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PIERRE LOUIS MOREAU DE MAUPERTUIS - A PRECURSOR OF MENDELIAN GENETICS?: AN INQUIRY INTO THE BIOLOGICAL IDEAS OF MAUPERTUIS, THE MENDELIAN PRINCIPLES OF HEREDITY AND THE NATURE OF THE PRECURSOR.

UNIVERSITY OF WASHINGTON, PH.D., 1979

MOREAU DE MAUPERTUIS, Pierre
Louis [1698-1759]
BIOLOGY : 18 cent.
GENETICS : 19 cent.
MENDEL, Gregor Johann [1822-84]

PIERRE LOUIS MOREAU DE MAUPERTUIS - A PRECURSOR OF MENDELIAN GENETICS?: AN INQUIRY INTO THE BIOLOGICAL IDEAS OF MAUPERTUIS, THE MENDELIAN PRINCIPLES OF HEREDITY AND THE NATURE OF THE PRECURSOR

By

Iris Levine Sandler

A dissertation submitted in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

University of Washington

1979

Approved by Thomas L. Hankins
(Chairperson of the Supervisory Committee)

Program Authorized
to Offer Degree Department of History

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Doctoral Dissertation

Signature Iris Louise Sandler

Date May 25, 1979

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I dedicate this dissertation to my husband, Laurence Sandler, and my children, Jack and Dianne, for their patience, good humor and generous support, without which I could never have accomplished it so joyfully; and to my mother who was the first to encourage me to undertake the whole endeavor so many years ago.

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INTRODUCTION

One of the relatively new areas of study in the field of Biology is Genetics. Without hesitation, both geneticists and historians of science would agree that the origins of this discipline as we know it, that is, the first full statement of the concepts basic to the science and the methodology involved in solving genetical problems, is to be found in the 1866 paper Versuche über Pflanzen-Hybriden by Gregor Mendel.

For the geneticist, the contribution of Mendel is fundamental and complete in itself. The practicing geneticist is quite content to accept the findings and principles of Mendel and carry on from there, applying Mendel's concepts and method to other problems in heredity, including of course the study of the physical mechanism of inheritance itself.

For the historian of science, the contribution of Mendel merely opens the door to a flood of questions, many of which are concerned with the period prior to this first statement of the nature of the discipline. From where did Mendel derive his concepts? Who, prior to him, discussed these concepts? What and who influenced him in his investigations?, etc.

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Bentley Glass, in his capacity as an historian of science (he was originally a geneticist), is interested in the precursors of Mendel, suggesting specifically that all of the Mendelian concepts were natucipitated by an eighteenth century French mathematician-biologist-philosopher: Pierre Louis Moreau de Maupertuis.

> Eminent as were these contributions to physical science and to philosophy, it is in his biological ideas that Maupertuis was most clearly gifted with prevision. Here he must be reckoned as fully a century and a half before his time.
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> ... he may be justly claimed as the first person to record and interpret the inheritance of a human trait through several generations. He was also the first to apply the laws of probability to the study of heredity. He was led by the facts he had uncovered to develop a theory of heredity that astonishingly forecast the theory of the genes. He believed that heredity must be due to particles derived from both the mother and from the father, that similar particles have an affinity for each other that makes them pair, and that for each such pair either the particles from the mother or the one from the father may dominate over the other, so that a trait may seemingly be inherited from distant ancestors by passing through parents who are unaffected... . There might even be complete alterations of particles - what today we would call "mutations" - and these fortuitous changes might be the beginning of new species if acted upon by a survival of the fittest and if geographically isolated so as to prevent their intermingling with the original forms. In short, virtually every idea of the Mendelian mechanism of heredity and the classical Darwinian reasoning from natural selection and geographic isolation is here combined... .*

The historian of science owes Glass a gesture of gratitude because Glass has brought to the attention of the historian the existence of a man whose life and works have, for too long, been neglected and all but forgotten. In igniting a contemporary interest in Maupertuis, Glass has chosen to recognize Maupertuis as a precursor to Mendel. I am indebted to Glass for having taken this position, because in so doing, he has been instrumental in raising several questions, the answers to which constitute the contents of this

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* Forerunners of Darwin, edited by B. Glass, O. Temkin, W. Straus (Baltimore, Johns Hopkins, 1959), p. 59

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At a more general level, Glasses' discussion of Maupertuis as a precursor elicits interest in the concept of the precursor itself, and raises the questions which do affect the analysis of the precursor. First and foremost is the obvious question -- What do we mean by the term precursor, i.e., what are the essential elements of the concept? In recalling the various people to whom the term has been applied, one is led to question the homogeneity of the term. Are there different kinds of precursors? What are the criteria for assessing whether or not a person is a precursor? Who ought to make these decisions?

More specifically, Glasses' choice of Maupertuis as a precursor to Mendel generates a reaction to the statement itself. Is Maupertuis a precursor to Mendel? In an analysis of Maupertuis as a presumptive precursor, we must examine Maupertuis' work as a product of eighteenth century scientific curiosity, methodology and philosophy. And, of course, the investigation must incorporate Mendel's own work, seeing it as a product of the nineteenth century scientific milieu. If we can determine what Maupertuis really means when he speaks of themes found in Mendel's work, then we can make a genuinely valid judgment as to the anticipatory nature of Maupertuis' work. The attempt to accurately assess Maupertuis' biological ideas and Mendel's principles of heredity, and the comparison of the works of the two to see if Maupertuis' ideas were of a "precursory" nature, constitutes the heart of this dissertation.

