THE SCIENTIFIC EXPEDITION OF JEAN RICHER TO CAYENNE (1672-1673)[1]

By JOHN W. OLMSTED

Reprinted from ISIS, Volume XXXIV
Part 2, No. 94, Autumn, 1942, 117-128

The scientific expedition of JEAN RICHER to Cayenne in 1672-73, however little it may be understood, is not unknown. A number of accounts of seventeenth-century science at least mention it; in a few it is discussed more fully. By comparison with the contemporary and closely related expedition of the Abbé JEAN PICARD to Uraniborg in Denmark, RICHER's voyage may not appear to have been particularly neglected. Actually, however, no even partially adequate discussion of its origins exists, while accounts of its aims, results, and scientific consequences are characteristically neither accurate nor adequate[2]. In addition, the general importance of the expedition in the history of seventeenth-century science and scientific voyaging has been largely overlooked.

Such a situation is, really quite surprising. For, with one possible exception, no important expeditions of a strictly scientific character had taken place before 1671-72.[3] The voyages to Uraniborg and Cayenne offer all the interest of novelty and originality. Moreover, they are the first of a long series of important and even renowned expeditions organized and dispatched by the *Académie Royale des Sciences* (1666-1793).[4] Yet most histories of this body give little attention to its first pioneering ventures overseas.[5] Like the general historians of science, persons writing of the Academy tend either to neglect or to misrepresent and misinterpret these early voyages. For this situation, eighteenth-century accounts of the expedition to Cayenne are largely responsible.

Until quite recently, in most discussions of RICHER's voyage and its results, attention has been centered on the justly famous discovery of the shortening of a seconds pendulum near the equator. Here later writers have merely followed such men as VOLTAIRE, MAUPERTUIS, and D'ALEMBERT. As active participants in the bitter and portentous conflict over the shape of the earth, the latter naturally saw the expedition to Cayenne largely in terms of the discovery about the behavior of a seconds pendulum, a discovery which had done much to bring about the epic struggle of "flatteners" and "elongators", Newtonians and Cassinians or Cartesians.[6] For RICHER this was a guarantee against oblivion. But it was also, in view of the eminence and the persuasiveness of his champions, the means of distorting both the aims and the achievements of his expedition. This is most apparent in the subsequent neglect of the extensive and fruitful astronomical work of the expedition, which included numerous joint observations by RICHER at Cayenne and CASSINI at Paris, and was the principal inspiration of the entire enterprise, as well as of some of its most notable successors.[7]

Another reason the true character and importance of the expedition has been lost sight of comes from a general failure to recognize that scientific expeditions, like other organized human activities, themselves have a history. Once this is admitted, the expedition to Cayenne will be seen in an entirely different light. It will be recognized for what it was, the prototype of the best modern scientific expeditions, the first notable example of a new and distinctive kind of expedition largely inspired by and devoted to the investigation of specific scientific problems. Indeed, with this expedition, the history of modern scientific expeditions will be seen to have begun. A critical examination of its origins, its purposes, and its results, will, it is hoped, substantiate these various assertions.[8]

I

"On this eleventh day of January 1667 M. AUZOUT presented to the assembly a memoir which was read to the company on the observations that should be made at Madagascar."[9] The memoir to which this brief entry in the manuscript minutes of the Academy of Sciences refers, occupies about seven pages in the same folio volume.[10] Its author, ADRIEN AUZOUT was a leading spirit in scientific circles in Paris, active in the establishment of the Academy and in the plans for the Observatory, an able and progressive astronomer who had recently perfected, if not invented, the important filar micrometer.[11] To the many claims to recognition of this almost paradoxically obscure figure, it seams another should be added. His memoir of 1667 appears to be the earliest known proposal for the type of scientific expedition which RICHER five years later was to carry out, not in Madagascar, but at Cayenne in French Guiana.

AUZOUT's proposal was made with dramatic suddenness about three weeks after the first formal meeting of the new Academy. Madagascar was then much in the public eye. It was expected to become the principal headquarters of COLBERT's recently founded East India Company.[12] Plans to send an observer to the island had been discussed in scientific circles in Paris at least as early as October 1666.[13] AUZOUT now came forward with suggestions of what the scientists selected for the expedition might observe.[14] He had discerned with remarkable insight the great scientific possibilities of such a voyage. Moreover, the ends of the expedition as he conceived them were exclusively scientific. In the memoir there is no naïveté, no crudely economic motivation. The spirit is that of science in the age of NEWTON — far more of the eighteenth than of the sixteenth century. A considerable gulf thus separates these lucid proposals from the confused ideas about scientific voyaging current in scientific circles in Paris and in London at the time — ideas from which even a HUYGENS and a BOYLE had not yet been freed.[15]

Specific plans for carrying out the proposed expedition were discussed by the Academy during the early months of 1667. At the end of April, it was intended to select in the near future the two men who were to make the observations. In addition, three of HUYGENS' marine pendulum clocks for determining longitude were being constructed at royal expense for testing during the voyage.[16]

But nothing immediate was to come to these preparations. The times were unpropitious. Late in May the French armies under TURENNE invaded the Spanish Netherlands. The War of Devolution thus begun dragged on into 1668 and provoked the threatening Triple Alliance; the affairs of the company in Madagascar were seriously disturbed; officialdom moved slowly. The Academy, of course, was an official body, under royal patronage. Any expedition would normally have to be sanctioned in the King's name by COLBERT, the minister responsible for the direction of the Academy's affairs. When finally approved, however, the costs would be borne by the royal treasury. The inevitable delay had certain practical advantages.

COLBERT at the time was most directly interested in scientific voyages of a different sort, with very restricted and utilitarian ends. The marine pendulum clocks earlier designed by the great Dutch scientist, CHRISTIAAN HUYGENS, a resident member of the Academy, needed further testing. The vital problem for navigation of finding longitude at sea, was still, after great efforts, unsolved. It was hoped that the new clocks would provide the ready solution only finally obtained with the chronometers perfected about a century later.[17]

During 1668 and 1669 two voyages to test the clocks were made in the Mediterranean on ships of the fleet of the DUC DE BEAUFORT, the second on the occasion of the expedition to relieve the Turkish siege of Candia.[18] On each occasion the clocks were in charge of a M. DELAVOYE, like RICHER an *élève* of the Academy.[19] DELAVOYE's first voyage was largely unsuccessful. The results of the second, completed by October of 1669, seemed encouragingly good.[20]

HUYGENS' delight gave rise to almost immediate plans for a third voyage, a long and exacting one. COLBERT'S assent was readily obtained. The official ledgers show that in December 1669 DELAVOYE, referred to as a *mathématicien* designated to go to the East Indies to test the marine pendulum clocks, was paid his stipend for the next four months, and, in addition, was given a substantial sum to cover the cost of transportation for himself and his instruments to La Rochelle.[21] In these plans JEAN RICHER, quite unwittingly, was involved.

During the course of 1668 and 1669 important events had taken place which were to affect the scientific expeditions in which the Academy of Sciences was interested. Before the end of 1668 AUZOUT was an exile in Italy, victim of a "cabal" according to one statement. Details are lacking, and the entire episode is extremely obscure.[22] In the same year, as a result of the publication of the first satisfactory ephemerides of Jupiter's satellites, a valuable method of determining longitude, at least on land, finally became practicable.[23] Numerous observations in Paris, Florence, Rome, and even Danzig, showed the good results now, possible from simultaneous observations of the eclipses of Jupiter's satellites.[24] Largely in consequence of this success, CASSINI was invited on very generous terms to come to Paris as a member of the Academy, and was assured an important place in the affairs of the Observatory, then in process of construction. The astronomer JEAN PICARD, among others, appears to have urged COLBERT to make the offer.[25] By April 1669, CASSINI, founder of what became almost a dynasty at the Observatory, was established in Paris.[26]

Very shortly the Academy, according to its secretary, DUHAMEL, "began to discuss sending observers under the patronage of our most munificent King into different parts of the world to observe the longitudes of localities for the perfection of geography and navigation."[27] A new and persuasive argument for scientific expeditions was thus presented. By the end of May, HUYGENS was writing of persons about to be sent by the Academy to America.[28] One of them apparently was a M. MEURISSE, who in July was receiving living expenses while awaiting his departure for Cayenne.[29] In January 1670, when their stipends for the coming year were paid, both he and RICHER were listed as "mathematicians designated to go to Cayenne to make astronomical observations of utility to navigation."[30] Thus a voyage to Cayenne, intended perhaps as a more comprehensive scientific expedition by the Academy, was apparently being prepared some months before it was decided to send DELAVOYE and his clocks to the East Indies.[31] It was two years, however, before the expedition to Cayenne took place; that to the east did not occur at all.

