come scattered throughout the cell not only peripherally but especially among the secretory granules. In the vertebrates, there is the usual network, at first of simple type, later showing a progressive increase in complexity. But the most interesting feature in this type of cell is that the network gradually extends itself among the accumulating secretory granules, so that (with an exception of no importance here) it is brought into contact with many or all of the developing granules. The behavior of the Golgi apparatus thus enables one to distinguish a serous from a mucous cell by the mere difference in the relation set up between the granules and the Golgi network. It would appear that mucous granules are rapidly synthesized and separated from the Golgi area upon completion; while serous granules undergo a more gradual development (as shown indeed long ago by Altmann in the parotid, for example), the entire granular complement coming simultaneously to maturity at the end of a secretory cycle.

Cells producing lipoidal secretions have been studied in the oil glands of the chicken and duck, in the inguinal and Harderian (white portions) glands of the rabbit and in the Meibomian glands of the cat. The details differ somewhat in these different glands, but all agree in the fact that the Golgi apparatus, beginning as a more or less temporary polarized mass or network, is eventually disrupted and scattered as separate Golgi fragments or bodies throughout the cell. In some cases this is accompanied by a complete loss of cellular polarity, the nucleus moving into an indifferent central position. At the end of the secretory cycle, the entire cell is in all cases lost together with the secretory products. In the secretion thus produced, the Golgi pieces can in some cases (oil gland of duck and one part of the white portion of the rabbit's Harderian gland) actually be seen, still retaining, though outside of cellular boundaries, their identity and often their original intracellular shape—a striking demonstration of the real, material existence, often denied, of the Golgi apparatus.

In addition, the vas deferens and epididymis of the cat and rabbit and the liver of the cat have been examined, revealing networks of characteristic development and the usual polarity, but of types not readily classified in the groups indicated above.

These studies bring out in a surprising way the interdependence of the topography of the Golgi apparatus in a gland cell and the type of secretion being produced. In no case is this better demonstrated than in the submaxillary of the cat, where the demilune cells have been shown to possess a Golgi network obviously different from that in the mucous cells. This demonstrates beyond a doubt that these cells belong to different categories, and are in no way related to each other histologically—as many have supposed. Further, the topography of the Golgi apparatus in the demilunes indicates that they are cells of the serous type—a view reached on different grounds by other workers.

A detailed report of this work is now being prepared for publication.

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THE NATIONAL ACADEMY OF SCIENCES

ABSTRACTS OF PAPERS PRESENTED AT THE WASHINGTON MEETING, APRIL 25 AND 26

Deviation from the regular as an art principle: DR. C. E. SEASHORE and MILTON METFESSEL, State University of Iowa. This paper contains an exhibit of various renditions of the song "Annie Laurie" as transcribed by a photographic method. Records of this type permit us to express quantitatively and in fine detail the expression of artistic emotion in singing in terms of variations in pitch, time and intensity. Volume, timbre and other complex factors may also be determined by an extension of the same principle of measurement. One complete score of "Annie Laurie" as sung by Wells is exhibited with illustrative sections from twelve other singers in support of general principles discovered.

The rôle of mental measurement in the discovery and motivation of the gifted student: DR. CARL E. SEASHORE, University of Iowa. The paper discusses the scope and significance of measurements of first, magnitude; second, fixity; and third, intricacy in organization of varieties of individual differences; and illustrates this by new methods of procedure in the progressive selection and elimination of students at the college level. New aspects of three procedures are discussed, namely: first, diagnostic examinations in determining fitness for college work near the end of the high school course; second, placement examinations measuring, (a) training and (b) aptitude for each of the subjects open to freshmen; and third, a scientific approach to the building of the achievement examinations.

