertus Strughold, head of the unique Department of Space Medicine. Because of the great importance of his pioneer study in defining the medical problems of space flight, we have asked Dr. Strughold to give us an account of his findings.

First, though, will you tell us, Dr. Strughold, how you began your investigation of conditions in space?

DR. STRUGHOLD

Gladly, Dr. Rider. You might say that our work was the outgrowth of a concept known as the Time of Useful Consciousness.

DR. RIDER

The Time of Useful Consciousness?

DR. STRUGHOLD

Yes. Let me explain. Some years before my colleagues and I began our study, experiments were carried on in low-pressure chambers, both here and abroad, to determine how long a flyer would survive, if he were suddenly exposed to a very much higher altitude by what we call explosive decompression.

DR. RIDER

That is, if he were flying in a pressurized cabin, and all at once it lost its pressure?

DR. STRUGHOLD

Exactly. That could happen if the fuselage were penetrated by gunfire, or through some failure of the pressurizing system.

DR. RIDER

And what did those experiments reveal?

DR. STRUGHOLD

Just this: that if the pressure were lost at 26,000 feet, the flyer would have about two minutes in which to descend to a safe altitude, or to take some other remedial action. At 30,000 feet he would have only a minute and a half; at 33,000 feet the time would be less than one minute; and at 46,000 feet it would be only fifteen seconds. After that brief period, he would become unconscious, and be unable to help himself.

DR. RIDER

Hence the term, Time of Useful Consciousness.

DR. STRUGHOLD

That is right. In German it is called <u>Zeitreserve</u>, or Time Reserve, a much simpler and more expressive phrase.

DR. RIDER

I take it that the reason for the sharp decline from two minutes to fifteen seconds in a climb of only 20,000 feet is due to the rapid thinning of the oxygen supply with increasing altitude?

DR. STRUGHOLD

Primarily, yes; and also to certain physiological processes in the body.

Now, the interesting thing about this Time Reserve, to us, is that it drops to a minimum of 13 seconds at 52,000 feet, under the most favorable circumstances, and after that it does not decrease further. No matter how far above 52,000 feet you may go — even into the depths of interstellar space — if your cabin should be punctured, you have 13 seconds in which to save yourself, if possible.

DR. RIDER

Why is that, Dr. Strughold?

DR. STRUGHOLD

Because the blood will contain a certain amount of oxygen when the puncture occurs. It is carried to the brain and consumed very quickly; but the body's own supply of oxygen will not be exhausted before 13 seconds have gone by, even in a total vacuum.

DR. RIDER

That should be encouraging to the space traveler.

DR. STRUGHOLD

Yes, if he can take emergency action within that time. Now, with my colleagues in the Department of Space Medicine — they were Dr. Heinz Haber, Dr. Konrad Buettner, and Dr. Fritz Haber, when this work was done — I began to reflect on the implications of that finding. What it meant was that, with respect to the flyer's Time Reserve of oxygen, space began not 600 miles above the ground, where the astronomers had placed the border, but at only 10 miles, or 52,000 feet.

DR. RIDER

In other words, physiologically speaking, space is nearer than we thought?

DR. STRUGHOLD

Much nearer. As Mr. Bill Bridgeman told us on the first of these programs, several pilots had already flown above 10 miles when we made our study, and since then a height of 24 miles has been attained.

DR. RIDER

Then space flight was already a reality when you began your work?

DR. STRUGHOLD

With regard to this reaction, yes. Now, we asked ourselves: In what other respects are the upper regions of the air similar to space, in so far as the human body is concerned? And so we evolved the idea of space-equivalent levels within the atmosphere — altitudes at which the atmosphere ceases to be effective for the flyer, with respect to certain specific functions, even though some air still remains.

DR. RIDER

And this idea was the basis of your paper, "Where Does Space Begin?"

DR. STRUGHOLD

That was the fundamental idea, Dr. Rider.

DR. RIDER

Tell us, Dr. Strughold, what some of the other space-equivalent levels are.

DR. STRUGHOLD

Let us take them in order, as we ascend. At 12 miles, if the flyer is exposed to the low pressure outside the cabin, his body fluids will begin to vaporize, just as they do in outer space. We will go into that problem more fully later on in our discussions.

DR. RIDER

And into all the others, I hope?

DR. STRUGHOLD

Indeed we will. Then, at 15 miles, we find ourselves in the ozone layer of the atmosphere. As you know, ozone is a form of oxygen containing three atoms of the element, instead of two. It is produced in the upper air by photochemical reaction with the ultraviolet radiation from the Sun. In high concentrations, ozone is extremely irritating to the delicate membranes of the respiratory tract. In fact, ozone has been used in medicine as a strong antiseptic, and also as a disinfectant.

DR. RIDER

Of course there is no ozone in outer space.

