quantum transfer of momentum in three rectangular directions may be written:

$$mv\alpha - mv^1\alpha^1 = n_1 \frac{h}{d_1}$$
$$mv\beta - mv^1\beta^1 = n_2 \frac{h}{d_2}$$
$$mv\gamma - mv^1\gamma^1 = n_3 \frac{h}{d_3},$$

The d's represent grating spaces, the Greek letters direction cosines and the n's whole numbers, in which v^1, the velocity of the corpuscle after reflection, may differ from v, its velocity before reflection. If v^1 is equal to v and if we put $\lambda = h/mv$, the above equations reduce to those derived from the theory of wave motion. If we look at the phenomenon of reflection of corpuscles from the point of view of the elementary wave theory, we may suppose the corpuscle to be replaced by a series of plain waves having a definite wave-length and we may suppose that these waves excite oscillations in the atoms of the grating which send out secondary waves. The interference of these secondary waves produces the reflected or diffracted beam. On this theory we would expect the frequency of vibration of the diffracted beam to be the same as that of the primary beam. We would expect, therefore, that the diffracted corpuscle would have the same energy, momentum and velocity as the corpuscle had before diffraction. It has been found, however, in the experiments which Davisson and Germer described in the December *Physical Review* that the reflected electron in general has less energy after reflection than before and that the loss of energy may amount to as much as twenty-five per cent. The fact that they observed electrons with such losses of energy appears to be explained by the above momentum equations as due to the sizes of the slits in their measuring apparatus.

No general solution of the equations representing the wave mechanics as applied to this problem has as yet been found. It may be that a general solution of the equations would indicate some loss of energy and momentum on reflection. If so, it will be interesting to see whether the angles at which reflection takes place are the same as predicted by the above momentum equations. According to these momentum equations, if the corpuscle loses a certain definite amount of energy, it must be reflected at certain definite angles from the crystal grating.

Although no completely satisfactory theory has been proposed for the radiation problem in general, it may be that we are gradually approaching a solution of it. A number of interesting physical theories have been proposed in recent years. A physical theory, however, does not represent what we might call real truth. A physical theory is a collection of fundamental hypotheses and general laws, which may be used to deduce particular laws that can be applied to concrete facts. Physical theories are useful, if they explain a large number of facts in simple ways, and if they furnish definitions of terms and a nomenclature to be used in describing phenomena. Physical theories are tools and not creeds, but one is at liberty to believe they represent reality, if one wants to. The belief in a physical theory, however, is a similar process of thought to the belief in religious tenets. The greater the number of useful physical theories that are proposed, the greater the number of good tools we shall have at our disposal, to use in discovering the real truth about the way in which nature acts; for it is the way in which nature acts that is the prime object of physical research. The multiplicity of theories in physics to-day really represents a healthy growth.

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FUNDAMENTAL SCIENCE AND WAR

MUCH has been said and written about war's effect on civilization; much has been said and written about war's effect on applied science and modern invention. Indeed the two are almost inseparable for the "degree of civilization of a people is commensurate with the extent to which they accumulate, correlate and utilize knowledge."[1] It is now universally realized that applied science progresses only after the foundation stones of pure science have been firmly laid. The process of laying this foundation consists in searching out, correlating and classifying knowledge. It is of this process that the layman is hardly aware, except that he knows it is carried on to a great extent in the academic world, in the laboratories of our colleges and universities. What would happen to civilization if this process were to cease? Is this process a continuous one? Is it affected by political influences? What is the effect of war on this apparently endless task?

It is the purpose of this paper to discuss the effect of the great war on one of the fundamental sciences—chemistry. In America we feel that chemistry is making great strides. We agree, and rightly, with Calvin Coolidge, who, in addressing the American Chemical Society on the White House lawn on April 24, 1924, said in part: "Wherever we look the work of the chemist has raised the level of our civilization, and has increased the productive capacity of the nation." We feel that the war caused an awakening in chemistry in this country. What its effect has been

1 J. Alexander, Preface of "Colloid Chemistry" (1926).

TABLE I

Year	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
Total number references	118	124	127	92	96	93	73	110	155	196	230	374
Non-U. S. A.	91	91	82	48	42	35	26	61	67	78	116	158

elsewhere we seldom ask; nor do we often find a satisfactory gauge with which to measure effects of this kind. It is hoped that the method of investigation chosen by the writer will serve as such a gauge to answer this question for the world as a whole, and more particularly for Germany, England and the United States.