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CHAPTER ONE

A Biographical Sketch of P. L. M. de Maupertuis

Pierre Louis Moreau de Maupertuis: Chevalier of the Order of Merit, President in perpetuity of the Royal Academy of the Sciences and Literature of Berlin, one of the forty members of the French Academy and member of the Royal Academies of Science in France, England, Sweden, and Italy, was born in St. Malo, France, in 1698, died in Bâle, Switzerland, 1759 -- and within this span of time lived a life which does in truth deserve the description given to it by Pierre de la Condamine, "La vie ardente et tourmentée."[1]

The tempestuous nature of his life is readily affirmed by three controversies which completely dominated his life. These controversies involved a) his introduction of Newtonian physics into the French Academy of Science, which had hitherto been dominated by Cartesian philosophy, b) his attempt to prove that the shape of the earth was a flattened spheroid, as hypothesized by Newton, and not an elongated spheroid, as interpreted by the majority of the members of the Academy, c) the Koenig/Voltaire affair.

The issues were so important, and the people involved were so prominent, that contemporary opinion about Maupertuis was completely polarized. Reactions to him seemed to have evoked the extremes of great affection and intense hate among his colleagues, critics and biographers.

A brief description of his physical appearance along with a character assessment is contained in the closing paragraph of the

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A brief description of his physical appearance along with a character assessment is contained in the closing paragraph of the biography written by La Beaumelle:[2]

> M. de Maupertuis had an appearance which was displeasing at first glance. He was stocky; his body always in motion. His face was full, square, his eyes round and full of fire. He had an unequalled humor, a lively and dry conversation, and a scrupulous integrity. Good parent, tender husband, hard working academician, generous enemy, he had some faults and many virtues.[3]

J. P. Grandjean de Fouchy, secretary of the Parisian Royal Academy of Science wrote an éloge for Maupertuis in which he described Maupertuis as one who:

> ...was always one of the most hardworking of the members... the limits prescribed by this Éloge permit me to give only a very slight idea of all of his work...[4]

The range of Maupertuis' interests is enormous. His collected works[5] include articles on pure mathematics, astronomy, practical problems in navigation, experiments and speculations in the area of natural history, philosophical questions involving morality and epistemology and on occasion, caustic satire (written anonymously). No subject was too great or too small to escape his discerning eye and inquiring mind.

A basic component of disquiet and discontent inherent in Maupertuis' personality is suggested by de Fouchy in the following passage:

> Covered in all the titles which the state could give to him, honored by the generosity and kindness of his king, enjoying the trust of ministers and the esteem of the public, admired and sought out by the greatest and most illustrious people, it only required that Maupertuis enjoy all this bounty in his country, among his own people; but he had within him the most unreconcilable enemy of happiness...[6]

And de Fouchy continues:

> he was singularly vivacious, and this always appeared in his manner; his conversation was, when he wished it,

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And de Fouchy continues:

> He was singularly vivacious, and this always appeared in his manner; his conversation was, when he wished it,

> sparkling in wit and infinitely amusing; he was always permeated by religion and this persevered until his death.[7]

Samuel Formey was the presiding secretary of the Berlin Academy during the presidency of Maupertuis. But he was more than just a colleague, he was a devoted friend. His _éloge_ to Maupertuis[8] is a warm, personal tribute. He describes Maupertuis as a man with "an insatiable desire to learn, which lasted all his life."[9] The figure that emerges is scarcely one to whom one could apply the term "serene".

> The fire which shone in his eyes and which burned in his blood was able to alight vehement passions in him.[10] However, a basic natural anxiety, magnified by the sorrow of several disappointments, did not allow Maupertuis the enjoyment of his accomplishments. ...I found in him, to the highest degree, the virtues of the most decent man. He was candid and forthright, incapable of deception. He was uncommonly generous and most noble in his manner.[11]

Formey speaks about:

> ...the infinite care he [Maupertuis] took in restudying his manuscripts, retouching them so as to eliminate any carelessness, the slightest flaws, the shadow of imprecision... and it is by this means that he achieves, in all that he writes, this degree of perfection to which only the great writers attain.[12]

The care that he lavished on his own work, and on the reorganization of the Berlin Academy is also evident in his role as leader of the Lapland expedition. According to Abbé Outhier, who was a member of the expedition, Maupertuis was the soul and fire of the group, and without his encouragement, the trip would have been less fruitful. "He sustained us by the gaiety and charm with which he engulfed our group."[13]

Though blessed with many devoted friends, Maupertuis did not lack for enemies. Collé, a French journalist, had been especially angered sparkling in wit and infinitely amusing; he was always persecuted by religion and this persisted until his death.[7]

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Though blessed with many devoted friends, Maupertuis did not lack for enemies. Coste, a French journalist, had been especially angered by the departure of Maupertuis for Prussia. The obituary that he wrote for Maupertuis was a devastating attack on Maupertuis' reputation and person.[14] He believed that Maupertuis' reputation was undeserved; and that Maupertuis, devoured by envy and the thirst for a reputation was the kind of man who would do anything to obtain one. Collé represents Maupertuis as a man of great pride and boldness, full of intrigue, and self-praise, followed "by a set of underling ignoramuses, by a prodigious number of fools, by women of quality whom he persuaded to learn geometry... he was loathsome to the men of letters of this country and an object of pity by decent men."[15]

D'Argens wrote:

> As vanity was always the greater part of all the actions of his life, and that it was his principal and unique motivation, he turned his sights to geometry. He knew that a mediocre talent, sustained by great patience and perseverance, could always make progress in this area of philosophy.[16]

It is obvious that an objective evaluation of Maupertuis is not forthcoming. It is also difficult to obtain a self-assessment by Maupertuis because he left no diaries or journals, and much of his extensive correspondence was destroyed. Before his death, Maupertuis sent most of his letters to his trusted friend of many years, La Condamine, with specific instructions to burn all the letters that Maupertuis had written. These instructions were carried out, to the decided detriment of history.[17] Other correspondence between Maupertuis and his friends in the Berlin Academy were also destroyed, again at the request of Maupertuis.[18] However, there is some personal correspondence of Maupertuis still available from which we might glean a more intimate picture of Maupertuis.

