BioMedical Program at Space Biospheres Ventures

Roy Walford, M.D.
Chief of Medical Operations, Space Biospheres Ventures
Professor of Pathology, UCLA Medical School

There are many similarities and some important differences between potential health problems of Biosphere 2 and those which might be anticipated for a station in space or a major outpost on Mars. We shall not have to deal with microgravity within Biosphere 2, nor with the remote distances of a planetary or even moon base. The demands of time, expense, and equipment would not readily allow medical evacuation from deep space for a serious illness or major trauma, whereas we can easily evacuate personnel from Biosphere 2 if necessary. However, a major albeit self-imposed constraint is to avoid doing so by mistake, i.e., for an illness that could in fact be handled inside Biosphere 2, without breaking closure. Thus, our diagnostic facilities must be first-rate, approaching or fully equivalent to those of a Martian base. Treatment facilities can be somewhat less inclusive, since distance would not compel us to undertake heroic measures or highly complicated surgical procedures on site, and with personnel not fully trained in these procedures.

Now for the similarities between medical requirements of Biosphere 2 and the complex closed ecological systems of biospheres in space or on Mars. The major problems common to all these would seem to be trauma, infection, and toxicity. Handling these requires prompt and effective diagnosis, therapy appropriate to the locale, effective training of personnel, and adequate consultative backup. Regarding this last, we will have computer and high-resolution video communications between Biosphere 2's medical facility and stations at the University of Arizona and UCLA Schools of Medicine. For initial training, a 100-hour "introduction to medicine" course, slanted towards clinical history and physical examination, was given to selected Biosphere 2 personnel by Dr. Dan Levinson of the University of Arizona School of Medicine. This was followed by a week's course in baseline dentistry at the U.S. Naval Hospital in San Diego, Biosphere 2 personnel being permitted to participate in this phase of the Navy's course for Advanced Hospital Corpsmen assigned to isolated stations. Other training is ongoing and will include an intensive course in practical microbiology specifically tailored for Biosphere 2 by the UCLA Hospital Clinical Laboratories.

It is planned that minor and moderate degrees of trauma, including debridement and suturing of wounds, X-ray evaluation of fractures, will be done within Biosphere 2. Portable X-ray equipment and polaroid-like X-ray films (which do not require use of liquid solvents for development) are available. Major trauma will probably be cause for evacuation of the victim(s). Nevertheless, such trauma requires a swift and effective response during the critical first hour, until assistance and evacuation can be mobilized. In short, the Biospherian trauma team must be very good during the first hour. To this end, selected Biosphere 2 personnel are enrolled in the three-day course in immediate (first-hour) management of trauma given by the University of Georgetown School of Medicine, and sponsored by the American College of Surgeons.

We expect bacteriologic and fungal infections, and possibly allergies to pollen or spores, to be the commonest medical problem within Biosphere 2.

The warm, humid, semitropical climate, the rain forest, ocean, savannah, desert and marsh biomes, the agricultural station and animal farm (goats, pigs, chickens), and the daily association of the eight Biospherians with all these areas will assure intimate contact with microbial agents. An atmosphere richer than normal in carbon dioxide will potentiate growth of many of these microorganisms. Of course many human pathogens such as cholera, typhoid, AIDS will not be present at all within our closed space, having been denied entry. However, the rate of evolutionary turnover may well be speeded up within Biosphere 2, with emergence of organisms following mutation/selection, or just the selective pressures of an unusual adaptive stress, which we are not quite accustomed to dealing with in Biosphere 1. For these reasons, microbiology has received considerable emphasis in our program. Using no more than six to eight media and an anaerobic gas pack, we should be able to do primary culture and isolation of all or most organisms that we have to deal with. Primary isolation must be followed by specific identification. This will be done by use of the highly automated Vitek system. The fundamental unit of the Vitek system is a small plastic plate containing thirty micro-wells, each with a different culture medium. Vitek provides at the moment ten different plates, i.e., 300 different culture conditions, some including antibiotic sensitivities. Besides bacteria, the Vitek system will handle yeast identification, but not fungi. These we propose to identify, at least in part, by more old-fashioned culture and microscopic technics. The same is true for (atypical) acid-fast microorganisms.

