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# Lunar Receiving Laboratory

## Unique requirements for handling lunar samples and quarantining for back-contamination are provided.

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The arrival on Earth of samples of lunar rock carefully collected by Project Apollo will present an unparalleled opportunity to examine extraterrestrial materials under controlled conditions. Unless such samples are collected and handled with great care, a considerable amount of unique scientific information will be lost (*1*). The scientific importance of these samples has prompted the National Aeronautics and Space Administration (NASA) to obtain the expert opinions and guidance of many scientists in establishing the requirements for the Lunar Receiving Laboratory now under construction at the Manned Spacecraft Center in Houston, Texas (Figs. 1 and 2). Contributions have come from many NASA-sponsored advisory groups and, in particular, on a continuing basis, from a group established for that purpose by the NASA Office of Space Sciences and Applications (*2*).

It was soon established that the receiving laboratory should have four major functions: (i) distribution of lunar samples to the scientific community for detailed investigations after a period of biologic quarantine; (ii) performance of scientific investigations of samples that are time-critical and must be accomplished within the quarantine period; (iii) permanent storage under vacuum of a portion of each sample; and (iv) quarantining and testing of the lunar samples, spacecraft, and astronauts for unlikely, but potentially harmful, back-contamination (contamination of extraterrestrial origin).

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### Sample-Handling Procedures

The samples of rock will arrive on Earth aboard an Apollo spacecraft in two vacuum-sealed containers totaling about 56 liters in volume. The total allowance of weight for scientific material coming from Moon is 36.2 kilograms; this will include approximately 23 kilograms of packaged samples of lunar rock. It is planned that each of the general-purpose samples collected on Moon will be individually packaged in a vacuum-sealed bag and packed into the larger boxes; exceptions may be very small samples (of which several may be packaged together) and samples collected for special purposes. Special-purpose samples include two "lunar-environment" rock samples, rock samples reserved for experiments in gas analysis, and samples aseptically collected for biologic examination. The "lunar-environment" samples will be packaged in containers designed to hold statically the best possible vacuum and transport the specimens under a pressure as close to that of the lunar atmosphere as is possible within weight and volume constraints. The gas-analysis and biologic samples will be collected and packaged on Moon by use of techniques, now under development, that will prevent contamination that might lead to incorrect conclusions from the investigations.

The main operational areas of the receiving laboratory for processing the returned samples are the Sample Laboratory and Vacuum Laboratory, which contain the cabinet barrier systems behind which the samples are handled (Fig. 3). Many of the operations in connection with the samples must be performed under vacuum in order to minimize terrestrial organic and inorganic contamination. The Vacuum Laboratory contains a unique vacuum system that is ultra clean, provides a primary biologic barrier, and has manipulative capability for handling the samples. The primary function of the vacuum system is to serve as a receiving center for the samples and as a distribution point for other portions of the receiving laboratory and, later, for the scientific community; some of the vacuum systems are used for outgassing and sterilizing tools and containers for outbound flights.

Dry heat is the primary means of sterilizing the vacuum systems and the equipment being prepared for flight. Cryogenically trapped pumps comprise the primary pumping systems. The use of elastomeric material is minimized; it is restricted to specific fluorocarbons that can be easily discriminated as contaminants. Most of the sample operations in the chamber are conducted under a pressure of $1 \times 10^{-6}$ torr or lower. The special lunar-environment rock samples are opened, divided, and repackaged for distribution under a pressure no higher than $1 \times 10^{-11}$ torr.

The operations performed on incoming samples in the vacuum systems and cabinetry of the Vacuum Laboratory are: unwrapping and sterilizing the outside of the containers; opening and unpacking the containers under high vacuum; sampling of effluent

gases; visual examination, photography, and division, and delivery of portions of the samples to other areas of the receiving laboratory for specific investigations. Chips removed from each sample in the high-vacuum system are repackaged in small vacuum containers and passed through transfer tubes to the Physical-Chemical Test Laboratory and the Biological Preparation Laboratory.

