bacterial chromosome. He also reported details of a cell-free system for the demonstration of repair of ultra-violet-irradiated DNA *in vitro*. Dr. P. C. Hanawalt (United States) dealt with known repair/replication mechanisms in the bacterial genome. It is possible that some form of non-conservative DNA replication mechanism has a necessary function in the normal replication and transcription process, and that it may also function in the repair of a variety of defects in DNA. Repair of damage may also be related to the normal processes involved in genetic recombination, and this problem was reviewed by Dr. B. M. Wilkins (United Kingdom).

Prof. D. Shugar (Poland) outlined the fundamental chemical changes known to be induced by ultra-violet light in pyrimidine analogues and in model oligo- and polynucleotides. The processes involved in the reversal of a number of these changes are now well understood, and attempts may be made to relate them to photochemical transformations in nucleic acids. Dr. S. Robev (Bulgaria) discussed X-ray damage to some informational micromolecules. Investigations of the formation, after irradiation, of a DNA/*m*RNA hybrid indicate a similar intrinsic radiosensitivity for both molecules, and it is possible to explain many apparent differences on the grounds of the number and rapid turnover of *m*RNA molecules.

The last session of the panel took the form of a general discussion of some of the major topics which arose from the papers presented, and an attempt was made to interrelate observations at the chromosomal, genetic and molecular levels. The first question to be considered was concerned with the nature of the basic lesions in nucleic acids brought about by ultra-violet light, ionizing radiation and chemical mutagens. Work using ultra-violet light forms the current basis for the interpretation of much of the radiation chemistry of nucleic acids, and the panel emphasized the importance of pursuing comparable investigations with ionizing radiations.

The relative contributions of the various types of damage to such end-points as cell lethality and mutations were considered, and while some answers could be given for phages and bacteria, no assessment could be made for more complex systems. The panel then discussed known repair processes and how they operate. On almost all occasions, repair is of an enzymatic nature, and several genetic loci seem to be involved in its control. The DNA synthesis required in repair will occur in the absence of normal DNA replication.

Much information has been obtained from investigations of the factors which influence repair mechanisms (for example, metabolic inhibitors). In some systems these factors act by preventing the formation of enzymes required for repair, although in most cases these enzymes are already present. There is also a possibility that some radioprotective agents may exert their effects by way of promoting repair, rather than by radical scavenging.

The panel next examined models recently proposed for genetic recombination, and their possible relationships with known repair systems for irradiation damage. All these models involve single DNA molecules, and one of the major obstacles in any attempt to extend them to events at meiosis in higher organisms is an almost complete lack of information as to the fine structure of large chromosomes, which contain not only DNA but at least two types of protein and some RNA. There is increasing cytological evidence that such chromosomes are multistrand, despite the fact that genetically they behave like a single DNA molecule.

Finally, consideration was given to radiation-induced achromatic chromosomal lesions (gaps) which appear to be completely reparable. Further progress in understanding their nature requires biochemical investigation, and in particular, whether DNA loss is involved in their formation.

MORTON W. MILLER
JOHN R. K. SAVAGE

OBITUARIES

Dirk Brouwer

WITH the unexpected death of Dirk Brouwer on January 31, 1966, the subject of celestial mechanics suffered an irreparable loss. It is almost entirely due to Brouwer, directly or through his former students, that this mainly nineteenth-century discipline has been able to meet the quite incredible demands made upon it by recent space research. In addition to his many contributions to what may be termed the classical branch of the subject, he pioneered and developed the methods of numerical integration which must still be the mainstay of current orbital calculations for artificial satellites; and he gave a completely general solution, of great practical as well as theoretical interest, of the effect of the oblateness of the Earth on the motions of satellites. Not content with his unique personal contributions, he created in 1959 an annual series of summer institutes in dynamical astronomy, supported by the National Science Foundation, from which have already come over 600 workers in this field, mainly in the space sciences.

Brouwer was born on September 1, 1902, in Rotterdam, and in due course studied mathematics and astronomy at Leiden, where he was greatly influenced by Willem de Sitter. After taking his doctorate (in celestial mechanics) he went to the United States in September 1927 with a post-doctoral fellowship for study at the University of California at Berkeley, and later at Yale. He there became research assistant to E. W. Brown, and, remaining at Yale, became in turn professor, director of the University Observatory (in 1941), chairman of the Department of Astronomy, and Munson Professor (in 1944). He was to carry forward brilliantly the work of both his famous mentors and, moreover, to prove a worthy successor of Frank Schlesinger as director of the Observatory. Yale's traditional observational activity has been in the field of astrometry, particularly in the construction of photographic star catalogues and the derivation of proper motions. Brouwer pursued this activity with characteristic thoroughness and vigour, both scientifically and administratively. He himself developed new techniques of observation and measurement, as well as pioneering the reference system of the minor planets.

With his unique experience, Brouwer was in constant demand as chairman of or adviser to commissions and, more recently, to various ambitious projects. He served as President of Commissions 7 (Celestial Mechanics) and 20 (Minor Planets) of the International Astronomical Union; and on many special committees, such as those on astronomical constants. He was editor of the *Astronomical Journal* from 1941 and its rapid growth owes much to his influence. But, far from being overwhelmed by such administrative demands, he seemed to thrive on the additional work and responsibility.

Probably the most significant of Brouwer's many contributions to celestial mechanics are his work on planetary theory, using rectangular co-ordinates (1944); his discussion of the secular variations in the solar system (1950); his share of the numerical integration of the orbits of the five outer planets (1951); and the explanation of the "asteroid gaps" in the distribution of the minor planets (1963). But his work on astronomical constants, stretching from his completion of de Sitter's work in 1938 through the introduction of Ephemeris Time (1950) to the IAU System of Astronomical Constants in 1964 must not be overlooked.

Brouwer was a friendly and approachable man, willing at all times to discuss problems with his research associates and students, and capable of inspiring leadership; it is to be hoped that his monumental work at Yale can be continued, and even expanded, to meet still further challenges from space research, for this is surely what he would have most wished.

D. H. SADLER