conclude that sufficient time has not elapsed for the tidal forces of the neighboring stars to appreciably modify the elements of binary orbits with separations in the range stated. This implies that 10^{10} years represents a true upper limit to the time scale, and would suggest a time scale of the order of, say, 5×10^9 years.

The discussion of the mean lives of galactic clusters and the statistics of binary stars agree therefore in pointing to a time scale of the order of a few billion years. We may now briefly summarize the other evidences which also point to a similar time scale. First, we have the geochemical evidence derived principally from the lead content of minerals containing uranium salts and leading to the ages of the igneous rocks containing these minerals. In our present context most interest is naturally attached to those determinations which lead to the greatest ages. Thus, the analysis of a pegmatite in Manitoba containing uranite, monozite and mica leads to three independent determinations of age ranging from 1,600 to 1,900 millions of years. We may say then that a billion and a half years represents a true lower limit to the age of the earth. An upper limit can also be found (as was first indicated by H. N. Russell) from the entire lead content of the earth's crust on the assumption that all of it has been derived as the end products of radioactive disintegrations. In this manner an upper limit of three and a half billion years has been estimated. In other words, the age of the earth has been bracketed between one and a half and three and a half billions of years. Similar ages have also been found for the meteorites from their helium content.

Still another evidence for the time scale comes from the velocity interpretation of the "red shift" shown by the extra-galactic nebulae and the velocity-distance relationship of Hubble. As is well known, this relationship can be interpreted as meaning that some two billion years ago all the nebulae were confined to a relatively very small volume and that they were projected with their present speeds in their present directions. It is, of course, possible that the velocities of the nebulae were different at earlier epochs, but the interpretation given is probably adequate for drawing inferences concerning the time scale.

Finally, we may also draw attention to the information that can be derived from clusters of extragalactic nebulae such as the Coma and the Virgo clusters. The Virgo cluster, for example, includes some 400 nebulae in a spherical volume of about 200,000 parsecs radius. It is not certain that the Newtonian laws of gravitation can be applied to objects of this size. But we can probably apply the theory which we have described for the galactic star clusters to the clusters of nebulae to obtain very rough estimates. In this manner Miss Tuberg[9] has recently estimated for the Virgo cluster a mean life of the order of 10^{11} years.

To conclude, then, we see that the geochemical evidence bearing on the age of the earth and meteorites, the galactic star clusters, the statistics of binary stars, the clusters of extragalactic nebulae and finally the system of the nebulae, all agree in pointing to a time scale of the order of a few billion years. It does not seem that this can be accidental.

[9] *Astrophysical Journal*, 98: 501, 1943.

SOVIET STUDIES ON VIRUSES[1]

By Dr. W. M. STANLEY

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, PRINCETON, N. J.

ON February 12 in 1892 a young man, Dmitrii Iwanowski, appeared before the Academy of Science at St. Petersburg and presented his second scientific contribution, a short four-page paper entitled "On the Mosaic Disease of the Tobacco Plant."[2] Most of this short paper was devoted to an innocuous discussion of the symptomatology of the disease as he had observed it in the Crimea, and it is only near the end that there was given a one-sentence description of an experiment which has come to be recognized as a landmark in medical history. This sentence goes as follows: "Yet I have found that the sap of leaves attacked by the mosaic disease retains its infectious qualities even after filtration through Chamberland filter-candles." This filtration experiment by Iwanowski led to the discovery of viruses, which we now recognize as a large group of infectious agents, smaller than ordinary living organisms, that may cause disease in man, animals, plants and bacteria. To this group belong the agents responsible for such diseases as smallpox, yellow fever, poliomyelitis, influenza, the virus pneumonias of man, horse encephalomyelitis, foot-and-mouth disease of cattle, hog cholera, rabies, dog distemper, fowl pox, certain types of tumorous growths in fowls and other animals, jaundice of silk-worms, various yellows and mosaic diseases of plants and

[1] Address at the Science Panel of the Congress of American-Soviet Friendship, New York, November 7, 1943. The complete proceedings of the Science Congress including the Medical Session will be published at a later date by the National Council of American-Soviet Friendship.

[2] D. Iwanowski, *Bull. Acad. Imp. Sci. St. Petersburg*, 3: 67, 1892.

the transmissible lysis of bacteria. Although vaccination as a means of protection against smallpox was in use long before the recognition of the existence of viruses and notable success in the prevention of yellow fever and encephalomyelitis has been achieved recently by vaccination with mild virus strains or with inactivated virus, there remain many important diseases, such as the virus pneumonias, influenza, poliomyelitis and several afflictions of animals and plants, for which there now exists no acceptable means of protection of whole populations. The newer wonder materials, such as the sulfa drugs and penicillin, generally have not been found to be effective in the treatment of virus diseases. From a medical standpoint, therefore, the viruses have come to represent a most important group of infectious disease-producing agents.