Research in fundamental science is of little or no value to the progress of a nation unless it is more or less widely disseminated among scientific men, so that they may use the results to strengthen the structure which they are attempting to build. This dissemination usually is carried out by publication in the journals of scientific organizations. If we page through the current chemical publications we find that an investigator is giving us continually citations to previous work of former investigators. It is by studying these citations that we can answer the question which we have set for ourselves. If we choose the most representative publication of American chemistry, the *Journal of the American Chemical Society,* we find that in the last complete volume, 1926, there are reported the results of 459 separate investigations in pure chemistry. The writers of these reports give us 4,857 citations to previous work. These references are to 247 different periodicals and the international scope of science is manifest when one sees that there are represented journals from almost every civilized country in the world.

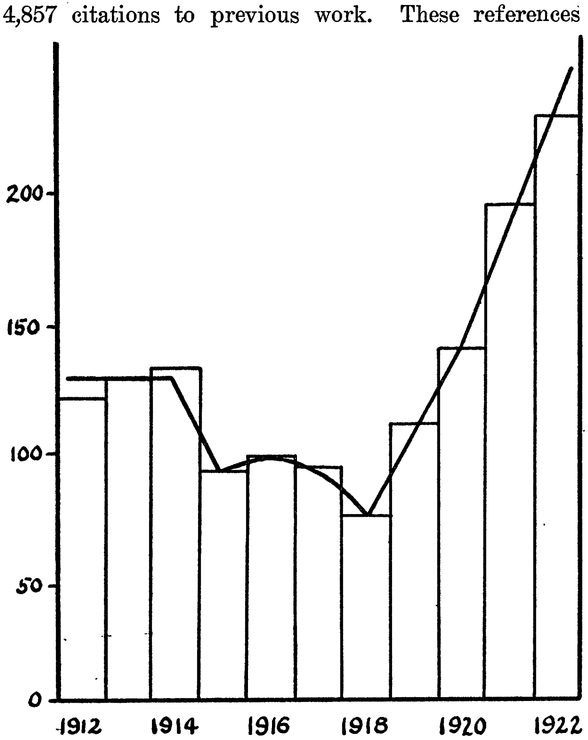

FIG. 1

If we first tabulate the references to articles published from 1912 to 1923, inclusive, according to the year of publication but without reference to the specific country of origin the results in Table I are obtained.

In Figure 1 we have graphically represented the first row of figures. The solid line is not supposed to represent a continuous functional relationship but serves only to show the trend of results from year to year. It will be seen at once that there is a marked decrease in the number of references to articles published in 1915 when compared with the practically static level reached in 1912, 1913 and 1914. We must conclude that there was indeed a falling off in the amount of research in chemistry successfully completed in 1915.

It must be remembered that there will be quite naturally more references to the years immediately preceding the year of publication (1926) of the articles from which the citations have been taken. We should also expect the slope of the "trend-curve" to become greater the nearer we approach 1926. It is because of this difficulty of deciding what might be called "normal behavior" that the years following 1923 are omitted from consideration. Undoubtedly, however, this effect is noticed in the high figure for 1923 and possible also to some extent in that for 1922. That this is true will be seen when one considers that much of the work published in 1926 in the *Journal of the American Chemical Society* was completed and submitted for publication in 1925. Conditions under which academic work is carried out make it highly probable that many of the researches were begun in 1924. In a sense, then, 1923 is very recent as far as literature citation is concerned.

Consideration of the method of investigation here employed will show that we are concerned not merely with the quantity of work published during this period (1912–1923), but that in reality we are concerned only with the good work, the work which has survived and which has proved of value to the investigators who followed. The method, therefore, has a distinct advantage over any method which counts pages or number of papers published in various journals for its basis of comparison.

If we examine the trend-curve in Figure 1 more closely we find an increase to a maximum in 1916–17. A maximum, to the chemist, at once suggests compound formation. In this case it would indeed seem to indicate a compounding of two results: a decrease in one country coupled with an increase in another, the latter becoming more rapid than the former in 1916. That this is actually the case will be shown in the subsequent analysis.

