performance, and perhaps contributing directly to Ranger failures.

Since experience with the earlier Rangers, as outlined previously, indicated that a reliable sterilized spacecraft could not be built and launched based on the present state-of-the-art, NASA procedures for future lunar spacecraft have been changed. In spite of the low probability for contamination (as calculated by CETEX and Sagan), NASA's current procedures require that the microbial load of the spacecraft be reduced to a minimum by assembly and check-out in bacteriological clean rooms and also be treated with surface sterilants after final assembly and check-out. In this way, contamination, if any, will be localized to very small areas on the moon; there will be very low probability of microbial proliferation; and the moon will continue to offer a source of sub-surface samples from which to seek the desired clues as to the existence of life forms or the origin of life.

NASA has definite plans for the eventual landing of a capsule on the planet Mars. The procedures being established for Mars missions require that the capsule or spacecraft which might encounter Mars be sterilized, after complete assembly and check-out, using effective methods and sealed units which will not be opened. The earlier flying spacecraft will be aimed in such a manner that the probability of encountering the planet is less than 10^{-4}. Laboratory facilities are being prepared which will provide, with a high degree of assurance, the necessary sterilization. Assay techniques and survey methods for determining that the sterilization techniques have been applied properly and effectively, with a high degree of certainty, are being developed.

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Mutations and Aging

Aging processes have only recently attracted the attention of large numbers of biologists and, since meaningful data are still quite scarce, a multitude of theories can be advanced at no great risk. Occasionally, when one of these views appears to be proved untenable, it is brought back in full strength to bemuse the next generation of investigators. Curtis (*1*) has thus attempted to explain aging on the basis of somatic mutations. I would like to make three points based on that report: (i) There is essentially no evidence from irradiation experiments linking mutations causally with aging. (ii) Curtis's own data present a strong argument against the view that mutations cause aging. (iii) Organ reserve capacity would overcome loss of function due to mutations.

The main reasons advanced for suspecting a role for mutations arise from experiments utilizing irradiation—treatment known to cause both mutations and life shortening. However, it is extremely unlikely that the life-shortening effect is due to accelerated "normal" aging in that irradiation does not accelerate the onset of some specific age-related lesions (*2*), nor does it cause age-changes in collagen which are the most precise measurements of biologic age (*3*). It has also not been shown that the life shortening effect of irradiation is due to mutations. It is more likely to be caused by degenerative changes in the vascular system (*4*).

Curtis has shown that an increasing number of chromosomal aberrations occur in liver cells with increasing age. However, the animals do not die from, or with, liver failure, and there do not appear to be any important age-related changes in liver. This suggests that even though chromosomal aberrations occur in that organ, they have little functional significance and certainly can not be used to explain aging. Curtis's irradiated animals had a greatly increased number of chromosomal aberrations but they appeared to recover their vigor with time and get rid of altered cells as well. This would certainly argue against the role of chromosomal changes in aging, as noted by Curtis. His explanation of why these animals were not conspicuously aged could be used, with some modifications, to explain why "normal" chromosomal aberrations do not cause "normal" aging. The data showing that the strain of short-lived mice had more chromosomal changes are, at best, a correlation. Questions arise as to whether or not these mice really age faster, are more susceptible to specific diseases, or have some altered metabolism which affects liver cells.

Finally, the functional reserve of most organs is enormous—well over 100 percent in the case of liver. A fraction of most organs can handle the demands of the body, at least for short periods. When parts of many organs are damaged or lost, they can undergo regeneration, hyperplasia, or hypertrophy to meet body demands. This can occur even in old age and is particularly true in the case of liver. This knowledge tends to minimize the importance of not only mutations, but of cells in general in aging processes. Reasons for implicating connective tissue and the vascular system in aging have been summarized elsewhere (*5*).

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I was interested in Kohn's comments on my recent paper even though I cannot agree with his objections to it. When we observed a single correlation between mutations and aging, we were not impressed; but after we had observed many such correlations quantitatively relating these two phenomena, we became convinced that there is a causal relation between them.

I submit that there is a wealth of information indicating that irradiated animals contract the same kinds of fatal illnesses as do normal animals, but that they do so sooner. The exceptions to this statement are minor and can easily be explained on other grounds. Since the only quantitative definition of aging which has any degree of acceptance states that aging is something which leads to death, it does not seem unreasonable to speak of radiation-accelerated aging. The objection raised by Kohn that radiation does not cause the same changes in collagen as does natural aging is quite minor, since, like greying of the hair, changes in collagen are almost certainly symptoms rather than causes of aging. Likewise, degenerative changes in the vascular system are symptoms of aging in the mammal. It should be pointed out that animals without a vascular system and without collagen also age.