Biology and the principles of physics: PROFESSOR WOLFGANG KOHLER, University of Berlin. Wherever we find order in the processes of nature, we are inclined to assume that special arrangements bring about this order, compelling the forces of nature to work along certain lines with exclusion of others. Greek astronomy is an instance of this tendency. But in our times again, biology and psychology are used to explain the striking order in organic processes by the assumption of an extraordinary amount of special arrangements or machine-structures that are said to produce the observed order of functions. We have learned to regard our sun-system as a whole maintaining itself and its order by free intercourse of natural forces. But we generally forget

that perhaps much of the orderly functions and the self-maintaining reactions of organisms might be also the natural consequences of free intercourse of forces and processes in the whole of a living body. The processes and reactions in an inorganic system under given circumstances tend towards a certain equilibrium-order or distribution, and, before assuming that all the order and "fittedness" in organic processes is enforced by the constraints of special arrangements for all the special cases, we ought to examine how far that other kind of order, produced by relatively free interaction, may happen to occur in organisms and how far it may explain the striking features of organic life. Even in modern technics we find already some instances where the free tendency of systems towards an orderly equilibrium-distribution produces the same order that usually is enforced by clumsy machine-arrangements. And—surprising for many, not for the physicist—the order produced in the new way is more exact, is a better order than all the order artificially produced by means of machine-constraints. If we could give more attention to possibilities of this kind in organic life, some of the arguments of vitalism might perhaps lose their force.

Protoplasmic action of copper and gold: CARL VOEGTLIN, J. M. JOHNSON and HELEN A. DYER, Hygienic Laboratory, Washington, D. C. This work represents part of an investigation dealing with the toxic action of various heavy metal salts. These compounds are usually referred to as protoplasmic poisons, which means that in high dilution they exert a toxic action in all kinds of protoplasm. To illustrate, 1 part of copper in 100,000,000 parts of water will kill spirogyra in a few minutes. On account of this property the heavy metal salts are widely used as antiseptics, germicides and fungicides. The mechanism whereby these traces of heavy metal salts exert their toxic action is very little understood, and therefore, the main object of this work was to secure some information along this line. Most of the experiments were carried out with albino rats, but some work was also done with lower animals, for instance, tadpoles and plant cells (spirogyra). It was found that copper and gold salts can be detoxicated by the simultaneous injection of certain organic sulphur compounds containing a SH group. In the case of copper, glutathione and cystein are effective antidotes in rats. In the case of gold chloride, glutathione alone is effective. Similar observations were made on tadpoles and spirogyra. Inasmuch as some of these sulphur compounds are normal constituents of protoplasm this evidence suggests that copper and gold salts exert their toxic action through combining with these sulphur substances in the cells. In order to further support this hypothesis copper and gold derivatives of glutathione and cystein were actually prepared, thus showing that these heavy metal salts enter into chemical reaction with these substances.

Solubility of carbon dioxide in various organic solvents at low temperatures: FRANK PORTER. The solubility of carbon dioxide in sixteen organic liquids and in mixtures of these were investigated at -76.84 degrees centigrade. The effect of temperature on the solubility was also determined for acetone, ether and one of the mixtures. The solutions of carbon dioxide in ketones and esters of organic acids were found to approximate the ideal solution calculated from Raoult's law. Solutions in the hydrocarbons and sulfides show much greater deviations from the ideal solution at low temperatures than at room temperature. Neither the internal pressure nor the polarity as indicated by the dielectric constant serve as a satisfactory guide in predicting the solubilities of carbon dioxide. A similarity of structure is much more useful, the compounds containing the group $\begin{array}{c}|\\ C=O\\ |\end{array}$ being the best solvents.

The origin of terrestrial helium and its association with nitrogen and hydrogen: S. C. LIND, U. S. Bureau of Mines. Helium occurs in dilute concentration in the atmosphere and in rocks, radioactive minerals and waters of the earth's crust. In much greater concentration it occurs in certain natural gases associated principally with the lower paraffin hydrocarbons and nitrogen. Notwithstanding the increasingly larger quantities of helium found stored in natural gas pools, they do not exceed possible accumulation from radioactive processes extended over known geological time, without assuming improbable modes of collection.

The question has been raised as to how helium is liberated from minerals and rocks. The fact that a large proportion of it *is* liberated is borne out by the low He: Pb ratios found in the radioactive minerals. If all products of atomic disintegration retained *in loco*, lead and helium would accumulate in the ratio of 8 He: 1 Pb in uranium minerals, and 6 He: 1 Pb in thorium minerals. In reality only one third to one sixth or less of the theoretical helium is retained, which may be regarded as direct proof of leakage, either into gas structures or into the atmosphere.