So much for trauma and infection. In some ways a stickier problem is the possibility of toxicity in Biosphere 2. There may be offgassing from plastics or other materials, leachates from cement or metal alloys — of no overriding importance outside but dangerous within a totally closed, recycling system. And gases may be locally produced, from composting, for example, or in some instances directly by plants (e.g., ethylene by tomatoes). Many of these agents will be removed by the soil bed reactors inside Biosphere 2. It is not established that all potentially toxic gases can be so removed, and research into this area is part of our present program. Acute toxicity is in one sense the lesser problem because it announces itself with

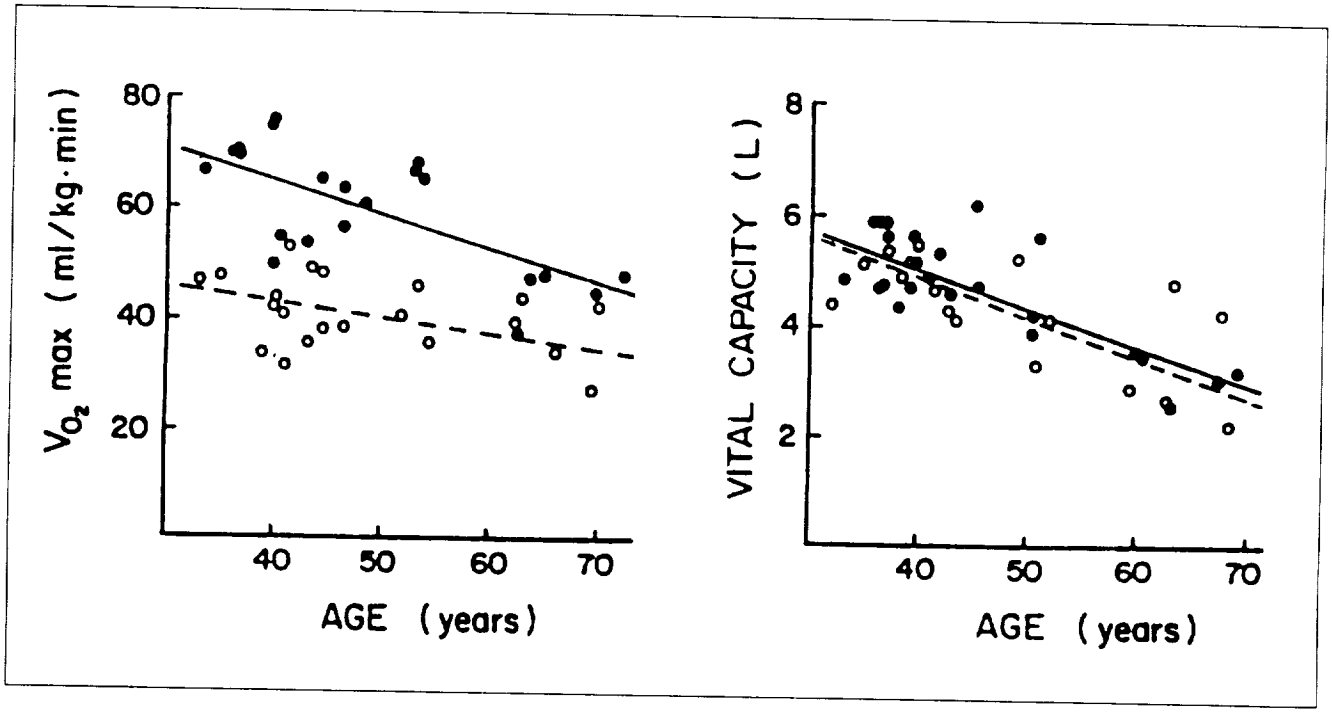

Figure 1. Maximum oxygen consumption and pulmonary vital capacity in relation to age in physically fit (•, —) and sedentary (o, - - - - -) individuals (from Suominen et al., 1980).

obvious symptoms: acute respiratory distress, gastric upset, etc. At least one knows that something is wrong. But poisoning may be insidious, asymptomatic until irreversible damage has been done, for example to bone marrow, liver, or possibly brain, and once started may continue to be progressive even if the patient is removed to a non-toxic environment.

Frequent quantitative analyses of blood indices, and qualitative (microscopic) analyses of blood morphology, with bone marrow aspiration if indicated, may help detect early signs of hematologic injury. Developing liver injury may be foreshadowed by altered blood chemistry, particularly selected enzymes. To estimate these changes but avoid the self-defeating use of organic solvents in the methodology, we shall employ Eastman Kodak's Ektachem system for dry reagent chemistry. Like Vitek, this is a compact system. At the moment 28 different blood chemistries, including enzymes, protein, glucose, bilirubin, the electrolytes, cholesterol, and lipoproteins can be measured accurately. Complete reagents for each test are contained in dry state on a small square about the same area and thickness of a quarter. A large number can thus be stored in Biosphere 2 before closure.

