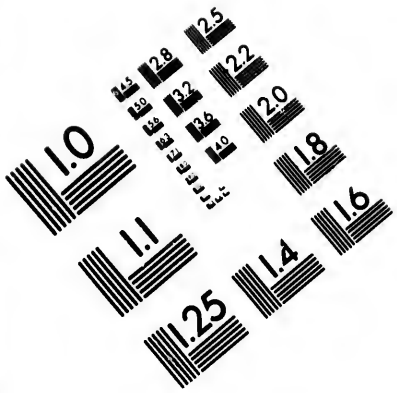

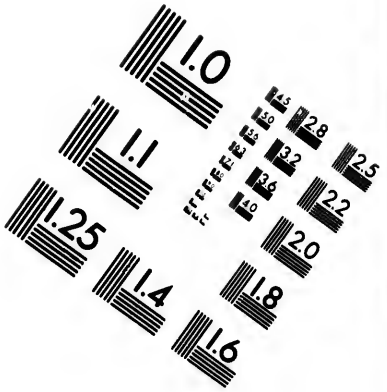

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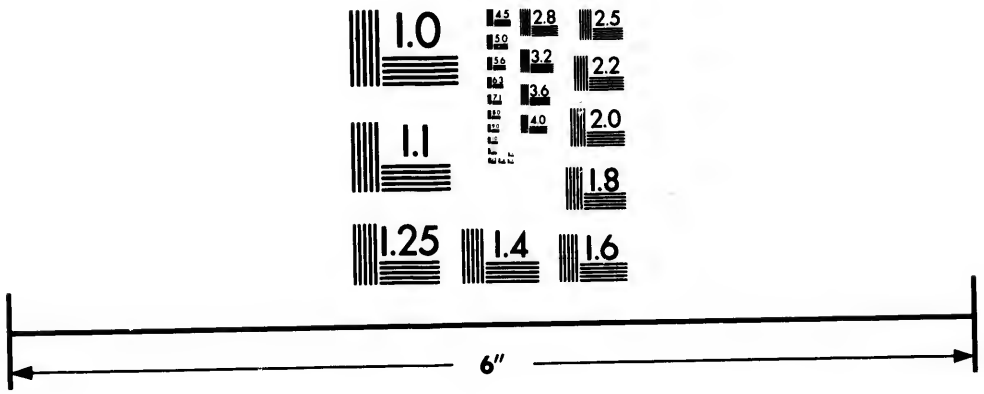

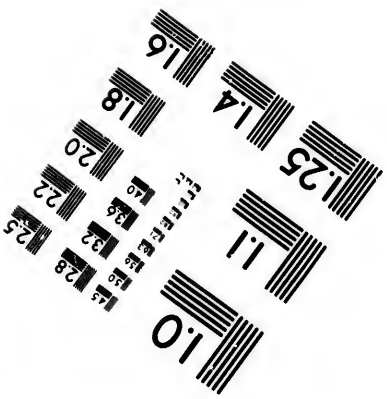

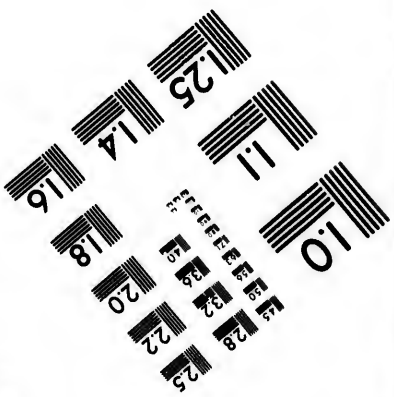

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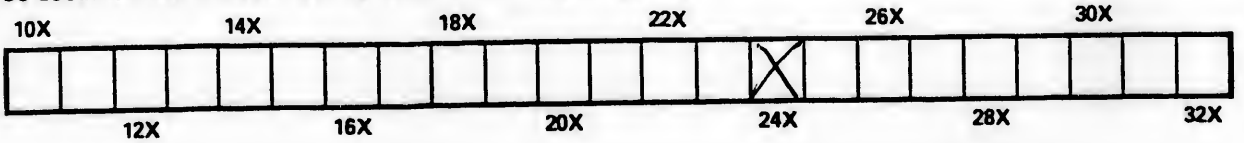

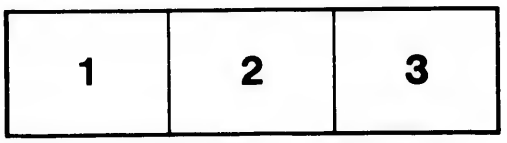

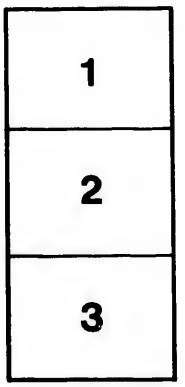

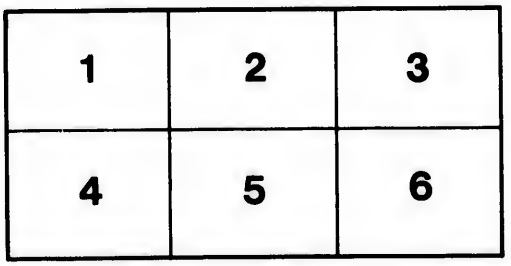

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ASPECTS OF AMERICAN ASTRONOMY

SIMON NEWCOMB

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ASPECTS OF AMERICAN ASTRONOMY.[1]

By Simon Newcomb.