DELAVOYE --- a *fripon* HUYGENS called him --- apparently could not stand success. His personal conduct and general unreliability became intolerable.[32] As a result he was dropped, and on March 10, 1670, COLBERT formally referred to RICHER as assigned to make a voyage to the East Indies, evidently, although this is not specifically stated, in DELAVOYE's place.[33] But apparently plans to send the clocks eastward were suddenly abandoned.[34] Instead, sometime after March 21, 1670, RICHER and MEURISSE sailed from La Rochelle to test their accuracy on a voyage to the west in the course of which at least two points on the New England and Acadian coasts were visited.[35] By late September both men were back in La Rochelle; at the end of the year they were in Paris.[36]

Almost at once plans for the Cayenne expedition were taken up again. The formal sanctioning of the expedition may have occurred even before the end of 1670 — in any case not later than the following spring.[37] Preparations still went slowly, however. The expedition of the Abbé PICARD to Uraniborg to determine the exact position of the observatory of TYCHO BRAHE may have occasioned some of the delay.[38] RICHER's passport was not issued until late in September.[39] Early in October, COLBERT officially requested transportation for RICHER and MEURISSE and their equipment and supplies. On the twelfth and thirteenth of the same month, RICHER's octant, a mate to one retained by CASSINI for the corresponding observations which were to be made, was finally verified and packed.[41] A month later at the Observatory these two men had their final discussion about the observations to be made in America. Immediately thereafter, RICHER left for La Rochelle to embark with MEURISSE.[42] The vessel, a merchantman of the French West India Company, ultimately sailed, according to RICHER's own statement, on the eighth of February, 1672.[43]

II

The aims of the expedition were well served by the choice of Cayenne rather than Madagascar as its destination. In general, a point only five degrees of latitude from the equator was more suitable than one which would have been nearer twenty-five degrees from it.[44] Speedier and more certain communications were a practical advantage. CASSINI deemed it important, as in the case of his joint work with PICARD at Uraniborg, to be able to exchange observations and keep in fairly close touch with RICHER. A principal raison was to make certain that an adequate series of reliable corresponding or simultaneous observations had actually been obtained. Moreover, the long delay in sending out the expedition insured the presence of the observers at Cayenne during the early autumn of 1672 when Mars, after an interval of about fifteen years, was closest to the earth. The importance of these facts will be clear if the program of observations which had been agreed upon for the expedition is examined.

The principal questions with which the expedition was concerned were three in number: the movements of the sun and the planets, refraction, and parallaxe.[45] CASSINI, and also PICARD, hoped that a station close to the equator, where the planets and the sun were nearer the observer's zenith, would practically eliminate the effects of refraction. A great improvement in existing tables of solar and planetary motions would thus be made possible. In addition to testing the accuracy of existing tables of refraction, it was hoped to discover the observational errors which might result from any considerable parallax of the planets. The successful determination of solar parallax, a fundamental astronomical constant, would open the way to the long-sought knowledge of the actual dimensions of the solar system.[46] No one appears to have regarded the investigation of the length of a seconds pendulum as a principal task of the expedition.[47]

What specific observations were to be made is most clearly stated in RICHER'S own account of the expedition's work. This, he says, needed to be carried on at a distant point near the equator to reduce the effect of refraction, and also to give considerable differences in meridian altitudes as compared with Paris. Observations were to be made of the obliquity of the ecliptic, the moment of the equinoxes, and the parallax and movements of the sun, Venus, Mars, and the moon. In addition, the movements of Mercury — a planet rarely observable in Europe — were to be given particular attention. Finally, the positions and magnitudes of southern stars not visible from Paris were to be carefully observed.[48]

The physical observations were to be limited to the duration of twilight, the refraction of light, the height of the column of mercury in a barometer, the length of a seconds pendulum, and the condition and times of the tides.[49] Actually a few rather naïve observations of animals and fishes were also made.[50]

RICHER does not mention certain other matters which CASSINI in his special instructions urged him to observe.[51] In these CASSINI suggested, and with RICHER later carried out, simultaneous observations of the eclipses of the satellites of Jupiter in order to determine the difference in longitude between Paris and Cayenne. In addition, he recommended the observation of specific lunar eclipses and the occultations of certain fixed stars, as well as some additional physical observations.

It was also, intended that RICHER and MEURISSE carry with them a specially remodeled marine clock for testing during the voyage. This, however, was not ready in time. HUYGENS, who was inclined to blame those in charge of his clocks for failures which were really mechanical, declared he was just as glad.[52]

The range of the observations which RICHER was expected to undertake should now be clear. There was nothing particularly original about the actual items which were included. Every one of importance, the length of a seconds pendulum not excepted, had been proposed by AUZOUT in his memoir of 1667.[53] Moreover, certain valuable observations which he had recommended, the Cayenne expedition apparently did not undertake. AUZOUT had urged the observation of the diameters of the sun, moon, and, by inference, the planets, work about which CASSINI does not seem to have been very keen, and which required a micrometer which RICHER either did not have or did not use. He had also suggested a telescopic description of the Milky Way to determine whether it was non-nebulous and composed of little stars or whether it was like the nebula in Andromeda. In addition, he had proposed many more physical observations, for the most part of a general character, than RICHER attempted to carry out.[54]

On the whole RICHER's agenda was probably superior. For one thing, the emphasis was different. If observations of importance proposed by AUZOUT were omitted, against this could be set greater simplicity and clearer, more unified, and more restricted objectives. By limiting its work principally to the observation of the pendulum, and to the three basic problems already indicated, the success of the expedition became more likely. The advantages of dealing with definite problems and relatively simple phenomena were clearly illustrated in the results which were to be obtained by the Academy's first overseas scientific expedition.

III

One may well ask why, in the two decades after 1650, certain fundamental problems of astronomy, and incidentally of geodesy and mechanics, assumed new prominence; and how --- in part through the work of RICHER's expedition --- they were later successfully investigated. One factor is, of course, the very rapid advance being made by astronomy. Between 1650 and 1670 three great inventions, pendulum clock, filar micrometer, and the application of telescopes to the graduated circles of astronomical instruments in place of the conventional sights or *pinnules*, combined to effect a revolution in observational astronomy.[55] An entirely new standard of accuracy and refinement became possible.

