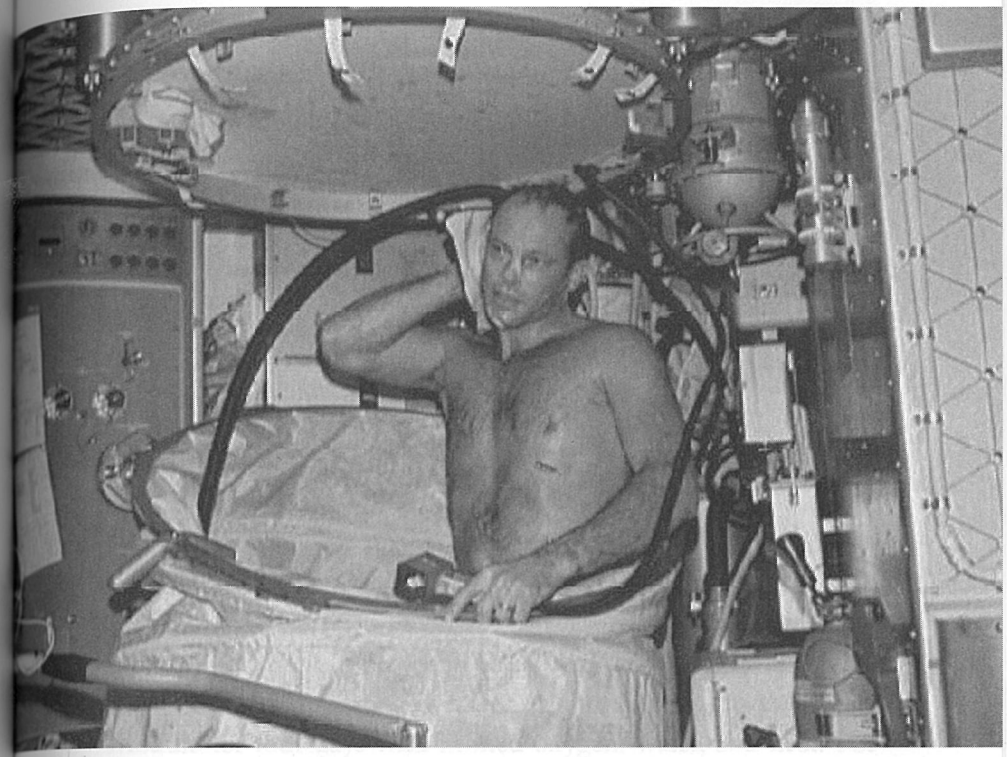
plan, prepare, train. I've been an astronaut for six years, and I've been in space for eight days."

Hadfield told me that the famous Apollo 13 incident—the explosion on the way to the moon and the solution Jim Lovell and his crewmates undertook—had actually been "simmed" by NASA at least once. Apparently *everything* Lovell did in space had been simmed on the ground. Including not taking a bath for two weeks.



10

HOUSTON, WE HAVE A FUNGUS

Space Hygiene and the Men Who Stopped Bathing for Science

Jim Lovell is best known as the commander of Apollo 13, the astronaut with the problem. As anyone who's seen the Tom Hanks movie knows, an oxygen tank exploded on the way to the moon, knocking out power in the Command Module and forcing Lovell and his two crewmates to hunker down in the Lunar Module for four days with limited oxygen, water, and heat. For forty years, people have been coming up to Lovell saying, "My god, what an ordeal." I said that to him too, but not in reference to Apollo 13. I was talking about Gemini VII: two men, two weeks, no bathing, same underwear. Inside a pressure suit, inside a capsule so cramped that Lovell could not straighten his legs.

Gemini VII, launched on December 4, 1965, was a medical dress rehearsal for the Apollo lunar program. A round-trip moon mission takes two weeks, and no astronaut had spent that much time in zero gravity. (NASA's record at that point was eight days.) If a medical emergency was going to develop on, say, the thir-

teenth day, the flight surgeons wanted to learn about it when the astronauts were 200 miles from Earth, not 200,000.

There was concern that wearing a spacesuit for two weeks in a space the size of the front seat of a VW Beetle might be unendurable. The ever-heedful NASA proposed to Lovell and his crewmate Frank Borman that they undertake a real-time simulation of Gemini VII inside a mock-up of the capsule—a rehearsal rehearsal. "Fourteen days sitting in a straight-up ejection seat on Earth?" says Borman in his NASA oral history. "We were able to get that nonsense kicked out in a hurry."*

In fact, there was no need for the nonsense, because similar nonsense was already underway out at Wright-Patterson Air Force Base in Ohio. From January 1964 to November 1965, a series of nine experiments on "minimal personal hygiene"—including a two-week Gemini VII simulation—had been taking place in an aluminum space capsule simulator inside Building 824 of the Aerospace Medical Research Laboratories. The AMRL people did not mess around. *Minimal* was defined as "no bathing or sponging of the body, no shaving, no hair and nail grooming . . . , no changing clothes and bed linen, the use of substandard oral hygiene, and minimal use of wipes" for, depending on the experiment, anywhere from two to six weeks. One team of subjects lived and slept in spacesuits and helmets for four weeks. Their underclothes and socks deteriorated so completely that they had to be replaced. "Subject C became so nauseated by body odor that he was forced to remove his helmet after wearing it for less than ten hours. Subjects A and B had already removed their helmets by that time." It didn't help. With the helmet off, body odors were "forced

* Borman could be a bit crusty. As Lovell put it, "Two weeks with Frank Borman anyplace is a trial."

out around the neck of the pressure suit," a situation described by B, on day four, as "absolutely horrible." This explains why Frank Borman, in the mission transcript for the second day of Gemini VII, asks Lovell if he has a clothespin. He's about to unzip his suit. ("For your nose," he tells the perplexed Lovell.)

For a different set of subjects, the heat was turned up to 92 degrees Fahrenheit. The Gemini VII simulated crew not only spent two weeks, day and night, in a spacesuit, but had to struggle with the same waste collection systems that would soon bedevil Lovell and Borman.

To quantify the squalor, the Air Force scientists would usher the men—most of them students from the nearby University of Dayton—into a portable shower, one by one, and collect the runoff for analysis. John Brown was the officer in charge of the simulated space capsule, formally known as the Life Support Systems Evaluator and casually known as "the chamber." Oddly, the showers were the part Brown recalls the men complaining about. Because the water was unheated. "They didn't want the hot water cooking the skin flakes," he said, speaking four words together that have no business being so.

As unsavory as this project must have been for the subjects, it was no bowl of rose petals for the researchers. It was their meandering sniffs that made possible the conclusion: "Body odor strongest in axilla, groin, feet."

Axilla (armpits) and groin occupy the top two slots because that's where the body's apocrine sweat glands are. Unlike the body-cooling eccrine sweat glands, which secrete mainly water, the apocrine glands produce a cloudy, viscous secretion that, when broken down by bacteria, creates the hallmark BO punch. I don't know quite how to phrase this or what it reveals about me, but I have never detected BO in the pubic region. O, for sure, but not BO. I asked University of Pennsylvania dermatologist and body

odor researcher Jim Leyden about this. He verified the apocrine presence in the groin, and insisted there's a similar smell. "It's just not that easily appreciated," he said, "because the sensing device is farther away." I decided to let it ride.