The University of Chicago yesterday accepted one of the most munificent gifts ever made for the promotion of any single science and with appropriate ceremonies dedicated it to the increase of our knowledge of the heavenly bodies.

The president of your university has done me the honor of inviting me to supplement what was said on that occasion by some remarks of a more general nature suggested by the celebration. One is naturally disposed to say first what is uppermost in his mind. At the present moment this will naturally be the general impression made by what has been seen and heard. The ceremonies were attended, not only by a remarkable delegation of citizens, but by a number of visiting astronomers, which seems large when we consider that the profession itself is not at all numerous in any country. As one of these, your guests, I am sure that I give expression only to their unanimous sentiment in saying that we have been extremely gratified in many ways by all that we have seen and heard. The mere fact of so munificent a gift to science cannot but excite universal admiration. We knew well enough that it was nothing more than might have been expected from the public spirit of this great West; but the first view of a towering snow peak is none the less impressive because you have learned in your geography how many feet high it is, and great acts are none the less admirable because they correspond to what you have heard and read, and might therefore be led to expect.

The next gratifying feature is the great public interest excited by the occasion. That the opening of a purely scientific institution should have led so large an assemblage of citizens to devote an entire day, including a long journey by rail,

[1] Address delivered at the University of Chicago, Oct. 22, 1897, in connection with the dedication of the Yerkes Observatory.

to the celebration of yesterday is something most suggestive from its unfamiliarity. A great many scientific establishments have been inaugurated during the last half century, but if on any such occasion so large a body of citizens has gone so great a distance to take part in the inauguration the fact has at the moment escaped from my mind.

That the interest thus shown is not confined to the hundreds of attendants, but must be shared by your great public, is shown by the unfailing barometer of journalism. Here we have a field in which the nonsurvival of the unfit is the rule in its most ruthless form; the journals that we see and read are merely the fortunate few of a countless number, dead and forgotten, that did not know what the public wanted to read about. The eagerness shown by the representatives of your press in recording everthing your guests would say was accompanied by an enterprise in making known everything that occurred and, in case of an emergency requiring a heroic measure, what did not occur, showing that smart journalists of the East must have learned their trade, or at least breathed their inspiration in these regions. I think it was some twenty years since I told a European friend that the eighth wonder of the world was a Chicago daily newspaper. Since that time the course of journalistic enterprise has been in the reverse direction, to that of the course of empire eastward, instead of westward.

It has been sometimes said—wrongfully I think—that scientific men form a mutual admiration society. One feature of the occasion made me feel that we, your guests, ought then and there to have organized such a society, and forthwith proceeded to business—this feature consisted in the conferences on almost every branch of astronomy by which the celebration of yesterday was preceded. The fact that beyond the acceptance of a graceful compliment I contributed nothing to these conferences relieves me from the charge of bias or self-assertion in saying that they gave me a new and most inspiring view of the energy now being expended in research by the younger generation of astronomers. All the experience of the past leads us to believe

that this energy will reap the reward which nature always bestows upon those who seek her acquaintance from unselfish motives. In one way it might appear that little was to be learned from a meeting like that of the present week — each astronomer may know by publications pertaining to the science what all the others are doing. But knowledge, obtained in this way, has a sort of abstractness about it a little like our knowledge of the progress of civilization in Japan, or of the great extent of the Australian continent. It was, therefore, a most happy thought on the part of your authorities to bring together the largest possible number of visiting astronomers from Europe as well as America, in order that each might see, through the attrition of personal contact, what progress the others were making in their researches. To the visitors at least I am sure that the result of this meeting has been extremely gratifying. They earnestly hope, one and all, that the callers of the conference will not themselves be more disappointed in its results; that however little they may have actually to learn of methods and results, they will feel stimulated to well directed efforts and find themselves inspired by thoughts which, however familiar, will now be more easily worked out.

We may pass from the aspects of the case as seen by the strictly professional class to those general aspects fitted to excite the attention of the great public. From the point of view of the latter it may well appear that the most striking feature of the celebration is the great amount of effort which it shows to be devoted to the cultivation of a field quite outside the ordinary range of human interests.