The stimulus to observational astronomy was immediate. And it was particularly consequential in France. The program of astronomical work which the Academy of Sciences early laid out for itself was based on a clear recognition that an entirely new degree of accuracy had become possible.[56] Manifestly, without correction, the old tables of the sun, the planets, and the stars could no longer be regarded as satisfactory.[57] The distances and the apparent motions of the sun and the planets, as well as the positions of the fixed stars, all needed to be checked or perhaps carefully redetermined. In the process, it was necessary to give attention to the imperfectly understood effect of refraction and parallax on the apparent positions of the heavenly bodies. Existing tables of refraction, particularly those which CASSINI had published in 1662, together with the hypotheses on which these tables were based, needed verification.[58] Moreover, if earlier observations were to be critically used and checked, it was necessary to know the latitude, as well as the difference in 1ongitude from Paris, of such important early observatories as those of HIPPARCHUS and PTOLEMY at Alexandria, and particularly that of TYCHO BRAHE at Uraniborg in Denmark.[59]

As a practical incentive to undertake some of these tasks, a good method for determining longitude, almost essential to successful observations for parallax, was introduced in I668.[60] And in 1669-70, PICARD, using the new instruments, completed geodetic operations for something equally important, a more accurate determination of the diameter of the earth.[61] This latter work quickened an interest --- already quite general on physical grounds --- in the behavior of the seconds pendulum.[62] For if it was uniform in length at all latitudes, the seconds pendulum would, as PICARD recognized, serve as an ideal universal natural standard of linear measurement.[63] RICHER's decision to investigate its behavior at Cayenne was more than likely a consequence of PICARD's urging.[64]

All these circumstances favored the formulation of the specific proposals for scientific expeditions made in France in 1667 and after; they also favored the success of RICHER's expedition. All the practical means for meeting the current needs of astronomy and investigating some of its more important problems were at hand. And since, as AUZOUT had indicated, the investigation of a number of these matters required observations made at distant points, the need for scientific voyages was pressing.[65] All that was necessary to ensure the fame and success of RICHER's expedition was CASSINI's brilliant recognition of the possibilities for the investigation of parallax inherent in the impending proximity of Mars to the earth in I672.[66] If FONTENELLE could later refer to RICHER's returning ship as bringing, figuratively, all the scientific riches of America to the Academy, it was in part because a practicable, although indirect, method of investigating solar parallax had been hit upon.[67]

IV

Taking the less dramatic results of the expedition first, it is noteworthy that, for the first time, the positions of a number of southern fixed stars were determined with some assurance of accuracy.[68] MARCGRAFF's observations in Brazil had been made before the great mid-century advance in astronomical instruments. Moreover, they were never printed and seem to have remained quite obscure.[69]

From the numerous observations of the sun, mainly meridian altitudes, a more accurate knowledge of its movements was obtained.[70] The obliquity of the ecliptic was determined very closely, as was the time of solstices and equinoxes.[71] RICHER pointed out in his account of the expedition that previously it has been quite difficult to find the exact instant of time at which the equinoxes arrived. Hence it had been difficult to determine accurately the right ascensions of the fixed stars. He surmised correctly that his observations would help to eliminate this problem.[72]

The observations which were made of the planets and of the moon provided valuable knowledge of their respective movements.[73] Naturally, these observations served, as did the solar and stellar observations, as a check on the accuracy of existing astronomical tables, thus conforming to the wishes of those who had inspired the expedition.[74]

Together, all of the observations of position helped to make possible a better knowledge of the effect of refraction, and of the amount of displacement occasioned by it at different altitudes.[75] The increasingly accepted view of CASSINI and others that the effect of refraction was sensible all the way to the zenith was corroborated. And CASSINI's tables of refraction, which gave the amount of displacement at different seasons for all altitudes from the horizon to the zenith, were shown to be quite accurate.[76] The table for summer, which appeared at the time to be the best, was thereafter adopted by CASSINI and for many years appeared regularly in the important official ephemeris, *La Connaissance des Temps*, first published in 1679.[77]

In the case of the planet Mercury, RICHER was able because of climatic conditions to observe it satisfactorily only three times.[78] The hope of adding appreciably to the knowledge of this little known planet could not be fulfilled. However, a few observations of Jupiter and its satellites were made. From corresponding observations of an eclipse of one of the latter, and from an eclipse of the moon, a satisfactory value for the difference in longitude of Paris and Cayenne was obtained.[79] This was important for the reduction of the observations for the parallax of Mars from which came the most dramatic results of the expedition.

Efforts to obtain the parallax of the sun directly were made in the early months after reaching Cayenne.[80] Possibly never more than half-hearted, they seem to have ceased rather quickly. With Mars it was different. In August, September, and October of 1672 when the planet was nearest the earth, RICHER was assiduous in observing it.[81] Its meridian altitude, as well as that of certain near-by fixed stars, was carefully measured, the time of the meridian transit being noted in each case.[82] Corresponding observations were made in France, by CASSINI and the Danish astronomer ROEMER in Paris, and later by both PICARD and CASSINI in the provinces.[83] From several sets of corresponding observations, CASSINI later calculated the value for the horizontal parallax of Mars and of the sun which appears in his important account of the astronomical results of the expedition, first published in 1684.[84]

The method employed was sound. What CASSINI first obtained by the reduction of RICHER's observations to the meridian of Paris, and their comparison with his own observations, was a value for the parallactic displacement of Mars as observed from Paris and from a hypothetical point on his own meridian having the same latitude as Cayenne.[85] Using a somewhat arbitrarily determined mean value of 15", he calculated the amount of Mars' horizontal parallax as being 25 1/3".[86] From additional calculations, a figure of 9 1/2" for the parallax of the sun was obtained.[87] This compares with the best modern values of about 8"80. CASSINI's use of the work done by the expedition had resulted in a brilliant, if rather lucky, success — an experience in no way unique, one suspects, in the history of science.[88] In this way, a basic problem of astronomy was successfully investigated, and with greater accuracy than was later recognized.[89]

The consequences of a much more accurate knowledge of solar parallax were great. Astronomy now possessed a carefully determined value for one of its most fundamental constants. Previous determinations, because of the conditions under which they had been made, could command little confidence.[90] For one thing, none of them had been made since the great mid-century improvements in astronomical instruments. CASSINI's result, like that which FLAMSTEED also obtained from observations of Mars in 1672, was in a somewhat different class.[91] Because the growth of scientific journalism now made possible the early publication and subsequent popularization of the results of the expedition, knowledge of its principal achievements soon became quite widely disseminated --- a fact of some importance.[92] Traces of the discussion of RICHER's expedition and its results in certain of the Paris salons of the day are to be found. HUYGENS in 1673 is said to have read some of RICHER'S letters from Cayenne to a group of ladies at the salon of Madame DE CHAUNES.[93]

The great consequence of the expedition for contemporaries was, of course, the revelation of the tremendous dimensions of the solar system, as well as the prodigious size of the sun and some of the planets. The disclosure, with some certainty, of the gigantic distances and masses involved was, for the general public, almost overpowering.[94] FONTENELLE's account of the principal results of the expedition, misleadingly placed under the year 1673, gives a clear sense of the consequences for the popular mind.[95] Small wonder if the young VOLTAIRE and his contemporaries sometimes felt that the place of the earth and man upon it had shrunk almost to insignificance.[96]

The most impressive results of the expedition were thus largely astronomical. The dramatic controversy which grew in part out of the careful observations made by RICHER on the length of the pendulum did not really begin until later.[97] The establishment of the fact of shortening near the equator was clearly, however, one of the important scientific consequences of the expedition — ample vindication of the soundness of its methods and aims.[98] Moreover, some of the scientific implications of the discovery of the pendulum's shortening were soon to be made manifest through its brilliant application to the analysis of the shape of the earth by HUYGENS, and particularly by NEWTON.[99]

V

From the necessarily rather detailed discussion of RICHER'S expedition some conclusions may be reached. Evidence has been presented to show that the results of the expedition for seventeenth-century science, especially astronomy, were considerable. From the problems facing the latter discipline, the idea of an expedition had been born; quite naturally the program of observations laid down for it was predominantly astronomical, as — despite later misconceptions — were the results.

Needless to say, the success of RICHER'S expedition gave an impetus in France to the preparation and dispatch by the *Académie des Sciences* of others like it. Circumstances affected the character, aims, and success of those which followed. In part because of RICHER's work, and also because of doubt about the validity of his findings on the pendulum, several observers later visited equatorial America and the West Indies. RICHER's expedition thus provoked a certain number of successors in the period between 1673 and 1735, the year of the well-known expedition of LA CONDAMINE to the Quito region of Peru, or rather Ecuador, to measure an arc of a meridian for the determination of the shape of the earth. The names of VARIN, DE GLOS, DESHAYES, COUPLET, Father FEUILLÉE, will at once suggest scientific expeditions to tropical America in the years from 1682 to 1715, which, in their investigations of the pendulum, at least, stemmed directly from the first expedition to Cayenne.[100] Does it follow that the latter was really an example of an important and distinctive type of scientific expedition ?