In Figure 2 we have represented in a similar man-

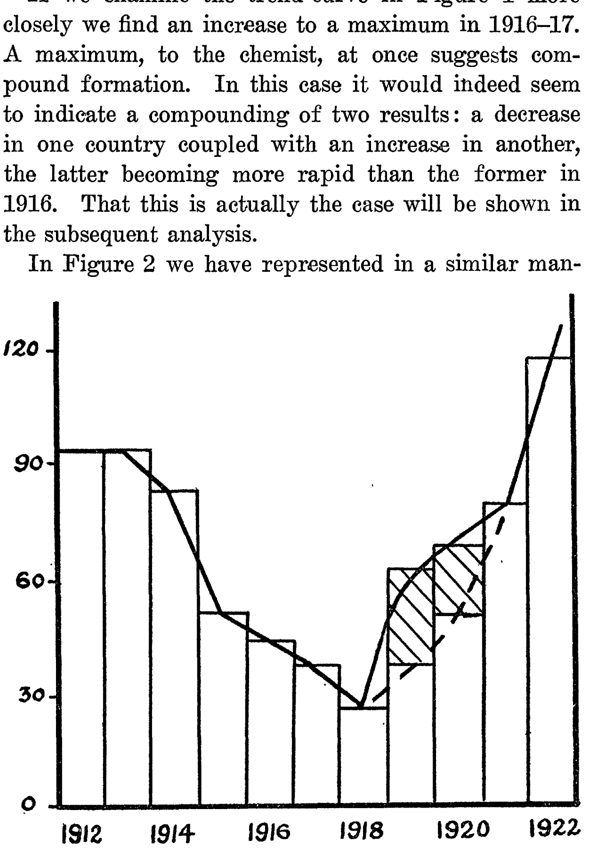

FIG. 2

ner the references to articles which originated outside of the United States. Here we see the falling off in 1915 is even more marked and continues in 1916–17 (instead of rising again as in the previous figure), finally reaching a minimum in 1918. It will be argued by some that research was carried on but was not published during this period because of prohibitive costs and general unsettled conditions in Europe. There are two answers to this objection. In the first place, it has already been pointed out that unpublished research is not completed research, because dissemination of knowledge is essential to scientific progress. Secondly, the trend-curve actually shows that some of this research was published in 1919 and 1920 after hostilities had ceased. If we consider what would be normal recovery from the minimum reached in 1918 we must conclude that the trend-curve should increase in slope with time; it should be concave upward. The dotted line in the figure indicates such a normal recovery curve. The actual curve is, however, decidedly convex. In other words, if we were to choose 1921 as a temporary standard, the number of references to articles published in 1920 and 1919 is too large. The cross-hatched section of these columns is meant to represent the excess over normal recovery. This then is thought to represent research completed during the war but not published until later. This effect will also be found to an equally marked extent in the curves which follow.

It is obvious from consideration of Figure 2 that the course of research in the United States from 1914 to 1919 was different from its course in the rest of the world. We might investigate this still further by studying separately the trend in Germany, England and the United States. This can be done by considering the references to four or five typical journals in each of these countries.

In Table II we find the results of a tabulation of the references to five representative German journals. They were chosen to represent the fields of general, organic, inorganic, physical and biological chemistry. References to *Berichte der deutschen chemischen Gesellschaft* far outnumbered those to any other single periodical in 1926. There was a total of 686 references to this journal. In other words, over 18 per cent. of all references, excluding those to the *Journal of the American Chemical Society,* were to this single periodical. It is the more remarkable, therefore, that there was in 1926 not a single occasion for the investigators in America to refer to work published in the *Berichte* in 1918. It might be said that this is because the *Berichte* for 1918 was not available to American workers, but it should be remembered that although this might have been the case in 1919–20–21, it was not true after that. By 1923 the files of the *Berichte* in American scientific libraries had been brought up

TABLE II

Year	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
Ber.	16	18	10	12	6	5	0	8	11	12	19	21
Ann.	11	3	13	2	3	1	1	1	2	3	2	5
Z. phys. Chem.	4	9	5	1	4	0	0	0	2	5	11	11
Z. anorg. Chem.	1	1	1	1	2	0	2	4	3	6	4	2
Biochem. Z.	2	2	4	1	0	2	0	0	0	1	2	4
German	34	33	34	17	15	8	3	13	18	27	38	43

Ber. *Berichte der deutschen chemischen Gesellschaft,* *Z. phys. Chem.* *Zeitschrift für physikalische Chemie,*
Ann. *Annalen der Chemie* (Liebig's), *Z. anorg. Chem.* *Zeitschrift für anorganische Chemie,*
Biochem. Z. *Biochemische Zeitschrift.*

to date, and therefore this journal was as available as any other when the work we are considering was being carried out.