The apocrine glands are hooked up to the autonomic nervous system; fear, anger, and nervousness prompt an upswing in secretions. (Companies that test deodorants call it "emotional sweat," to distinguish it from the temperature-triggered kind.)* You would think that being strapped to a launching rocket would be a situation in which a man would be, to quote Leyden, "milking those glands for everything they're worth." I asked Jim Lovell, in a telephone conversation, if he could recall the comments made by the frogmen who opened the Gemini VII hatch after splashdown.

"You're investigating a rather unusual aspect of spaceflight," he said. He didn't remember, but he did recall comments made by some of the Apollo hatch-openers. "They'd get a whiff of the inside of that spacecraft and it smelled . . ."—Lovell's gentlemanly instincts intervened—"different than the fresh ocean breezes outside."

Underarm sweat supplies both food and lodging for bacteria. Eccrine sweat is mostly water; it provides the moisture bacteria need to thrive. Protein-rich apocrine secretions are the twenty-four-hour diner. (Though eccrine sweat does contribute edible elements whose breakdown products are, as Leyden says, "part of the overall bouquet, if you will." It's a milder, lockerroomy smell.)

The armpit is not entirely the bacterial paradise it would seem to be. Sweat has natural antimicrobial properties. Though they

* That is why some deodorant and antiperspirant efficacy tests include an "emotional collection." A group of subjects sit with pads under their arms to absorb secretions while being forced to sing karaoke or speak in front of a group. The pads are then weighed and the armpit smells rated by professional odor judges. I was once, as part of an article on body odor, invited to be a guest judge. "Take little bunny sniffs," I was told.

don't by any means render the skin sterile, there are limitations to what can grow there. That may be one reason why the Air Force boys' odors hit a plateau, rather than growing ever worse as the weeks wore on. The technical report states that the men's body odor reached its "maximum height" at seven to ten days, and then began to subside. Height is an odd attribute for smell, but it's possible to imagine how in this case the odor could seem to be taking on physical proportions, growing taller, sprouting heads, limbs, quills.

Soviet space biologist V. N. Chernigovsky, in 1969, carried out a restricted-bathing experiment of his own, this one including bacteria colony counts. The bacteria populations in subjects' armpits and groins plateaued somewhere between the second and third weeks. At which point there were roughly three times as many colonies as on freshly washed skin. (Except on the feet* and buttocks, where there were seven to twelve times as many.) A Navy study turned up similar findings; here some subjects' bacteria counts even began to drop after two weeks.

The other explanation for the odor plateau is that the men's body odor had become so strong that it was impossible for whoever was judging it to detect incremental changes. Weber's Law provides the explanation. The detection threshold for changes in a particular smell (or sound or sensation) varies according to the intensity of the background smell (or sound or sensation). Say you are in a noisy restaurant. If the noise level rises a few decibels, you can't tell. Had the room been quiet, you could easily tell. If someone's armpits have been shouting for a few days, it's hard

* Because of all the sweat and dead skin (calluses), the bottoms of the feet and the spaces between the toes are a Mecca for bacteria—high numbers, much more variety. One class of dead-skin-eating bacteria, *L. brevis*, excretes compounds that smell like ripe cheese. Though it may be technically more accurate to say that certain ripe cheeses smell like feet: Cheesemakers routinely inoculate certain of their creations with *L. brevis*.

to tell when they're shouting a little louder. Jim Leyden gives the example of his son, who was a rower in college. One year the team decided they were going to wear the same rowing outfits until they lost. "Well, they became national champions that year. You could not get near that boat. The smell may have plateaued, but as far as I was concerned, it was just constantly horrible."

Eventually the mind stops registering the body's smell. In Leyden's words, "It's going, 'I don't need to bother telling you this anymore.' " Unfortunately for a group of AMRL subjects in a twenty-day no-bathing Apollo simulation, this point didn't arrive until day eight.

NASA would have done well to add body odor anosmia to its list of desired astronaut traits. Some people* are genetically unable to smell (i.e., they're anosmic to) one or both of the two BO heavies: 3-methyl-2-hexanoic acid and androstenone. "Have you ever been on an elevator with someone and wondered, 'How can he come on here smelling like that?' Well, he may be anosmic to his odor," Leyden says. "And those of you who have never experienced that, you may be one of those people on the elevator that everyone's wondering about."

Aside from body odor, the most common contributor to what one researcher called "perceptions of personal dirtiness" is not dirt per se, but bodily emanations that have built up on the skin: grease, sweat, and scurf,† to be specific. Where you have hair, you

* And possibly deer. A 1994 issue of *Crop Protection* details the failed but entertaining efforts of botanists at the University of Pennsylvania to deter white-tailed deer by dousing an assortment of ornamental shrubbery with 3-methyl-2-hexanoic acid. Which raises the unusual marketing question, Will a homeowner abide a rhododendron that smells like BO?

† A.k.a., shed skin. *Dorland's Medical Dictionary* defines scurf as "a branny substance of epidermic origin"—an evocative pairing of dander and breakfast cereal. *Try new Kellogg's Dandruff Flakes!*

have sebaceous glands; that is to say, everywhere but your palms and the soles of your feet, where greasiness is a slip, trip, and fall hazard and thus a survival liability.

The 1969 Soviet restricted-hygiene experiments monitored the build-up of oils, or sebum, in male volunteers. (Here, in addition to not bathing, the subjects had to spend "most of their time sitting in an armchair." The simulated astronaut of the sixties was a stinky guy watching TV in a dirty undershirt.) For the first week without bathing, the skin's oiliness remained constant. Why didn't it increase? Because clothes are surprisingly effective absorbers of sebum and sweat. The Soviet researchers collected wash water from the subjects' skin in one basin, and wash water from their clothes in another. They compared the amounts of grease, sweat, and dander in the two tubs. Eighty-six to 93 percent of the skin's emanations were in the water where the clothing had been. In other words, all but 7 to 14 percent of the men's filth had been absorbed by the fabric of their clothing. This was true of cotton, cotton-rayon blend, and, to a lesser extent, wool.

The Soviet findings help explain the lackadaisical hygiene practices of the sixteenth and seventeenth centuries. Renaissance doctors discouraged washing with water. Removing the protective layer of oil from the skin, they believed, left the bather vulnerable to plagues, tuberculosis, and a host of other ills then believed to spread via "miasmas" that seeped into the body through the pores. Queen Elizabeth I, her era's version of a clean freak, famously wrote, "I bathe once a month, whether I need it or not." Many let it go a year.