The principal characteristics of RICHER's expedition are perhaps evident. It grew out of an attempt to solve certain problems which stood in the way of the establishment of the "*règles certaines des mouvements célestes*" with which the Academy was so greatly concerned. It had an observing program which had been carefully prepared in advance. It had instruments specially selected for carrying this out. Moreover, its observing program was such that the successful investigation of the phenomena under consideration, e.g., solar parallax, or the behavior of a seconds pendulum, was a practical possibility. In short, the successful investigation of the questions being asked of nature necessitated the expedition and determined its character. The basic purpose was to investigate, not to collect; not to see things that were new and different; not to collect materials or data of general interest to science. Instead, the purpose of the expedition was to investigate certain definite scientific problems. Any notable examples of expeditions of this type prior to RICHER's voyage to Cayenne, or PICARD's expedition to Uraniborg, have not been found.[101]

The aim of typical seventeenth-century, scientific voyages was to collect materials or data of current or potential interest to science. The history of the widespread collecting activities thus carried on in behalf of science during the century is a subject in itself.[102] The enthusiasm was great; the energy in proportion; the results at times disappointingly small.[103] Without precise or limited aims, universal curiosity could often be more readily served than could the actual needs of science.

Many factors combined to encourage collecting during this period. For one thing, a number of sciences, particularly botany, zoology, mineralogy, and other branches of "natural history," were still in the predominantly collecting stage in their development, the stage of simple empirical observation, description, and classification. New species, new specimens, were what were most eagerly sought. In addition, there was widespread curiosity about the "wonders" and all the natural productions of newly discovered regions. The eyes of Europe were being opened to the remarkable things to be found overseas, a fact probably quite important in the history of the scientific movement just as it was in the movement of opinion.[104]

Furthermore, BACON's influence was an encouragement to collecting, and even gave it a more orderly character and a lofty purpose. Anyone thinking of the materials necessary for the preparation of the great "natural and experimental history" which was envisaged by BACON will quickly see why collecting seemed so important.[105] The Baconian spirit and the Baconian ideal affected not only individual scientists, but associations of scientists also. Some of the activities of the Academy of Sciences as well as those of the Royal Society offer undeniable evidence on this point.[106]

Actually, such work as that of GEORG MARCGRAFF and WILLEM PISO in Brazil from 1638 to 1643, seems about the best of the normal type of seventeenth-century scientific activity overseas.[107] Had *MARCGRAFF* not died before his return to Holland, two important books would certainly have come from his pen: a descriptive natural history of the Brazilian fauna and flora; and some astronomical tables of the positions of many southern stars and also the movements of the planets.[108] For *MARCGRAFF* and PISO had collected a staggering mass of material and data during the course of their Brazilian residence.[109] At its best, the collecting type of scientific expedition was indeed capable at this time of producing impressive results; at its worst, mere curiosities and bric-a-brac for a great lord's cabinet of natural history. But with few exceptions, voyaging — good or bad — devoted to the collection of the raw materials of science was only a normal expression of the dominant state of scientific knowledge and opinion.[110]

Much of the collecting which was done seems to have been of a random and haphazard sort, uncritical and undiscriminating. It was extensive rather than intensive; general instead of specific. A number of branches of science no doubt lacked the criteria essential to a critical selection of materials and data. But where these did exist, the fact that the voyaging, collecting, and observing was characteristically left either to a professional voyager or to almost anyone chancing to go on a distant journey, usually precluded any critical selection being made or any critical judgment exercised.[111] By contrast, a carefully planned voyage by a trained scientist for the investigation of significant problems or phenomena was a remarkable innovation. It was also a great advance in scientific technique and the procedure and methods of scientific investigation.

That this new cooperative technique was not perfected or utilized earlier its perhaps not surprising. Only when a particular science, in this case astronomy, had reached a point in its development at which it required the assistance of observations made at distant points was a formal scientific expedition likely to be thought of in any detail and with any urgency. Even then, unless an active and more or less permanent center of scientific studies, such as an academy or observatory, existed, the fullest comprehension of the potentialities of scientific expeditions could have little practical effect. Moreover, before an expedition which an academy or observatory had planned could actually be sent out, not only royal consent, but royal backing and financial assistance, was almost indispensable. Apparently these conditions were first fulfilled in France shortly before 1670. The expedition to Madagascar, later diverted to Cayenne, was conceived of in circumstances in which the need, the technical and scientific means, and the requisite political and financial support, all existed. It was very likely for want of this favoring combination of circumstances --- possibly for want also of someone with the profound insight of ADRIEN AUZOUT — that expeditions of the same type had not previously been carried out.

Thus there was much that was significant in the expedition undertaken by JEAN RICHER in 1672-73. And the interest of the expedition is all the greater because it so well mirrors some of the scientific and astronomical activity of the period; mirrors also something of the institutional and social context in which this was set. It was an exception, and a notable one, to much that was characteristic of scientific activities at the time. Moreover, it may well have been the product of an older scientific tradition and a better scientific method.[112] Possibly in this lies the deeper significance of this first modern scientific expedition.

THE SCIENTIFIC EXPEDITION OF JEAN RICHER TO CAYENNE (1672-1673)[1]
By JOHN W. OLMSTED

Reprinted from ISIS, Volume XXXIV
Part 2, No. 94, Autumn, 1942, 117-128

LES RENVOIS DU TEXTE :

1
Presented in a slightly different form at the joint session of the History of Science Society and the American Historical Association in New York City in December 1940. The title was then given as "Some Early French Scientific Expeditions to America."

2
Typical as regards RICHER's expedition are FRIEDRICH DANNEMANN, *Die Naturwissenschaften in ihrer Entwicklung* ... (2nd ed.; Leipzig, 1920-23), II, 316; MAXIMILIEN MARIE, *Histoire des sciences mathématiques et physiques* (Paris, 1883-88), V, 102-03; WILLIAM WHEWELL, *History of the inductive sciences* . . . (3rd ed.; New York, 1875), I, 454. A. WOLF, *A History of science, technology and philosophy in the XVIth and XVIIth centuries* (London, 1935), pp. 67, 175-76, is somewhat more adequate, but less good than the brief notice by HENRI ANDOYER and PIERRE HUMBERT in *Histoire de la nation française*, ed. GABRIEL HANOTAUX (Paris, [c. 1920-29]), XIV, 111-12, 113. Certain histories of astronomy are fuller than these last two accounts, but hardly more critical or adequate.

3
The exception was the expedition of GEORG MARCGRAFF and WILLEM PISO to Brazil with Prince JOHAN MAURITS OF NASSAU-SIEGEN in 1637-43, referred to *infra*, p. 129.

4
Best known are probably the LA CONDAMINE expedition to Ecuador (1735-43), that of MAUPERTUIS to Lapland (1736-37), and of LACAILLE to the Cape of Good Hope (1750-54), together with some of the expeditions to observe the transit of Venus in 1761 and 1769.

5
Cf., on RICHER, JOSEPH BERTRAND, *L'Académie des Sciences* (Paris, 1869), pp. 27-29, 33-36; ALFRED MAURY, *L'ancienne Académie des Sciences* (2nd ed.; Paris, 1864), p. 31. The principal sources on which these are based are little better: cf. J. B. DUHAMEL, *Regiae scientiarum Academiae historia* (2nd ed.: Paris, 1701), pp. 104-12, which is much fuller but discursive and uncritical; BERNARD DE FONTENELLE, *Histoire de l'Académie royale des Sciences*, vol. I, Depuis son établissement en 1666 jusqu'à 1686 (Paris, 1733), in *Mémoires de l'Académie royale des Sciences depuis 1666 jusqu'à 1669* (11 vols.; Paris, 1727-33), I, 157-58. (Subsequent references, unless otherwise indicated, are to this edition, cited as M.A.S.). FONTENELLE gives no indication of the antecedents of the expedition, but does give a good account of its aims and results.

6
An important contemporary summary of the history and results of the conflict is the article, "Figure de la terre", by J. C. LE R. D'ALEMBERT in *L'Encyclopédie . . .* (Paris, 1751-65), VI, 749-62. For a useful recent discussion and some bibliography on the question see P. BRUNET, MAUPERTUIS (Paris, 1929), II, 89-166, covering the period *circa* 1650--1750.