The evolution of helium from minerals or rocks may be promoted by the "sweeping" action of other gases generated *in loco* by the action of the initial particles on compounds capable of being decomposed to form gases such as nitrogen, hydrogen or carbon dioxide. The ratio of He to foreign gases might vary over a wide range, depending on the proportion of material in the structure capable of decomposition. The fact that the He: N_2 ratio is much higher within radioactive minerals than in natural gases indicates that adsorption is not responsible for their presence in the mineral, but rather the reverse, evolution from the mineral and later further dilution with extraneous sweeping gases. The possible genetic origin of nitrogen from uranium is discussed.

The foundations of electric circuit theory: J. R. CARSON. Electric circuit theory is that branch of general electrical theory which deals with electrical oscillations in electrical circuits and networks: more precisely stated, with the distributions of currents and charges in the free oscillations of the network or under the action of impressed forces.

The enormous importance of electric circuit theory in electrotechnics does not require emphasis: it is funda-

mental to the engineering theory of transmission and to the design of all terminal apparatus as well as transmission lines.

Historically, the development of electric circuit theory preceded that of electromagnetic theory in the hands of Maxwell and later of Lorentz. In fact, circuit theory is based entirely on the simple laws of Faraday and Kirchhoff. It is true that Maxwell developed a dynamical theory of electric circuits, but this amounts to little more than a more elegant way of deriving the equations of circuit theory and is based on the same assumptions and subject to the same restrictions as is the Faraday-Kirchhoff theory.

The object of this paper is to examine the foundation of electric circuit theory from the fundamental equations of electromagnetic theory. This will involve a derivation of the laws of electric circuit theory directly from the electromagnetic equations in the course of which the assumptions, approximations and restrictions of circuit theory will be explicitly stated.

Such an analysis is believed to be both desirable and necessary. In the first place, circuit theory, by reason of its early development, is based on a philosophy which for the most part is quite foreign, and in its implications often contradictory to the underlying concepts of electromagnetic theory. This is evidenced by the complete divorce, in treatises on electromagnetic theory, such as that of Jeans, between the chapters on general theory and those dealing with the theory of currents in linear networks. In fact, in no treatise known to the writer is there any attempt to bridge the gap or to bring circuit theory within the scope of electromagnetic theory in a satisfactory manner. Furthermore, as circuit theory is usually taught to technical students, a general picture of electromagnetic theory is not given, and the student comes to regard inductance, resistance, capacity, voltage, etc., as fundamental concepts.

A second consideration is believed also to justify the present study: This is the fact that in the course of technical development an increasing number of problems is being encountered, which lie quite outside the scope of circuit theory, or in which the conclusions derived from circuit theory must be interpreted with great care.

This situation may be illustrated by an analogy from mechanics. Suppose that the laws and theory of rigid mechanics were accepted as fundamental and that the elastic properties of the mechanical constraints were ignored. It is obvious that, while little error would follow in a large class of problems, a whole range of phenomena would lie completely outside the scope of mechanics. This analogy is more than a superficial illustration because the dynamic theory of electric circuits is precisely the same as that of rigid mechanics and its limitations of precisely the same character.

The odorous constituents of the cotton plant; emanation of ammonia and trimethylamine from the living plant: FREDERICK B. POWER and VICTOR K. CHESNUT, Bureau of Chemistry, U. S. Department of Agriculture. It has been recognized that the cotton plant possesses a specific attraction for the boll weevil, and this has been attributed to some volatile odorous substance emitted by the plant which could be perceived by the insects at a considerable distance. It has accordingly been considered by Dr. L. O. Howard, chief of the Bureau of Entomology, U. S. Department of Agriculture, that if any odorous substance could be identified, which by chemotropic tests would be found attractive for the insects, it might be possible to produce it in sufficient quantities to permit of its use as a bait.

In pursuance of the above-mentioned plan the Bureau of Chemistry was requested to undertake a comprehensive study of the subject, and the investigation was begun in the summer of 1923. As the primary purpose was to ascertain the chemical character of the odorous or volatile substances, it was apparent that these could best be obtained by the distillation of the cotton plant with the aid of steam. This operation was conducted during the months of July and August at Tallulah, Louisiana, where all the facilities of the Delta Laboratory of the Bureau of Entomology were generously placed at our disposal.