But here's the thing: Instead of showering once or twice a day, Renaissance men and women would change their undersmocks and chemises. The men of Gemini VII and the AMRL chamber, on the other hand, couldn't change their underthings. The authors of the AMRL chamber study noted that the subjects' clothes eventually began "sticking to the . . . groin and other body fold areas and were very odorous and starting to decompose," a condition described as

"very troublesome." Lovell told me the Gemini VII long johns were in bad shape by the end of the mission. "They were," he allowed, "pretty smudged around the crotch area"—even more so than those of the average person who didn't bathe or change his underwear for two weeks, because the average person wasn't testing a new NASA urine management system that "leaked considerably sometimes." For instance, on the second day of the flight, when Lovell, reporting to Mission Control that he was ejecting urine from the spacecraft, noted, "Not too much of it; most of it's in my underwear."

At a certain point, clothes reach their saturation point, and sebum begins to accumulate on the skin. According to the Soviet researchers, who monitored oil levels on subjects' chests and backs, it takes five to seven days for a cotton garment to reach this point. It is difficult to pinpoint the day when the Gemini VII astronauts began to notice the buildup on their skin. By day ten, they were "starting to itch" and "getting a little crummy" in the scalp and crotch. Here they are on day twelve:

MISSION CONTROL: Gemini VII, this is Surgeon. Frank, do you have any lotion remaining?

BORMAN: Any lotion?

MISSION CONTROL: Roger.

BORMAN: We have some but we sure don't need it, Jack. We are as greasy as can be.

It is unusual to come across the word *lotion* in a NASA mission transcript. Borman seemed nettled by NASA's preoccupation with skin care, as though it were compromising the overall manliness of the mission. At one point, the flight surgeon comes on the microphone to ask, "And how are your skins?" Earlier, he'd accosted Borman out of the blue with the inquiry, "Are you having any difficulty with drying of your lips?" "Say again please?" answers Borman. You

get the sense he heard him fine. On the fourth day, Mission Control fixated on how much Borman was perspiring. Borman, like his epidermis, had reached the saturation point. He refused to answer, forcing Mission Control to try to enlist Lovell's help.

MISSION CONTROL: Do you notice in looking at him that his skin is moist?

LOVELL: I'll let him answer that.

BORMAN: [silence]

MISSION CONTROL: Have you been sweating at all, Frank?

BORMAN: [silence]

MISSION CONTROL: Gemini VII, this is Carnarvon. Did you copy?

BORMAN: About sweating? I'd say, yes, I'm perspiring a little.

MISSION CONTROL: Very well. Thank you.

Once a set of clothes becomes saturated and oil starts to build up on the skin, what's the end point? Does uncleansed skin grow ever greasier as the days pass? It does not. According to the Soviet research, the skin halts its production of sebum* after five to seven days of not bathing and not changing one's increasingly well-greased clothing. Only when the person changes his shirt or takes a shower do the sebaceous glands get back to work. Skin seems

* Roughly 4.2 milliliters per day, according to a table in a paper by Mattoni and Sullivan, entitled "Synopsis of Weight and Volume of Waste Product Generation from All Sources in the Closed Environment of a High Performance Manned Space Vehicle." That is just under a teaspoon of skin oil, an equivalency made with the help of a recipe conversion table. Employed in tandem, the two tables would enable the deranged or geographically isolated baker to substitute sebum for vegetable shortening or calculate the equivalent of a cup of flour in desquamated epithelium.

happiest with a five-day buildup of oils. Listen to Professor Elaine Larson, editor of the *American Journal of Infection Control*, talking about the stratum corneum, the outermost layer of human skin: "This horny layer has been compared to a wall of bricks (corneocytes) and mortar (lipids)" and helps "maintain the hydration, pliability, and barrier effectiveness of the skin."

Do we compromise our skin's health by constantly scrubbing off the mortar? Does our skin want us to bathe every five days? Hard to say. It's true that especially zealous hand washers—hospital personnel and certain obsessive-compulsives—often develop irritation and eczema. Twenty-five percent of the nurses in one study, writes Larson, had dry, damaged skin. Ironically, the nurses may be exacerbating the very thing that hand-washing seeks to prevent: the spread of infectious bacteria. Larson says healthy skin sheds 10 million particles a day, and 10 percent of those harbor bacteria. Dry, damaged skin flakes off more readily than healthy, lubricated skin and thus disperses more bacteria. Damaged skin also harbors more pathogens than healthy skin. As Larson says, "Perhaps sometimes clean is too clean." Most Americans don't wash often enough to cause skin problems, but they certainly wash more than necessary. In the words of some academic I can't name because I've lost the first page of his paper, "Personal hygiene as practiced in the U.S. today is largely a cultural fetish, actively promoted by those with commercial interests."

In space, as in the military, bathing is more an issue of morale than of health. Space agencies, recognizing what one researcher called "the psychological inadequacy of sponge baths," devoted a lot of time and money in the 1960s trying to develop a zero-gravity shower for space stations. One of the earliest prototypes tested was a "shower suit." The technical report I read included the following less-than-encouraging summary: "Results leave much to be desired in the showering, rinse, and drying procedures." The usual arrangement doesn't work; the water sprays from the shower

head for a few inches and then collects in an expanding blob: fascinating, but of little ablutionary help. If you hold the shower head close enough to forestall the big blob, then the water ricochets off your skin, forming floating drops that you then have to spend ten minutes chasing down to keep them from floating out into the station. "It turned out to be easier just to forget the whole thing," said astronaut Alan Bean, of the collapsible Skylab shower.

The shower on the Soviet space station Salyut used air flow to try to draw the water down toward the cosmonauts' feet. It was minimally successful. Blobs formed, and blobs tend to cling to the body's concavities, including the mouth and nostrils. To keep from choking, cosmonaut Valentin Lebedev and his crewmate Tolia Berezovoy wore snorkeling gear. "What an exotic sight it was," wrote Lebedev in his diary. "A naked man [flying] across the station, . . . with snorkel in his mouth, goggles over his eyes, a clip on his nose." Understandably, the crew of Salyut 7, like Elizabeth I, showered just once a month. These days there are no space showers. Astronauts wipe themselves with moistened towels and rinseless shampoo.

Bathing is more important on the space stations, because the missions are longer and they include daily exercise regimens that ratchet up the sweat level. As an adjunct to body wiping, Japanese astronauts on the ISS have been wearing "J-Wear," developed at Women's University in Tokyo out of fabric "with the function of dissolving foulness and body odor by photocatalyst and prevention of the rotten smell of sweat by the antibacterial nano-matrix finishing technique." Astronaut Wakata Koichi (pronounced, perhaps aptly, *co-itchy*) wore the same J-Wear underpants for twenty-eight days without complaint.

The astronauts of Gemini VII could only dream of "comfortable everyday clothes for life in a spaceship," as one press release calls J-Wear. They wore hot, heavy, bulky spacesuits for pajamas.