### Tests and Analyses of Samples

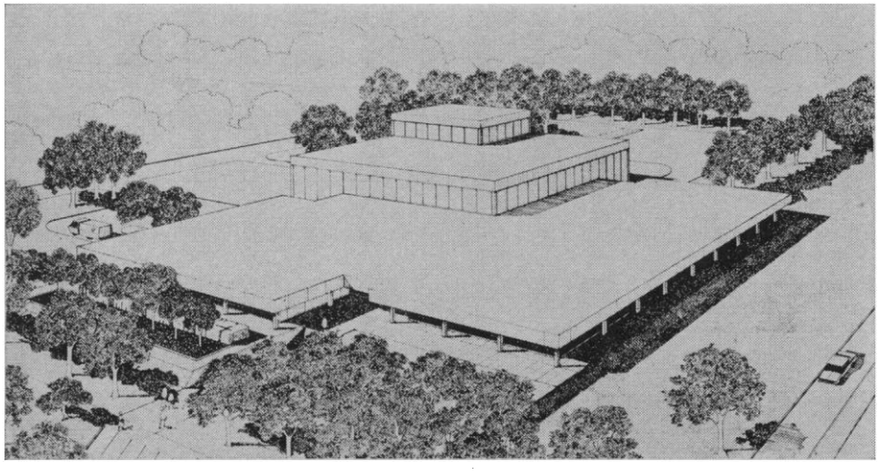
The chips and aseptically collected biologic samples will be prepared, for quarantine testing, in the sterile environment of the Biological Preparation Laboratory cabinet system; preparation will consist in extracting biologic materials from each sample and preparing the extracts for specific quarantine examinations in other cabinet systems in the Sample Laboratory. These examinations will include aerobic and anaerobic culturing; inoculation of plants, eggs, tissue cultures, amphibia, invertebrates, and normal and germ-free animals; and biochemical analyses. A detailed, comprehensive test protocol is currently under development.

The chips and small samples passed to cabinets in the Physical-Chemical Test Laboratory will first be tested for reactions with atmospheric gases and water vapor. These tests are designed to determine whether lunar samples will suffer any degradation, or significant change in their mineralogic composition or physical properties, as a result of exposure to Earth's atmosphere, that will seriously affect subsequent handling and examination. Only small chips will be exposed in this manner while the main portion of each sample is maintained under vacuum. The chips will then pass into another cabinet containing dry, sterile nitrogen, where preliminary examination of the mineralogy, petrography, and chemistry of the samples will be performed. Such basic equipment as petrographic microscopes, chemical reagents, an optical spectrograph, and small hand tools for investigation of physical properties will provide information about each sample.

Detailed investigations of the mineralogic, petrologic, geochemical, and physical properties of the samples will be performed in many laboratories throughout the scientific community after the quarantine period; they will include comprehensive analyses of major and minor elements and of isotopes, mineral identification and description, analyses of any organic compounds, and determinations of physical properties. However, two experiments, effluent-gas analysis and gamma-radiation counting, are time-critical or are linked to basic operations in the receiving laboratory; they will be performed there in a more sophisticated manner.

An early determination will be made, by visual inspection in the $10^{-6}$-torr chambers, of which individual large samples may be the most interesting for gamma-ray spectrometry. Samples collected on the surface of Moon, where they are not protected from cosmic rays and solar protons by a shielding atmosphere or a substantial magnetic field, will contain induced radioactive nuclides in addition to the radioisotopes found in terrestrial rocks. Analysis of the gamma radioactivity will yield information on the composition of the sample and on the history of the activating radiation; thence may come clues to the origin and history of the lunar material. Gamma-ray spectrometry will be performed in the receiving laboratory during the quarantine period, before many of the shorter-lived nuclides decay; later recounting of each sample will yield better information regarding the abundance of some isotopes after the shorter-lived nuclides have decayed.