Iwanowski was certainly unaware of the great importance and significance of the filtration experiment which he described in 1892. He regarded the mosaic disease as bacterial in nature and suggested that his unusual results might be due to a defect in the filter candle or to the presence of a bacterial toxin. However, six years later Beijerinck confirmed Iwanowski's filtration results and proved by serial passage of the filtrate that the infectivity was due to a filterable agent and not to a bacterial toxin.[3] Beijerinck referred to the active agent as a "contagious living fluid" and appeared to believe that it was not bacterial in nature but was an unorganized entity. The same year, Loeffler and Frosch reported that the foot-and-mouth disease of cattle was due to a virus,[4] and in 1901 yellow fever was found by Reed and co-workers to be a virus disease of man.[5] It is not surprising that Iwanowski failed to grasp immediately the full significance of his 1892 filtration experiments, for the results were directly contrary to all accepted scientific knowledge. However, when similar results were obtained with diseases of man and animals, he seemed to have recognized the challenge which was presented and immediately set about to learn something of the nature of tobacco mosaic virus. He reported his extensive experiments on this virus in a 40-page paper published in 1903.[6] The nature of the experiments which he conducted and the manner in which they were carried out and discussed serve to mark Iwanowski as a most able investigator. He was aware that tobacco mosaic virus represented the first of a new kind of infectious disease-producing agent, and he recognized fully the great difficulty in describing exactly the nature of an agent that could pass a Chamberland filter but not a dialysis membrane and one which could reproduce only within living cells and not on artificial media. The ideas that he expressed are quite similar to those held to-day by many leading virus workers. Iwanowski's 1903 paper is also notable for his accurate description of the intracellular inclusions in the cells of mosaic-diseased plants. His description of the needle crystals formed within diseased cells upon the addition of acid is of interest, for in the light of present-day knowledge it seems likely that this material was crystalline tobacco mosaic virus. Iwanowski's claim to fame has grown with the years and, although his life has not been treated biographically and even the place of his birth and early training appear to be unrecorded in the scientific literature, I believe that his relationship to viruses should be viewed in much the same light as we view Pasteur's and Koch's relationship to bacteriology. There is considerable justification for regarding Iwanowski as the father of the new science of virology, a field of endeavor which to-day is of great importance not only in medicine but in several closely allied fields of study.

For over thirty years, studies on viruses were at a low ebb in Russia as well as in other countries. Most of the work consisted of the description of new virus diseases, of the pathology involved therein and of the ways by means of which viruses are transmitted from host to host. However, the coming importance of plant viruses was recognized by Rischkov, then professor of plant pathology at Charkow, who in 1935 published a book entitled "Virus Diseases of Plants."[7] The isolation in this country in 1935 of tobacco mosaic virus in the form of a crystalline nucleoprotein of high molecular weight[8] was immediately recognized in Russia as providing a new approach to the study of viruses. This finding was soon repeated and confirmed by Rischkov at the Microbiological Institute in Moscow.[9] In 1937 and again in 1938 Rischkov published reviews in the Russian language of the extensive work which had been carried out in this country and in England on purified virus preparations.[10,11] In 1938 he published with Gromyko a description of a new method for the purification of tobacco mosaic virus.[12] Rischkov also demonstrated with Soukhov the important fact that crystalline tobacco mosaic virus possesses no enzymatic activity other than that of virus activity.[13] Goldin, working at the Microbiological

[3] M. W. Beijerinck, *Verh. Akad. Wetensch., Amsterdam, II, no. 5*, 6: 1, 1898.
[4] F. Loeffler and P. Frosch, *Zentralbl. Bakt., I, Orig.*, 28: 371, 1898.
[5] W. Reed, J. Carroll, A. Agramonte and J. Lazear, see *Senate Documents*, 66(822): 156, 1911.
[6] D. Iwanowski, *Zeitschr. Pflanzenkr.*, 13: 1, 1903.
[7] V. L. Rischkov, "Virus Diseases of Plants," Moscow, 1935.
[8] W. M. Stanley, SCIENCE, 81: 644, 1935.
[9] V. L. Rischkov, Private communication.
[10] *Idem, Microbiologiia*, 6(6): 830, 1937.
[11] *Idem, Progress of Contemporary Biology U.S.S.R.*, 9: 351, 1938.
[12] V. L. Rischkov and E. P. Gromyko, *Compt. rend. acad. sci. U.R.S.S.*, 19: 203, 1938.