A little more than two centuries ago Huyghens prefaced an account of his discoveries on the planet Saturn with the remark that many, even among the learned, might think he had been devoting to things too distant to interest mankind an amount of study which would better have been devoted to subjects of more immediate concern. It must be admitted that this fear has not deterred succeeding astronomers from pursuing their studies. The enthusiastic students whom we see around

us are only a detachment from an army of investigators who, in many parts of the world, are seeking to explore the mysteries of creation. Why so great an expenditure of energy? Certainly not to gain wealth, for astronomy is perhaps the one field of scientific work which, in our expressive modern phrase, "has no money in it." It is true that the great practical use of astronomical science to the country and the world in affording us the means of determining positions on land and at sea is frequently pointed out. It is said that an Astronomer Royal of England once calculated that every meridian observation of the Moon made at Greenwich was worth a pound sterling, on account of the help it would afford to the navigation of the ocean. An accurate map of the United States cannot be constructed without astronomical observations at numerous points scattered over the whole country, aided by data which great observatories have been accumulating for more than a century, and must continue to accumulate in the future.

But neither the measurement of the Earth, the making of maps, nor the aid of the navigator is the main object which the astronomers of today have in view. If they do not quite share the sentiment of that eminent mathematician, who is said to have thanked God that his science was one which could not be prostituted to any useful purpose, they still know well that to keep utilitarian objects in view would only prove a handicap on their efforts. Consequently, they never ask in what way their science is going to benefit mankind.

As the great captain of industry is moved by the love of wealth, and the politician by the love of power, so the astronomer is moved by the love of knowledge for its own sake, and not for the sake of its application. Yet he is proud to know that his science has been worth more to mankind than it has cost. He does not value its results merely as a means of crossing the ocean or mapping the country, for he feels that man does not live by bread alone. If it is not more than bread to know the place we occupy in the universe, it is certainly something which we should place not far behind the means of subsistence. That we now

look upon a comet as something very interesting, of which the sight affords us a pleasure unmixed with fear of war, pestilence, or other calamity, and of which we therefore wish the return, is a gain we cannot measure by money. In all ages astronomy has been an index to the civilization of the people who cultivated it. It has been crude or exact, enlightened or mingled with superstition, according to the current mode of thought. When once men understand the relation of the planet on which they dwell to the universe at large, superstition is doomed to speedy extinction. This alone is an object worth more than money.

Astronomy may fairly claim to be that science which transcends all others in its demands upon the practical application of our reasoning powers. Look at the stars that stud the heavens on a clear evening. What more hopeless problem to one confined to earth than that of determining their varying distances, their motions, and their physical constitution? Everything on earth we can handle and investigate. But how investigate that which is ever beyond our reach, on which we can never make an experiment? On certain occasions we see the Moon pass in front of the Sun and hide it from our eyes. To an observer a few miles away the Sun was not entirely hidden, for the shadow of the Moon in a total eclipse is rarely one hundred miles wide. On another continent no eclipse at all may have been visible. Who shall take a map of the world and mark upon it the line on which the Moon's shadow will travel during some eclipse a hundred years hence? Who shall map out the orbits of the heavenly bodies as they are going to appear in a hundred thousand years? How shall we ever know of what chemical elements the Sun and the stars are made? All this has been done, but not by the intellect of any one man. The road to the stars has been opened only by the efforts of many generations of mathematicians and observers, each of whom began where his predecessor had left off. We have reached a certain stage where we know much about the heavenly bodies.

We have mapped out our solar system with great precision. But how with that great universe of millions of stars in which

our solar system is only a speck of star dust, a speck which a traveler through the wilds of space might pass a hundred times without notice? We have learned much about this universe, though our knowledge of it is still dim. We see it as a traveler on a mountain top sees a distant city in a cloud of mist, by a few specks of glimmering light from steeples or roofs. We want to know more about it, its origin and its destiny; its limits in time and space, if it has any; what function it serves in the universal economy. The journey is long, yet we want, in knowledge at least, to reach the stars. Hence we build observatories and train observers and investigators. Slow indeed is progress in the solution of the greatest of problems, when measured by what we want to know. Some questions may require centuries, others thousands of years for their answer. And yet never was progress more rapid than during our time. In some directions our astronomers of today are out of sight of those of fifty years ago; we are even gaining heights which, twenty years ago, looked hopeless. Never before had the astronomer so much work, good, hard, yet hopeful work before him as today. He who is leaving the stage feels that he has only begun, and must leave his successors with more to do than his predecessors left him.

To us an interesting feature of this progress is the part taken in it by our own country. The science of our day, it is true, is of no country. Yet we very appropriately speak of American science from the fact that our traditional reputation has not been that of a people deeply interested in the higher branches of intellectual work. Men yet living can remember when in the eyes of the universal church of learning all cisatlantic countries, our own included, were *partes infidelium*.