Lunar samples may not be much more active than meteorites, and the weaker activities in meteorites cannot be adequately detected and measured with existing facilities. Thus one must analyze the lunar samples by use of



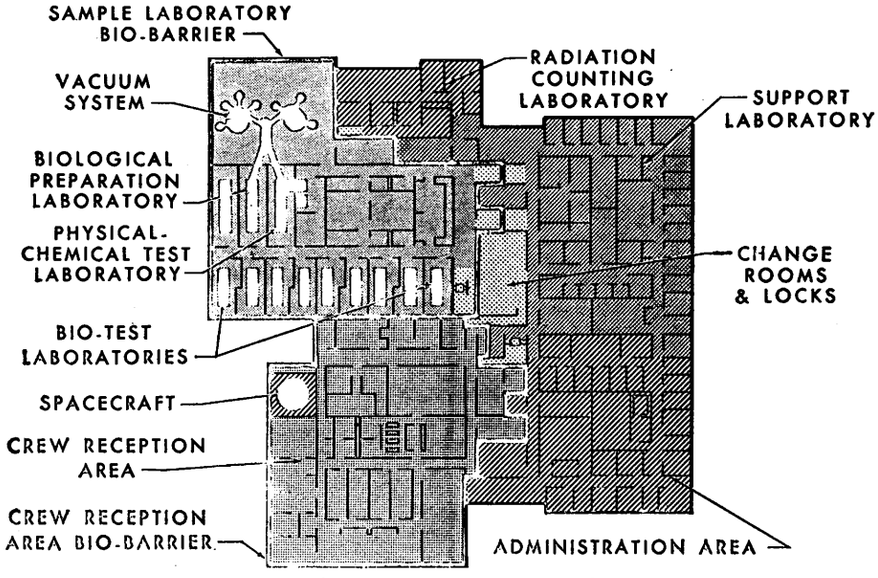



Fig. 1 (top). Perspective drawing of the Lunar Receiving Laboratory now under construction at NASA Manned Spacecraft Center. Fig. 2 (bottom). Schematic floor plan of part of the receiving laboratory, showing some of the major functional areas.

the best possible counting equipment and shielding in an environment of steady, low-radiation background. The gamma-ray counting room (Fig. 4) will be located approximately 15 meters underground; the walls of the room will be lined with 91 centimeters of crushed dunite held in place by a steel liner. Selection of construction materials for low activity, and a radon-free atmosphere provided by a special ventilation system, will combine with the underground location to reduce the radioactive background to an expected 0.1 to 0.2 count per minute per cubic centimeter of detector in the energy range 0.1 to 2.0 Mev. Anticoincidence mantles enclosing the 23- by 13-centimeter sodium iodide detectors will further reduce the background by a factor of 10 to 100.

The radiation-counting data-acquisition system will be capable of handling data from two coincidence spectrometers. The system will consist of four analog-to-digital converters, each with a 4096-channel full-scale range and a fast memory capable of storing the equivalent of an array of 128 by 128 channels for each coincidence system.

The return of lunar samples in vacuum-tight containers will offer the first opportunity for comprehensive study of the gases in extraterrestrial materials without the usual problems of terrestrial contamination; similar investigations of meteorites have yielded a wealth of data. Facilities will be provided within the Gas Analysis Laboratory of the receiving laboratory for several individual but closely related experiments in analyses of gases:

1) Gas in the outer box containing the samples and in the inner sample bags will be analyzed in the high-vacuum chamber as each individual container is first penetrated. This analysis will provide a sensitive test of the quality of the seal of each container, of the outgassing of the container itself, and of the composition and amount of gas that may have been released from the sample under ambient conditions.

2) Analysis of gas evolved during the splitting and preliminary examination of the lunar-environment rock samples, which will be accomplished in the $5 \times 10^{-11}$-torr chamber; this analysis should provide the same types of information as will experiment 1, except that some occluded and interstitial gas may be released during the splitting process.

