Clairaut, Alexis-Claude | Encyclopedia.com

(*b*. Paris, France, 7 May 1713; *d*. Paris, 17 May 1765),

mathematics, mechanics, celestial mechanics, geodesy, optics.

Clairaut's father, Jean-Baptiste Clairaut, was a mathematics teacher in Paris and a corresponding member of the Berlin Academy. His mother, Catherine Petit, bore some twenty children, few of whom survived. Of those who did, two boys were educated entirely within the confines of the family and showed themselves to be notably precocious children. The younger died around 1732 at the age of sixteen, however.

Alexis-Claude would probably have learned the alphabet from the figures in Euclid's *Elements*. When he was nine years old his father had him study Guisnée's *Application de l'algèbre à la géométrie*. Guisnée, who had studied under Varignon, taught mathematics to several important people, notably Pierre-Rémond de Montmort, Réaumur, and Maupertuis. His work, which was subsidized by Montmort, is a good introduction to the pioneering mathematics of that era: analytical geometry and infinitesimal calculus.

At the age of ten Clairaut delved into L'Hospital's posthumous *Traité analytique des sections coniques* and his *Analyse des infiniment petits*, which was based on Johann Bernoulli's lessons. Clairaut was barely twelve when he read before the Académie des Sciences "Quatre problèmes sur de nouvelles courbes," later published in the *Miscellanea Berolinensia*.

Around 1726 the young Clairaut, together with Jean Paul de Gua de Malves, who was barely fourteen years old; Jean Paul Grandjean de Fouchy, nineteen; Charles Marie de la Condamine, twenty-five; Jean-Antoine Nollet, twenty-six; and others founded the Société des Arts. Even though this learned society survived for only a few years, it was nonetheless a training ground for future members of the Académie des Sciences.

Around this time also Clairaut began his research on gauche curves. This work culminated in 1729 in a treatise (published in 1731) that led to his election to the Academy. The Academy proposed his election to the Crown on 4 September 1729, but it was not confirmed by the king until 11 July 1731, at which time he was still only eighteen.

In the Academy, Clairaut became interested in geodesy through Cassini's work on the measurement of the meridian. He allied himself with Maupertuis and the small but youthful and pugnacious group supporting Newton. It is difficult, however, to specify the moment at which he turned toward this new area of physics, for which his mathematical studies had so well prepared him.

He became a close friend of Maupertuis and was much in the company of the marquise du Châtelet and Voltaire. During the fall of 1734 Maupertuis and Clairaut spent a few months with Johann Bernoulli in Basel, and in 1735 they retired to Mont Valérien, near Paris, to concentrate on their studies in a calm atmosphere.

On 20 April 1736 Clairaut left Paris for Lapland, where he was to measure a meridian arc of one degree inside the arctic circle. Maupertuis was director of the expedition, which included Le Monnier, Camus, the Abbé Outhier, and Celsius. This enthusiastic group accomplished its mission quickly and precisely, in an atmosphere of youthful gaiety for which some reproached them. On 20 August 1737 Clairaut was back in Paris.

His work turned increasingly toward celestial mechanics, and he published several studies annually in *Mémoires de l'Académie des sciences*. From 1734 until his death, he also contributed to the *Journal des sçavans*. Clairaut guided the marquise du Châtelet in her studies, especially in her translation of Newton's *Principia* and in preparing the accompanying explanations. Even though the work was so sufficiently advanced in 1745 that a grant could be applied for and awarded, it did not appear until 1756, seven years after the marquise's death.

This translation of the *Principia* is elegant and, on the whole, very faithful to the original. It is, furthermore, most valuable because of its second volume, in which an abridged explanation of the system of the world is found. It illustrates, summarizes, and completes, on certain points, the results found in the *Principia*, all in about 100 pages. There is also an "analytical solution of the principal problems concerning the system of the world." Clairaut's contribution to this volume is a fundamental one, even greater than that to the translation. Many of his works are used in it. For example, in the section devoted to an explanation of light réfraction there is a condensed version of his "Sur les explications cartésienne et newtonienne de la réfraction de la lumière," and the approximately sixty pages devoted to the shape of the earth constitute a very clear résumé of the *Figure de la terre*.

Clairaut's contribution to science, however, lies mainly in his own works; *Théorie de la figure de la terre* (1743), *Théorie de la lune* (1752), *Tables de la lune* (1754), *Théorie du mouvement des comètes* (1760 [?]), and *Recherches sur la comète* (1762). When we add to these works on celestial mechanics the two didactic works *Élémens de géométrie* (1741) and *Élémens d'algèbre* (1746) and the controversies that arose around these works, we have an idea of the intensity of Clairaut's effort.