The results of Table II are graphically portrayed in Figure 3. Here again the effect of the war is very marked and we must conclude that research in this most fundamental science was at a very low ebb in Germany in 1918; that Germany was hard pressed. The typical recovery curve noted in Figure 2 is also present here. Undoubtedly the areas cross-hatched in 1919 and 1920 represent work completed during the war but unpublished until later. Another point should be noticed here. It is that, apparently, recovery in Germany was not complete even in 1923, because, as we have mentioned earlier, we would expect much higher figures for 1922 and 1923 than for 1912 and 1913, because of the nearness of the former to 1926 researches. The broken line in the figure might well represent the normal curve excluding the effect of the war. The area between the broken line and the solid trend-curve is then a representation of the loss to fundamental science in Germany due to the war's effect.

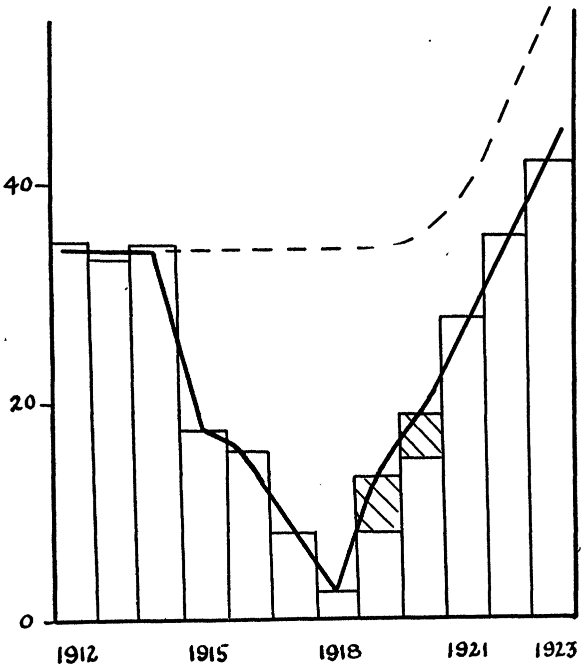

FIG. 3. References to five typical German periodicals.

Turning our attention next to British research we find the results shown in Table III.

It will be seen in Figure 4 that the effect of the war on British chemistry was very similar to the effect noted in Germany, except perhaps that it was not so marked. The British loss was not so great because they did not have so much to lose. The typical convex recovery curve in the cross-hatched area should be noted.

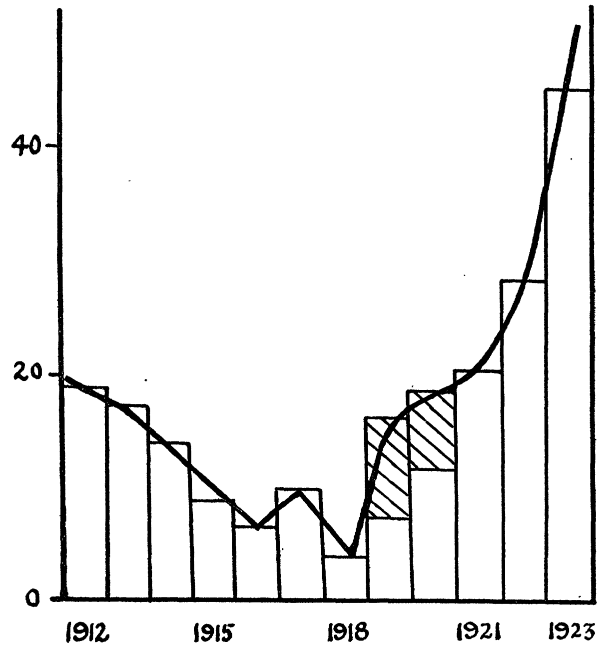

FIG. 4. References to four typical British periodicals.