7
The astronomical aspects of the expedition are discussed *infra*, pp. 121-26.
JEAN RICHER (1630-96), was an *élève astronome*, or assistant for astronomy, from the founding of the Academy. In 1674 he became an *ingénieur du roi* in the service of fortifications under VAUBAN.
GIOVANNI DOMENICO CASSINI (1625-1712), famous Italian astronomer, was brought to France in 1669 on a large royal pension, and attached to the new Observatory, although not as its director. He became a member of the Academy as an *astronome* the same year.

8
What follows is based on an examination during 1936 of the relevant manuscript materials in the archives and libraries of Paris, and the archives of the Royal Society in London.

9
Paris, Archives de l'Académie des Sciences, *Registres de l'Académie des Sciences*, II (*Mathématiques*, 1666-68), 155 (cited hereafter as R. A. S.). From 1667 until 1684 the minutes of the meetings devoted to *physique* were kept in separate volumes, the volumes, however, forming one general file and being numbered consecutively. Since all the volumes cited hereafter are for the *séances de mathématiques*, only the years covered by the volume being cited will be indicated. Unfortunately those for 1670-74 are wanting.

10
Ibid., II, 43-50.

11
AUZOUT was baptized 28 January 1622 : Paris, Académie des Sciences, *Annuaire pour 1940*, p. 117. The year of his birth is usually given as 1630. He died in 1691.

12
LAVISSE et RAMBAUD, eds., *Histoire générale* ... (Paris, 1893-1901), VI, 237.

13
M. THEVENOT to Prince LEOPOLD DE MEDICI, 16 October 1666, quoted by A. J. GEORGE, *Annals of Science*, III (1938), 385.

14
R. A. S., *loc. cit.* This unpublished memoir is the fundamental document for the history of the first French scientific expeditions, but is too lengthy to reproduce in this article, even in summary. AUZOUT distinguishes astronomical observations which can be made anywhere, but which should be confirmed in the southern hemisphere, front those which can be made only in a place like Madagascar. Of the latter, those requiring corresponding or simultaneous observations at Paris are differentiated from those which

may be made independently at Madagascar. The sixteen types of astronomical observations proposed constitute a comprehensive observational program, adequate for a permanent observatory, and for the most part significant. In addition, some eleven terrestrial or physical observations are proposed, quite a number to be made during the course of the voyage to the island.

15
Cf. ROBERT BOYLE, "General Heads for a Natural History of a Countrey, Great or small . . .," *Philosophical Transactions*, nos. 11, 18, 19 (1666), 186-89, 315-16, 330-43; *Oeuvres complètes de Christiaan Huygens publiées par la Société hollandaise des sciences* (La Haye, 1988 ff.), IV, 326-28.

16
Ibid., VI, 129.

17
HUYGENS' first marine pendulum clock was completed in 1662. Much of the early testing of these instruments (1663-65) took place on English ships under the eyes of the Royal Society. The French were eager rivals for the potential advantages this invention might confer. *Ibid.*, IV, V, *passim*; A.J. GEORGE, *Annals of Science*, III (1938), 230-33.

18
AUZOUT to OLDENBURG, 17 March 1668, London, Royal Society, *Letters*, A, 21; HUYGENS, *Oeuvres*, VI, 200, 218, 226. On the voyage of 1669, [Christiaan Huygens], "Sur l'Essay des Horloges sur mer par M. La Voye dans le Vaisseau de M. de Beaufort au voiage de Candie en 1669," *ibid.*, VI, 501-03; also *ibid.*, XVIII, 633-35; F. MARGUET, *Histoire générale de la navigation du XV^e au XX^e siècle* (Paris, 1931), pp. 133-35.

19
Otherwise known as DE LA VOYE-MIGNOT (?-1684), an astronomer and engineer. According to the contemporary, CHARLES PERRAULT (*Mémoires de ma vie* [Paris, 1909], p. 46), these *élèves*, or *aides*, of whom there were five, were included in the Academy "... pour écouter et pour exécuter ce qui avoit été résolu par la compagnie, et particulièrement pour faire des observations dont elle avoit besoin."

20
HUYGENS, *Oeuvres*, VI, 379, 500; VII, 26-27. For the actual observations see *ibid.*, XVIII, 116-19.

21
Comptes des bâtiments du roi sous le règne de Louis XIV, ed. JULES GUIFFREY (Paris, 1881-1901) ["Collection des documents inédits sur l'histoire de France"], I, col. 379 (cited hereafter as *Comptes*). For this projected third expedition cf. HUYGENS, *Oeuvres*, VI, 26-27; LEIBNIZ, *Sämtliche Schriften und Briefe*, Zweite Reihe, I (Darmstadt, 1926), 69-70. The date of OLDENBURG's letter to LEIBNIZ in this last (8/18 December 1670), offers some difficulty, unless, as both external and internal evidence suggest, it should actually be dated 1669.

22
Cf. HUYGENS, *Oeuvres*, VI, 267, n. 1; H. BROWN, *Scientific organizations in 17th century France* (Baltimore, 1934), pp. 138-40; AUZOUT to OLDENBURG, Rome, 24

August 1673, in S. P. RIGAUD, ed., *Correspondence of scientific men of the seventeenth century* ... (Oxford, 1841), 1, 208. In this letter AUZOUT says that he bas been " ... toujours ... dans l'incertitude de [son] retour," merely camping in Italy.

23
Ephemerides Bononienses mediceorum syderum, ex hypothesibus et tabulis Joan. Domin. Cassini (Bologna, 1668). The accurate prediction of the times at which eclipses of Jupiter's satellites would take place greatly facilitated simultaneous observations of these occurrences in two or more widely separated places. A comparison of the local solar or sidereal time at which an eclipse was observed to occur immediately gave the difference in time, i.e., in longitude, between the stations concerned. The method had been known ever since GALILEO'S discovery of the four brighter satellites in 1610, but had not previously been entirely practical.

24
Cf. "Vie de Jean-Dominique Cassini, écrite par lui-même," in J. D. CASSINI (1748-1845), a descendant often referred to as Cassini IV, *Mémoires pour servir à l'histoire ... de l'Observatoire royal de Paris ...* (Paris, 1810), pp. 285-87, 297-99; G. BIGOURDAN, *Histoire de l'astronomie d'observation et des observatoires en France* (Paris, 1918-30), I, 121; A. G. PINGRE, *Annales célestes du dix-septième siècle*, Ed. BIGOURDAN (Paris, 1901), pp. 280-82, the last with considerable bibliographical information to make up for some factual omissions; *Manuscrits de l'Observatoire de Paris*, B.4.1, pp. 387-444.

25
J. B. J. DELAMBRE, *Histoire de l'astronomie moderne* (Paris, 1821), II, 598. PICARD (1620-82) became an *académicien astronome* in 1666.

26
C. WOLF, *Hist. de l'Observ.*, pp. 5-7; J. D. CASSINI (Cassini IV), *op. cit.*, pp. 284-91.

27
DUHAMEL, *op. cit.* (1701 ed.), p. 44.

28
HUYGENS, *Oeuvres*, VI, 427-28, 440.

29
Comptes, I, col. 379.

30
Ibid., col. 476, under date of 30 January 1670. The term *mathématicien* was regularly used to describe persons skilled in astronomical and related scientific observations.

31
HUYGENS first specifically mentions Cayenne as the destination of the observers for America in a letter of 4 September 1669 to OLDENBURG: *Oeuvres*, VI, 486.

32
Ibid., VII, 26-27. There is a faint intimation of similar difficulties at an earlier date in a letter of DELAVOYE to COLBERT, 23 April 1669, Bibliothèque Nationale, Mélanges de Colbert, 151 bis, fol. 687.

33
HUYGENS, *Oeuvres*, VII, 26-27; P. CLEMENT, ed., *Lettres, instructions, et mémoires de Colbert* (Paris, 1861-70), V, 294-95; *Comptes*, 1, col. 470. The difficulties of C. WOLF (*Hist. de l'Observ.*, pp. 143-44), and of the editors of HUYGENS' *Oeuvres* (XVII, 633 and note 2), with this proposed voyage are entirely removed by a careful examination of all the available documents.