A field of choice Upland cotton, comprising about ten acres, had been selected for our use, and this was comparatively free from infestation with weevils. The plants were cut off a few inches above the ground, and the material employed consisted chiefly of the foliage, together with the flowers, squares and a few small bolls, the coarse woody stems having been rejected. Not more than about two hours elapsed between the cutting of the plant in the field and the beginning of distillation. The total amount of material distilled was 7,255 pounds or 3,290 kilograms and the total original distillate amounted to about 1,400 gallons or 5,300 liters.

The next step in the process was to concentrate the original distillate in order that the odorous constituents might be contained in a smaller volume, and this was accomplished by its redistillation from a smaller apparatus. The complete examination of this concentrated distillate, which amounted to 78 gallons or 295 liters, was conducted in the laboratory of the Bureau of Chemistry.

The so-called *essential oil* of the plant was obtained by extracting a portion of the concentrated distillate with ether, and the yield of this product was about 0.003 per cent. of the material employed. It was a pale brownish-yellow, limpid liquid, having a strong, rather agreeable and persistent odor.

The concentrated distillate, which represented all the odorous and volatile constituents of the plant, was the product employed for their separation and identification. It was found to contain the following individual substances: (1) Methyl alcohol, in large amount, and traces of acetone; (2) amyl alcohol, in relatively small amount, together with small amounts of higher homologues; (3) acetaldehyde, and traces of an aldehyde of higher carbon content; (4) vanillin, $C_8H_8O_3$, in very small amount; (5) a phenol, in exceedingly minute amount. This substance is either a derivative of *m*-cresol or a phenol that possesses very similar characters; (6) an optically inactive, dicyclic Sesquiterpene, $C_{15}H_{24}$; (7) a new, optically active, tricyclic Sesquiterpene, $C_{15}H_{24}$; (8) a small amount of a paraffin hydrocarbon, m. p. 62°, which apparently is

triacontane, $C_{30}H_{62}$; (9) a blue oil, which probably contains the highly unsaturated hydrocarbon, azulene, $C_{15}H_{18}$; (10) formic, acetic and caproic acids, the latter in small proportion, which probably were present to some extent in combination with the previously mentioned alcohols as esters; (11) ammonia; (12) trimethylamine.

The two last-mentioned basic substances were present in appreciable amounts in the distillate, but the ammonia largely predominated. Both ammonia and trimethylamine were also found to be emanations from the living plant, and they have been identified in the dew collected from the foliage. It has been recorded that so small an amount of trimethylamine as 0.0000005 gram can be distinctly detected by its odor.

The more complete details of this investigation must necessarily be reserved for a future publication.

Report on southern nebulae: DR. HARLOW SHAPLEY, Harvard Observatory. (1) The absolute magnitudes and linear dimensions of a large number of diffuse nebulae have been measured recently in the course of studies on the star clouds of Magellan. These extensive star systems are themselves now taken as representative of a large class of non-galactic nebulae. They are, in a sense, the nearest of the spiral nebulae, and being only one hundred thousand light years distant are most suitable for detailed analysis of structure and content.

(2) Recent photometric measures have shown that the absolute magnitudes of the diffuse nebulae and nebulous clusters are approximately −5. Their diameters range from five to twenty light years.

(3) The greatest diffuse nebula now known is 30 Doradus, the Looped Nebula in the Large Magellanic Cloud, for which the diameter is nearly five hundred light years and the absolute brightness about −14.

(4) The spiral Messier 33 compares closely with the Large Magellanic Cloud in linear dimensions and integrated absolute brightness, but it is nearly nine times as far away. The nuclei in the arms of the spiral are of about the same brightness and dimensions as the gaseous nebulae and smaller nebulous clusters in the Magellanic Clouds.

(5) In the investigation of faint southern nebulae of the spiral family, several thousand new objects have been catalogued at the Harvard Observatory. A statistical examination of this material shows that the spheroidal subclass furnishes four fifths of the nebulae that lie outside the Milky Way.

(6) As a contribution to the problem of nebular distribution and form, the whole southern sky is being systematically covered with long exposure photographs, made with the Bruce telescope at Arequipa, Peru. The program is considerably more than half completed.

Measurements of the variation: DR. C. G. ABBOT, Smithsonian Institution. Mr. Clayton, who is about to address you, will present evidence that the variation of the sun is of importance for weather forecasting. It is for me to try to show you just what he means by the variations of the sun, and why he believes that it is a reality.