The subjects in the Air Force Gemini VII simulation were plagued by "chafing and much irritation in groin." In case you have ever questioned the value of thorough wiping and regular changes of underwear, here's a reason. In people with poor bathroom habits or 1960s Air Force hygiene restrictions, fecal bacteria migrate. Wright-Patterson researchers sampled thirteen sites on the men's bodies to check for *E. coli.* It was a remarkable Diaspora. Fecal bacteria had made its way to the men's eyes, ears, and, in two cases, toes. Five out of six of the Soviet subjects who sat in armchairs for thirty days developed folliculitis—bacterial infection in the hair follicles on the skin. Three developed boils—especially bad, swollen, painful, infected follicles. (The Soviet paper uses the old-timey term "furuncle." You almost want one just to be able to go around saying "furuncle.")

Lovell doesn't recall any skin problems. "The difference is zero G," he told me. "That's the key to the whole deal." When a man floats a few inches above his chair, when his arms hover out away from his sides, he has less of the chafing and irritation normally caused by damp, filthy clothes rubbing sweaty, unwashed skin. The astronauts' underwear didn't get plastered to their buttocks. Whatever bacteria lurked in their sweat, it wasn't getting ground into their follicles. There is a condition called hot-tub folliculitis, which often appears on hot tubbers' buttocks and the backs of their thighs—just where the friction and pressure is. (The water in a hot tub is hot, but not hot enough to kill bacteria. An undertreated hot tub is essentially, quoting University of Arizona microbiologist Chuck Gerba, " *E. coli* soup.")

Day six of Gemini VII. Frank Borman is on the mic. The exchange is proceeding in the macho, jargony manner of pilot-to-ground communications. Until:

MISSION CONTROL: Stand by for the Surgeon, Gemini VII.

BORMAN: [silence]

MISSION CONTROL: Gemini VII, this is Surgeon. Have you had any dandruff problem up there, Frank?

BORMAN: No.

MISSION CONTROL: Say again.

BORMAN: N. O. No, negative!

Commander Borman did not wish to discuss skin care. But later, in his memoir, he would write about "our scalps" and about the case of "terminal dandruff" he had. Though it probably wasn't, technically speaking, dandruff. Dandruff is caused by an inflammatory skin response to oleic acid, which the scalp fungus *Malassezia globosa* excretes after dining on your scalp oils. Either you're sensitive to oleic acid or you're not. If Borman didn't have dandruff before he went into space, he didn't have it afterward, says dermatologist Jim Leyden. Leyden once paid prisoners to not wash their hair for a month, specifically to see if they developed dandruff. They did not. The flakes on Borman's head and skin were most likely the accumulation of millions of shed skin particles—particles normally washed away in the shower—mixing with sebum and clumping together.

The atmosphere in Antarctic field camps is similarly dry and shower facilities similarly nonexistent or cumbersome, making the six-week Antarctic Search for Meteorites field season a good analog for space hygiene. "Six weeks of dead skin is like two whole layers," says team leader Ralph Harvey. Sometimes it all comes off at once, in the first wash. Harvey admits to being fascinated by the spectacle. "I remember coming back and taking a shower and the whole end cap of my finger would just come off."

What makes the dander situation bearable in Antarctica is that you can step outside your domicile and shake out your long johns

and sleeping bag. You can't do this in space or simulated space. The description of the Navy space cabin simulator at the end of the experiment was like a ski report. "A fine layer of powdery scales was found to cover the floor of the chamber."

In zero gravity, the flakes never fall. I asked Lovell about this. I believe my exact words were, "Was it just like a snow globe in there?" He said he didn't recall anything like that. Or not "of such magnitude that it would stick in my mind all these years." (For the thing that did stick in his mind all these years, see chapter 14.)

The head in general is a problem. The majority of our sebaceous glands are attached to hair follicles, thus the unwashed scalp quickly becomes a greasy thing. So much so that the bathphobic hordes of the sixteenth century would rub powder or bran into their scalps before retiring for the night, much as homeowners today sprinkle kitty litter on motor oil spills. Like sweat, sebum develops a distinctive aroma as bacteria break it down. "At least two of the Skylab astronauts reported that their heads developed offensive odors," noted space psychologist Jack Stuster in a 1986 NASA report on space station habitability.

BORMAN AND LOVELL did not stay in their suits the entire flight, as NASA had originally planned. On day two, flight surgeon Charles Berry began lobbying NASA management on their behalf. A compromise was struck: Only one man had to stay suited (in case of a depressurization emergency). Borman drew the short straw, and Lovell squirmed out of his suit. For years, Lovell recalls, his son would tell friends, "Dad orbited the Earth in his underwear!"

By hour 55, Borman has his suit unzipped and halfway off. By hour 100, he petitions NASA management to let him take it all the way off. Five hours pass. Houston comes back on the line. Borman may take off his suit, but only if Lovell gets back in his.

Lovell tries to resist ("I would prefer to leave it this way if you don't mind"), but NASA stands firm. Hour 163: Lovell is in, and Borman is out. Eventually, Berry prevails, and both suits come off. Otherwise, Berry recalls in his oral history, "I don't think we would have completed fourteen days in that spacecraft. . . . You've got two guys in spacesuits and they're sitting like this, your leg over in the other guy's lap. It's a really difficult situation."

It could be worse. Try living in bed for three months.

11

THE HORIZONTAL STUFF

What If You Never Got Out of Bed?

Leon M. doesn't appear to have the "right stuff." He has a messy past and lingering debts. His most recent job was as a security guard. These days, Leon spends entire weeks in bed, watching movies and playing video games. Beneath the sweatpants and tattoos, however, there's an astronaut of sorts. Leon's skeleton has been diminishing at about the same rate as an astronaut's in space.

Leon is part of a NASA-funded bed-rest study at the Flight Analogs Research Unit (FARU) at the University of Texas Medical Branch in Galveston. For decades, space agencies around the world have been paying people rather handsomely to lounge around all day and night in their PJs. That's how it was presented to Leon, who heard about the gig on one of Howard Stern's oddball-headline roundups: NASA WILL PAY YOU TO LIE IN BED.

For three months, twenty-four hours a day, Leon does not get up—or even sit up—for anything: not to shower, not to eat, not to use the toilet. Bed rest is an analog, or mimic, of spaceflight in that staying off one's feet causes the same sorts of bodily degradations

that weightlessness causes. Most direly, the bones thin and the muscles atrophy. Space agencies study bed-resters to try to understand these changes and figure out how best to counteract them.

Bed-rest studies often assess the helpful (or not) effects of drugs or exercise devices—countermeasures, as they say in aerospace medicine lingo—but the one for which Leon has volunteered is simpler. The researcher is comparing certain changes in men versus women. Leon pauses an episode of *Magnum, P.I.* on the smartphone that he bought on the Internet with his first check. "So basically, yeah, I'm just deteriorating. And they just want to watch it." He reports this as cheerfully as someone else might report a promotion or a good night at the blackjack table. Leon has high cheekbones, longish, springy black hair, and an appealing smile.

The human body is a frugal contractor. It keeps the muscles and skeleton as strong as they need to be, no more and no less. "Use it or lose it" is a basic mantra of the human body. If you take up jogging or gain thirty pounds, your body will strengthen your bones and muscles as needed. Quit jogging or lose the thirty pounds, and your frame will be appropriately downsized. Muscle is regained in a matter of weeks once astronauts return to earth (and bed-resters get out of bed), but bone takes three to six months to recover. Some studies suggest that the skeletons of astronauts on long-duration missions never quite recover, and for this reason it's bone that gets the most study at places like FARU.

