science news
OF THE WEEK

ZERO GRAVITY'S DEADLY EFFECTS

Unable to survive prolonged lack of gravity, Bonnie poses questions for extended manned flight

NASA

All the efforts to save Bonnie after splashdown failed.

Weightlessness killed Bonnie.

And long-term manned space flight hangs in the balance.

After only eight and a half days in orbit aboard Biosatellite 3, life in zero gravity took its toll on the male astromonk. Bonnie died July 6 of heart failure, hours after his return from what was to have been a 30-day voyage in space (SN: 7/19, p. 46).

Ever since scientists began thinking about putting a man in space, fear of the unknown effects of weightlessness has occupied their thoughts. The fact that dozens of American and Soviet astronauts have ventured safely into zero gravity allayed their fear to some extent. Yet experience has been limited to travel lasting a matter of days, and no one has been willing to extrapolate to proposed missions of a matter of months and say confidently that man could survive weightlessness.

The flight of the pigtail monkey was designed, after five years of intensive planning, to answer the unknowns about weightlessness. Had Bonnie completed the mission and survived, the space scientists planning orbiting space stations and flights to Mars would have been encouraged, though even then the threat of zero gravity could not be discounted. But Bonnie died, and the preliminary findings, reported only last week after almost three months of analysis, show weightlessness was the lethal factor.

Just as positive results from the Biosatellite 3 experiment would have been inconclusive, negative findings, based on the fate of a single animal, do not preclude the possibility that man will be able to travel into space for prolonged periods. But they do raise serious questions that space biologists and a Presidential panel say must be answered before man can be put aloft for extended stays.

Declares Dr. W. Ross Adey: "The necessary biomedical basis does not exist in the National Aeronautics and Space Administration or in the scientific community generally . . .

"It is not realistic to go ahead with the planning of major new space systems and exclude from almost any consideration the question of the biomedical capability of man not merely to survive in space, which has been his requirement to this point, but to perform at a high level on a continuing basis." And, he says, a report soon to be issued by the President's Science Advisory Committee, will say so. Dr. Adey is chief scientist for Biosatellite 3 and a professor at the University of California at Los Angeles.

Biomedical data from manned space flights to date have been meager. During the flight of Apollo 11, NASA scientists monitored heart rate, blood pressure, heat expenditure and oxygen uptake (SN: 7/26, p. 75). Post flight studies were made of blood volume and calcium levels, among other factors. But the highly specific and constant flow of biological information space doctors would like is impossible without loading the astronauts with electrodes and catheters and other paraphernalia that would inhibit their ability to function in a basically engineering program.

After the moon flight, the astronauts' physician, Dr. Charles A. Berry, said, "We have no plans now to add additional biomedical tests in flight." Sending an animal into space provides kinds of information that cannot be obtained from man himself.

Thus, in spite of Bonnie's premature demise, the enormous amounts of previously unavailable data that were obtained from the brief flight mark it as a success. All physiological sensors functioned perfectly throughout, and the monkey was monitored for 33 types of information. From this, scientists are looking back with new perspective to information gleaned from manned flights.

Early on, signs appeared that Bonnie had lost his normal circadian or 24-hour rhythm; by the eighth day he was sleeping long into the morning instead of following a usual sleep-wakefulness pattern. No such changes were observed prior to launch in Bonnie, or in control animals duplicating Bonnie's flights as well as could be done on the ground.

Also related to sleep, Dr. Adey reports, "for the first time in any space flight of man or animals, the occurrence of rapid-eye-movement (REM) sleep was confirmed." This type of sleep is vital to emotional well-being and is associated with dreaming. However, brain waves indicated that Bonnie's sleep throughout the flight was marked by rapid changes from one of four sleep stages to another. These rapid shifts also characterized brain wave recordings made on Frank Borman during the flight of Gemini 7. In Bonnie and Borman, these rapid shifts were accompanied by marked fluctuations of heart rate, blood pressure and respiration.

Other disturbing signs appeared early in the Biosatellite mission. Again for the first time in man or animals, pendular eye movements—an abnormal swinging from side to side—were recorded, indicating an abnormality in the ear, a mechanism that is controlled by gravity. And a decrease in heart rate developed from 170 to 110 beats per minute, though scientists speculated that isolation in the capsule could account for this. In addition, the astromonk lost 20 percent of his body weight. Men in space have lost from 3 to 8 percent—a loss too significant to be ignored.

Then, on the eighth day, Bonnie deteriorated rapidly. His heart rate dropped to 70 beats per minute; immediately before recovery of the capsule it was down to 39 beats. Bonnie refused food and water. Brain temperature, which had been more than 100 degrees F. at launch, declined to 95 degrees. Body temperature followed brain temperature in its downward course.

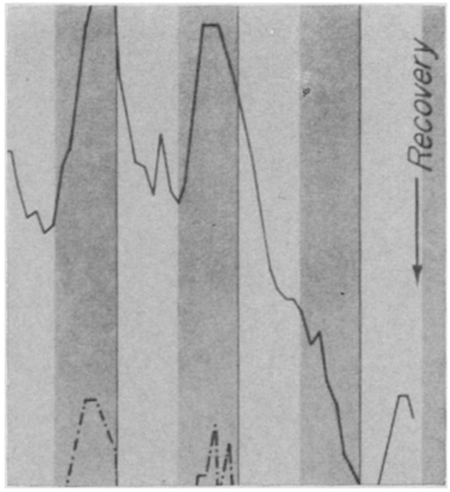
Most seriously, scientists observed a distinct rise in central venous pressure: the pressure in the veins going to the heart. Further, Bonnie lost an excessive amount of fluid, a factor that can be attributed, at least hypothetically, to the alteration in venous pressure, which, in turn, resulted from the weightless condition.