Yet American astronomy is not entirely of our generation. In the middle of the last century Professor Winthrop, of Harvard, was an industrious observer of eclipses and kindred phenomena, whose work was recorded in the transactions of learned societies. But the greatest astronomical activity during our colonial period was that called out by the transit of Venus in 1769, which was visible in this country. A committee of the

American Philosophical Society, at Philadelphia, organized an excellent system of observations, which we now know to have been fully as successful, perhaps more so, than the majority of those made on other continents, owing mainly to the advantages of air and climate. Among the observers was the celebrated Rittenhouse, to whom is due the distinction of having been the first American astronomer whose work has an important place in the history of the science. In addition to the observations which he has left us, he was the first inventor or proposer of the collimating telescope, an instrument which has become almost a necessity wherever accurate observations are made. The fact that the subsequent invention by Bessel was quite independent, does not detract from the merits of either.

Shortly after the transit of Venus, which I have mentioned, the War of the Revolution commenced. The generation which carried on that war, and the following one which formed our constitution and laid the bases of our political institutions, were naturally too much occupied with these great problems to pay much attention to pure science. While the great mathematical astronomers of Europe were laying the foundation of celestial mechanics their meetings were a sealed book to everyone on this side of the Atlantic, and so remained until Bowditch appeared, early in the present century. His translation of the *Mécanique Céleste* made an epoch in American science by bringing the great work of Laplace down to the reach of the best American students of his time.

American astronomers must always honor the names of Rittenhouse and Bowditch. And yet, in one respect, their work was disappointing of results. Neither of them was the founder of a school. Rittenhouse left no successor to carry on his work. The help which Bowditch afforded his generation was invaluable to isolated students who, here and there, dived alone and unaided into the mysteries of the celestial motions. His work was not mainly in the field of observational astronomy, and therefore did not materially influence that branch of the science. In 1832 Professor Airy, afterward Astronomer Royal of England, made a

report to the British Association on the condition of practical astronomy in various countries. In this report he remarked that he was unable to say anything about American astronomy because, so far as he knew, no public observatory existed in the United States.

William C. Bond, afterward famous as the first director of Harvard Observatory, was at that time making observations with a small telescope, first near Boston, and afterward at Cambridge. But with so meager an outfit, his establishment could scarcely lay claim to being an astronomical observatory, and it was not surprising if Airy did not know anything of his modest efforts.

If at this time Professor Airy had extended his investigations into yet another field, with a view of determining the prospects for a great city at the site of Fort Dearborn, on the southern shore of Lake Michigan, he would have seen as little prospect of civic growth in that region as of a great development of astronomy in the United States at large. A plat of the proposed town of Chicago had been prepared two years before, when the place contained perhaps half a dozen families. In the same month in which Professor Airy made his report, August 1832, the people of that place, then numbering twenty-eight voters, decided to become incorporated, and selected five trustees to carry on their government.

In 1837 a city charter was obtained from the legislature of Illinois. The growth of this infant city, then small even for an infant, into the great commercial metropolis of the West, has been the just pride of its people and the wonder of the world. I mention it now because of a remarkable coincidence. With this civic growth has quietly gone on another, little noted by the great world, and yet in its way equally wonderful and equally gratifying to the pride of those who measure greatness by intellectual progress. If it be true that in nature nothing is great but man; in man nothing is great but mind; then may knowledge of the universe be regarded as the true measure of progress. I therefore invite attention to the fact that American

astronomy began with your city, and has slowly but surely kept pace with it until today our country stands second only to Germany in the number of researches being prosecuted, and second to none in the number of men who have gained the highest recognition by their labors.

In 1836 Professor Albert Hopkins, of Williams College, and Professor Elias Loomis, of Western Reserve College, Ohio, both commenced little observatories. Professor Loomis went to Europe for all his instruments, but Hopkins was able even then to get some of his in this country. Shortly afterward a little wooden structure was erected by Captain Gilliss on Capitol Hill at Washington, and supplied with a transit instrument for observing Moon culminations in conjunction with Captain Wilkes, who was then setting out on his exploring expedition to the southern hemisphere. The date of these observatories was practically the same as that on which a charter for the city of Chicago was obtained from the legislature. With their establishment the population of your city had increased to 703.

The next decade, 1840 to 1850, was that in which our practical astronomy seriously commenced. The little observatory of Captain Gilliss was replaced by the Naval Observatory, erected at Washington during the years 1843–4 and fitted out with what were then the most approved instruments. About the same time the appearance of the great comet of 1843 led the citizens of Boston to erect the Observatory of Harvard College. Thus it is little more than a half century since the two principal observatories in the United States were established. But we must not for a moment suppose that the mere erection of an observatory can mark an epoch in scientific history. What must have made the decade of which I speak ever memorable in American astronomy was not merely the erection of buildings, but the character of the work done by astronomers away from them as well as in them.