Second, the liver was examined in these studies because it is the most convenient organ for this purpose. Other cell systems have been studied by other investigators. There is every reason to believe that deductions from these studies about the behavior of the cells of other organs will be valid, and it is the total picture which is important, and not just the liver. The liver itself, being an organ capable of undergoing cell division, does not demonstrate degenerative changes with age as much as do other organs containing fixed postmitotic cells.

Finally, I quite agree with Kohn, as amplified in the paper, that if cells continue active cell division they can essentially remain immortal; but the cells of many mammalian organs, such as the brain, lose the ability to divide and thus the ability to throw off mutations. Degeneration is the inevitable result, and they drag the other organs to the grave with them.

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Medical Students: Source, Selection, and Training

The shortage of properly trained physicians in the United States is a constant problem and one which is made even more complicated by the surprising amount of misinformation currently being circulated about the source, selection, and training of medical students.

The source of medical students is a varied one. It is sometimes assumed that many of them come from physicians' families. Some students do, but not a significant proportion of the doctors-in-training. Many medical students grew up on farms and there obtained an initial interest in biology—an interest which often leads a student into medicine. Others trained in the armed forces where some hospital work was included, and after World War II a considerable number of veterans found that their interests were in medicine, and they carried on successfully in spite of having families and being older. This maturity was advantageous rather than a handicap.

Many good students (male and female) come from hard-working families with no financial reserves—miners, laborers, construction workers, and others. Earning the needed money is hard and often lengthens the period of training, but scholarships, loans, and gifts are becoming more readily available. No student who thinks he would like to be a doctor should give up this ideal. A visit to a medical school may show him that he has a good chance of acceptance, and good work will mean financial assistance if it is needed.

There is an acute need for doctors and consequently for medical students. With this in mind parents should encourage their children to test their interest in medicine. Sometimes a summer spent working in a hospital or medical school may show a student that he does have a real interest in medicine.

Selection of medical students is of the utmost importance and presents many problems. An applicant should be healthy, strong, honest, and determined. A liking for people and a pleasant personality are very important—also evidence of leadership. Scholastic ability in biology, chemistry, and physics is important, and lack of this ability could exclude an applicant. Many able and even famous physicians have carried the burden of invalidism, but they succeeded in spite of a serious handicap. Scholastic ability alone will not qualify an applicant for medical school—for an honor student may have a very cold and unpleasant personality which would be a grave handicap to a physician. Aptitude tests do not tell the whole story, and personal interviews are an essential part of the final review for acceptance into medical school.

Graduate students working for Ph.D. or master's degree may develop a deep interest in medicine and should be given very careful consideration. Likewise, special students or junior members of the basic medical school departments deserve serious consideration if they wish to consider a shift to the medical student group.

College science teachers often supply the acceptance committee with invaluable information about prospective students. They have, through the years, followed the progress of the students trained in their departments and have observed the type of student who proved to have real ability in medicine, and have fostered and encouraged such interest.

Breadth of college training is an advantage. Some students concentrate their attention wholly on science courses. It is probably better in the long run to broaden their college program. Once the science courses needed for entrance have been covered with satisfactory grades, it is wise for the student to take such subjects as history, languages, and sociology, depending on individual preference.

Students and parents sometimes think that the burden of outside work is a disadvantage. On the contrary, it is usually beneficial, if the college courses are not neglected in favor of the outside work. A school candidate can learn as much from outside work as from the college courses. Work in summer jobs teaches the students how to contact and understand people—an essential when subsequently they deal with patients who have been injured by disease or accident.

Medical school teaching is largely a person-to-person business. Students cannot be taught medicine in large groups of 100 to 300 no matter how good the lectures may be. The important work in the laboratory and clinics is discussed by teachers (senior and junior), with medical students in close contact, individually or in very small groups. This emphasizes the importance of having no more than 50 to 100 students to a class. If more doctors must be trained and excellence of training is a factor, then there *must* be more medical schools rather than having larger classes in the present schools.

A medical school must not be satisfied with good training in all important medical subjects. The special interests of students should be aroused in the hope that they will participate in medical research. This may lead to a longer period of preparation before graduation and ultimately to the role of a medical teacher. The better medical schools are very proud of the students who become teachers, and obviously such teachers are needed. This type of medical-teacher training requires active medical research with the necessary space and equipment, laboratory personnel, and animal quarters. Provision for such facilities must be included in the school's annual budget and such costs increase the cost per student per year.

Perhaps this is not a fair appraisal, but it emphasizes the important point that the best instruction for medicine includes opportunities for special work and research. This usually means that scholarships are readily available to superior students and to those who have demonstrated a real interest in research or in some aspects of medical teaching.

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