For over twenty years, the Smithsonian Institution has been carrying on measurements of the solar constant. We have operated at eight different observatories at various levels and under a great range of atmospheric conditions. We have invented improved apparatus and processes for applying Langley's method of high and low sun spectroscopy. About six years ago we devised another very brief empirical method based upon it. By our new method it is possible for two observers to make and reduce five independent determinations of the solar constant in a working day. The new method also avoids errors from changes of atmospheric transparency during the interval of several hours between high and low sun.

For the past five years, we have maintained two observatories for this work. One is on a desolate mountain in central Arizona, called Mt. Harqua Hala. The other is on a completely barren mountain in northern Chile, where no living thing grows or moves. We receive daily telegraphic reports from both stations, and we make up from them daily morning telegrams to Mr. Clayton, giving him the solar constant value of the morning next preceding. This is the information on which his recent results are based.

Figure 1 shows the run of ten-day mean solar constant values from 1920 to 1924. You will perceive two different levels for the years 1920–21 and 1923–24, respectively. The year 1922 is a transition year. The two levels are nearly 3 per cent. apart and indicate prevailingly low values in more recent times. The mean of our entire series of nearly twenty years of observation has not been reached by more than a half dozen ten-day mean values for nearly three years.

Can we believe this? Does the sun really vary in this way? Figure 2 shows a comparison between sun-spot numbers and our solar constant values for twenty years. Evidently, according to past experience, we are to expect lower values at a period of sun-spot minimum such as has prevailed from 1922 to 1925.

But there is a more minute type of solar change revealed by our results. They show that irregular variations of one or more per cent. occur in the output of solar radiation in short periods of a few days. These changes are supported by the combined testimony of our two observatories. They seem to be associated with visible features upon the sun, such as sunspots and faculae. In other words, though presence of very numerous sunspots betokens high solar radiation, yet whenever one of them marches across the center of the sun's disk there is a brief interval of diminished solar radiation. It appears as if a solar cloud overshadows each sunspot, which, when it comes squarely between the earth and the sun, produces a small depression of radiation.

Without distinguishing between the two types of solar variation, I have sought to localize it in the spectrum, or in other words to see if all parts of the spectrum share it equally. Figure 6 shows that, far from this being the case, solar variation is almost wholly confined to wavelengths less than 0.5 microns, that is to the blue, the violet and the ultra-violet spectrum.

Mr. Clayton will tell you still more of interest relating to the solar variation. He will show that he is even able

to predict it five days in advance, with considerable success, from visual observations of the sun's surface. I leave the matter now in his hands, confident that I have presented enough to lead you to believe that the solar changes which he is connecting with weather and climate are real.

The dependence of the earth's weather on variations of the sun: H. H. CLAYTON, Canton, Mass. The investigations of Langley, followed by the persistent researches and efforts of Abbot and his colleagues, have demonstrated that our sun, like so many of the stars in space, is a variable. Its radiation of light and heat varies from day to day, from month to month, and from year to year. The change when measured in percentages of the total radiation is small, but is measurable by the delicate apparatus of modern science. "It was found that with every class of variation of solar radiation, whether of a few days', a few months,' or many years' duration, as in the sunspot period, the normal areas of high and low pressure in the earth's atmosphere swing north and south in unison with the changes in solar radiation, and thus determine excesses or defects of temperature and rainfall which swing north and south with the pressure, the effects increasing in intensity with increasing latitude," said Dr. Clayton. "In the northern United States and Canada these changes may amount to as much as 40 degrees Fahrenheit with a departure of only one per cent. of solar radiation on either side of the normal, and the rainfall may change from double the normal amount to less than half normal, which if long continued becomes a severe drought. In winter the excess of pressure is over the continents and in summer over the oceans.

"It was already known from Dr. Abbot's work that the amount of heat radiation from the sun varies with the number of sunspots in the eleven-year sunspot period, being greatest at maximum sunspots. Further research discloses that the day to day variations of solar radiation are closely related to the position of sunspots and faculae on the face of the sun as seen from the earth. When the spots and faculae are on the central meridian of the sun, there is a diminution of solar radiation, probably resulting from absorption, and an increase above normal when the spots and faculae are on the edges of the sun. The side of the sun on which the spot is located averages cooler than the opposite side, and there appear to be periodic oscillations of about 3½, 7 and 14 days, which are in some way related to solar conditions.