DR. STRUGHOLD

DR. STRUGHOLD

True. It reaches up to about 25 miles only. But the presence in the air of this toxic substance means that we can no longer draw on the atmosphere outside the craft for our oxygen supply, compressing it to a useful volume within. Beyond 15 miles we require a self-contained cabin, sealed off from the outside air, with its own artificial atmosphere — exactly as we do in space.

DR. RIDER

I see.

DR. STRUGHOLD

Now, the presence of that ozone layer in the air, harmful though it would be to a flyer breathing it, also serves a useful function. It filters a large part of the ultraviolet radiation out of sunlight, leaving only the comparatively mild amount that we are exposed to when we take a suntan at the beach. Above 20 miles we begin to meet the full effect of this radiation, as we do in space. It can produce severe sunburn in one-tenth the time it takes us on the beach.

DR. RIDER

That would be only a minute or so.

DR. STRUGHOLD

True. Fortunately, ultraviolet radiation is quite easily controlled.

Very little of it passes, for example, through ordinary window glass.

DR. RIDER

Then the ship's ports will shield us, so long as we are in the craft?

DR. STRUGHOLD

Exactly. And it is not difficult to deflect ultraviolet radiation from the helmet of a space suit, outside the craft. But beyond 25 miles we meet the full force of another kind of radiation, from which there is so far no practical way to shield the flyer. That is cosmic radiation. As a physicist, perhaps you will explain this form of energy.

DR. RIDER

Briefly and simply, the so-called cosmic rays are minute, sub-atomic particles of matter that appear to come from intergalactic space. They travel at velocities approaching the speed of light. About 90 per cent are protons, or the nuclei of hydrogen, the lightest and most abundant element in the universe. Another 9 per cent are alpha particles, or nuclei of helium, the next lightest and most abundant. The remaining 1 per cent are nuclei of heavier atoms, up to the weight of iron. Though relatively few, they are extremely powerful.

DR. STRUGHOLD

In fact, they will penetrate the wall of a space ship as if it were composed of so much air.

DR. RIDER

And it is air that stops them before they reach the ground. When one of these heavy primaries, as they are known, happens to encounter another particle of matter — whether it is air or metal or a living cell — one of two things may occur. The cosmic particle may strip away electrons from the atoms in its path, leaving behind it a trail of scattered electrons and ions. Or it may strike the nucleus of an atom, with an explosion that sends protons, electrons, neutrons, and other particles flying apart at high speed in all directions. In the atmosphere, these highly destructive reactions take place generally from an altitude of about 25 miles down to about 12 miles above the ground. The secondary cosmic particles that shower down upon us, as the debris from such collisions, have dissipated most of their energy, and are relatively mild in their effect.

DR. STRUGHOLD

Besides, we have been exposed to these secondary particles for many thousands of years. It may be that we have built up an immunity to them. Yet they are still powerful enough to penetrate several hundred feet down into water. That is possibly one reason why the most elemental forms of life appeared first in the sea, where they were better shielded from cosmic radiation.

DR. RIDER

DR. RIDER

At any rate, we have no protection against the heavy primaries above 25 miles.

DR. STRUGHOLD

No. But there is some reason to believe that their effects on living tissue may not be quite so damaging as we once thought. That is another question which we will return to later.

Now we come to still another kind of radiation, and that is heat. The Sun pours a constant amount of this radiance on the Earth — to be exact, enough on each square foot of surface, at the top of the atmosphere, to bring about three-quarters of a pint of frozen water to a boil in one hour. As this heat filters down through the atmosphere, roughly one-half of it is lost in producing various chemical reactions, and the physical phenomena which we know as weather. The remainder gives us our hospitable climate for living things. It is the heat energy from the Sun that governs all the processes of life on Earth.

At about 40 miles overhead, that friendly function of the air ceases. The side of the space craft which is turned toward the Sun receives the full intensity of this radiation. The other side dissipates heat from the cabin into space. The problem then is to maintain a constant balance. It may be more difficult to prevent the loss of heat, by radiation, than to control its absorption — particularly at night, within a few hundred miles of the Earth, when the craft would be in shadow.

DR. RIDER

There is another kind of heat that you haven't mentioned, Dr. Strughold. I mean convection heat, from friction of your rocket ship with the air.

DR. STRUGHOLD

I omitted that, for the moment, because there is no air in space. Hence, friction-heating is not a characteristic of space flight, but of high-speed flight within the atmosphere. The point at which friction with the air becomes a space-equivalent condition is where it ceases to exist.

DR. RIDER

Of course that's true. What difficulty do we come to next?