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A letter (May 3, 1750) written to Maupertuis by King Frederick II allows us to see behind the facade of gaiety, wit and sparkling conversation that seemed to characterize Maupertuis, the "social lion". We discover a quite different Maupertuis, one who is basically melancholy and brooding.

> Your Essay on happiness is a masterpiece. You are very difficult if you are not pleased with this work. For me, I found a great deal of philosophy and eloquence in it. The style is without adornment, but clear, elegant, energetic. This selection threw me into a state of agreeable melancholy. But you cannot persuade me that I am unhappy. I am chagrined that you are and it does disturb me...[19]

From another letter (October 23, 1745) written by Maupertuis to Frederick, one receives the impression that Maupertuis may have been a very lonely man because he believes that he has been allowed to lift the curtain that shields us from reality -- a reality that offers no genuine basis for happiness:

> Nature has provided us with senses which do not tell us a word of truth. For this unhappy scholar who would be exempt from all illusion, riches would only be base metal, the most superb palace a mass of stones whose utility is reduced to guaranteeing protection against the rain and wind... But thanks to an indulgent Nature, our senses represent to us all things as good, and even makes the good seem real... Wisdom consists in choosing which of the illusions would make us happy.[20]

Maupertuis seemed to harbor an extraordinary combination of contradictory attitudes. In his letter to Frederick, Maupertuis wrote:

> Can you doubt Sire, that Providence takes care of things down here, after all that has been done for you? Always wise, but often impenetrable in her decrees, it only answers even the most virtuous men with bitterness... There are things that our mind cannot fathom or comprehend. One of these marvels is the co-existence of human free will

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> with divine Providence. How can we remain free when God foresees and orders everything? We know liberty by the feeling which occurs in us, and Providence by all that we see in the universe. But the harmony of those two things remains unknown to us.[21]

This acceptance of both Divine Providence and Free Will, was only one of many contradictory beliefs maintained by Maupertuis. At the same time that he was accepting God and this world, on faith, he was actively skeptical of its "real" existence. Damiron says of him:

> Maupertuis is a skeptic, it is true, but a skeptic who forgets himself, who reforms, who more readily follows his conscience than his system and allows himself to have faith in God, in the soul, and in the world, thanks to his inconsistency[22] which happily does not stop him and allows him, without embarrassment to recognize as constants some truths which otherwise, and logically, he would be forced to reject, according to his hypothesis.[23]

That Maupertuis did not prize consistency too highly, is obvious from a statement made by him in a published collection entitled Lettres:

> My letters will be a journal of my thoughts: I will speak on each subject that which I think at the moment of writing; and what are the things on which one ought always to think of in the same way? They are indeed, small in number; and I shall scarcely speak of them.[24]

His adult life can conveniently be partitioned into three stages: the French period (1721 - 1745), the Berlin period (1745 - 1752) and that segment which Maupertuis himself alludes to as "le mal de vivre."[25]

It was in the French period that Maupertuis, a young cavalry captain, abandoned a military career and embarked upon a course of study in mathematics (1721 - 1723). His scientific career began when he became a member of the Academy of Sciences in 1723. He was an active member contributing to the Academy's Mémoires articles in mathewhich divine Providence. What can we retain from this: God foresees and orders every thing? We know this too by the feeling which occurs in us, and free choice by all that we see in the universe. But the harmony of these two things remains unknown to us."[32]

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It was in the French period that Maupertuis, a young cavalry captain, abandoned a military career and embarked upon a course of study in mathematics (1717 - 1723). His scientific career began when he became a member of the Academy of Sciences in 1723. He was an active member contributing to the Academy's Mémoires articles in mathematics, astronomy and navigation. However, his first mark of distinction came in 1732 with the publication of his Discours sur les differentes figures des astres. It was an unabashed endorsement of the Newtonian universe in opposition to the "whirlpool" system of Descartes, still so heavily favored by the Academy. The piece not only served to intrude Newtonian mechanics into the Cartesian dominated Academy, but it also created, for Maupertuis, an imposing array of enemies, including among them Fontenelle, the celebrated secretary of the Academy and the astronomer, Cassini.

Maupertuis next launched an attack on the long-held image of the shape of the earth. From data collected in the past (primarily by Cassini), the earth was supposed to be an elongated sphere. Based upon the Newtonian concept of gravitational pull and centrifugal force, the earth should not be elongated at all, but rather a spheroid, flattened at the poles.

Maupertuis suggested a means of determining which of the two interpretations was correct, but it involved two expeditions, one to the arctic and one to the equator to measure the curvature of the earth. The results of the trip supported Newton's theory. The expedition also catapulted Maupertuis into instant fame within the Parisian salons but, concomitantly, increased hostility to him.