Vivacious by nature, attractive, of average height but well built, Clairaut was successful in society and, it appears, with women. He remained unmarried. He was a member of the Royal Society and the académies of Berlin, St. Petersburg, Bologna, and Uppsala. Clairaut maintained an almost continuous correspondence with Gabriel Cramer and Euler and with six corresponding members of the Académie des Sciences; Samuel Koenig, whom he had met in Basel during his visit to Johann Bernoulli; François Jacquier and Thomas Le Seur, publishers of and commentators on the *Principia;* Samuel Klingenstierna, whom he had met during his trip to Lapland; Robert-Xavier Ansart du Petit Vendin; and the astronomer Augustin d'Arquier de Pellepoix.

In 1765 Clairaut wrote, concerning his theory of the moon; "A few years ago I began the tedious job of redoing all the calculations with more uniformity and rigor, and perhaps some day I shall have the courage to complete it...." He was lacking not in courage, but in time; he died that year, at fifty-two, following a brief illness.

Although the expression "double-curvature curve" (gauche curve) is attributed to Henri Pitot (1724), Clairaut's treatise on this type of figure is no less original, representing the first serious analytical study of it. The curve is determined by two equations among the three orthogonal coordinates of its "point courant" (locus). Assimilation of the infinitesimal arc to a segment of a straight line permits Détermination of the tangent and the perpendiculars. It also permits rectification of the curve. This work also includes quadratures and the generation of some special gauche curves. "Sur les courbes que l'on forme en coupant une surface courbe quelconque par un plan donné de position" (1731) deals with plane sections of surfaces. The essential implement in this is a change in the reference point of the coordinates. Clairaut used this device mainly for explaining Newton's enumeration of curves of the third degree and the generation of all plane cubics through the central projection of one of the five divergent parabolas.

Clairaut's "Sur quelques questions de maximis et minimis" (1733) was noteworthy in the history of the calculus of variations. It was written, as were all his similar works, in the style of the Bernoulli brothers, by likening the infinitesimal arc of the curve of three elementary rectilinear segments. In the same vein was the memoir "Détermination géométrique... à la méridienne..." (1733), in which Clairaut made an elegant study of the geodesics of quadrics of rotation. It includes the property already pointed out by Johann Bernoulli: the osculating plane of the geodesic is normal to the surface.

What we call "Clairaut's differential equations" first appeared in the *Mémoires de l'Académie des sciences* for 1734. They are solved by differentiation and, in addition to the general integral, also allow for a singular solution. Brook Taylor had made this discovery in 1715.

In his research on integral calculus (1739–1740) Clairaut showed that for partial derivatives of the mixed second order, the order of differentiation is unimportant; and he established the existence of an integrating factor for linear differential equations of the first order. This factor had appeared in 1687, in the work of Fatio de Duillier. A lesson given by Johann Bernoulli to L'Hospital on this subject was summarized by Reyneau, in 1708. Euler also dealt with this subject at the same time as Clairaut.

As a result of the experiments of Dortous de Mairan, Clairaut proved in 1735 that slight pendulum oscillations remain isochronous, even if they do not occur in the same plane. His most significant paper on mechanics, however, is probably "Sur quelques principes... de dynamique" (1742), on the relative movement and the dynamics of a body in motion. Even though he did not clarify Coriolis's concept of acceleration, he did at least indicate a method of attacking the problem.

In 1743 the *Théorie de la figure de la terre* appeared. It was to some degree the theoretical epilogue to the Lapland expedition and to the series of polemics on the earth's shape—an oblate ellipsoid, according to Newton and Huygens, and a prolate ellipsoid, according to the Cassinis. Newton had merely outlined a proof; and Maclaurin, in his work on tides, which was awarded a prize by the Académie des Sciences in 1740, had set forth a general principle of hydrostatics that allowed this proof to be improved upon. Clairaut gave this principle an aspect that he felt was more general but that d'Alembert later showed to be the same as Maclaurin's. He drew from it an analytical theory that since George Green (1828) has been called the theory of potential. It allowed him to study the shape of the stars in more general cases than those examined by his predecessors. Clairaut no longer assumed that the fluid composing a star was homogeneous, and he considered various possible laws of gravitation. It was also in this work, considered a scientific classic, that the formula named for Clairaut, expressing the earth's gravity as a function of latitude, is found.

It was through the various works submitted for the 1740 competition on the theory of tides, and this work of Clairaut's, that Newton's theory of gravitation finally won acceptance in French scientific circles.