34
There is no positive evidence as to the reasons which prompted this change in plan. Considering all the circumstances, it seems more than likely that the objections which caused COLBERT to rescind his earlier order came from members of the Academy of Sciences, including PICARD and CASSINI, who for scientific reasons preferred to have RICHER and MEURISSE sent to Cayenne.

35
RICHE is himself the principal authority for this voyage. See his *Observations astronomiques et physiques faites en l'isle de Cayenne* (Paris, 1679), reprinted in *M. A. S.*, VII[1], 233-329. The two points can be readily identified. HUYGENS was not at all pleased with RICHER's handling of the marine clocks during this voyage and charged him with nonchalance, attributing to this the poor results obtained: *Oeuvres*, VII, 54-55.

36
Comptes, I, col. 476.

37
The evidence for the earlier date is entirely inferential, but in the aggregate seems fairly conclusive. From internal evidence, CASSINI's undated instructions for RICHER, entitled, "Pro expeditione Brasiliana," were written well before 30 January 1671. The text is in *R. A. S.*, IX (1679-83), 137-39.

38
PICARD did not leave until 21 or 22 July 1671, his passport not being issued until the 17th of that month: Paris, Archives Nationales (hereafter cited as A. N.), *Marine*, $B^7$54, fol. 21, "Passeport en faveur du S^r Picard s'en allant en Dannemarck"; HUYGENS, *Oeuvres*, VII, 84.

39
"Passeport pour S^r Richer s'en allant en l'Isle de Cayenne," Versailles, 29 September 1671: A. N., *Marine*, $B^7$54, fol. 116-17. Expense money had been provided on the 27th: *Comptes*, I, cols. 549-50, 556.

40
Correspondance administrative sous le règne de Louis XIV, ed. G. B. DEPPING (Paris, 1850-55), ["Collection des documents inédits sur l'histoire de France"], IV, 579. COLBERT's letter included the order to provide suitable lodging at Cayenne for both men, and to transport them back to France when their work was completed.

41
CASSINI to PICARD, 15 October 1671, *Manuscrits de l'Observatoire de Paris* (hereafter cited as *Observ.*), A.4.2, fol. 17, G. The two octants and a medium-sized quarter circle were carefully compared by means of meridian altitudes of various stars. During September and October MEURISSE and RICHER often observed with CASSINI in

preparation for the joint observations to be made at Paris and Cayenne: *ibid.*, fol. 17, F; C. WOLF, *Hist. de l'Observ.*, pp. 141-42.

42
Observ., D.1.1, 15 November 1671, quoted by C. WOLF, *op. cit.*, p. 142, n. 1.

43
RICHER, *op. cit.*, *M. A. S.*, VII^1, 235.

44
The town of Cayenne, in French Guiana, lay in latitude 40° 56' N. on the northwest extremity of the island of Cayenne near the mouth of the river of that name, and had been in French possession again since 1664, following a period of Dutch influence. At the time, *Cayenne* and *isle de Cayenne* appear to have been used interchangeably to designate the settlement on the island. The principal French settlement in Madagascar was Fort Dauphin at the southeast tip of the island in lat. *ca.* 25° S. Of the intended observations, only those of the more southerly fixed stars and of Mars could have been made more effectively in this latitude.

45
These matters where all fundamental to the general program of astronomical observations laid down by the Academy in 1667 and outlined again by PICARD in a memoir presented in 1669. See infra, p. 123. The Academy's program was described by DELAMBRE as the construction of good tables of the sun, a good catalogue of the stars and good tables of refraction: DELAMBRE, *op. cit.*, II, 624, 739; J. DE LALANDE, *Astronomie* (2nd ed.; Paris, 1771), II, 661-63, 672; BIGOURDAN, *op. cit*, I, 140-43.

46
Parallax refers to the apparent displacement of a body which is observed from two different points. In astronomy, horizontal parallax may be defined as the angular semi-diameter of the earth as seen from the sun or one of the planets (another way of defining the amount of the apparent displacement of the body when observed from two different points on the earth's surface). Actually the angle involved is so small in the case of the sun as to make its direct determination almost impossible. Only when solar parallax is accurately known, however, can the distance of the earth and the other planets from the sun (in linear units) be determined.

47
At the very end of his memoir AUZOUT merely noted (*R. A. S.*, II, 49) : "On remarquera s'il ne faut pas acourcir ou alonger le pendule." CASSINI's instructions to RICHER do not even mention the matter, although other physical observations are suggested: *ibid.*, IX (1679-83), 137-39.

48
RICHER, *op. cit.*, p. 2 (edition of 1679, reprinted in 1693 in *Recueil d'observations faites en plusieurs voyages, par ordre de Sa Majesté, pour perfectionner l'astronomie et la géographie . . .*), which differs slightly from the version in *M. A. S.*, VII^1, 233-34, printed in 1729.

49
M. A. S., VII^1, 234-35.

50
Ibid., VII[1], 325-26.

51
"Pro expeditione Biasiliana," *R. A. S.*, *loc. cit.*

52
HUYGENS, *Oeuvres*, VII, 117, 142. Cf. *ibid.*, XVIII, 117, for HUYGENS' later summary of his grievances against those who had been charged with the testing of his clocks.

53
R. A. S., *loc. cit.* Even the testing of HUYGENS' marine clocks had been suggested by AUZOUT for the proposed expedition to Madagascar.

54
Ibid., p. 49.

55
For an informative recent account, with good illustrations of some of the instruments, see A. WOLF, *op.cit.*, pp. 112-14, 165-74.

56
PICARD and AUZOUT were the chief spokesman for this point of view, very definitely expressed before the Academy on a number of occasions, first in 1666 or 1667: *R. A. S.*, II (1666-68), 30-33 (quoted in part by J. BERTRAND, *op. cit.*, pp. 10-11, without indication of source); III (1668-69), 145-50 (24 October 1668); V (1669), 126-28 (31 July 1669).

57
The need for the correction and improvement of existing tables was discussed at length in the memoir of 1666-67 just cited, and in another (by PICARD) *circa* 27 November 1669: *ibid.*, II, 30-33; V, 226-28.

58
These appeared in CORNELIO MALVASIA, Ephemerides novissimae motuum coelestium . . . additis ephemeridibus solis, et tabulis refractionium ex novissimis hypothesibus . . . Joannis Dominici Cassini . . . (Mutinae [Modena], 1662). The minutes of the Academy for the period circa 1667-70 contain numerous references to the problems of refraction and parallax.

59
PICARD, *Voyage d'Uraniborg, ou observations astronomiques faites en Dannemarck* (1680), in *M. A. S.*, VII[1], 193-94. PICARD never abandoned his plan for an expedition to Alexandria and was preparing to set out shortly before his death in 1682: HUYGENS, *Oeuvres*, VIII, 400. The greater urgency of the voyage to Uraniborg arose from the fact that the observations made there and incorporated by KEPLER in his so-called Rudolphine Tables (1627), although seriously in error in some respects, were still the best available: R. A. S., II (1666-69), 30; Pingré, *op. cit.*, p. 10.

60
Supra, p. 120, and n. 23, 24.

61
PICARD, *Mesure de la terre* (1671), in *M. A. S.*, VII[1], 133-93.

62
For illustrations of this interest, cf. HUYGENS, *Oeuvres*, XVII, 247; XVIII, 636; F. CAJORI in History of Science Society, *Sir Isaac Newton, 1727-1927* (Baltimore, 1928), p. 172, quoted by T. D. COPE, *Pennsylvania History*, VI (1939), 213. A seconds pendulum is a pendulum of such length that its period of oscillation is one second.

63
R. A. S., V (1669), 126-28 (31 July 1669); *Mesure ...*, *M. A. S.*, VII[1], 139-42.

64
It was to help settle the question that PICARD made a number of determinations of the length of a pendulum at Uraniborg: *ibid.*, VII[1], 142, 208. Moreover, there is no doubt that PICARD and RICHER were in touch with one another during their respective expeditions. HUYGENS, from his theoretical interest in the question, was the other person most likely to have pressed for careful observation of the pendulum at Cayenne.