Institute in Moscow, reported that putrefactive bacteria do not decompose crystalline tobacco mosaic virus and that virus may be adsorbed by various microorganisms.[14] Goldin also published a paper on "Some Data Concerning Crystalline Inclusions in the Mosaic Virus Disease of Tobacco," in which he called attention to the similarity between the properties of crystalline tobacco mosaic virus and those of the crystalline material described by Iwanowski in 1903.[15] The effect of ether on bacteriophages and tobacco mosaic virus was studied by Goldin, who found neither agent to be soluble in ether.[16]

In addition to the work that I have described, Russian investigators have made studies of a practical nature on several virus diseases, chiefly of virus diseases of cereal crops. Studies of importance have also been made on virus diseases of man and animals. For example, in 1937 Smorodintseff and coworkers reported the results of a study in which volunteers were inoculated experimentally with influenza virus[17] and in 1940 an investigation was described in which biweekly inhalations of vaporized influenza antiserum were given to a large number of persons before and during an influenza epidemic.[18] These two methods of approach to the influenza problem have subsequently been employed by American workers. It should perhaps be noted that the inhalation of antiserum has yielded the most favorable results yet reported in connection with the prevention of influenza in man. The war does not appear to have interfered seriously with virus studies in Russia, for in a paper in last month's *Phytopathology* entitled "The Nature of Ultra-Viruses and Their Biological Activity," Rischkov[19] mentions a conference on plant virus diseases which was held in Moscow in 1941 and describes researches which were reported at a meeting of the Ukrainian Academy of Sciences in January, 1942. In 1942 a number of the Russian journal *Microbiology*[20] was issued in celebration of the fiftieth anniversary of Iwanowski's filtration experiment with tobacco mosaic virus. In the introductory article Koshtoiants[21] not only describes and evaluates Iwanowski's early findings but also much of the contemporary work on viruses. The author's defense of the importance of Russian science and the occasional indulgence in polemics appear unnecessary. The important researches of Engelhardt and Ljubimowa on the enzyme activity of myosin, of Rischkov on plant viruses, of Graschenkoff on encephalitis, of Petroff on tumors, of Gamali on immunity and of Smorodintseff on influenza are mentioned with justifiable pride. In the second paper Rischkov[22] discusses the origin of viruses and in two succeeding articles Suchov[23] and Vovk[24] describe some recent work on plant viruses.

Let us all hope that it will not be long before the rich promises of Iwanowski's early work on viruses will be even more fully realized in Soviet Russia.

OBITUARY

RECENT DEATHS

ARTHUR KEITH, from 1894 until his retirement in 1934 geologist of the U. S. Geological Survey, died on February 7 at the age of eighty-one years.

DR. BERNARD SACHS, formerly professor of clinical neurology at the College of Physicians and Surgeons of Columbia University and director of the division of child neurology at the Neurological Institute, died on February 8 at the age of eighty-six years.

DR. ARTHUR RENWICK MIDDLETON, since 1939 emeritus professor of inorganic chemistry at Purdue University, a member of the faculty for forty years, died on February 6 in his seventy-fifth year.

DR. DAVID ELDRIDGE WORRALL, professor of organic chemistry and director of the chemical laboratory at Tufts College, died on February 7. He was fifty-seven years old.

SCIENTIFIC EVENTS

THE POLISH FACULTY OF MEDICINE AT EDINBURGH UNIVERSITY

A CORRESPONDENT of the *Journal* of the American Medical Association writes: "The only existing scientific institution with university standing which a great European nation has maintained is the Polish School of Medicine in the University of Edinburgh. It is unique in the fact that never before has any state set

[13] V. L. Rischkov and K. S. Soukhov, *Compt. rend. acad. sci. U.R.S.S.*, 21: 265, 1938.
[14] M. I. Goldin, *Compt. rend. acad. sci. U.R.S.S.*, 20: 735, 1938.
[15] *Idem, Microbiology U.S.S.R.*, 7: 353, 1938.
[16] *Idem, Bull. Acad. Sci. U.R.S.S.*, 173, 1938.
[17] A. A. Smorodintseff, M. D. Tushinsky, A. L. Drobyshevskaya, A. A. Korovin and A. I. Osetroff, *Am. Jour. Med. Sci.*, 194: 159, 1937.
[18] A. A. Smorodintseff, A. G. Gulamow and O. M. Tschalkina, *Zeitschr. klin. Med.*, 138: 756, 1940.
[19] V. L. Rischkov, *Phytopathology*, 33: 950, 1943.
[20] The writer is especially indebted to Dr. S. A. Waksman of Rutgers University for providing this number of *Microbiology* (Vol. 11, No. 4, 1942) and to Dr. M. Kunitz of the Rockefeller Institute for assistance in reading two of the articles.
[21] C. S. Koshtoiants, *Microbiology U.S.S.R.*, 11: 139, 1942.
[22] V. L. Rischkov, *Microbiology U.S.S.R.*, 11: 149, 1942.
[23] K. S. Suchov, *Microbiology U.S.S.R.*, 11: 168, 1942.
[24] A. M. Vovk, *Microbiology U.S.S.R.*, 11: 177, 1942.