The body's foreman on call is a cell called the osteocyte, embedded all through the matrix of the bone. Every time you go for a run or lift a heavy box, you cause minute amounts of damage to your bone. The osteocytes sense this and send in a repair team: osteoclasts to remove the damaged cells, and osteoblasts to patch the holes with fresh ones. The repaving strengthens the bone. This is why bone-jarring exercise like jogging is recommended

to beef up the balsa-wood bones of thin, small-boned women of northern European ancestry, whose genetics, postmenopause, will land them on the short list for hip replacement.

Likewise, if you stop jarring and stressing your bones—by going into space, or into a wheelchair or a bed-rest study—this cues the strain-sensing osteoclasts to have bone taken away. The human organism seems to have a penchant for streamlining. Whether it's muscle or bone, the body tries not to spend its resources on functions that aren't serving any purpose.

Tom Lang, a bone expert at the University of California, San Francisco, who has studied astronauts, explained all this to me. He told me that a German doctor named Wolff figured it out in the 1800s by studying X-rays of infants' hips as they transitioned from crawling to walking. "A whole new evolution of bone structure takes place to support the mechanical loads associated with walking," said Lang. "Wolff had the great insight that form follows function." Alas, Wolff did not have the great insight that cancer follows gratuitous X-raying with primitive nineteenth-century X-ray machines.

How bad can it get? If you stay off your feet indefinitely, will your body completely dismantle your skeleton? Can humans become jellyfish by never getting up? They cannot. Paraplegics eventually lose from one-third to one-half of their bone mass in the lower body. Computer modeling done by Dennis Carter and his students at Stanford University suggests that a two-year mission to Mars would have about the same effect on one's skeleton. Would an astronaut returning from Mars run the risk of stepping out of the capsule into Earth gravity and snapping a bone? Carter thinks so. It makes sense, given that extremely osteoporotic women have been known to break a hip (actually, the top of the thighbone where it enters the pelvis) by doing nothing but shifting their weight while standing. They don't fall and break a bone; they

break a bone and fall. And these women have typically lost a good deal less than 50 percent of their bone mass.

NASA funded the work that led to Carter's computer models. "But it seems like no one there read our report," he says. "They have this idea that they can send astronauts up and the bone loss will level off in a few months, but the evidence that has come back doesn't support that view. If you look at a two-year mission to Mars, it's kind of a scary prospect."

SOME BED-REST FACILITIES call their volunteers "terranauts." At first I assumed this was done to confer a sense of importance to the pursuit, like calling a janitor a sanitation engineer. But the day-to-day existence of the three-month terranaut bears similarities to that of an astronaut orbiting Earth. Each day begins with wake-up music on the speaker system. (It was Metallica* on the space station this morning; "some Beethoven thing" at FARU.) You spend your time confined to a small room, or cluster of rooms, and if you try to go outside, you are in trouble. Privacy is hard to come by. At FARU, closed-circuit cameras are aimed at the beds, so staff can be sure everyone is staying flat. (Subjects are allowed to pull the curtain that surrounds their bed only when they use the bedpan.) Whiners are not a good fit. Leon says he

* Astronauts' families take turns picking it. In the Gemini era, Mission Control would pipe in music, not always in a pleasing manner, as this Gemini VII exchange suggests:

> CAP COM [capsule communicator]: . . . How do you like the music?
> COMMAND PILOT FRANK BORMAN: We turned it off. We got a little busy there and we turned if off for a while.
> CAP COM: Okay. They've got some good Hawaiian stuff coming up to you.

went through an irritable patch at the halfway point of his stay, but that he is "so chipper they didn't notice." In the half hour I've spent with Leon, I have heard only one complaint. It involved the chicken. "It's little squares. I want chicken with a bone and skin on it! Don't give me those cubes."

Leon excuses himself, because the masseuse is coming. Unlike astronauts, bed-resters get a massage every other day to help with the lower back pain that is a common side effect of taking a load off. Obliviously, doctors used to prescribe bed rest for patients with lower back pain. According to a 2003 article in *Joint Bone Spine*,* regardless of what ails you, it is almost always a good idea to get out of bed as soon as you can.

Without the weight of a body compressing it, the spine's curvature lessens and the discs between the vertebrae expand and absorb more water. Astronauts are as much as 2.5 inches taller after about a week in space. (The typical gain is 3 percent of one's height.) Like children, they will "outgrow" their suits if a "growth" spurt has not been factored in.

AARON F. HAS BEEN "head-down" for eight weeks. (The term refers to the 6-degree tilt of the beds. Since weightlessness causes body fluids to shift to the upper part of the body, so must bed rest.) A large fan by his bed is running at top speed, not to cool him but to mask the noises out in the hall. He's been feeling trapped, unable to get away from it. Not helping matters: His roommate Tim is still in his "ambulatory period." He goes head-down in a

* An unusual display of syllabic restraint in journal naming. Only *Gut* earns my higher praise. Take note, *American Journal of Orthodontics and Dentofacial Orthopedics, Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics.*

couple days, but for now he's allowed to pad around the unit in his slippers and sit cross-legged on his bed, which he is doing now.

A kitchen worker pushes a serving cart into the room.

"The high point of my day!" says Tim. He looks genuinely excited over the prospect of hospital food. Aaron accepts his tray without comment. He props himself on one elbow. It is odd to see people reclining for a meal. It's a drab, antiseptic take on a scene from the Arabian Nights, men lounging on pillows, eating with one hand.

Tim takes me on a guided tour of supper, pointing with his fork. "We've got chicken . . ."

I think of Leon. "Diced?"

"Diced, yes. You could almost roll them! And over here are carrot coins, . . ." There is a rapt quality to his speech, as though we were gazing at gold doubloons. ". . . apple slices, milk, two rolls, Jell-O. I really love the food here."

Aaron searches for something positive to say. "It's a good variety." But is struggling. "Then again, it's the same variety. We get a lot of fish—"

"Oh my god." Tim again. "The fish is *amazing*!"

Tim reenlisted after his first stint here, a few years ago. A sign on his wall says WELCOME BACK, 9290 in glitter paint borrowed from the pediatric oncology unit next door.

Before I can stop him, Tim slides off his bed to go ask the kitchen staff whether there is an extra dinner for me.

Aaron is antsy and squirmy, alternately bringing his legs up to form an A-frame under the sheets and then stretching them flat again. Like Leon and others I spoke with, he is here because he's trying to pay off some credit card bills. Bed-rest studies are a modern-day debtor's prison. It's not just the amount of money—$17,000 for three months of service—but the limited opportunities to spend it. For three months, there is no rent to pay, no groceries or gas to

buy, no bar tabs, no air fares. A bed-rest stint is a way to force oneself out of bad habits. (Though not entirely effective: Internet shopping has made FARU one of the busiest stops on the local UPS route.)