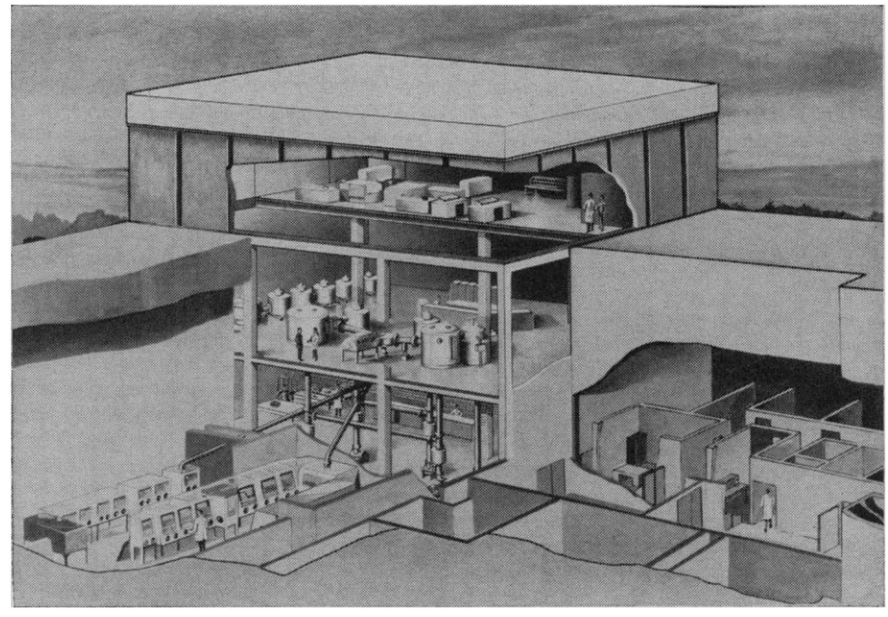


Fig. 3. Cutaway view of part of the Sample Laboratory of the receiving laboratory. The third floor is the Gas Analysis Laboratory. The first and second floors are the Vacuum Laboratory, containing the vacuum chambers, pumps, and associated control equipment. Containment cabinets in the biologic-preparation and physical-chemical test laboratories appear in the foreground.

3) Analysis of the gases evolved upon opening and heating of the special gas-analysis samples; this should provide a complete gas composition-temperature profile for several lunar samples, which will include gas already in the container when it is opened, gas adsorbed on the surface of the sample, and interstitial and occluded gases.

4) Analysis of gas released or gaseous reaction products evolved during the atmospheric-reaction tests in the Physical-Chemical Test Laboratory.

## Back-Contamination

Much of the design of the receiving laboratory is based on the fact that lunar samples must be considered a potential source of back-contamination. Various responsible scientific bodies, including the Space Science Board of the National Academy of Sciences, have expressed serious concern with the possibility of biologic back-contamination from extraterrestrial exploration (*3*). In the case of Moon, the low atmospheric pressure, large surface-temperature variation, probable absence of free water, severe surface-irradiation environment, and continual impingement of meteroids on the surface make the existence of a near-surface lunar biosphere, containing terrestrially compatible forms of life, highly unlikely. The probability of finding such forms in the less stringent environment of the lunar subsurface may be somewhat higher. However, it is widely believed that lunar material must arrive more or less continually on Earth as meteorites; that these pieces have escaped from the lunar surface as secondary ejecta when a primary meteoroid impacted the lunar surface. Such lunar material could reach Earth without its entire microbial load being killed, yet no forms of life are known to have arrived on Earth in this manner. Nevertheless, the return of men and samples from the surface of a foreign celestial body entails some very small risk of back-contamination that could adversely affect the terrestrial biosphere.

For specific guidance in matters relating to back-contamination, NASA is relying on the expert advice of the Interagency Committee on Back Contamination (*4*), which was established for this purpose at the request of NASA.