The ultimate test of this method of measuring the war's effect on fundamental science should come when one considers a typical group of periodicals published in the United States. In 1914, there were in America basic industries, long dependent on Germany for certain essential chemicals; these industries found

TABLE III

Year	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
J. Chem. Soc.	15	13	14	8	5	5	4	10	12	13	17	28
Proc. Roy. Soc.	2	2	0	0	2	1	0	1	1	2	3	7
Phil. Mag.	2	2	0	0	0	4	0	5	5	4	2	2
Trans. Far. Soc.	0	0	0	1	0	0	0	0	0	1	6	8
British	19	17	14	9	7	10	4	16	18	20	28	45

J. Chem. Soc. *Journal of the Chemical Society* (London),
Proc. Roy. Soc. *Proceedings of the Royal Society,*
Phil. Mag. *Philosophical Magazine,*
Trans. Far. Soc. *Transactions of the Faraday Society.*

TABLE IV

Year	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923
J. Am. Chem. Soc.	12	20	31	31	43	43	34	35	61	84	80	157
J. Phys Chem.	4	1	1	2	1	5	3	1	3	2	2	4
J. Biol. Chem.	0	1	4	6	2	2	3	2	7	5	4	13
J. Ind. Eng. Chem.	0	0	3	0	3	1	1	3	2	4	1	11
Phys. Rev.	0	1	0	0	2	3	0	0	3	2	1	2
American	16	23	39	39	51	54	41	41	76	97	88	187

J. Am. Chem. Soc. *Journal of the American Chemical Society,*

J. Phys. Chem. *Journal of Physical Chemistry,*

J. Biol. Chem. *Journal of Biological Chemistry,*

J. Ind. Eng. Chem. *Journal of Industrial and Engineering Chemistry,*

Phys. Rev. *Physical Review.*

themselves suddenly cut off from this source of supply. If we call to mind the need of the textile industry for dyestuffs, the seriousness of such a situation is at once apparent. It is to be expected, therefore, that the war should give scientific research in this country a decided impetus. There should be no marked falling off in 1915. In fact, we should not expect any decrease until after our entry into the war or even until 1918. Let us consider the facts uncovered by this method of investigation.

In Figure 5 the results of Table IV are graphically

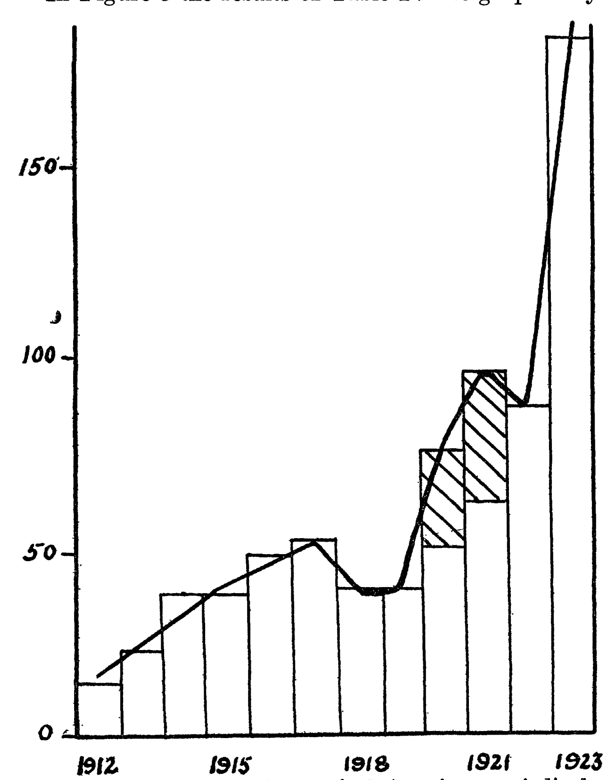

FIG. 5. References to five typical American periodicals.

shown. It will be seen at once that our predictions are correct. The trend-curve instead of dropping off as in the previous cases in 1915 continues to rise until 1917. A slight decrease is found in 1918 and 1919. It will be noted further that there is a difference in the location of the cross-hatched area in this figure. Instead of being in the usual place (1919–20) it is shifted a year to the right (1920–1921). This shift may be explained as due to two causes. The first is that in America, especially in the case of the *Journal of the American Chemical Society,* publication is much slower after submission of the manuscript because of the delay occasioned by sending the manuscript to three or more referees for judgment before publication. This often delays publication for fully six months. The second reason, not an unimportant one, is found in the fact that in America immediately after the war there was an unprecedented rush of the demobilized men to the graduate schools of science. This undoubtedly increased the ordinary curricular and academic duties of the research man in the universities and caused a further delay in the preparation of manuscripts, the work for which was completed during the war. In still other cases, the necessary permission of the War Department had to be obtained before work of this kind could be published. The maximum in 1921 may also be due in part to the work of graduate students who took part in this general return to schools immediately after the cessation of hostilities.

In conclusion we may summarize our findings as follows:

(1) War acts as a serious deterrent on research in combatant countries.