Tim graduated with a business degree and no money with which to start a company. He moved into a Vipassana ashram because he felt a need to ponder his future and because "they feed you, and it's free!" After much thought and rice, he decided to become an actor. He spent the next four years as "a starving artist, literally," and then he heard about a study here at FARU. When he finished, he returned to acting, joining a New Hampshire theater troupe doing "children's Macbeth," the very thought of which alarms me. When the chance came to re-up at FARU, he took it. These days he's weighing wildly diverging career options: joining the Houston police force, opening a coin-op laundry, enrolling in Navy officer candidate school, starting a landscaping business, and becoming a motivational speaker. He is having, as he puts it, "a quarter-life crisis."

According to FARU manager Joe Neigut, 30 percent of the people who sign on to bed-rest studies say they are doing so not only for money, but to be a part of the space effort. As Leon says, "It's as close as I'm going to get to being an astronaut." At the very least, the association with spaceflight puts a luster on the undertaking. Knowing this, the staff entreat astronauts to write thank-you messages on 8-by-10 glossies. Every now and then, an astronaut drops by to deliver them in person. Aaron got an in-person visit but does not recall the man's name. Tim received an autographed photo of Peggy Whitson. ("A total BAMF* astronaut," he called her.)

---

* I had to look up BAMF on Google. It stands for Bad Ass Motherfucker, but don't tell that to the Berkeley Avenue Mennonite Fellowship or the Builders' Association of Metropolitan Flint.

Tim is back from the kitchen. There is no extra food for me, and that's okay. "Did I miss anything?"

"Yuh," Aaron says. "I moved to the left a bit."

THE BIGGEST SKELETON at Johnson Space Center belongs to John Charles. Charles is 6 feet 7. When he was ten, he knew he wanted to be an astronaut. His skeleton, as though aware of its fate in space, sabotaged Charles's dreams by growing past the astronaut height cutoff. Charles got his Ph.D. in physiology and went to work for NASA. It is his job to do what he can to protect the bodies and bones of astronauts.

Charles and I spoke one recent afternoon in the Lyndon B. Johnson Meeting Room in the public affairs building at Johnson's namesake, the Johnson Space Center. A chaperone from the Public Affairs Office sat quietly in the corner, as though Charles and I might otherwise leap into each other's arms there amid the plaques and signed proclamations of the Johnson era. Charles must put the public affairs people on edge. He is known for speaking his mind freely and sits high enough on the ladder of command not to worry too much about the consequences.

As on Earth, weight-bearing exercise is the best way to hang on to your bone. In zero gravity, of course, you have to create your weight. The problematic and expensive way to do this is to outfit the space station with a rotating room, a huge, inhabitable centrifuge that spins astronauts outward toward the walls, creating artificial gravity. (Keir Dullea can been seen jogging on one in *2001: A Space Odyssey.*) The funky and affordable alternative is to mimic weight by pulling astronauts' bodies down into a treadmill belt as they jog. Typically this involves a harness and bungee cords and much cursing and chafing. It is not tremendously effective. Bone loss researcher Tom Lang says this kind of device pulls exercisers

against the belt with about 70 percent of their bodyweight, a scenario that still translates to "massive bone loss."

It's unclear how much exercise helps. "Exercise is probably better than not exercising in space," says Charles, "but we don't know how much better, because we've never done the experiment." No one wants to expose a control group to the sort of bone loss that could result from doing no exercise at all. "If you have hundreds of astronauts who've done different levels, you can pool them into groups and see that this group did slightly less and it had this effect, and this group used a treadmill, not a bike, and it had that effect. But we don't have those large numbers. We have one person that used a bicycle and not a treadmill, one person that used a bike and then changed to a treadmill, and the first is a female in her forties and the second is a male in his sixties. All we can do is a sort of grouped average. The grouped average says that we have countermeasures that still are not protecting astronauts as much as we would like them to be protected." According to Lang, astronauts are coming home from six-month space station stints with 15 to 20 percent less bone than they had when they left.

FARU has lately run a study on vibration as a means of preventing bone loss. Subjects exercised while pulled by elastic cords into a vibrating plate installed at the foot of their bed. It's the same kind of vibrating plate you see advertised on the Internet with promises to build bone and muscle, trim fat, flatten bellies. I was surprised to find them here. So was John Charles. When I asked him about vibration as a bone-loss countermeasure, he said, "It's over with. It's not working." The FARU consent form notes that the investigator has a "relationship" with the vibration machine. He helped invent it.

Carter, too, was surprised to hear about the vibration study. He says the only promising data came from an animal study in which vibration appeared to speed fracture healing. "But in ani-

mals that just had low bone mass, it hardly changed the bone mass at all."

Vibration has had an enduring quack appeal. Medical journals from 1905 to 1915 are rife with articles on "vibratory massage" and the many things it cures. Weakened hearts and floating kidneys. Hysterical cramp of the esophagus and catarrh of the inner ear. Deafness, cancer, bad eyesight. And lots and lots of prostate problems. A Dr. Courtney W. Shropshire, writing in 1912, was impressed to note that by means of "a special prostatic applicator, well lubricated, attached to the vibrator, introduced to the rectum" he was "able to empty the seminal vesicles of their secretions." Indeedy. Shropshire's patients returned every other day for treatment, no doubt also developing a relationship with the vibration machine.

Neither Tim nor Aaron is involved in an exercise study. "Me allowing myself to atrophy is going to be the hardest thing I've ever done in my life," says Tim. Before he began the study, Tim was running three to five miles three times a week. He has a countermeasure plan of his own devising. "I heard a story of a POW in Vietnam." He pauses for some Jell-O. The spoon clicks against the glass bowl. "He was locked in a cage." Click-click-click. "Every day he played golf mentally. He improved his golf score by six strokes!" He leans back against his pillow. "So, mentally, I can go on a jog."

Aaron has been pinching off pieces of dinner roll and listening without comment. He turns to face us. "I've been mentally doing squats." He says he has considered suggesting to NASA that they enlist yoga masters or Buddhist monks to teach astronauts how to train their minds to fight the effects of zero gravity. I'm mentally enjoying the image.

The dinner cart returns, and the trays are taken away. The attendant places Tim's glass on his table. "You didn't finish your milk," she says. Food intake is documented as part of the studies.

Students hired to monitor the bed-resters make sure they don't stuff food under their mattresses or behind the ceiling tiles. (Both have happened.)

"You have to eat everything," says Aaron. "They will bring back your little tub of maple syrup and make you drink what's left in it."

PEGGY WHITSON HAS lived through the scenario that worries Dennis Carter and John Charles. In this scenario, astronauts who have been weightless in space for months or years, bone and muscle compromised, find themselves in an emergency situation: enduring the G forces of a crash landing, jumping out of capsule hatches, pulling colleagues to safety. For Whitson, as we learned earlier, it came to pass in 2008. She and two crewmates returning from the International Space Station endured a ballistic reentry and a 10 G landing. Sparks from the landing set the grass afire, and crewmate So-yeon Yi injured her back.