The biologic-containment systems used in the receiving laboratory must not only prevent the escape of material that could adversely affect the terrestrial biosphere; they must also prevent terrestrial organisms from contaminating the lunar samples. Biologic integrity of the samples must be

maintained to prevent incorrect interpretations of biologic and organic analyses.

The astronauts, having been on the lunar surface, will be considered exposed to lunar material and potentially exposed to any lunar biologic material; thus they will be quarantined in the receiving laboratory. Recovery and transport of the astronauts to this laboratory will be accompanied by appropriate means of biologic isolation. During the biologically isolated recovery operation, the astronauts will remove the two rigid, vacuum-sealed containers of lunar samples from the spacecraft and take them into the mobile isolation unit; there the containers will be wrapped and sealed within biologic barriers, decontaminated, and passed for rapid jet transport to the receiving laboratory. The interior of the command module (the returning element of the spacecraft) may come in contact with a small amount of lunar material that has been tracked in by the astronauts; in any case it will contain the astronauts for more than 2 days after their lunar exposure. Thus it must be considered contaminated; after removal of the astronauts and sample containers, it will be sealed for the duration of the quarantine.

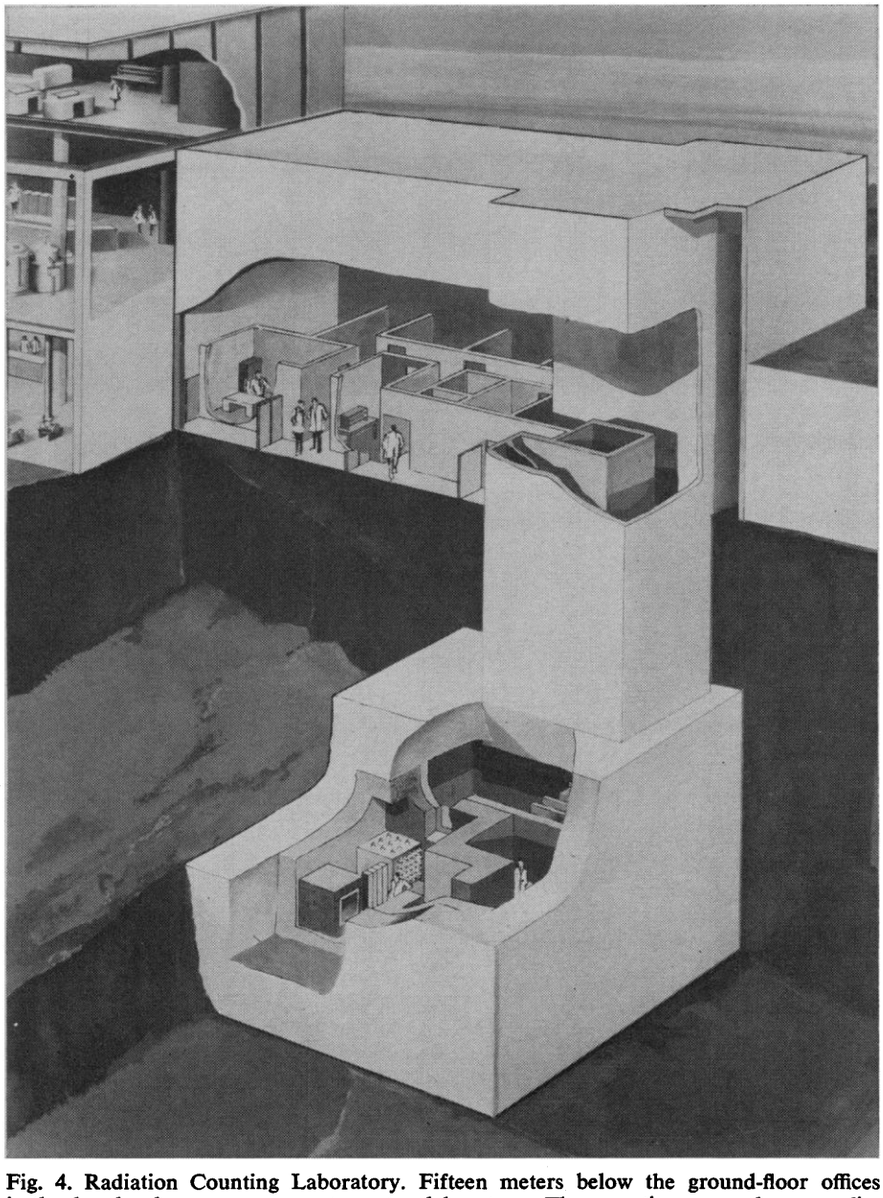


Fig. 4. Radiation Counting Laboratory. Fifteen meters below the ground-floor offices is the low-level-gamma-ray spectrometry laboratory. The counting room has a radiation-baffle entrance and thick walls of low-activity material. Apparent in the counting room are a lead shield (left), a multiparameter pulse-height analyzer, with associated electronics and accessories (center), and a detector-shield anticoincidence-mantle assembly (right).

The exterior of the spacecraft will be considered biologically clean because the command module will not have contacted the lunar surface, and because of the high temperatures experienced by the whole surface during reentry. The sealed spacecraft will be transported to the receiving laboratory for secure biologic isolation where it will be available for any essential postflight examination. The samples will arrive first at the receiving laboratory where they will be introduced immediately into the biologic-barrier system. Photographic film and magnetic data tapes from the spacecraft will arrive with the samples, and will be sterilized, by ethylene oxide treatment, for retrieval of data outside the biologic barrier. Arriving some hours later in their mobile isolation unit, the astronauts will be transferred to the crew-reception area of the receiving laboratory.