"When the meteorological data in the United States are compared with the pressure and temperature in the United States, the same relations are found as would be expected from the correlated changes in solar radiation. The passage of spots across the central meridian of the sun is immediately followed by low pressure at central continental stations like Winnipeg, and higher pressure is found at the same stations on the average when the spots and faculae are on the eastern and western limbs of the sun.

"The relation to the temperature is opposite to that of the pressure. When studied separately for the four seasons, winter, spring, summer and autumn, similar relations to the position of the spots and faculae are found for each season, but the effect is delayed about one day in spring and autumn, and two days in summer, as compared with winter. The high correlation of the separate independent relations with each other is a further proof of the reality of the relations.

"It is thus evident by several different lines of research that there is an intimate relation between solar changes and weather, and the results promise to revolutionize the art of weather forecasting. Already the Argentine Weather Service is practically applying the observations of solar radiation and visual observations of the sun to forecasting, and has established a solar observatory for independent research. That other national weather services will follow in the near future is certain."

Evidences of recurrent glaciation in the Sierra Nevada of California: F. E. MATTHES, U. S. Geological Survey. The glacial history of the Sierra Nevada has been a subject of popular as well as scientific interest ever since the early seventies of the last century, when John Muir and Professor Josiah D. Whitney engaged in their historic controversy over the origin of the Yosemite Valley. Yet it is only since 1913 that any really definite information has been at hand concerning the extent of the main glaciers on the west flank of the range, nor of the history of their successive advances. In that year a systematic and detailed survey of the moraines and other glacial features of the Yosemite region permitted for the first time a definition of the exact extent reached by the ancient Yosemite Glacier in each of two distinct glacial stages. Supplementary studies of a similar nature have since been carried on in the basins of the Stanislaus, Tuolumne, Merced and San Joaquin rivers. The results may be summarized as follows:

(1) There are on the west flank of the range two distinct series of moraines, an older and a younger, that record two stages of glaciation divided by a lengthy interval of essentially nonglacial conditions. The older series itself probably will prove upon further study to embody a multiple record.

(2) The last stage of glaciation is comparable in point of recency to the Wisconsin stage of the continental ice sheet. The earlier stage or stages remain as yet uncorrelated.

(3) That the two great ice extensions recorded in the moraines took place in two distinct glacial stages and were not mere fluctuations in an otherwise continuous cycle of glaciation is abundantly attested by:

(a) The marked contrast in the degree of preservation of the two moraine series, the younger being conspicuous for its fresh, sharp-crested forms and unweathered boulders; the older being dimmed and in part destroyed by disintegration and erosion, and composed of boulders so badly decayed that many are readily trenched with a pick;

(b) The equally marked contrast in the aspect of the rock floors that were covered by the earlier and later glaciers, respectively, the latter still retaining polish and

striae over large areas, the former being eroded into irregular forms and having completely lost their glacial facies;

(c) The considerable depth of stream erosion accomplished since the deposition of the older drift, as compared with the insignificant depth of the postglacial stream erosion; the ratio being approximately 10 to 1.

(4) The remoteness of the earlier glaciation, further, is strikingly attested by the fact that some boulders of the earlier drift are perched on rock pedestals several feet in height; also by the presence of residual rock forms that stand five to fifteen feet high above the old glaciated rock surfaces.

Most clean-cut and instructive are the residual rock features situated north of the Little Yosemite Valley, on the summit of Moraine Dome, which locality may be said, indeed, to hold the key to the glacial history of the Sierra Nevada. They resemble little garden walls, and are formed by dikes of aplite that disintegrate with extreme slowness as compared with the surrounding granite. Their height—seven to ten feet—affords a minimum measure of the stripping which the dome has suffered since the departure of the earlier ice, and permits an estimate to be made of the time that has since elapsed. As the same granite on the lower slopes of the dome still retains the polish of the last glaciation, which is conservatively estimated to be 10,000 to 15,000 years old, the stripping indicated by the aplite walls on the summit would indicate a lapse of time expressible in terms of hundreds of thousands of years.