DR. STRUGHOLD

A most alarming one — the possibility of colliding with a meteor. These are generally small bits of rock or metal, ranging in size from very fine dust up to pellets the size of buckshot. A really large meteor is so exceptional that the chance of meeting one can be disregarded. But the speed with which they travel is enormous, by our standards on Earth. It varies between about 40,000 and 120,000 miles per hour. At such velocity, the force of a collision with a meteor no larger than a grain of sand is great enough to vaporize both the meteor and the hull of the space craft at the point of impact.

The shooting stars that we see in the night sky are tiny fragments of this kind, vaporizing as they penetrate the Earth's air. The great majority become visible at a height of about 70 miles, and are consumed in a second or two, before they can drop down as low as 50 miles. Above 70 miles, we have no protection from the atmosphere against meteors. We are then exposed to them as we would be in space.

DR. RIDER

Flying, as it were, through a barrage of cosmic flak.

DR. STRUGHOLD

That is it exactly, Dr. Rider. At about the same altitude, we begin to have another problem. The air becomes so thin that it no longer scatters light, distributing it by reflection over the sky. At a height of 75 miles the sky is as dark as on a moonlit night. At about 95 miles it is totally black. The stars shine with an unwinking brilliance never seen on Earth, and the Sun blazes in a jet-black sky with the blinding glare of a search-light turned on an enemy airplane at night.

DR. RIDER

Is that disturbing to the flyer?

DR. STRUGHOLD

Indeed it is. You will recall that Mr. Bill Bridgeman mentioned the difficulty he had in reading his instruments, when he flew the Douglas "Skyrocket" in the intense light only 16 miles up. At 95 miles, objects in shadow within the craft are completely black, while objects in direct sunlight are intolerably bright. And this is the way that things normally appear in space — at least until we travel so far from the Sun that it gives us only a cold and distant light.

DR. RIDER

As it would, say, on one of the outer planets — Neptune or Pluto.

DR. STRUGHOLD

Yes. Another strange effect above 95 miles is that sound waves can no longer be transmitted. The air molecules are too far apart to be affected by the wave-length of sound. And so, when we are less than one-sixth of the way to the physical end of the atmosphere, we find ourselves in the darkness and the perpetual silence of outer space.

DR. RIDER

But that is not the last of your space-equivalent boundaries?

DR. STRUGHOLD

No. There is one more. You will remember that we spoke a while ago about aerodynamic heating, by friction of the rocket craft with the air around it. Actually, this is not necessarily any great problem for a space ship, as it is for high-speed craft within the atmosphere. As you pointed out earlier, the density of air rapidly diminishes as the rocket rises, accelerating to tremendous speed in the upper atmosphere. It takes only a short time to penetrate the denser layers of air near the Earth. But even the very thin air at a height of 75 miles, as we have seen, can vaporize a meteor almost instantly.

DR. RIDER

Of course the speed of a rocket ship will be nothing remotely approaching that of a meteor — at least, not until it is well out into space.

DR. STRUGHOLD

No. But it might reach a velocity in the order of 5,000 to 6,000 miles per hour at an altitude above 100 miles. In that case, the temperature of the air compressed around it might rise to several thousand degrees.

DR. RIDER

That would be more than any materials known today could endure.

DR. STRUGHOLD

Including especially human tissue. However, we have here a chart showing how the density of air decreases with altitude. You will notice that the scale of density, on the left, is logarithmic rather than arithmetical— that is, each line as you go down indicates a reduction in the number of air particles to one-tenth of the number at the line above.

Now, at an altitude of 24 miles, the highest that any rocket craft has attained so far, the density of air is only one-half of 1 per cent of its value at sea level. Yet there still remain more than 2 times 10^{18} — or 2 billion billion — molecules in a single cubic inch of air. And that is enough to create a serious friction problem at hypersonic speed.

But at 120 miles, as you see, the number of molecules per cubic inch is reduced to only 2 times 10^{12}, or ~~200~~ 2,000 billion. That is still an impressive number of molecules. But engineers consider that, at this point, they are scattered so widely apart that they can transfer only a small amount of heat to the craft. The individual molecule may be extremely hot — that is, in violent motion. But the ship encounters so few of them — and a molecule is an infinitesimally small particle — that the effect is no longer noticeable.

This altitude of 120 miles, then, is the one that we consider the last barrier to space, so far as physiological conditions in the atmosphere are concerned.

DR. RIDER

I notice, on this chart of yours, that when you reach an altitude of 600 miles there still remain a few scattered particles of air.

DR. STRUGHOLD

True. As you know, Dr. Rider, there can be no exact dividing line between the atmosphere and space. Even in the depths of the cosmos, there are many wandering particles of all the elements, including those of which our atmosphere is composed, not to speak of larger aggregations of matter, such as dust clouds and gases. That is why we consider our physiological and aerodynamic boundaries more realistic than the arbitrary physical border established by astronomers.

DR. RIDER

In other words, you consider 120 miles the final limit of the atmosphere?

DR. STRUGHOLD

For all useful purposes, yes.