65
Loc. cit., supra.

66
Infra, p. 125.

67
FONTENELLE, *op. cit., M. A. S.*, I, 168, writing of the history of the Academy for 1673.

68
In RICHER's account of the expedition, most of the observations of the fixed stars are tabulated in chapter VIII, "Hauteurs méridiennes de plusieurs fixes observées en l'isle de Caïenne en 1672 et 1673." Of eighteen pages, fifteen are devoted to observations of stars with a southerly declination: *op. cit., M. A. S.*, VII[1], 259-77.

69
On the work of MARCGRAFF and PISO in Brazil, *infra*, p. 127, and notes. The astronomical work is still very little known, but not, as so often stated, almost completely lost. There is a copy of observations by MARCGRAFF extending from 9/19 September 1638 to 22 June 1643 among DELISLE's papers at the Paris Observatory, *Observ.*, B.4.5. It was from this that PINGREÉ got the observations which appear in his *Annales célestes ...*, which deserve to be more widely known. The problems offered by MARCGRAFF's observations are well discussed, *ibid.*, pp. 138-41.

70
RICHER, *op. cit.*, ch. III: "Du Soleil," *M. A. S.*, VII[1], 239-47, for the observations made. RICHER's greatest advantage was the proximity of the sun to his zenith, by which the effect of refraction was greatly reduced. The results served as a valuable check on the accuracy of existing tables of the sun and of refraction, and also provided materials for their improvement: DUHAMEL, *op. cit.* (1701 ed.), p. 111.

71
For an evaluation of the importance of the determination of the obliquity of the ecliptic, and of the accuracy of the results obtained, cf. LALANDE, *op. cit.*, II, 662-63; DELAMBRE, *op. cit.*, II, 740. RICHER's observed value as corrected by CASSINI was apparently in error only ± 1".0 —a better value than DELAMBRE recognized. CASSINI himself thought the accurate determination of the obliquity of the ecliptic alone warranted the expedition: J. D. CASSINI, *Les elemens de l'astronomie verifiez par M. Cassini par le rapport de ses tables aux observations de M. Richer faites en l'isle de Caïenne . . .* (Paris, 1684), as reprinted in *M. A. S.*, VIII, 56, 58-60. (All further references to this work are to the above edition).

72
RICHER, *op. cit.*, *ibid.*, VII[1], 277-78. LEMONNIER (*Histoire céleste . . .* [Paris, 1741], pp. vii, xxxviii-xlii) points out that these observations of RICHER, when compared with those which were continued at the Observatory, gave rise to a "règle générale" for finding the altitude of the upper limb of the sun at the instant of the equinox, accurate within 10-20". The great importance of this result in relation to the work being done by the astronomers of the Academy and the Observatory, particularly on the direct determination of the absolute right ascension of the fixed stars, is convincingly shown by BIGOURDAN, *op. cit.*, I, 140-44.

73
RICHER, *op. cit.*, ch. IV-VII, *M. A. S.*, VII[1], 247-59, for the observations made.

74
Cf. *supra*, pp. 121-22, 123, and n. 57.

75
The importance of this question at the time has already been indicated: *supra*, pp. 121-23, and notes. For a contemporary view of its urgency, cf. CASSINI, *op. cit.*, *M. A. S.*, VIII, 56-60. The history of the investigation of the problem to *circa* 1740 is summarized by LEMONNIER, *op. cit.*, pp. vii ff.

76
Cf. LALANDE, *op cit.*, II, 621-23, 672-73; ROBERT GRANT, *History of physical astronomy . . .* (London, n.d. [1852]), pp. 321-35; LEMONNIER, *op. cit.*, pp. vii-viii; also for the background, DELAMBRE", *op. cit.*, II, 722-27, 737-39. (There are evident errors of fact in all these accounts). CASSINI himself evaluates the results obtained, *op. cit.*, *M. A. S.*; VIII, 87-93.

77
For a critical evaluation of CASSINI's tables see Abbé N. L. LACAILLE, "Recherches sur les refractions astronomiques . . ., *Mém. Acad. Sci.*, 1755, pp. 549-50, 576-77.

78
RICHER, *op. cit.*, ch. IV, *M. A. S.*, VII[1], 247-50.

79
CASSINI, *op. cit.*, *ibid.*, VIII, 69-72; RICHER, *op. cit.*, *ibid.*, VII[1], 237-38, 278 ff. The values used by CASSINI correspond closely to the difference in longitude now commonly accepted.

80
RICHER to CASSINI, 20 July 1672, *Observ.*, B.1.12, *Lettres Autographes . . .*, recommending his observations of the sun before and after the recent solstice as very accurate.

81
Writing on 20 July 1672 (*loc. cit., supra*), RICHER had assured CASSINI that he would apply himself especially to the observations of the meridian altitude of Mars from 1 August until the end of October.

82
RICHER, *op. cit.*, *M. A. S.*, VII[1], 256-59, 263-77, 280-313, for the details of the observations made. PINGRÉ, *op. cit.*, pp. 304-06, reproduces some of the more important data.

83
PINGRÉ, *op. cit.*, pp. 304-06, prints the more important of these, indicating the sources from which he obtained them. The fullest account of the observations of PICARD and CASSINI in the provinces is in *M. A. S.*, VII[1], 327 ff., 349 ff.

84
CASSINI, *op. cit.*, *M. A. S.*, VIII, 96-105.

85
The method is very neatly and succinctly, but somewhat misleadingly, described by FONTENELLE in his history of the Academy for 1673: *M. A. S.*, I, 170. CASSINI's longer statement in the *Elemens . . .* (*ibid.*, VIII, 98-99), if less clear, is more exact. In section XXX of the same work (pp. 102-03) may be found an effective illustration of the actual use of a set of corresponding observations to obtain the parallactic difference of Mars as seen from Paris and from a hypothetical point on the same meridian having the latitude of Cayenne.

86
The corresponding observations used by CASSINI were those of 5, 9, and 24 September 1672. The parallactic differences derived from them were respectively 12", 13", and 17", with a mean of 14". For reasons which are not entirely clear, CASSINI adopted a mean of 15" (actually had he used 14", the resulting horizontal parallax of Mars and of the sun would have been even more accurate–*circa* 9" for the latter): *ibid.*, VIII, 99-105. For some elaboration of the procedure followed, and an example of its application in the determination of horizontal parallax, see JACQUES CASSINI, *Eléments d'astronomie* (Paris, 1740), pp. 20-21.

87
M. A. S., VIII, 113-14.

88
Cf. DELAMBRE, *op. cit.*, II, 741.

89
HALLEY, in 1719, following some observations of POUND and BRADLEY made that same year, could only conclude that the parallax of the sun was between 9" and 12". In

France, LA HIRE appears to have regarded it either as insensible or at most 6". Other observers, prior to LACAILLE's work with LALANDE in 1751-52, accepted limits of 11" and 15" respectively, and LACAILLE himself got 10" or 10".5. Only with the second transit of Venus in 1769 was a more accurate result than that of CASSINI obtained. Cf. LALANDE, *op. cit.*, II, 413-15; HUYGENS, *Oeuvres*, IX, 379. There is a concise summary of the principal determinations of parallax during the 17th and 18th centuries in F. ARAGO, *Astronomie populaire* (Paris, 1867), III, 363-68.

90
These uncertainties about the value of solar parallax are discussed by LALANDE, *op. cit.*, II, 407-10.

91
JOHN FLAMSTEED (1646-1719), the first English Astronomer Royal. His results (25" for the parallax of Mars and 10" for that of the sun), appeared in *Philosophical Transactions*, no. 96 (21 July 1673 o.s.), P. 6000 (mistake for 6100). NEWTON appears to have adopted a value for the parallax of the sun of 10".5, closely akin to that of FLAMSTEED: *Philosophia naturalis Principia Mathematica*, ed. CAJORI (Berkeley, Calif., 1934), p. 416.