The advisability of quarantining in a single facility all possibly hazardous material arriving from Moon has been pointed out by many consultants as necessary to increase positive control of biologic integrity. Container-opening operations and subsequent tests and examinations of samples will be conducted behind the two-way biologic-barrier system composed of gas-tight glove cabinets and vacuum chambers. This system is unique in that conventional containment systems are designed to prevent contamination in one direction only. The two-way system will protect laboratory scientists and technicians on the outside from contact with possible lunar biologic materials; at the same time it will protect the samples on the inside from terrestrial biocontamination. Second-line containment to guard the public health in the event of a break in this system is provided by features of building design and construction that establish a biologic barrier surrounding the entire area of sample operations. This barrier is characterized by such features as sealed walls, floors, and ceilings; control of leak-path direction by air-pressure differentials; single-passage air conditioning, with biologic filters on intake and exhaust; incineration of effluent air; and control and sterilization of liquid effluents.

The immediately adjacent Crew Reception Area, where the astronauts are isolated during quarantine, is similarly built. The area not only provides for the crew, postflight medi-

cal team, and support personnel during the quarantine period; it also has the contingency capability of housing all personnel that might be exposed to biologic hazards in the sample laboratory by failure in a barrier system. It is anticipated that the period of quarantine for samples will be about 30 days, which period the laboratory is capable of extending if a specific problem of back-contamination emerges.

### Conclusion

The Lunar Receiving Laboratory will be the permanent depository of a portion of the collection of lunar samples; it will safeguard the collection, providing continuing security and ensuring scientific integrity. In carrying out the time-dependent experiments and continuing functions of the laboratory, NASA will rely on visiting expert scientists supplementing a relatively small resident staff; outside scientists will be relied upon for most investigations and detailed analyses of samples. It is believed that the designed procedures and facilities provided will ensure the maximum scientific return from the Apollo Program in the way of information from lunar samples.