Because of the physically closed, electronically open nature of Biosphere 2, inside personnel must be capable not only of using but of repairing the above various equipment items. Training in these aspects is ongoing with the various parent companies.

I want to branch off now into ways of monitoring health, besides doing these various above-mentioned tests. One of the keys to that actually comes from gerontology. Gerontologists have been concerned with monitoring age specific biomarkers in humans and have developed a substantial battery of tests to that end, with the goal of measuring "functional age" as opposed merely to chronological age. These include, for example, vital capacity, maximum work rate, suppressor cell response, presence or absence of autoantibodies, delayed type hypersensitivity, serum albumin and globulin levels, reaction time, tapping time, hearing threshold at a fixed frequency, plus others (Weindruch and Walford, 1988). A few of these are illustrated

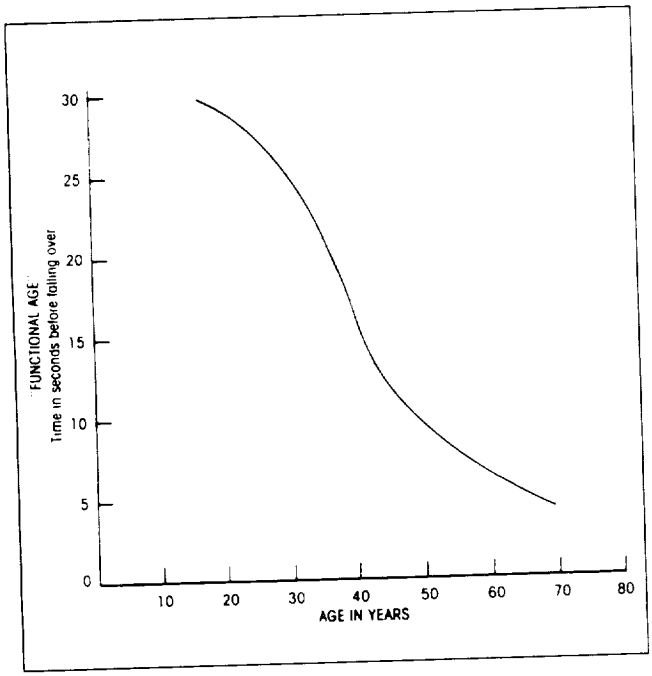

Figure 2. Static balance as a biomarker of age. Close eyes, stand on one leg (left if you are right-handed), don't move foot. How long before you fall over? Score = average of 3 trials. (From Walford, 1986.)

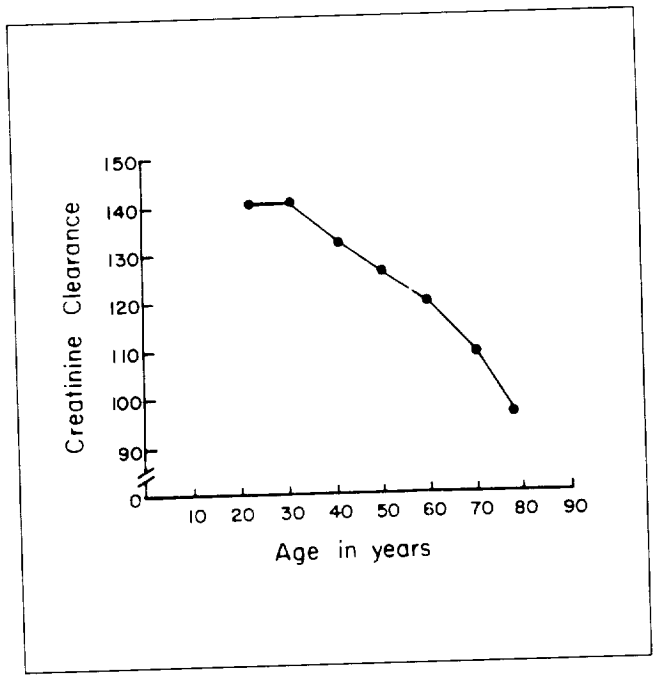

Figure 3. The effect of age on the important measure of kidney function known as Creatinine Clearance (adapted from J.W. Rowe *et al.*, *Journal of Gerontology*, 31:155, 1976).