I talked to Whitson* about the incident. The day the interview was scheduled, there were technical problems with the phone system. By the time Whitson's voice came on the line, six of my allotted fifteen minutes were up. I lurched from niceties straight into

---

* Like all astronaut activities, interviews are exactingly planned and timed. They are like tiny space missions. Whitson's and mine was aborted and rescheduled twice. When the moment finally arrived, my call was relayed via an operator to a booth where Whitson would be sitting. Time passed. "I'm not getting an answer," the operator said. "What time are you scheduled for?" I told her 12:30. "Okay, you're calling early," she said. "I've got 12:28 P.M." You'll hear the NASA TV commentator say things like "The sleep shift is scheduled to start at 1:59 A.M. Central Time. Crew due to awaken at 9:58 A.M. Central Time." Sleeping pills? You betcha.

fire and snapping bones. "Commander, I am a huge admirer. Were you worried that your legs would break when you had to run away from the Soyuz capsule?"

"Nah," said Whitson. She had more pressing concerns. Breathing during the 8 G's of reentry, for instance, and not throwing up in front of Kazakh farmers in the field where they'd landed.

On her first ISS mission, Whitson said, she exercised so much that some of her bones were denser* than they were before she left. Her overall loss was less than 1 percent. "I did so many squats that I actually increased some in my hips." Tom Lang, who has studied the skeletons of ISS astronauts, is not overly reassured by things like this. The returning astronaut's total bone mass can be very similar to what it was before the mission, but that mass is distributed differently. Most of the regrowth takes place in the parts of the bone needed to support walking. But the parts of the hip that would break in a fall were nowhere near where they had been, leaving women like Whitson vulnerable to fractures in their retirement years.

When you fall, the top of your hip—or more specifically, the femoral neck and greater trochanter at the top of your thighbone—takes the brunt of the force in a side-smack manner. That's not the same architecture that gets strengthened when you jog or

* You often read that astronauts' skulls get thicker in zero G. I assumed that this was because the extra fluid in the top half of the body plumps the brain, and that the body responds to the increased pressure by thickening the cranium—just as it responds to increased blood pressure by thickening the arteries. "Interesting hypothesis," said NASA physiologist John Charles. Then he told me it's not true that living in space makes astronauts' skulls thicker. Or not literally anyway. Charles says they do routinely develop the "space stupids"—cognitive impairment brought on by "sleep deprivation, over-scheduled timelines, and all the other indignities we heap onto astronauts."

do squats. The parts of the bone that are stressed by walking and everyday activity hold up surprisingly well with age. The body tends to redistribute bone to those areas—at the expense of other structures, including the ones you fall onto. For this reason, some osteoporosis experts feel that fall prevention is a better way to avoid broken hips than is load-bearing exercise.

I asked Tom Lang whether anyone had looked into the possibility of preventing hip fractures by simply thwacking the aged on the sides of their hips a few times a day. Not hard enough to break anything, obviously, but vigorously enough that the impact would stimulate the osteocytes to strengthen the structure. I didn't expect him to say yes. He told me to contact Dennis Carter at Stanford University.

"It was just a concept," said Carter when I called. "We never built it." It didn't thwack, it squeezed. "You'd sit in a lounge chair and have things at your sides squeezing your hips, right at the greater trochanter, where people fall and hit their hips." It seems like a smart idea, but the companies Carter approached wouldn't touch it. Because they thought the hips might break and the ladies would sue? "That, yes. And I think it was just too weird for them."

Is it possible to bolster one's hip bones by doing some type of controlled fall? Here too, I did not expect a yes. Carter told me that a graduate student at the Oregon State University Bone Research Laboratory had looked into this. As part of her thesis, Jane LaRiviere had subjects lie on one side, raise themselves up 4 inches, and then drop onto a wood floor. They did this thirty times in a row, three times a week. At the end of the trial, scans showed a statistically significant, though small, increase in bone density in the femoral neck on that side, as compared with the undropped-upon side. One of LaRiviere's professors, Toby Hayes, felt that if the impacts had been a bit harder and the study lengthier, the results might well have been more impressive.

When you get right down to it, nothing works particularly well. Calcium's a bust. To a certain extent, so is exercise. Bisphosphonates have come under scrutiny for giving some patients necrosis of the jawbone. "The state of the art for countermeasures right now," John Charles allowed, "is the same as it was forty years ago."

The astronauts don't care. "They want to go to Mars," says Charles. "That's what they joined the program for."

WHITSON IS CONFIDENT that someone will come up with a good, safe drug solution by the time a manned Mars mission becomes a reality. A more likely scenario is that genetic testing will by then play a part in astronaut selection. (There's a large hereditary component to bone loss.) Charles envisions NASA recruiting Mars astronauts who are "almost bulletproof—people who never had a kidney stone in their lives, that come with high bone density, good cholesterol numbers, high radiation insensitivity . . ."

The bones of black women are 7 to 24 percent denser, on average, than those of white and Asian women. (I don't have statistics for black men, but presumably they have sturdier bones as well.) I asked Charles whether NASA ought to consider an all-black crew for Mars. "Why not?" he said. "For decades, we had an all-blond, blue-eyed program."

An all–black bear crew would be another way around the bone-loss conundrum. Black bears emerge from their dens after four to seven months in bed with bones as strong as when they turned in. There are researchers who believe that hibernating bears may hold the key to treating and preventing bone loss. I talked to one of them, Seth Donahue, an associate professor of biomedical engineering at Michigan Technological University. Donahue said that hibernating bears' bones do break down, just like bed-resters' and astronauts' bones. What's different is that their bodies take the calcium and other breakdown minerals out of the blood and reapply it to their bones. Otherwise the calcium level in their blood would build to a lethal concentration. Because during those four to seven months, the bears don't get up to go to the bathroom. All the bone minerals that get dumped in the bloodstream as the bones dismantle themselves would stay there, accumulating. "So they've evolved a method to recycle that calcium." And therefore not die. The bone protection is "a lucky consequence."

Donahue and others have been studying the hormones that control bear metabolism to see whether they can identify some component that will help postmenopausal women (and astronauts) grow new bone. They've nominated bear parathyroid hormone. Donahue has a company that makes a synthesized version, injections of which are being tested in rats and eventually, if all goes well, will be tested in postmenopausal women. Even human parathyroid hormone makes women grow bone. It's one of the most effective ways to increase postmenopausal bone density. Unfortunately, high doses make rats grow bone cancers, and thus the Food and Drug Administration limits prescriptions to one year and for women who've already had fractures. Donahue said bear parathyroid hormone doesn't appear to have any adverse side effects, so keep your claws crossed that it pans out.

There's another reason hibernating bears are interesting to NASA. If humans could be made to hibernate, to breathe one-fourth as much oxygen and eat and drink nothing for six months of a two-to-three-year Mars mission, imagine how much less food and oxygen and water one would need to launch. (The less baggage on board a spacecraft, the cheaper it is to launch. Once it reaches the speed needed to escape the pull of Earth's gravity and leaves behind the air drag of Earth's atmosphere, a spacecraft basically coasts to Mars.) Each extra pound of weight launched adds

thousands of dollars to the project budget. Science-fiction writers glommed onto the idea decades ago, outfitting fictional spacecraft with high-tech, climate-controlled hibernaculums.