The Naval Observatory very soon became famous by two remarkable steps which raised our country to an important position among those applying modern science to practical uses. One

of these consisted of the researches of Sears Cook Walker on the motion of the newly discovered planet Neptune. He was the first astronomer to determine fairly good elements of the orbit of that planet, and, what is yet more remarkable, he was able to trace back the movement of the planet in the heavens for half a century, and to show that it had been observed as a fixed star by Lalande in 1795, without the observer having any suspicion of the true character of the object.

The other work to which I refer was the application to astronomy and to the determination of longitudes of the chronographic method of registering transits of stars or other phenomena requiring an exact record of the instant of their occurrence. It is to be regretted that the history of this application has not been fully written. In some points there seems to be as much obscurity as with the discovery of ether as an anæsthetic, which took place about the same time. Happily no such contest has been fought over the astronomical as over the surgical discovery—the fact being that all who were engaged in the application of the new method were more anxious to perfect it than they were to get credit for themselves. We know that Saxton of the Coast Survey, Mitchell and Locke, of Cincinnati, Bond at Cambridge, as well as Walker and other astronomers at the Naval Observatory, all worked at the apparatus, that Maury seconded their efforts with untiring zeal, that it was used to determine the longitude of Baltimore as early as 1844 by Captain Wilkes, and that it was put into practical use in recording observations at the Naval Observatory as early as 1846.

At the Cambridge Observatory the two Bonds, father and son, speedily began to show the stuff of which the astronomer is made. A well-devised system of observations was put in operation. The discovery of the dark ring of Saturn and of a new satellite to that planet gave additional fame to the establishment.

Nor was activity confined to the observational side of the science. The same decade of which I speak was marked by the beginning of Professor Pierce's mathematical work, especially

his determination of the perturbations of Uranus and Neptune. At this time commenced the work of Dr. B. A. Gould, who soon became the leading figure in American astronomy. Immediately on graduating at Harvard in 1845, he determined to devote all the energies of his life to the prosecution of his favorite science. He studied in Europe for three years, took the doctor's degree at Göttingen, came home, founded the *Astronomical Journal*, and took an active part in that branch of the work of the Coast Survey which included the determination of longitudes by astronomical methods.

An episode which may not belong to the history of astronomy must be acknowledged to have had a powerful influence in exciting public interest in that science. Professor O. M. Mitchell, the founder and first director of the Cincinnati Observatory, made the masses of our intelligent people acquainted with the leading facts of astronomy by courses of lectures which, in lucidity and eloquence, have never been excelled. The immediate object of the lectures was to raise funds for establishing his observatory and fitting it out with a fine telescope. The popular interest thus excited in the science had an important effect in leading the public to support astronomical research. If public support, based on public interest, is what has made the present fabric of American astronomy possible, then should we honor the name of a man whose enthusiasm leavened the masses of his countrymen with interest in our science.

The Civil War naturally exerted a depressing influence upon our scientific activity. The cultivator of knowledge is no less patriotic than his fellow-citizens, and vies with them in devotion to the public welfare. The active interest which such cultivators took, first in the prosecution of the war and then in the restoration of the union, naturally distracted their attention from their favorite pursuits. But no sooner was political stability reached than a wave of intellectual activity set in, which has gone on increasing up to the present time. If it be true that never before in our history has so much attention been given to education as now; that never before did so many men devote

themselves to the diffusion of knowledge, it is no less true that never was astronomical work so energetically pursued among us as now.

One deplorable result of the Civil War was that Gould's *Astronomical Journal* had to be suspended. Shortly after the restoration of peace, instead of reëstablishing the journal, its founder conceived the project of exploring the southern heavens. The northern hemisphere being the seat of civilization, that portion of the sky which could not be seen from our latitudes was comparatively neglected. What had been done in the southern hemisphere was mostly the occasional work of individuals and of one or two permanent observatories. The latter were so few in number and so meager in their outfit that a splendid field was open to the inquirer. Gould found the patron which he desired in the government of the Argentine Republic, on whose territory he erected what must rank in the future as one of the memorable astronomical establishments of the world. His work affords a most striking example of the principle that the astronomer is more important than his instruments. Not only were the means at the command of the Argentine Observatory slender in the extreme when compared with those of the favored institutions of the North, but, from the very nature of the case, the Argentine Republic could not supply trained astronomers. The difficulties thus growing out of the administration cannot be overestimated. And yet the sixteen great volumes in which the work of the institution has been published will rank in the future among the classics of astronomy.

Another wonderful focus of activity, in which one hardly knows whether he ought most to admire the exhaustless energy or the admirable ingenuity which he finds displayed, is the Harvard Observatory. Its work has been aided by gifts which have no parallel in the liberality that prompted them. Yet without energy and skill such gifts would have been useless. The activity of the establishment includes both hemispheres. Time would fail to tell how it has not only mapped out important regions of the heavens from the north to the south pole, but

analyzed the rays of light which come from hundreds of thousands of stars by recording their spectra in permanence on photographic plates.