(5) Systematic mapping of the two moraine series shows that the earlier glaciation was much the more extensive of the two. The earlier glaciers attained lengths of over sixty miles—they were the largest glaciers that existed in southern latitudes in the United States, and together formed a continuous system that far exceeded in extent any similar glacier system in the southern Rocky Mountains. It is clear, moreover, that the bulk of the glacial excavating in the Yosemite Valley, as well as in the other Sierra canyons, was performed by the earlier glaciers.

(6) At no time was the Sierra Nevada completely domed over; its highest peaks and crests always stood well above the ice. Neither did the glacial mantle extend more than half way down the west flank. Even the trunk glaciers did not reach within thirty miles of the foothills, and the intercanyon divides remained uncovered up to altitudes ranging from 5,000 to 7,000 feet.

(7) The variations in the extent of the glacial mantle of the Sierra Nevada, from north to south, reflect the intercepting effect of different parts of the Coast Ranges on the water vapor borne landward by the winds from the Pacific Ocean. Within certain geographic limits this intercepting effect was a stronger factor in determining the distribution of the ice on the Sierra Nevada than either latitude or altitude.

(8) The ice lines of the two glacial stages, though 3,000 feet apart in altitude in the Yosemite region, rapidly approach each other in the High Sierra and practically coincide in the summit cirques. These cirques, which were the ultimate sources of the glaciers, evidently were filled to no greater depth in the earlier than in the later glaciation. This circumstance, taken together with the fact that the lowest level of glacier generation was about the same in either stage, would show that the climatic conditions in the two glacial stages were closely similar. The greater extent and volume of the earlier glaciers is to be attributed, therefore, largely to the greater duration of the period of snow accumulation in the earlier stage.

Report of ether drift experiments: DR. DAYTON C. MILLER, Case School of Applied Science, Cleveland, Ohio. Observations on the Michelson-Morley ether drift experiment have been continued at Cleveland in 1923 and 1924, and at Mount Wilson in 1924 and 1925. The Mount Wilson observations consistently give results indicating a small positive effect. The final interpretation will depend upon observations to be made later in this year.

Distribution of the stars with respect to brightness and distance from the milky way: DR. FREDERICK H. SEARES, Mt. Wilson Observatory, and P. J. VAN RHIJN, Kapteyn Astronomical Laboratory, Groningen, Holland. A new determination of the numbers of stars of different degrees of brightness within the reach of large telescopes and their distribution over the sky is the culmination of several years work by Frederick H. Seares, of the Mount Wilson Observatory, and P. J. van Rhijn, of the Kapteyn Astronomical Laboratory at Groningen, Holland. The results show that in the whole sky at least a billion stars could be photographed with the 100-inch reflector of the Mount Wilson Observatory, and that from 20 to 40 times as many more stars are too faint to be directly observed.

It has long been known that the stars form a system, filling a flattened, watch-shaped region of space, with the Milky Way lying in the central plane of the "watch." It is also known that the stars thin out in passing from the sun, which is not far from the center of the system, to regions more and more remote.

The stars whose distances can be directly measured are all so near that they do not determine the structural features of the system, which must be learned from star counts, such as those just completed, whose numerical values reflect the way in which stars are scattered through space. Were the stars all equally luminous, the obvious differences in brightness noted by the eye would be merely the effect of differences in distance, which could easily be calculated. Actually, the range in stellar luminosity is enormous; this complicates the problem, but the structure of the system can still be determined from star counts, provided the numbers of stars of different luminosity in a given region of space can be found. The way in which luminosity is apportioned among the stars is at present imperfectly known, although well enough defined for provisional use of the counts.

To be useful such counts must be to accurately determined limits of brightness, and therein lies the chief difficulty in the way of obtaining satisfactory results. Modern telescopes cover a range of 20 magnitudes or more, and the establishment of standards of brightness over this interval to serve as reference objects for the counts requires the ultimate comparison of sources of light whose intensities are to each other as 100,000,000 to 1. Even when the sources are of nearly equal intensity, the uncertainty of comparison is at least one per cent., and usually more. Comparable difficulty in the measurement of lengths would mean, for example, an error of several inches in the determination of the dimensions of a room. When the difference in the intensity of the light sources is large, the errors of measurement become very troublesome and, except for unusual precautions, seriously affect the results.