In the years until 1745, Maupertuis continued to discuss his trip, his conclusions and the practical navigational results arising from his picture of the shape of the earth. He also began studies on motion, and did some work in biology. But, he felt thwarted by the continued resistance of the Cartesians to him. Hence, in 1745, he matics, astronomy and navigation. However, his first work of distinction came in 1732 with the publication of his Discours sur les différentes figures des astres. It was an unabashed endorsement of the Newtonian universe in opposition to the "vorticist" system of Descartes, still so heavily favored by the Academy. The piece not only served to intrude Newtonian mechanics into the Cartesian dominated Academy, but it also created, for Maupertuis, an imposing array of enemies, including among them Fontenelle, the celebrated secretary of the Academy and the astronomer, Cassini.

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So began the second period of Maupertuis' life. He married soon after coming to Berlin and entered the charmed circle of the court of Frederick, the philosopher-king. He continued to contribute to the re-established Berlin Academy, expanding his interests to cover speculations on epistemology, morals and metaphysics. His power in the Berlin Academy was absolute; his prestige was at its peak. Then, in 1751, Maupertuis became involved in the Koenig affair and what started as a scientific dispute over priorities[26] rapidly degenerated into a crude, libellous attack on Maupertuis' reputation, led by Voltaire, a former friend of Maupertuis now turned venomous.

The publication and distribution of vindictive volleys against Maupertuis, and his own deteriorating health (Maupertuis had tuberculosis) initiated the third stage of Maupertuis' life. It was a period of extreme physical suffering and mental anguish. But it was also a period in which Maupertuis was able to fall back on the support, love and devotion of his wife, his king and his many close friends.

This period of recurrent bouts of fever and bedrest lasted until 1759. In March of that year, in a letter to Formey, written in Bâle, where Maupertuis was staying with his very dear friends, the Bernoullis, Maupertuis wrote: "It is true, that I have been very sick this past week; I have seen death closer than I have ever seen it... Well, God did not wish me to go this time: he might want to return me to that state another time."[27] This "other time" came in July of that same year, 1759. He died surrounded by his friends, in the arms of a priest.

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Testimonies to the character of Maupertuis come from another source, namely the prefaces and contents of his works. The prefaces, often written some years after the initial publication, were by and large, chatty, personal comments wherein Maupertuis lets the reader know why he wrote the piece, what the reactions to his ideas had been and his current defense of these ideas. From the regularity with which his prefaces were essentially apologies of his ideas, it would appear that controversy was the very staff of life to Maupertuis. There never seemed to be any period in his scientific career when he was not immersed in some minor or major dispute; this in spite of Maupertuis' repeated statements that he preferred to keep away from disputes:

> When I allowed myself to send to the public some of my thoughts, I promised myself, that in case I was attacked, I would not spend my time defending things which perhaps did not deserve to be defended and which surely were not worth the repose that one sacrifices in disputes.[28]

It would certainly seem that Maupertuis quite enjoyed his self-imposed role of gadfly. The ideas that he championed were generally not original. The quality that they had in common was that they were singularly unpopular with the scientific community at large.

One of the earliest hints that we have of Maupertuis' dissatisfaction with maintaining the scientific status quo, emerges in an early memoir (1727) describing his experiments with the salamander.[29] The avowed purpose of the experiment had been to see if salamanders were indeed resistant to fire, as the ancients thought; but one could readily believe that the true purpose behind his experiment was to undermine the well-entrenched position of the ancient scholars:

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> Although the story of the non-combustible animal appears completely incredible, I wished to verify it. As a physicist, I was somewhat ashamed of making such a ridiculous experiment (i.e. setting fire to the animal), however it is the price that the physicist has to pay to buy the right to destroy the opinions sanctified by the accounts of the Ancients.[30]

One of Maupertuis' most famous tilts at windmills came with his writing of the Vénus Physique (1745)[30a]. This little book espoused the almost dormant concept of epigenesis as the explanation for the formation of new organisms. But, not only did Maupertuis elect to champion such a neglected doctrine, he also had the effrontery to write about this medical subject, not in Latin for physicians, but in French for popular consumption.

The Essai de Philosophie Morale (1749)[31] treated Christianity as if it were a philosophy, comparing it to Stoicism and Epicureanism. In the preface, Maupertuis discusses his various attackers: a) theologians, reacting to his apparent sympathy for the act of suicide and for stating that religion, unlike a geometric proof, cannot be rigorously demonstrated; b) philosophes, who viewed him as being too devout; c) almost everyone, who disagreed with his final conclusions, that the amount of evil in this world exceeded the amount of good.

In 1750, the Essai de Cosmologie[32] appeared. Its purpose was to elaborate his Principle of Least Action and then to use the principle as a proof of the existence of God. Once again, Maupertuis uses the preface for his public forum, describing the electrifying reactions to the Essai. Leibnizians berated Maupertuis for disagreeing with Leibniz on the question of the hard body, and the law of continuity; other critics reproached Maupertuis for his use of the term "action"

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That Maupertuis recognized that his books seemed destined to create a furor as soon as they were released, is obvious in the action that he took in the writing of one of his most famous works, the Système de la Nature (1754)[33]. It was first published in Latin under the title Dissertatio inauguralis metaphysica and it bore the pseudonym Dr. Baumann of Erlangen. The reason for the psuedonym is made clear in the preface:

> I believed that the work of an unknown, foreign author would be a lesser target to objections and at least I would not be obliged to answer the objections.[34]

This book carried Maupertuis' most detailed account of his theory of the "single" substance universe, as opposed to the dual matter theory of the world. The dual matter theory, the then-dominant and most respected theory on the nature of things divided matter into two classes, the material "stuff" that is characterized by such basic properties as extension, hardness, impenetrability, from which all sensible bodies are composed, and that immaterial substance from which our soul, our conscious, thinking mind is composed. There was no interaction between the material and immaterial phases; i.e., the immaterial could not influence the material body and vice versa. Maupertuis in popularizing the ancient doctrine of hylozoism, held that there was only one substance, which had as inherent properties both extension and thinking capacity. Unfortunately, this statement was remarkably similar to the one-substance doctrine of Spinoza; and instead of force; theologians and deists objected to the use of such an argument to prove the existence of God, and the philosophes attacked Maupertuis for ascribing recourse to final causes.