DR. RIDER

Dr. Strughold, you haven't said anything so far about the techniques developed by space medicine to deal with the conditions you have described.

DR. STRUGHOLD

No, Dr. Rider, because we will be examining all these problems in more detail later on. What we have had today is only a survey of the field in which our studies are carried on.

DR. RIDER

Perhaps you can give us a general idea of the direction your research takes?

DR. STRUGHOLD

Indeed I can. You will remember that the crucial problem was the ozone layer of the atmosphere, beginning only 15 miles above the ground. At that point we require a radically different type of cabin — one insulated completely from the air outside, providing its own self-sufficient atmosphere.

DR. RIDER

A little capsule of Earth's air, that you take with you into space.

DR. STRUGHOLD

In effect, yes. Now, at the School of Aviation Medicine, we have the first experimental cabin of this type. Here you see it, with my assistants, Dr. James G. Gaume and Captain Emanuel M. Roth, who carry on this research under my direction.

DR. RIDER

So this is a space cabin?

DR. STRUGHOLD

The laboratory prototype of one. The real thing would not be a heavy steel chamber like this. But we made it very strong, in order to study different pressure variations.

DR. RIDER

And a man in this cabin has no contact with the air outside?

DR. STRUGHOLD

None whatever. Fresh oxygen is provided constantly from within. The carbon dioxide which he exhales is chemically absorbed. The cabin is airconditioned, to control the rise of temperature from his own body heat in a confined area, as well as from outside sources. Excess moisture — from water vapor in the lungs, perspiration, and other body fluids — can be recirculated to help cool the air, and purified to give him a continual supply of drinking water. Unpleasant odors are removed, to prevent nausea. And a constant air pressure is maintained inside the cabin, so that no pressure suit is needed — he can wear the same clothing in space that he would wear at home or in his office.

DR. RIDER

Is the air pressure the same as at sea level?

DR. STRUGHOLD

Not quite. The total pressure is about half an atmosphere — equivalent to an altitude of 18,000 feet. We have determined that the body can tolerate a pressure that low without discomfort, while the engineers have determined that a cabin can be built to maintain this pressure without disintegrating in space. But the proportion of oxygen is greater than it would be at that altitude on Earth. By doubling the normal ratio of oxygen to other gases — making it 40 per cent instead of 20 per cent — we can provide an oxygen supply equivalent to sea level. In actual practice, it might be better to have an oxygen pressure equal to 8,000 feet, as in an ordinary pressurized airplane. That is enough for a person unless he has certain medical abnormalities, and such people of course will not be flying in space — not for some time to come, at any rate.

DR. RIDER

Otherwise, the cabin air is just like the air in our studio?

DR. STRUGHOLD

Even purer, I hope, Dr. Rider — and cooler also. But there may be one other difference. About 80 per cent of the air we breathe is nitrogen, an inert gas that serves no useful purpose and can give us trouble at high altitude under certain conditions. For example, it causes the "bends," when nitrogen bubbles form in the joints and tissue. Now, we may substitute another inert gas for nitrogen, such as helium, which does not have this effect.

DR. RIDER

So that the artificial atmosphere in your space ship might be better actually for the flyer than the natural one that he is accustomed to on Earth?

DR. STRUGHOLD

That is true. On Earth we have adapted ourselves to the air we find. In space we can adapt the air to fit our needs.

DR. RIDER

And people actually have tested the artificial environment in your cabin?

DR. STRUGHOLD

Indeed they have. Both Dr. Gaume and Dr. Roth have spent periods up to several hours in the cabin. Here we find them monitoring a longer experiment, with a young airman as their volunteer subject. Dalton F. Smith Jr., whose reactions they are watching, was the first subject to spend a full 24 hours in this tiny cubicle. As you see, Dr. Gaume is just about to open up the hatch after such a test with Airman Smith.

Cut with sound to Dr. Gaume and Dr. Roth, outside Space Cabin Simulator

DR. GAUME

Come on out, Smitty. Your 24 hours are up.

SMITTY

Okay, sir.

DR. GAUME

How do you feel, Smitty?

SMITTY

Fine, Dr. Gaume.

CAPT. ROTH

Are you ready for a three-day test?

SMITTY

Yes, sir. Any time. . . .

Cut to Studio again

DR. STRUGHOLD

DR. STRUGHOLD

We figure that three days is about the time it would take a flyer in a real space ship to reach the Moon.

DR. RIDER

Dr. Strughold, let me thank you again for your clear and vivid account of the space-equivalent levels in our Earth's own atmosphere. You have convinced me that space begins almost directly overhead, and not far away in the remote upper air, as we all once thought.

On our next program, we will see more of the work that Dr. Strughold and his associates are doing, in coöperation with aircraft engineers, to make it possible for men to live and carry on their work in the hostile climate of space.

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