In 1743 Clairaut read before the Academy a Paper entitled "L'orbite de la lune dans le systeme de M. Newton," Newton was not fully aware of the movement of the moon's apogee, and therefore the problem had to be reexamined in greater detail. However, Clairaut—and d'Alembert, and Euler, who were also working on this question—found only half of the observed movement in their calculations.

It was then that Clairaut suggested completing Newton's law of attraction by adding a term inversely proportional to the fourth power of the distance. This correction of the law elicited a spirited reaction from Buffon, who opposed this modification with metaphysical considerations on the simplicity of the laws of nature. Clairaut, more positive and more a pure mathematician, wanted to stick to calculations and observations. The controversy that arose between these two academicians appears in the *Mémoires* of the Academy for 1745 (published long afterward). Nevertheless, the minimal value of the term added soon made Clairaut think that the correction—all things considered—could apply to the calculations but not to the law. While the latter-day Cartesians were delighted to see Newtonianism at bay, Clairaut found toward the end of 1748, through a consideration that was difficult to hold in suspicion, given the state of mathematical analysis at the time, that in Newton's theory the apogee of that moon moved over a time period very close to that called for by observations. This is what he declared to the Academy on 17 May 1749.

He wrote to Cramer around that time;

Messrs. d'Alembert and Euler had no inkling of the strategem that led me to my new results. The latter twice wrote to tell me that he had made fruitless efforts to find the same thing as I, and that he begged me to tell him how I arrived at them. I told him, more or less, what it was all about [Speziali, in *Revue d'histoire des science et de leurs applications*, p. 227, letter of 26 July 1749.

This first approximate resolution of the three-body problem in celestial mechanics culminated in the publication of the *Théorie de la lune* in 1752 and the *Tables de la lune* in 1754.

The controversies arose anew when Clairaut, strengthened by his first success, turned to the movement of comets.

In 1705 Edmund Halley had announced that the comet observed in 1552, 1607, and 1682 would reappear in 1758 or 1759. He attributed the disparity in its period of appearance to perturbations caused by Jupiter and Saturn. The attention of astronomers was therefore drawn toward this new passage, and Clairaut found in it a new field of activity. The conditions favorable, in the case of the moon, to solving the three-body problem did not exist here. The analysis had to be much more precise. It was essentially a question of calculating the perturbations brought about by the attractions of Jupiter and Saturn, in the movement of the comet. Clairaut thus began a race against time, attempting to calculate as accurately as possible the comet's passage to perihelion before it occurred. For purely astronomical calculations such as those of the positions of the two main planets, he enlisted the services of Lalande, who was assisted by a remarkable woman, Nicole-Reine Étable de Labrière Lepaute.

These feverishly completed calculations resulted in Clairaut's announcement, at the opening session of the Academy in November 1758, that passage to perihelion would occur about 15 April 1759. "You can see," he said, "the caution with which I make such an announcement, since so many small quantities that must be neglected in methods of approximation can change the time by a month."

The actual passage to perihelion took place on 13 March. By reducing his approximations even more, Clairaut calculated the date as 4 April. Then, in a paper awarded a prize by the Academy of St. Petersburg in 1762, and through use of a different method, he arrived at the last day of March as the date of passage. It was difficult to do any better. Nevertheless, there were arguments, particularly from d'Alembert.

Several anonymous articles appeared in 1759 in the *Observateur littéraire, the Mercure*, the *Mercure*, and the *Journal encyclopédique*. The latter, which Clairaut attributed to d'Alembert, was actually by Le Monnier. Clairaut offered a general reply in the November issue of the *Journal des sçavans*. "If," he stated, "one wishes to establish that Messrs. d'Alembert et al. can solve the three-body problem in the case od comets as well as I did, I would be delighted to let him do so. But this is a problem that has not been solved before, in either theory or practice."

In the fourteenth memoir of his *Opuscules mathématiques* (1761), d'Alembert attacked Clairaut ruthlessly. In December of that year Clairaut replied in the *Journal des sçavans;* "Since M. d'Alembert does not have the patience to calculate accurate tables, he should let alone those who have undertaken to do so," D' Alembert replied in the February 1762 issue of the *Journal encyclopédique* and Clairaut put an end to the debate in the June issue of the *Journal des sçavans* by congratulating his adversary for his research on the comet "since its return."

In 1727 James Bradley made public his discovery of the aberration of light and the Lapland expedition scrupulously took this phenomenon into consideration in the determination of latitudes. Bradley had not given any theoretical proof, however; and in paper writter in 1737, immediately following his return from the expedition, Clairaut offered the neglected proffs. He dealt with this question several times again; and in 1746 he indicated how to make corrections for the aberration of planets, comets, and satellites.