The present investigation was therefore preceded by a redetermination of the magnitude scale, which resulted in the standard magnitude of stars at the North Pole published by Seares in 1915. To the sixteenth magnitude these results have since been confirmed by measures at several other observatories, and are the basis of the scale adopted by the International Astronomical Union at Rome in 1922. For the fainter stars the Mount Wilson values are still the only ones available.

The number of stars is so large that a complete enumeration for the whole sky is hopeless, and, indeed, unnecessary, for the underlying unity and regularity of the system is such that representative samples comprising but a minute percentage of the total is sufficient to reveal the chief characteristics of distribution.

The regions actually observed were the 139 Selected Areas of Kapteyn, uniformly distributed over the sky between the North Pole and declination —15 degrees. Measures made at Mount Wilson on photographs of 15 minutes exposure determined the scale in each area and the magnitudes of 65,683 stars. Similar measures made at Groningen on Mount Wilson photographs of an hour's exposure gave the magnitude of 44,910 stars. The total number of individual stars is about 70,400.

The numbers of stars in each half-magnitude interval were counted separately for each series of measures. The results for the different areas were arranged in order of increasing distance from the Milky Way (galactic latitude) and combined into groups to reduce the influence of irregular fluctuations in the number of stars from area to area. The counts were further combined so as to give for different galactic latitudes the total numbers of stars per square degree from the brightest down to successive half-magnitude limits of brightness. The mean results for the two series of counts, which are practically identical, completely determine the distribution of the stars between photographic magnitudes 13.5 and 18.5.

The distribution between the fourth and the ninth magnitudes is based on counts published by van Rhijn in 1917, which had only to be referred to the International scale of magnitudes to make them directly available. The gap between the ninth and thirteenth magnitudes was filled in with the aid of results published by Turner for about 1,400,000 stars in 33 zones of the Astrographic Catalogue, a cooperative undertaking begun forty years ago. The magnitudes for these stars were determined by comparing the counts with van Rhijn's tables of distribution after the latter had been reduced to the International Scale.

The final combination and adjustment of the results from these various sources showed the progression in the numbers to be so regular that they could be extended to the twenty-first photographic magnitude, which is the practicable limit attainable on long-exposure photographs with the largest telescopes. The resulting distribution table thus covers an interval of 17 magnitudes. It confirms and more precisely determines what in a general way was previously known and is a basis for further detailed study of the way in which stars are distributed in space.

At all points in the sky the total number of stars to the fifth magnitude is 2.9 times the total to the fourth magnitude. This ratio of totals to successive magnitude limits falls off with decreasing brightness, most rapidly in the direction of the poles of the Milky Way, so that in passing from the twentieth to the twenty-first magnitude the total in the Milky Way is increased 1.8 times while at the poles the increase is only about 1.4 fold. These ratios show that the stars thin out with increasing distance from the center; that at great distances they thin out more rapidly than near the sun; and that the phenomenon is most pronounced in the direction of the poles of the Milky Way, results which are directly related to the flattened, watch-shaped form of the system.

Stars of all magnitudes are most numerous in the Milky Way, but the concentration in the Galaxy is very much greater for faint than for bright stars. For the stars of the fourth magnitude the ratio of the numbers per square degree in the Milky Way and at the poles is 3.4; for the twenty-first magnitude it is 45. The actual totals per square degree to this latter limit are 74,000 and 1,660, respectively. The corresponding total for the entire sky is 890,000,000. With allowance for the fact that the very faint stars are red, this last number is the equivalent of a billion stars to the twentieth *visual* magnitude.

The decrease in the ratio of the totals to successive magnitude limits can be used to estimate the probable number in the whole system. If the rate of decrease shown by the stars within telescopic reach holds for those too faint to be directly observed, the total must be 30 to 35 billions; but the assumption involved is extremely precarious and probably the limits must be widened to something like 20 and 40 billion. In any case, the number of stars beyond the limit of direct observation is certainly many times that within the reach of the most powerful telescopes.

The great importance of the Milky Way as a structural feature of the system is indicated by the fact that 95 per cent. of all the stars are within 20 degrees of the galactic plane; the remaining two thirds of the sky contains but 5 per cent. The lateral extent of the stellar system is therefore many times its thickness.