Do space agencies ever discuss human hibernation? They have, and they do. "It never dies," says John Charles. "It just hibernates." Charles puts little stock in the possibility. "Even if it did work, would we really short-supply a crewed vehicle on a three-year mission to Mars? What if the hibernaculum malfunctioned, and everyone woke up? How much food and oxygen do you carry, just in case? And when is that amount sufficiently large that the savings due to hibernation are lost?"

Here's another reason it won't work. Hibernating bears derive all their water and energy from reserves of fat that they build up by bingeing before they den. According to the Bear Center at Washington State University, a small (astronaut-sized) bear gorging on apples and berries consumes up to 40 percent of its body weight each day during this period. That's about 65 pounds of food a day.

Six months of living on nothing but fat—even your own—probably isn't healthy unless your body has somehow adapted to it. Little known fact: Hibernating bears have high "bad" cholesterol levels. (They also have very high "good" cholesterol—which probably explains why heart disease is unknown in bears.)

BED-RESTERS ARE not bears. They have to eat and drink and excrete, and that last one was Tim's undoing. At FARU, B's are to be M'd in bed, and no place else. Using a bedpan while lying flat on one's back is an awkward and unnatural way to "make," as my mother-in-law Jeanne likes to say. Tim sat up, and was caught on film by the camera aimed at his roommate Aaron's bed. (He hadn't drawn the curtain around that side of his bed because Aaron was out of the room.) "I didn't think it would have that much of an

impact," he told me. "But it really threw off the scientific data."* Tim was asked to leave.

Leon had no trouble with this particular aspect of bed rest. "After the first couple times, it's second nature. And I go . . . *a lot.* I go at least four or five times more than any subject here. By the end of three months, I'll be at around 260. . . ." This is one way bed-resters are different from astronauts. With bed-resters, there are no taboo interview topics.

Including sex. Earlier, Joe Neigut was showing me the shower area, a tiled room the size of a horse stall, outfitted with a waterproof gurney. "So the shower," I said, "is their only . . . *private* time, do you know what I mean?"

"Yes . . ." Joe replied. Then he began talking about the new shower head, which had replaced an industrial sprayer of the type used by restaurant dishwashers. I wasn't sure he did know what I meant, so I asked Leon. Leon confirmed that the shower was "where most of them do it." As with astronauts in orbit, masturbation is not formally addressed in the FARU rules or orientation. Leon, being Leon, asked the unit psychologist. "I mean, if it's something that would throw off the test or something, I wouldn't do it." The psychologist blushed and then gave Leon the go-ahead, leaving the logistics up to him.

In a memoir, astronaut Michael Collins relates a story of a physician back in the Apollo era who recommended regular masturbation on long missions, lest astronauts develop prostate infections. The flight surgeon for Collins's moon mission "decided to ignore that advice," and ignoring seems to have been the basic

---

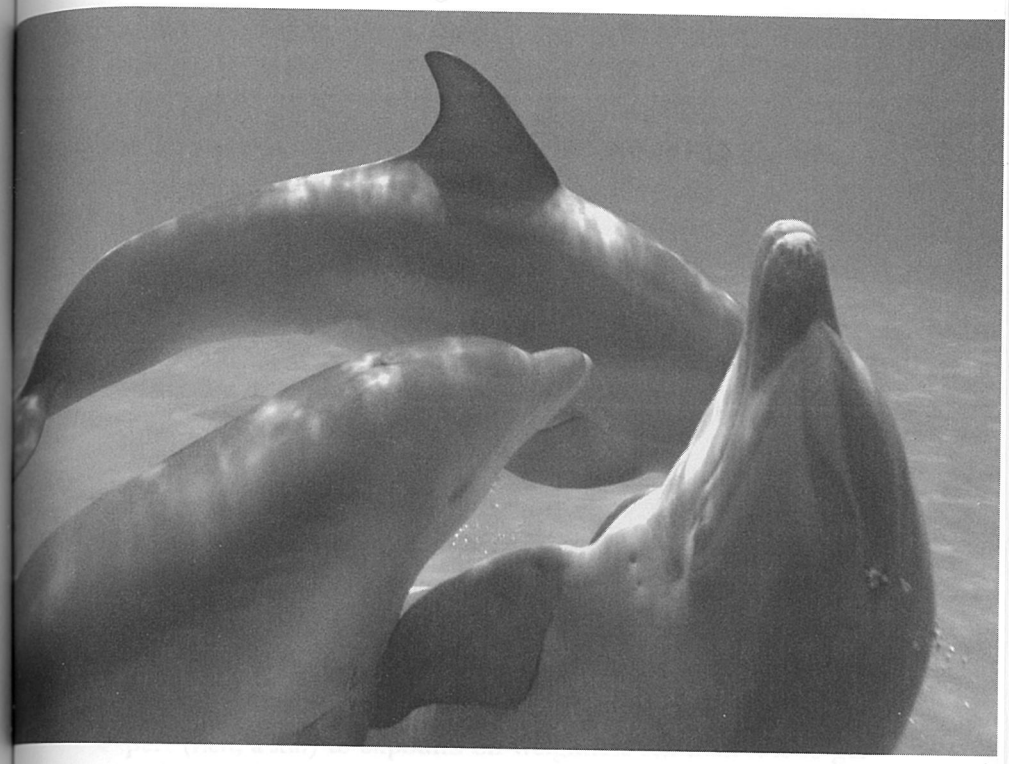
* How often do research subjects cheat? From skimming the posts on Guinea Pig Zero, I'd say pretty often. "Everyone cracks open their pills to see if they're cornstarch," says one drug study subject on the topic of supposedly blind control groups.

approach to the human sex drive ever since. It's the same way at the Russian space agency. Cosmonaut Alexandr Laveikin told me he too had heard that lengthy abstinence could cause prostate infections, but that the space agency pretends the issue doesn't exist. "It's up to yourself how you will deal with it. But everybody is doing it, everybody understands. It's nothing. My friends ask me, 'How are you making sex in space?' I say, 'By hand!'" As for the logistics: "There are possibilities. And sometimes it happens automatically while you sleep. It's natural." John Charles told me he'd heard about the link between prostate health and "self-stim"—at NASA, there's an abbreviation for everything—but never heard any formal discussion, pro or con, of orbital masturbation.

Or two-party sex, for that matter. Here at FARU, that is covered in the rules, though indirectly. Visitors can't sit or lie down on the beds. "My wife didn't mind," jokes Leon. "That was a plus of me leaving!" I had stopped in to his room again to say good-bye. He's been showing me family photos on his computer.

"I should probably get going. I know you've got . . ."

Leon grins. "Nothing to do?"



12

THE THREE-DOLPHIN CLUB

Mating Without Gravity