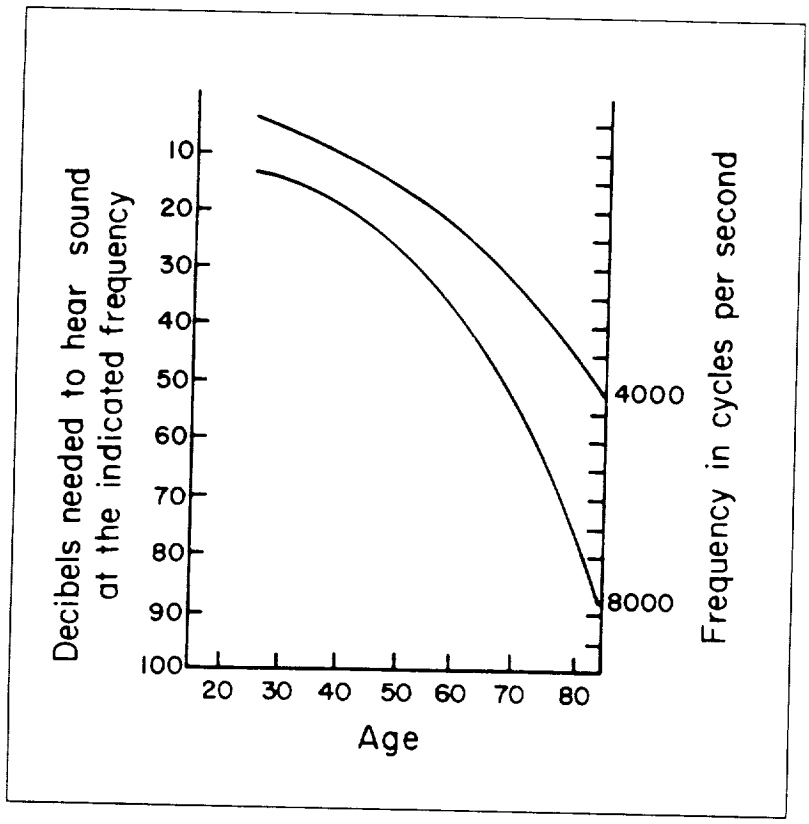

Figure 4. Auditory threshold in decibels in relation to age in women, at sound frequencies of 4000 and 8000 cycles per second (adapted from J.F. Corse, in *Lectures on Gerontology, Vol. 1, part B., Biology of Aging,* ed. A. Viidik [New York: Academic Press, 1982], p. 441).

1. Vibrotactile sensitivity
2. Memory
3. Vital Capacity
4. Forced expiratory volume-1
5. Alternate button tapping time
6. Highest audible pitch
7. Visual accommodation
8. Auditory reaction time
9. Visual reaction time(VRT)
10. Muscle movement speed (MMS)
11. VRT with decision
12. MMS with decision

Figure 5. Physiological functions measured automatically by H-Scan (Hoch Company, 2915 Pebble Drive, Corma del Mar, CA 92625).

in Figures 1, 2, 3, and 4. Automated equipment for measuring some of these is available on a commercial basis (see Figure 5).

The biomarker approach is quite applicable to health assessment in Biospherians and, I suggest, also in astronauts and cosmonauts. I understand from personal conversations with some of the astronauts, including some who have reached retirement age, that most of them return every year to run through a large battery of physiologic tests, but as far as I know very little is being done with this data. The data should be quite susceptible to biomarker analysis according to technics worked out by gerontologists.

BIBLIOGRAPHY

1. Weindruch, R., and Walford, R. L.: The Retardation of Aging and Disease by Dietary Restriction. Charles C. Thomas, Springfield, 1988.

2. Suominen, H., Heikkinen, E., Parkatti, T., Forsberg, S. and Kiiskinen, A.: Effects of lifelong physical training on functional aging in men. Scand. J. Soc. Med. 14:225, 1980.

3. Walford, R. L.: The 120-Year Diet. Simon and Schuster, New York, 1986.

4. Rowe, J.W., Andres, R., Tobin, J.D., Norris, A.H., and Shock, N.W.: The effect of age on creatinine clearance in men: a cross-sectional and longitudinal study. J. Gerontol. 31:155, 1976.