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Spinozism in the eighteenth century was the equivalent of atheism. It was not surprising that the epithet "atheist" was laid upon Maupertuis. One of the most famous of his attackers on this matter, was Diderot who in his Interprétation de la Nature tried to force Maupertuis to admit that he was either an atheist or a pantheist.

Through this welter of attack and defense, parry and counter-thrust, a picture of Maupertuis does emerge. He is a man who loves the excitement of dispute; he is a scientist who is quite fearless in championing unpopular or even lost causes; he is a scholar who has the uncanny ability to arouse opposing groups into temporary alliance against himself.

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The preceding controversies pale to levels of insignificant skirmishes when compared to the three titanic campaigns that Maupertuis found himself involved in. These included his brazen introduction of Newtonian mechanics into the Paris Academy of Science; his support of the Newtonian postulated "flattened spheroid" shape of the earth, which directly challenged an accepted belief in an elongated shaped earth; and the "Koenig affair" which led to his disastrous encounter with his one-time-friend, Voltaire.

We might not expect the introduction of Newtonian mechanics into the French scientific community of the eighteenth century to have been an especially difficult feat. However, the Paris Academy, during this period, still strongly supported Cartesian physics; and hence an attempt to de-throne (or at least unsettle) Descartes' system, was, in

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So strong was the Cartesian hold over the Academy that as late as the second and third decade of the eighteenth century, the annual prize winning memoirs of the years 1726 and 1730 went to avowed Cartesians writing about problems in Cartesian physics[35], and the Cartesian doctrine continued to inspire numerous memoirs.[36]

It would be inaccurate to say that Newton's work was unknown to the Academy. By the year 1728 (the year that Maupertuis made his trip to London) the Principia and the Opticks had been installed in the library of the Academy for some years. Newton himself had been named one of the first eight associés étrangers of the Academy in 1699.

It would also be inaccurate to cite Maupertuis as the first Frenchman to support and make use of Newton's work. As early as 1712, Malebranche's sixth edition of La récherche de la vérité contains an appended XVIth Éclaircissement, which holds distinctly Newtonian concepts on opticks.[37] However, A. Rupert Hall says that these "distinctly Newtonian concepts are embedded by Malebranche in a Huygenian neo-Cartesian context."[38]

Similarly, Hall refers to the work of Jacques-Eugène d'Allonville, Chevalier de Louville, who in his article "Construction et théorie des des tables du soleil"[39] gave an exposition of Newtonian physics without ever mentioning Newton. As a matter of fact, the Newtonian concepts are carefully masqueraded as derivations from Kepler's equations. But why disguise Newton's work? It is Hall's surmise that:

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> must be that he is being deliberately disingenuous. Of course there may have been something in Newton's Principia of which we are ignorant to which Louville had some objection of principle. But it is more likely that this disingenuity was born of discretion, just as rejection of the tourbillons is most discreet.[40]

It would seem that there was no one as yet quite ready to baldly support Newtonian mechanics in opposition to the well-entrenched system of Descartes.

> As Henry Guerlac has rightly emphasized, French recognition of achievements of Newton in mathematics and experimental physics increased rapidly after 1715, and matured with the publication of the Paris Optiques. From that point the Academy was genuinely proud to claim Newton as a member. But Brunet was equally right in holding that in mechanical and physical theory the transfer of French allegiance had hardly begun by 1720.[41]

It is only with Maupertuis that we come at last to a French scientist daring enough to confront the French Academy, putting forth the mechanical and physical theory of Newton as true principles of science.

It was in the summer of 1728 that Maupertuis made his trip to London. Voltaire has described the difference, at that time, between Newton's London and Descartes' Paris in a well-known passage from letter 14 of his Philosophical Letters.

> A Frenchman arriving in London finds quite a change, in philosophy as in all else. Behind him he left the world full; here he finds it empty. In Paris one sees the universe composed of vortices of subtile matter; in London one sees nothing of the sort. With us, it's the pressure of the moon that causes the rising of the tide; with the English, it's the sea gravitating toward the moon... According to your Cartesians, everything is done by means of an impulse that is practically incomprehensible; according to Mr. Newton it is by a kind of attraction, the reason for which is no better known. In Paris you picture the earth as shaped like a melon; in London it is flattened on both sides. Light, for a Cartesian, exists

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Maupertuis arrived in London not long after the death of Newton. However, he was able to meet and talk with many of Newton's friends and disciples, such as Clark, Pemberton, and Desaguliers. According to Brunet, "we cannot exaggerate the importance of this voyage which appeared truly decisive for the ultimate orientation of the work of Maupertuis."[43]

Interestingly enough, Harcourt Brown[44] asserts that Maupertuis had been a Newtonian before he left France:

> Maupertuis was a Newtonian before he left France, but he gained confidence in England from the discovery that an entire academy of intelligent men was convinced that the Cartesian cosmos of vortices, nearly unanimously accepted in France, was without foundation in observed fact or confirmation in mathematical or physical theory, and was in fact, a figment of the imagination, a useless substitute for a sound theory of the universe.[45]

Maupertuis' exposition of section XII and XIII of Book 7 of the Principia appeared in an article entitled "Sur les loix de l'attraction" (1732).[46] It was soon expanded into the "Discours sur les differentes figures des astres."[47] That it was a monumental step can be seen in the reaction of a contemporary, La Beaumelle:

> This moment in France was the first epoch of a revolution in philosophy. We had learned from Descartes to admit as physical causes only those of which one had a clear idea and we recognized, according to him, only the mechanical cause of impulsion. The name above, attraction, revolted minds... The courage of Maupertuis was needed to dare fight against such recognized prejudices.[48]

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That Maupertuis had courageously taken on the united weight of some of the most prominent Cartesians in the Academy was recognized by d'Alembert:

> Maupertuis was the first among us who dared to openly declare himself a Newtonian. He believed that one could be a good citizen without blindly adopting the physics of his country and to attack this physics he had need of a courage for which we ought to be grateful.[49]

A more mature, considerably mellowed Maupertuis looked back on this period in his life, in his Lettre XII, Sur l'Attraction.[50] From this vantage point he recognized that not only had he to fight Cartesians, he also had to fight that old bogey, "the occult qualities" which scientists had done so much to dislodge from science, and which Newton's law of attraction seemed to be resurrecting. Moreover, he recalls, still with some bitterness, the enemies that his challenge had made for him.

> It was not a great accomplishment to have presented to one's compatriots a discovery made by others fifty years ago; thus I dare to say that I was the first who dared to propose, in France, attraction, at least as a principle to examine; it was in the Discours sur la figure des astres. One can see with what circumspection I presented this principle, the timidity with which I dared to compare it to impulsion, the fear when I tried to make clear the reasons why the English abandoned Cartesianism. All that was useless; and if this Discours was well received in some foreign countries, it made personal enemies for me, in my country.[51]

Maupertuis himself recognized that there were some men who in their contributions to science and mankind transcended the territorial boundaries of their fatherland.[52] But that science itself, and the search for truth could likewise transcend such geographical limits was not readily acknowledged in the eighteenth century.

> Science was still a matter of belief and unconscious prejudice for the majority and it would take much education and liberation of spirit to accept the view that truth has no nationality and demands no patriotism.[53]

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Maupertuis himself recognized that there were some men who in their contributions to science and mankind transcended the territorial boundaries of their nationalities,[61] and that science itself, and the search for truth could likewise transcend such geographical limits was not readily acknowledged in the eighteenth century.

> Science was still a matter of belief and superstitious prejudice for the majority and it would take much discussion and liberation of spirit to accept the idea that truth has no nationality and demands no patriotism.[62]

The dispute about the shape of the earth had been festering for some fifty years when Maupertuis, acting in his usual catalytic manner, jumped into the fray, announcing that Newton was right and providing the Academy with a new, more exact method for determining the shape of the earth.[54]

But once again, Maupertuis found himself at odds with the rest of the Academy, who, in general, supported the views of Cassini. But despite the opposition to the Newtonian belief in a flattened spheroid, the Academy, on orders from the King (Louis XV), equipped two teams to make appropriate measurements of the length of the arc of a meridian at the equator (in Peru) and at the pole (in Lapland). La Condamine headed the equatorial expedition; Maupertuis found himself the leader of the polar expedition. Maupertuis wrote in his Lettre XIII:

> It was without doubt the most famous epoch that the Sciences had... I had the honor of being in charge of the polar expedition; we were rather happy to overcome the horrors of the climate and to measure with the greatest precision, in 1736, the degree of the meridian which cut the polar circle. ...But before our departure the Academy of Science had already made a decision in this affair. The measures of the meridian which crossed France had given some lessening of the degrees from the south to the north; and from that, instead of a flattening at the poles, one had to conclude that the poles elongated: the Academy seemed to have adopted these measurements which gave to the earth the shape of an elongated spheroid instead of a flattened spheroid. Our measurements showed the opposite and made the earth flattened... Paris, whose inhabitants can not remain indifferent about any thing divided into two parties; one for our findings, the others believed that they were upholding the honor of the country in not allowing the earth to have a foreign shape, a shape which had been imagined by an Englishman and a Dutchman. They sought to spread doubts about our measurements: we maintained our position with a little more enthusiasm; we in turn attacked the measurements that had been made in France: disputes arose and these disputes produced injustices and enmities.[55]

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Hostility towards him was, at this time, not unknown to Maupertuis. Even before he had gone on his Lapland voyage, he had been the object of attack in the Academy because of his Discours sur la figure des astres. But while he was away, hostility to him flourished even more. Voltaire, in a letter to Maupertuis wrote about this increased animosity during Maupertuis' absence:

> It is not at the present time [i.e. after Maupertuis' return to Paris] that jealousy has been unleased against you. Some people, incapable of knowing your worth, dared to write satirical songs about you while they were here in Paris, and when you toiled at the polar circle for the honor of France and for human reason. Last winter, in Amsterdam, I received such a tasteless song against some of your friends and you... .[56]

The resistance to Maupertuis' findings remained strong despite the data. So powerful was the reputation of the Cassini, that even after they capitulated the Newtonian theory on the shape of the earth[57], Maupertuis was led to remark:

> ...if they had held firm and not allowed themselves to panic, they had enough good friends at court and the Academy to have it maintained that the earth is elongated, whatever the polar or equatorial demonstration had proved; and all the cafes were full of people who would have supported an earth elongated like a cucumber, if it were necessary.[58]

However, Maupertuis did have his supporters -- and many of them. The reaction of Voltaire to the report made by Maupertuis about his trip, is indicative of the vicarious excitement and pleasure and pride that was aroused by this bold and hazardous journey:

> I followed you with joy and with fear across your waterfalls, and your mountains of ice. Certainly you known how to depict your experiences; it can only be maintained that you are our greatest poet as well as greatest mathematician; if your operations are those of Archimedes and your courage that of Christopher Columbus, your description of the snows of

Tornea is worthy of Michelangelo... .[59]

This trip was to remain for Maupertuis, the high point of his life. He referred to it continually in his later works. The trip itself was to have enormous repercussions on Maupertuis' life. Overnight he became the social lion of Parisian society, and simultaneously acquired a host of supporters and enemies. The trip also brought him to the attention of Frederick, soon to be King of Prussia. Several years later, after Frederick had ascended the throne he asked Maupertuis to reorganize the deteriorated Berlin Academy of Science and to remain as its President in perpetuity. Maupertuis accepted the offer, and thus it was that in the year 1750 Maupertuis and Voltaire both found themselves members of the court of the king of Prussia.

This brings us now to the third and most devastating encounter experienced by Maupertuis, the Koenig affair.

The "raison d'etre" of the affair was the Principle of Least Action, formulated and described by Maupertuis in a series of papers (1740, 1744, 1746) that had been read before the Paris and Berlin Academies[60] and expanded upon in the Essai de Cosmologie (1750).[61] Formey, in the Éloge for Maupertuis, recalls:

> This work (the Essai de Cosmologie) was still facing objections but they were, so to speak, only grumblings; when all of a sudden, and most unexpectedly, an explosion occurred; certainly the greatest philosophic dispute ever produced, which was laden with such extraordinary incidents that this even can be regarded as unique in literary history.[62]

The attack was launched inauspiciously by Samuel Koenig, a friend of Maupertuis, and a member of the Berlin Academy. Koenig, writing in the Acta Eruditorum of March 1751, stated that the Principle of Least

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The attack was launched anonymously by Samuel Koenig, a friend of Maupertuis, and a member of the Berlin Academy. Koenig, writing in the Acta Eruditorum of March 1751, stated that the Principle of Least

Action had in fact been an idea of Leibniz and that Leibniz had discussed the matter at length in a letter written to one Hermann in 1707. Maupertuis asked to see the letter, but Koenig, who had a fragment of the letter, was unable to provide the original, saying that the letter had come into the possession of a Swiss Captain Henzi, who had been executed in 1748 on charges of spying. The Berlin Academy and, at length, Frederick himself were drawn into the matter. Searches for the letter were made among the effects of Leibniz, Hermann, and Henzi but no letter was found.

In the meanwhile tempers were flaring, especially between members of the Academy and Koenig, who appeared to have accused Maupertuis their president of plagiarism. The upshot of all this was the decision taken by the Academy at large (with Euler rather than Maupertuis presiding) to regard the Koenig letter as a forgery. Koenig resigned from the Academy, but he did not allow the matter to settle. Instead, in August and September of 1752, he wrote Appel au public and a Defense,[63] explaining the reason for his resignation and lamenting the outrageous abuse that he had received at the hands of the Maupertuis-dominated Academy.

It is at this point that Voltaire entered the picture, and turned what had been a scientific controversy into a personal, envenomned harangue against Maupertuis. He represented Koenig as a "man of merit", a "great geometer", persecuted by a tyrannical assembly, presided over by a dictatorial president.

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In the Réponse d'un Académicien de Berlin à un Académicien de Paris (September 18, 1752), Voltaire wrote:

> Thus before the scholars of Europe, Monsieur de Maupertuis has been convicted not only of plagiarism and error, but of having abused his position by withholding liberty from men of letters, and by persecuting a decent man whose only crime was to disagree with him [Maupertuis]. Several members of the Academy of Berlin have protested against such outrageous conduct and would leave the Academy that Monsieur de Maupertuis tyrannizes over and dishonors, if they did not fear displeasing the king, his protector.[64]

Voltaire mercilessly ridiculed Maupertuis in his Diatribe du Dr. Akakia calling him, among other things "a harlequin disguised as a bishop", "an absurd, inconsiderate man", "an ass dressed in the skin of a lion", "an imposter."[65] These epithets are indeed a far cry from the honeyed expressions we read in the early correspondence between Voltaire and Maupertuis. There instead we see Voltaire as a penitent, begging scraps of knowledge from an awe-inspiring mentor.

> Letter from Voltaire to Maupertuis (October 30, 1732):
> Being at the court Monsieur, without being a courtier, and reading books of philosophy without begin a philosopher, I have recourse to you in my doubts, uneasy that I do not have the pleasure of consulting you in person. It is a question of the great principle of attraction of M. Newton. To whom better can I address myself than you, Monsieur, who understand him so well...
> My faith (as a Newtonian) will depend on you. If I am persuaded of the truth of this sytem, as I am of your worth, I will assuredly be the firmest Newtonian in the world.[66]

And later as friendship flourished between them, Voltaire came to look upon Maupertuis as more than a teacher, as a dear and valued friend.

> Letter from Voltaire to Maupertuis (Apr. 29, 1734):
> You know the respect that I have for you. Write me, either to give me news of the letters[67] or to console me. I am devotedly attached to you for life, as if I were worthy of your friendship.[68]
>
> (May 28, 1741):
> I love you always... . I beg you never to believe that I could think or write about you in any way that is displeasing to you. This is a truth as incontestable as the

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flattening of the poles.[69]

One can, not unreasonably, ask why Voltaire should have turned so viciously upon his old, respected and much admired friend? There was possibly a latent jealousy between the two friends which had remained dormant as long as the two saw each other only occasionally, spending only short periods of time in intimate contact, relying rather on letters to maintain and enrich their friendship. This pleasant state of affairs was likely to change when both men found themselves as favorites, at the court of the Prussian king, and each could come to regard the other as a rival.