The work of the establishment is so organized that a new star cannot appear in any part of the heavens, nor a known star undergo any noteworthy change, without immediate detection by the photographic eye of one or more little telescopes, all seeing and never sleeping policemen, that scan the heavens unceasingly while the astronomer may sleep, and report in the morning every case of irregularity in the proceedings of the heavenly bodies.

Yet another example, showing what great results may be obtained with limited means is afforded by the Lick Observatory, on Mount Hamilton, California. During the ten years of its activity its astronomers have made it known the world over by works and discoveries too varied and numerous to be even mentioned at the moment.

The astronomical work of which I have thus far spoken has been almost entirely that done at observatories. I fear that I may in this way have strengthened an erroneous impression that the seat of important astronomical work is necessarily connected with an observatory. In must be admitted that an institution which has a local habitation and a magnificent building commands public attention so strongly that valuable work done elsewhere may be overlooked. A very important part of astronomical work is done away from telescopes and meridian circles, and requires nothing but a good library for its prosecution. One who is devoted to this side of the subject may often feel that the public does not appreciate his work at its true relative value, from the very fact that he has no great buildings or fine instruments to show. I may, therefore, be allowed to claim as an important factor in the American astronomy of the last half century an institution of which few have heard and which has been overlooked because there was nothing about it to excite attention.

In 1849 the *American Nautical Almanac* office was estab-

lished by a congressional appropriation. The title of this publication is somewhat misleading in suggesting a simple enlargement of the family almanac which the sailor is to hang up in his cabin for daily use. The fact is that what started more than a century ago as a nautical almanac has since grown into an astronomical ephemeris for the publication of everything pertaining to times, seasons, eclipses and the motions of the heavenly bodies. It is the work in which astronomical observations made in all the great observatories of the world are ultimately utilized for scientific and public purposes. Each of the leading nations of western Europe issues such a publication. When the preparation and publication of the American ephemeris was decided upon the office was first established in Cambridge, the seat of Harvard University, because there could most readily be secured the technical knowledge of mathematics and theoretical astronomy necessary for the work.

A field of activity was thus opened, of which a number of able young men who have since earned distinction in various walks of life availed themselves. The head of the office, Commander Davis, adopted a policy well fitted to promote their development. He translated the classic work of Gauss, *Theoria Motus Corporum Cœlestium*, and made the office a sort of informal school, not, indeed, of the modern type, but rather more like the classic grove of Hellas, where philosophers conducted their discussions and profited by mutual attrition. When, after a few years of experience, methods were well established and a routine adopted, the office was removed to Washington, where it has since remained. The work of preparing the ephemeris has, with experience, been reduced to a matter of routine which may be continued indefinitely, with occasional changes in methods and data and improvements to meet the increasing wants of investigators.

The mere preparation of the ephemeris includes but a small part of the work of mathematical calculation and investigation required in astronomy. One of the great wants of the science today is the re-reduction of the observations made during the

first half of the present century, and even during the last half of the preceding one. The labor which could profitably be devoted to this work would be more than that required in any one astronomical observatory. It is unfortunate for this work that a great building is not required for its prosecution because its needfulness is thus very generally overlooked by that portion of the public interested in the progress of science. An organization especially devoted to it is one of the scientific needs of our time.

In such an epoch-making age as the present it is dangerous to cite any one step as making a new epoch. Yet it may be that when the historian of the future reviews the science of our day he will find the most remarkable feature of the astronomy of the last twenty years of our century to be the discovery that this steadfast Earth of which the poets have told us is not after all quite steadfast; that the north and south poles move about a very little, describing curves so complicated that they have not yet been fully marked out. The periodic variations of latitude thus brought about were first suspected about 1880, and announced with some modest assurance by Küstner, of Berlin, a few years later. The progress of the views of astronomical opinion from incredulity to confidence was extremely slow until, about 1890, Chandler, of the United States, by an exhaustive discussion of innumerable results of observations showed that the latitude of every point on the Earth was subject to a double oscillation, one having a period of a year, the other of 427 days.

Notwithstanding the remarkable parallel between the growth of American astronomy and that of your city, one cannot but fear that if a foreign observer had been asked only half a dozen years ago at what point in the United States a great school of theoretical and practical astronomy, aided by an establishment for the exploration of the heavens, was likely to be established by the munificence of private citizens, he would have been wiser than most foreigners had he guessed Chicago. Had this place been suggested to him I fear he would have replied that were

it possible to utilize celestial knowledge in acquiring earthly wealth here would be the most promising seat for such a school. But he would need to have been a little wiser than his generation to reflect that wealth is at the base of all progress in knowledge and the liberal arts, that it is only when men are relieved from the necessity of devoting all their energies to the immediate wants of life that they can lead intellectual lives, and that we should therefore look to the most enterprising commercial center as the likeliest seat for a great scientific institution.