In 1739 Clairaut became interested in the problem of refraction in Newton's corpuscular theory of light. The theory had just been presented in France by Voltaire (probably inspired by Clairaut) in his *Élémens de philosophie de Newton*. It was the first time that Newton's theory of light had been presented in its entirety by a member of the Académie des Sciences.

The unequal refrangibility of light rays made the astronomical (refracting) telescope imperfect, and Newton had therefore preferred the reflecting telescope. In 1747 Euler suggested making up two component glass object lenses with water enclosed between them. On the strength of Newton's experiments the English optician John Dollond rejected that solution, and Clairaut supported him. But in 1755 Klingenstierna sent a report to Dollond that led the latter to redo the Newtonian experiments and to go back to his original opinion. Thus, he used object lenses made up of two glasses having different optical qualities. His technique, however, still remained mysterious. Clairaut, thinking that it would be expedient to provide a complete theory on the question, undertook precise experiments in which he was assisted by the optician George and his colleague Tourniere. In April 1761 and June 1762 Clairaut presented to the Académie des Sciences three mémoires under the title "Sur les moyens de perfectionner les lunettes d'approche par l'usage d'objectifs composés de plusieurs matières differemment réfringentes."

Clairaut's intention to publish a technical work on this subject for carftsmen was interrupted by his death. Shortly afterward d'Alembert published three extensive studies on the achromatic telescope. The Academy of St. Petersburg had made this question the subject of a competition in 1762, and the prize was won by Klingenstierna. Clairaut translated Klingenstierna's paper into French and had it published in the *Journal des sçavans* in October and November of that year.

Clairaut's mathematical education, conforming so little to university traditions, influenced his ideas on pedagogy. The parallel with Blaise Pascal is obvious. However, we know Pascal's ideas only through a few pages preserved by Leibniz and through what survives in the Port Royal *Géométrie*. As for Clairaut, he left us two remarkable didactic works.

In geometry Euclid's authority had undergone its first serious attack in France in the sixteenth century by Petrus Ramus. The influence of this reformer, however, was felt most in the Rhineland universities. Criticism of Euclid's geometric concepts reappeared in the following century in the Port Royal *Logique* and gave rise to the Port Royal *Géométrie*. At that point one could observe the appearance in mathematical teaching of a more liberal and intuitionist school (alongside a dogmatic school and in contrast with it) represented especially by the teachings of the Oratorians.

Clairaut's *Élémens de géométrie* is linked to the more liberal school. He wanted geometry to be rediscovered by beginners and therefore put together, for himself and for them, a very optimistic history of mathematical thought that reflected the concepts of his contemporaries Diderot and Rousseau.

I intended to go back to what might have given rise to geometry; and I attempted to develop its principles by a method natural enough so that one might assume it to be the same as that of geometry's first inventors, attempting only to avoid any false steps that they might have had to take [*Élémens de géométrie*, preface].

He found that the measurement of land would have been the most suitable area to give rise to the first propositions. Through analogy, he went from there to more advanced and more abstract research, all the while resolving problems without setting forth theorems and admitting as obvious all truths that showed themselves to be self-evident.

This work is pleasant and has definite pedagogical value, but it remains on a very elementary level. The subject matter corresponds to books 1–4, 6, 11, and 12 of Euclid.

The *Élémens d'algèbre* was conceived in the same spirit. Clairaut again endeavored to follow a pseudohistorical path, or at least a "natural" one. First he deals with elementary problems and appeals to common sense alone. Then, gradually increasing the difficulty, he brings forth the necessity of an algebraic symbolism and technique. Much more scholarly than his geometry, his algebra extends all the way to the solution of fourth-degree equations.

The *Élémens d'algèbre* influenced the instructional technique of the *écoles centrales* of the Revolution. S. F. Lacroix, who republished and commented upon it, considered Clairaut to be the "first who, in blazing a philosophical path, shed a bright light on the principles of algebra."

However, the algebra of Bézout, which represented the dogmatic tendency in this field, frequently was victorious over Clairaut's. Euler's *Algebra* (1769) was in no way inferior to Clairaut's from the pedagogical point of view and greatly surpassed it from the scientific point of view. For example, it is very rich in material concerning the theory of numbers, an aspect of mathematics completely foreign to Clairaut's research and mathematical concepts.

As he says in the preface to the *Élémens d'algèbre* Clairaut wanted to complete his didactic works with an application of algebra to geometry in which, among other things, he would have been able to study conic sections. Nothing more of this work seems to exist, and it may not have been undertaken. However, there is a manuscript entitled "Premières notions sur les mathématiques à l'usage des enfants," sent by Diderot to Catherine II of Russia as a work by Clairaut

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