(2) War may give a distinct impetus to science in certain instances, especially in the case of research in countries which maintain neutrality. This is also magnified by the needs of a country (such as the United States in the last war) when it is suddenly cut off from supplies needed for basic industries, *e.g.,* dyestuffs for textiles, etc.

(3) Research in chemistry in Germany suffered far more than it did in England.

(4) The war, on the whole, had a distinctly beneficial effect on research in the fundamental science of chemistry in the United States.

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SCIENTIFIC EVENTS

AWARD OF THE CONWAY EVANS PRIZE TO SIR CHARLES SHERRINGTON

IN February, 1925, the residuary trust funds of the estate of the late Dr. Conway Evans, medical officer for the Strand district, who died in 1892, were transferred to the president of the Royal Society and the president of the Royal College of Physicians of London and their successors in office that, in accordance with the terms of his bequest, they

> shall apply the same in giving rewards to such person or persons who, in the opinion of the presidents, have rendered or shall from time to time render some valuable contribution or addition to science as it exists at the time of my death either by invention, discovery or otherwise.

In accordance with this trust, the president of the Royal Society and the president of the Royal College of Physicians of London have made the first award of the Conway Evans prize, amounting to five hundred guineas, to Sir Charles Sherrington, on the ground that his work on the physiology of the nervous system, and chiefly on the physiology of the brain and spinal cord of the higher animals, has brought many complex nervous functions for the first time within the range of investigation and analysis. His discoveries have had a profound influence throughout the world on the experimental sciences of physiology and psychology and have thrown a flood of new light on many of the symptoms of nervous disease. In making his first award for some valuable contribution to science as it existed at the time of the death of the testator, the presidents of the Royal Society and of the Royal College of Physicians state that they have had no hesitation in selecting as conspicuously worthy of such recognition the work of Sir Charles Sherrington, which they believe to be of outstanding value for science and for humanity.

EXPLORATIONS IN THE REGION OF LAKES TITICACA AND POOPO

AN important journey in the region of Lakes Titicaca and Poopo, according to the *Geographical Journal,* was undertaken last year, with the support of various German bodies, by Dr. K. Troll, of Munich, who describes some of his results in *Petermanns Mitteilungen,* 1927, Nos. 1–2 and 7–8. The program laid down was very extensive, and included a study of the geology and morphology of the Bolivian Altiplano and its surrounding ranges, as well as of the vegetation and the agriculture, actual and potential. The La Paz valley was first examined and its relation to the glacial epoch made out. A careful study of the shores of Lake Titicaca and its ancient terraces was next made, and it was ascertained that the highest level (representing the Lake Ballivian of Bowman) was considerably older than the last ice-age. The next piece of work was the examination of the Cordillera and its eastern escarpment between Illampu and Apolobamba, where little had been known of the direction taken by the crest of the range and its relation to the hydrography. The conditions were found very similar to those of the La Paz system, the range being several times broken through by the Rio Mapiri, so that here too the water-parting is merely the sharply cut edge of the Altiplano. As in the case of the La Paz, the trenching was pre-glacial. Dr. Troll was able to join Professor A. Possnansky in a descent of the Desaguadero from Titicaca to Poopo in a motor boat, this being the first occasion on which the whole course of the river had been navigated. It led to the discovery that the river has since 1922 shifted its course considerably to the east before entering the lower lake. While traversing the Pampa north of Poopo (which is dry and not swamp as shown in the 1–M map of the American Geographical Society) the river flows at a slightly higher level than the surrounding plain, and its bank seems to have been breached at high water. Much attention was paid to the history of the lake basins in recent geological times, and some of the conclusions of Bowman as to the relations of the two ancient lakes ("Ballivian" and "Minchin") are considered to be incorrect. Both the modern lakes have shown a decided rise in level of late years. This had been known for some time as regards Titicaca, but Dr. Troll was able to establish the fact for Poopo also, where much vegetation on the banks has been killed by the flooding. It seems that the cause is a climatic one. Even though the journey was made at the end of the dry season, Poopo was found to be discharging by the Lacahuira River towards the "Salar" of Coipasa, although the lake has been held (as by Neveu-Lemaire of the French Commission of 1903) to have no outlet. (May not the discharge be a recent phenomenon, due to the rise in the level of the lake?) Dr. Troll ends by speaking of small remnants of primitive inhabitants that are still to be met with on the Altiplano, distinct from the Aimara and Quechua, and discusses recent projects for using the Desaguadero for navigation and irrigation. At the time of writing he was continuing his researches.