#### References and Notes


1. NASA, *NASA 1965 Summer Conf. on Lunar Exploration and Science, NAS SP-88* (U.S. Government Printing Office, Washington, D.C., 1965), p. 421.
2. The following, as members of the OSSA *ad hoc* Committee or of the Lunar Receiving Laboratory Working Group of the Planetology Subcommittee, or of both, have been closely involved and especially helpful in defining the scientific requirements and reviewing progress of the receiving laboratory: E. C. T. Chao (U.S. Geological Survey); Clark Goodman (Univ. of Houston); J. R. Arnold and A. Burlingame (Univ. of California); P. R. Bell (Oak Ridge National Laboratory); James Devoe (NBS); D. A. Flory, E. A. King, Jr., and J. C. McLane, Jr. (Manned Spacecraft Center); Clifford Frondel (Harvard Univ.); W. F. Hardgrove and Jacob Trombka (Goddard Space Flight Center); Jonathon Klein (Ames Research Center); Herman Mark (Lewis Research Center); Charles Phillips (U.S. Army Chemical Corps); G. B. Phillips (USPHS); Oliver Schaeffer (State Univ. of New York); and Peter Signer (Eidgenosische Technische Hochschule, Zurich).
3. Space Science Board, Nat. Acad. Sci., *Conf. on Potential Hazards of Back Contamination from the Planets 29–30 July 1964*, p. 15.
4. Chairman: David Sencer (USPHS); members: John Bagby, Jr. (USPHS); Wolf Vishniac (NAS); Ernest Saulmon (USDA); John Buckley (USDI); and H. P. Klein, C. A. Berry, Aleck Bond, and Leonard Reiffel (NASA); executive secretary; J. E. Pickering (NASA); on-site liaison representative: G. B. Phillips (USPHS).


# Radiation Chimeras and Genetics of Somatic Cells

## Tissue cultures in vivo allow selection and detection of genetic variants of somatic cells.


Alena Lengerová


It took geneticists a fairly long time to admit that genetic analysis in mammals might in principle bypass sexual reproduction and take advantage of the processes of genetic recombination which have come to light in bacteria and viruses, or of similar processes (*1*). It may, however, take even longer before what seems theoretically possible will be generally possible. What are actually the prerequisites of success in any experimental system? They seem to be the following:

1) Existence of processes in somatic cells which can result, under appropriate conditions, in gene recombination.

2) Availability of suitable genetic markers—that is, alternative characters detectable at the cellular level.

3) Conditions which favor the variant phenotype on the basis of one or another of the possible principles.

4) Availability of techniques of handling somatic cells according to the requirements of formal genetic analysis.

The first of these four conditions seems to be critical, as it is much more independent of experimental skill, sophistication, or good luck than the other three are. It seems quite clear either that processes possibly resulting in gene recombination are very rare in mammalian somatic cells (if they occur at all) or that the recombinants have a low chance of surviving or of being phenotypically expressed. This might be due to the existence of some mechanism (or mechanisms) which keeps control over the uniformity of somatic cells. The possibility that the somatic recombinants might either come into being or happen to survive and express their phenotypic change just by some sort of accident does not necessarily mean that they could not be exploited in a systematic study. The parasexual cycle in filamentous fungi (*2*) is based on a series of rare and probably accidental events, and nevertheless it proved extremely useful as a means of genetic analysis. The first problem thus is to find whether there are at least some indications that gene recombination can occur, however rarely, in mammalian somatic cells.

A great deal of experimental evidence is based on immunoselection of homozygous (or hemizygous) cell variants arising in mouse tumors heterozygous at the *H*-2 locus (*3*). The results are fully compatible with somatic crossing-over as the underlying mechanism, although some other possibilities cannot as yet be excluded. Additional but still indirect evidence in favor of somatic crossing-over in the same experimental system was provided by the demonstration that the parent compatible variants are due to changes at the chromosomal rather than at the phenotypic level (*4*). Recently, reports of rare instances of animals heterozygous for a recessive coat-color gene but showing patches of fur with the recessive phenotype were extracted from the literature, and an attempt was made to find a common denominator for various peculiarities of such mosaics; in spite of the rather speculative nature of evidence after the event, the reported data seem to make "a strong case for the existence of somat-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