Weightlessness leads to a pooling of blood in the thorax and abdomen with consequent filling of receptors in blood vessel walls. A reflex reaction takes over. Blood volume sensors are activated, followed by rapid fluid loss through the kidneys and sweating. Resulting dehydration of tissues reduces the body's capacity to respond to stress. Additionally, X-ray studies of bone made before and after the flight showed a greater loss of calcium than was seen in the control animals. At autopsy, little tissue damage was seen except for small bruises in the liver and heart, probably from reentry shock.

Now, scientists must interpret these data in light of future plans and past evidence from manned flight. They inevitably suggest a hazard to man at work in zero gravity.

In addition to the problems noted from Frank Borman's Gemini ride, experience from Richard Gordon's walk in space during a Gemini mission is relevant. His job was to put a tether on the Agena craft. In simulated tests on earth, he managed the tethering in 25 seconds. In space, he could not perform the task in 25 minutes. And there have been a number of reports by astronauts of sweating, associated with subjective feelings of heat and cold, Dr. Adey recalls. Rapid heart rates and respiratory difficulty have also been reported from manned flights.

From available data, which are clearly preliminary and will be expanded as evaluation of Biosatellite 3 continues, weightlessness is the primary cause of Bonnie's death. However, space scientists admit that certain conditions peculiar to the experiment must be weighed before the final verdict is in.



NASA

Bonnie's heart rate fell sharply.

For one thing, the cabin temperature of the capsule remained at about 69 degrees F. throughout the flight, though 75 degrees was the desired level. The significance of this factor, coupled with the associated patterns of movement of air over the immobilized animal, will have to be tested further.

Total immobilization could have been another detrimental factor, though the scientists tend to put little emphasis on it.

A third factor, the monkey's diet, must also be weighed in evidence. Bonnie ate only a single form of protein—casein. Says Dr. Abraham Cockett, a Biosatellite investigator from the University of Rochester, "Had he had other sources of protein, he would have precipitated calcium phosphate in urine and might have developed urinary problems." This is a known tendency peculiar to monkeys, and the restricted diet was designed to avoid it. But the casein diet might have had other effects.

The open question at this point is what happens next. There are no plans for additional Biosatellite experiments and little evidence that they will be initiated. One suggestion is flights of man and monkey in concert.

Dr. Orr Reynolds, director of NASA's Bioscience Programs, reports that many investigators would like to see man-monkey flights with larger animals. Bonnie, a macaque, weighed about 14 pounds. Animals weighing from 25 to 50 pounds, such as the rhesus monkey, baboon and chimpanzee, are candidates.

The possibility of introducing artificial gravitational fields in spacecraft planned for long journeys has also been raised again as a result of Biosatellite 3, but whether that will be necessary is still unknown.

In short, Dr. Reynolds says, NASA simply does not know right now what it will do with the information from Biosatellite 3. But some changes are inevitable. □

DEEP DRILLING

Challenger extended

The cruise of the oceanographic vessel Glomar Challenger has been called one of the most successful scientific missions of all times.

The 40,000 miles of Atlantic and Pacific Oceans it has crossed in the last 14 months have yielded secrets to Challenger's scientists at an unprecedented rate.

Oil-bearing salt domes were discovered beneath the Gulf of Mexico (SN: 10/12/68, p. 361). Continental drift, through the mechanism of sea-floor spreading, was given strong support (SN: 5/10, p. 449). The northwestern Pacific was shown to be the remnant of an old basin in existence long before the birth of the Atlantic (SN: 9/13, p. 197). Every leg brought back new surprises (see p. 405).

"The Deep Sea Drilling Project," says Dr. William D. McElroy, director of the National Science Foundation, "has proven to be an outstanding scientific and technical success. It has excited not only the more than 300 scientists of this country who have been involved in the project's planning and execution, but many others throughout the United States and abroad who are following its progress."

This week the NSF insured that the historic mission will continue. The agency announced a three-year, $22.2 million extension of the original $12.6 million project. It will allow the Challenger to roam the rims of the Atlantic and Pacific Oceans in search of new discoveries and, for the first time, enter the Indian Ocean and the Mediterranean Sea. The contract extension will allow 30 months of additional drilling in 15 two-month cruises lasting from 1970 to 1973. The drilling will be followed by six months of further analysis. The extension almost triples the scope of the project as it was originally funded.

The initial 18-month scientific program, which will end in late January with the conclusion in Panama of the Challenger's ninth leg, was directed primarily toward reconnaissance of the deep ocean basins.

The major thrust of the next 30 months of drilling will be to take advantage of the next generation of ideas that come out of continental drift and sea-floor spreading—the interaction of the ocean floors with the continents.

"We are interested," says project chief scientist Dr. Melvin N. A. Peterson, "in what is known as tectonic relationships—the motions of the hard parts of the earth."

Not all the interactions occur on a global scale. The first leg of the extend-