Now we have the school, and we have the Observatory, which we hope will in the near future do work that will cast luster on the name of its founder as well as on the astronomers who may be associated with it. You will, I am sure, pardon me if I make some suggestions on the subject of the future needs of the establishment. We want this newly founded institution to be a great success, to do work which shall show that the intellectual productiveness of your community will not be allowed to lag behind its material growth. The public is very apt to feel that when some munificent patron of science has mounted a great telescope under a suitable dome and supplied all the apparatus which the astronomer wants to use success is assured. But such is not the case. The most important requisite, one more difficult to command than telescopes or observatories, may still be wanting. A great telescope is of no use without a man at the end of it, and what the telescope may do depends more upon this appendage than upon the instrument itself. The place which telescopes and observatories have taken in astronomical history are by no means proportional to their dimensions. Many a great instrument has been a mere toy in the hands of its owner. Many a small one has become famous. Twenty years ago there was here in your own city a modest little instrument which, judged by its size, could not hold up its head with the great ones even of that day.

It was the private property of a young man holding no scientific position and scarcely known to the public. And yet that little telescope is today among the famous ones of the world,

having made memorable advances in the astronomy of double stars, and shown its owner to be a worthy successor of the Herschels and the Struves in that line of work. A hundred observers might have used the appliances of the Lick Observatory for a whole generation without finding the fifth satellite of Jupiter; without successfully photographing the cloud forms of the Milky Way; without discovering the extraordinary patches of nebulous light, nearly or quite invisible to the human eye, which fill some regions of the heavens.

When I was in Zurich last year I paid a visit to the little but not unknown observatory of its famous polytechnic school. The professor of astronomy was especially interested in the observations of the Sun with the aid of the spectroscope, and among the ingenious devices which he described, not the least interesting was the method of photographing the Sun by special rays of the spectrum which had been worked out at the Kenwood Observatory in Chicago. The Kenwood Observatory is not, I believe, in the eye of the public one of the noteworthy institutions of your city which every visitor is taken to see, and yet this invention has given it an important place in the science of our day.

Should you ask me what are the most hopeful features in the great establishment which you are now dedicating I would say that they are not alone to be found in the size of your unequaled telescope, nor in the cost of the outfit, but in the fact that your authorities have shown their appreciation of the requirements of success by adding to the material outfit of the establishment the three men whose works I have described.

Gentlemen of the trustees, allow me to commend to your fostering care the men at the end of the telescope. The constitution of the astronomer shows curious and interesting features. If he is destined to advance the science by works of real genius he must, like the poet, be born, not made. The born astronomer, when placed in command of a telescope, goes about using it as naturally and effectively as the babe avails itself of its mother's breast. He sees intuitively what less gifted men have to learn by long study and tedious experiment. He is moved

to celestial knowledge by a passion which dominates his nature. He can no more avoid doing astronomical work, whether in the line of observations or research, than the poet can chain his Pegasus to earth. I do not mean by this that education and training will be no use to him. They will certainly accelerate his early progress. If he is to become great on the mathematical side, not only must his genius have a bend in that direction, but he must have the means of pursuing his studies. And yet I have seen so many failures of men who had the best instruction, and so many successes of men who scarcely learned anything of their teachers, that I sometimes ask whether the great American celestial mechanician of the twentieth century will be a graduate of a university or of the backwoods.

Is the man thus moved to the exploration of nature by an unconquerable passion more to be envied or pitied? In no other pursuit does success come with such certainty to him who deserves it. No life is so enjoyable as that whose energies are devoted to following out the inborn impulses of one's nature. The investigator of truth is little subject to the disappointments which await the ambitous man in other fields of activity. It is pleasant to be one of a brotherhood extending over the world, in which no rivalry exists except that which comes out of trying to do better work than anyone else, while mutual admiration stifles jealousy. And yet, with all these advantages, the experience of the astronomer may have its dark side. As he sees his field widening faster than he can advance he is impressed with the littleness of all that can be done in one short life. He feels the same want of successors to pursue his work that the founder of a dynasty may feel for heirs to occupy his throne. He has no desire to figure in history as a Napoleon of science whose conquests must terminate with his life. Even during his active career his work may be of such a kind as to require the coöperation of others and the active support of the public. If he is disappointed in commanding these requirements, if he finds neither coöperation nor support, if some great scheme to which he may have devoted much of his life

thus proves to be only a castle in the air, he may feel that nature has dealt hardly with him in not endowing him with passions like to those of other men.