92
On the rise of scientific journalism, see PRESERVED SMITH, *A history of modern culture* (New York, 1930-34), I, 172-75.

93
G. TOUCHARD-LAFOSSE, *Chroniques de l'Oeil de Boeuf* (Paris, 1864), III, 22, quoted by HENRI L. BRUGMANS, *Le séjour de Christiaan Huygens à Paris ...* (Paris, 1935), p. 80. Using the value of 9".5 for the parallax of the sun, CASSINI calculated its distance from the earth as 21,600 semi-diameters of the earth or 33,000,000 leagues (approximately 87,000,000 miles as against the nowadays accepted 92,800,000 miles, the league being between 21/2 and 3 miles). Mars he found distant by 8100 semi-diameters at the time of opposition. But he warned that an error of 2" to 3" in the parallax of Mars might easily exist, and that this might throw the distance of that planet out by as much as 1000 semi-diameters; that of the sun by 2000 to 3000 semi-diameters. The value of *circa* 22,000 semi-diameters for the sun's distance seems, however, to have become quite widely used. HUYGENS was one of the few making it larger still. CASSINI, *op. cit.*, *M. A.S.*, VIII, 115-17; HUYGENS, *Oeuvres*, XV, 192-93, 347, n. 7.

95
M. A. S., I, 173-74.

96
Cf. FONTENELLE, *op. cit.*, I, 132; P. SMITH, *op. cit.*, II, 148-49, based on evidence from BUFFON and POPE.

97
The case for the elongation of the earth at its poles was first put effectively by JACQUES CASSINI, *De la grandeur et de la figure de la terre* (Paris, 1720). Only in the years after its publication did the conflict in France between adherents of the Newtonian theory of flattening and the more numerous Cassinians become serious. For the origins and history of the controversy see the works cited *supra*, n. 6. The relevant contemporary scientific literature is analyzed in the informative but shapeless work of I. TODHUNTER,

A history of the mathematical theories of attraction and of the figure of the earth (London, 1873).

98
For some of the objections raised against the alleged shortening, e.g., by PHILIPPE DE LA HIRE, see HUYGENS, *Oeuvres*, IX, 162 ff.; Mém. Acad. Sci., 1703, 285-99. For important determinations of the length of a seconds pendulum from 1672 to 1704, see the convenient contemporary tabulation in NEWTON, *op. cit.*, ed. CAJORI, pp. 430-33.

99
Cf. NEWTON, *op. cit.*, ed. CAJORI, Propositions XVIII, XIX, XX of Book III, pp. 424-33 (the first edition was published in 1687); [Christiaan Huygens], *Traité de la Lumière ... par C. H. D. Z. Avec un Discours de la Cause de la Pesanteur* (La Haye, 1690). For the persistence of HUYGENS' doubts of the validity of RICHER's discovery until *circa* 1687 see his *Oeuvres*, IX, 130-33; XVII, 285-86; XVIII, 635-36.

100
Most of the pendulum observations by these persons are listed by NEWTON, *loc. ci., supra*. The most formal and ambitious expedition of those for which the Academy was directly or indirectly responsible was that of VARIN, DE GLOS, and DESHAYES to the island of Gorée in West Africa and thence to the West Indies in 1682-83: *M. A. S.*, VII^2, 431-63.

101
The only considerable expedition of any kind before 1671 appears to have been that of MARCGRAFF and PISO with Prince JOHAN MAURITS OF NASSAU-SIEGEN to Brazil (1637-43), which was entirely devoted to "collecting," astronomical, botanical, and biological. *Infra*, p. 127.

102
For French activities of this kind there is much to be gleaned from the documents in HENRI OMONT, ed., *Missions archéologiques françaises en Orient aux* $XVII^e$ *et* $XVIII^e$ *siècles* (Paris, 1902). ["Collection des Documents inédits sur l'histoire de France"]. These volumes give a remarkable cross section of French collecting of all kinds, much of it devoted to the enrichment or embellishment of royal *cabinets*, palaces, gardens, menageries, etc.

103
Compare the unimpressive results of the collection of information and specimens attempted by the Royal Society by means of its instructions and questionnaires for travelers with the equally unimpressive scientific observations and collecting attempted by those making archeological, commercial, or (with some notable exceptions in the case of the French Jesuits in the Far East) missionary voyages for the French government: T. BIRCH, *History of the Royal Society of London ...* (London, 1756-57), *passim*; *Philosoph. Trans.* (1665 ff.), *passim*; OMONT, *op. cit.*, *passim*.

104
For clear indications of such an influence on BACON's scientific outlook see the striking passage from *Novum Organum*, *Works*, ed. SPEDDING (1900), VIII, 117.

105
See *ibid.*, VIII, 353-81 ("Parasceve"), esp. 354, 359, 360, 375-76; VIII, 48 ("The Great Instauration"); V, 383-84, 409-10 (*New Atlantis*).

106
For the Royal Society, cf. MARTHA ORNSTEIN, *The rôle of scientific societies in the seventeenth century* (Chicago, 1928), p. 121 and notes 123, 124; BIRCH, *op. cit.*, I, 8-10, 297-99; II, 132-33, 151, 256, 471-72, 500. For the Academy of Science, HUYGENS, *Oeuvres*, IV, 325-29; *Lettres de Colbert*, V, 523-24. The influence of BACON'S ideas on the formation of scientific societies is discussed by ORNSTEIN, *op. cit.*, pp. 42-44. Such an influence is very evident in early volumes of the *Philosophical Transactions*, e.g., in OLDENBURG's brief introduction to no. 1 (6 March 1664-65), pp. 1-2.

107
For want of careful study, the circumstances in which the expedition originated are obscure. For pertinent information on Prince JOHAN MAURITS (1604-79), and PISO (1611-78), *Nieuw Nederlandsch Biografisch Wordenboek* (Leiden, 1911-37), I, cols. 1222-24, 1421-22; IX, cols. 805-06. For MARCGRAFF (1610-44) [so spelled in the following work], a German who had studied for some years in the Netherlands, *Allgemeine Deutsche Biographie* (Leipzig, 1875-1912), XX, 295-96. A painter, FRANZ POST, apparently was in Brazil with these persons. It is doubtful that his more famous brother, the architect PIETER POST, actually was. For some bibliography on the expedition and an account of its work in natural history, E. W. GUDGER, "George Marcgrave, the first student of American natural history," *Popular Science Monthly*, 1912, 250-74.

108
For some of the astronomical observations, largely made in the years 1639-41 and 1642-43 in a specially built observatory—allegedly the first regular observatory in the New World—cf. PINGRÉ, *op. cit.*, *passim*. The potential as well as the actual value of the work accomplished in natural history has been placed very high. Cf., GUDGER, *Pop. Sci. Monthly*, 1912, 261, 273.

109
The collections brought back by JOHAN MAURITS from this remarkable early expedition have been called "the richest ever brought to Europe in one vessel." *Ibid.*, 1912, 255.

110
The evidence from BOYLE and HUYGENS cited *supra*, n. 15, is significant, for these men were not from the rank and file of the scientists of the day. Indeed, in their physical investigations they were proponents of a far more progressive outlook and a better method.

111
OMONT, *op. cit.*, *passim*, provides good examples of the type. BACON's view that the collection of the materials needed for his history was "open to every man's industry" and "beneath the dignity" of an undertaking like his, may have affected the practice of the Royal Society in this matter: *Works*, ed. SPEDDING (1900), VIII, 354. The futility of such procedure is amusingly illustrated by the two entries in BIRCH concerning the astronomical quadrant (instead of an astronomer with a quadrant) sent to Portugal by the Society in 1667: *op. cit.*, II, 151, 256.

112
For at least a glimmer of this, cf. PICARD, *Voyage . . .* , *M. A. S.*, VII[1], 194; CASSINI, *op. cit.*, *ibid.*, VIII, 87, as well as the title of this work. PICARD was a pupil and protégé of PIERRE GASSENDI whose scientific outlook may well have been a dominant influence in French astronomy at this period.