In treating a theme of perennial interest one naturally tries to fancy what the future may have in store. If the traveler contemplating the ruins of some ancient city which in the long ago teemed with the life and activities of generations of men sees every stone instinct with emotion and the dust alive with memories of the past, may he not be similarly impressed when he feels that he is looking around upon a seat of future empire; a region where generations yet unborn may take a leading part in molding the history of the world? What may we not expect of that energy which in sixty years has transformed a straggling village into one of the world's great centers of commerce? May it not exercise a powerful influence on the destiny not only of the country but of the world? If so, shall the power thus to be exercised prove an agent of beneficence, diffusing light and life among nations, or shall it be the opposite?

The time must come ere long when wealth shall outgrow the field in which it can be profitably employed. In what direction shall its possessors then look? Shall they train a posterity which will so use its power as to make the world better that it has lived in it? Will the future heir to great wealth prefer the intellectual life to the life of pleasure?

We can have no more hopeful answer to these questions than the establishment of this great University in the very focus of the commercial activity of the West. Its connection with the institution we have been dedicating suggests some thoughts on science as a factor in that scheme of education best adapted to make the power of a wealthy community a benefit to the race at large. When we see what a factor science has been in our present civilization, how it has transformed the world and increased the means of human enjoyment by enabling men to apply the powers of nature to their own uses, it is not wonderful that it should claim the place in education hitherto held by classical studies. In the contest which has thus arisen I take no part but

that of a peacemaker, holding that it is as important to us to keep in touch with the traditions of our race and to cherish the thoughts which have come down to us through the centuries as it is to enjoy and utilize what the present has to offer us. Speaking from this point of view, I would point out the error of making the utilitarian applications of knowledge the main object in its pursuit. It is a historic fact that abstract science, science pursued without any utilitarian end, has been at the basis of our progress in the application of knowledge. If in the last century such men as Galvani and Volta had been moved by any other motive than love of penetrating the secrets of nature they would never have pursued the seemingly useless experiments they did, and the foundation of electrical science would not have been laid. Our present applications of electricity did not become possible until Ohm's mathematical laws of the electric current, which when first made known seemed little more than mathematical curiosities, had become the common property of inventors. Professional pride on the part of our own Henry led him, after making the discoveries which rendered the telegraph possible, to go no further in their application, and to live and die without receiving a dollar of the millions which the country has won through his agency.

In the spirit of scientific progress thus shown, we have patriotism in its highest form: a sentiment which does not seek to benefit the country at the expense of the world, but to benefit the world by means of one's country. Science has its competition, as keen as that which is the life of commerce. But its rivalries are over the question who shall contribute the most and the best to the sum total of knowledge, who shall give the most, not who shall take the most. Its animating spirit is love of truth. Its pride is to do the greatest good to the greatest number. It embraces not only the whole human race, but all nature in its scope. The public spirit of which this city is the focus has made the desert blossom as the rose, and benefited humanity by the diffusion of the material products of the earth. Should you ask me how it is in the future to use its influence for the

benefit of humanity at large, I would say, look at the work now going on in these precincts, and study its spirit. Here are the agencies which will make "the voice of law and harmony of the world." Here is the love of country blended with the love of the race. Here the love of knowledge is as unconfined as your commercial enterprise. Let not your youth come hither merely to learn the forms of vertebrates and the properties of oxides, but rather to imbibe that catholic spirit which, animating their ever gracious energies, shall make the power they shall wield an agent of beneficence to all mankind.

lished by a congressional appropriation. The title of this publication is somewhat misleading in suggesting a simple enlargement of the family almanac which the sailor is to hang up in his cabin for daily use. The fact is that what started more than a century ago as a nautical almanac has since grown into an astronomical ephemeris for the publication of everything pertaining to times, seasons, eclipses and the motions of the heavenly bodies. It is the work in which astronomical observations made in all the great observatories of the world are ultimately utilized for scientific and public purposes. Each of the leading nations of western Europe issues such a publication. When the preparation and publication of the American ephemeris was decided upon the office was first established in Cambridge, the seat of Harvard University, because there could most readily be secured the technical knowledge of mathematics and theoretical astronomy necessary for the work.

A field of activity was thus opened, of which a number of able young men who have since earned distinction in various walks of life availed themselves. The head of the office, Commander Davis, adopted a policy well fitted to promote their development. He translated the classic work of Gauss, *Theoria Motus Corporum Cœlestium*, and made the office a sort of informal school, not, indeed, of the modern type, but rather more like the classic grove of Hellas, where philosophers conducted their discussions and profited by mutual attrition. When, after a few years of experience, methods were well established and a routine adopted, the office was removed to Washington, where it has since remained. The work of preparing the ephemeris has, with experience, been reduced to a matter of routine which may be continued indefinitely, with occasional changes in methods and data and improvements to meet the increasing wants of investigators.

The mere preparation of the ephemeris includes but a small part of the work of mathematical calculation and investigation required in astronomy. One of the great wants of the science today is the re-reduction of the observations made during the