> Thiebault, a biographer of King Frederick wrote:
> If Maupertuis had had a pride less haughty, less exclusive, less unruly, he would have had greater regard for the feelings of the superior man who had just joined him: they would have been able to be friends; but one was too despotic and the other was too intolerant.[70]

The potential for enmity between Voltaire and Maupertuis was noticed by Buffon and remarked upon in a letter to the Abbé Le Blanc, Oct. 22, 1750:

> Maupertuis indicated to me that Voltaire ought to remain in Prussia, that he was a great acquisition for the king who has as much talent as taste. Between us, I believe that the presence of Voltaire is less pleasing to Maupertuis than to all the others; these two men are not made to remain together in the same room.[71]

Whatever the causes, in 1750 a rift had clearly been established between the two and an unspoken but ever present hostility was in evidence. The Koenig affair provided the opportunity for Voltaire to give voice to his pent-up hostility. The champion of Koenig hastily penned five or six brochures, intending to make it appear that they had been written by different people. The most vituperative and most flattering of the galant.[69]

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> Nothing is more common in the present age, than for young and ignorant authors to usher into the world, under well-known names, works unworthy of the supposed writers. There are quack in every profession. One of these imposters has had the impudence to assume the name of the president of a most illustrious academy, in order to vend some drugs of a very singular nature. It is certain that the respectable president is not the author of the books which are ascribed to him; for that admirable philosopher, who has discovered that nature always acts by the most simple laws and that she is ever sparing in the means she employs, would surely have spared his few readers the trouble of reading the same thing twice, first in his "Works" and then in his "Letters." ...This great man, who is so far removed from all suspicion of imposture, would never have published letters which were written to nobody, and far less would he have fallen into certain blunders which are excusable only in a young author.[73]
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> From this short account it plainly appears that if these imaginary letters were written by a president, it must have been by a president of Bedlam; and that they are, in fact, as we have already said, the work of a young man who has endeavored to set off his paltry production with the name of a philosopher respected, as is well known, all over Europe, and who has consented to have himself declared a "Great Man."[74]
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> We have but too frequently seen young authors who have begun by raising high expectations and publishing excellent works and who end at last by writing nothing but nonsense; because instead of able writers they wanted to be skillful courtiers. They substituted vanity in place of study, and dissipation, which weakens the mind, in place of recollection which strengthens it. They have been commended, and they have ceased to be commendable: they have been rewarded, and they have ceased to deserve rewards: they have endeavored to make a figure in the world, and their names have been entirely annihilated: for when in an author a sum of errors is equal to a sum of ridiculous propositions, "his existence is equal to nothing."[75]

Voltaire's lampoons were diffused throughout the salons of France damaging of these works was his _A Dissertation by Dr. Akakia, Physician to the Pope_.[72] The _Dissertation_ was a burlesque of a collection of _Letters_ that had been written by Maupertuis and published in 1752. The subject matter was varied and wide-ranging and provided Voltaire with a rich source of ridicule:

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> This quarrel of the action [the Principle of Least Action], if we are permitted to say so, ressembled certain religious disputes by the bitterness that attended it and by the quantity of people who spoke about it without understanding anything.[76]

Of genuine help to Maupertuis was the staunch support offered to him by King Frederick:

> I have read your letters, which in spite of your critics are well done and profound; I repeat what I have already said to you: Put your mind at rest, my dear Maupertuis, and do not bother yourself at all with the buzzing of insects in the air. Your reputation is too well established to be overthrown by the first wind; you must worry only about your bad health. Your character and genius are healthy and robust, sheltered from jealousy, libel and time.[77]

The king went even further in his show of support for Maupertuis. He ordered Voltaire not only from the court but from Prussia as well, emphasizing the gravity of his command by having Voltaire's satires burned in public squares throughout Berlin.

During the whole dreary episode, Maupertuis retained a dignified calm, unwilling to answer Voltaire with invective of his own. However, years after the quarrel had begun, Maupertuis broke his silence and revealed to his readers how deeply hurt and stricken he had been by the disheartening set of events.

> ...here is one which made sufficient noise to excite curiosity; or at least it will serve as an anecdote in the history of the human mind. One will see here how a literary fact first produced disputes, followed by invectives, and finally horrors.[78]
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The power of Voltiare's pen was such that his defamatory attacks on Maupertuis continued to poison biographers' minds throughout the eighteenth and the nineteenth centuries. Indeed, so damaging was Voltaire's fusillade against Maupertuis as a man and as a scientist, that many believe he was responsible for the elimination of Maupertuis from the scientific scene. How thoroughly Maupertuis had been effaced from the collective scientific memory is apparent in the following anecdote taken from a letter written by Sir Walter Scott:

> This extraordinary circumstance appeared in the Transactions of the Royal Society of Berlin, but it is thus stated by M. Thiebault in his Recollections of Frederick the Great and the Court of Berlin. It is necessary to premise that M. Gleditsch, to whom the circumstance happened, was a botanist of eminence, holding the professorship of natural philosophy at Berlin, and respected as a man of an habitually serious, simple and tranquil character.
>
> A short time after the death of Maupertuis, M. Gleditsch being obliged to traverse the hall in which the Academy held its sittings, having some arrangements to make in the cabinet of natural history, which was under his charge, and being willing to complete them on the Thursday before the meeting, he perceived, on entering the hall, the apparition of M. de Maupertuis, upright and stationary, in the first angle on his left hand, having his eyes fixed on him. This was about three o'clock in the afternoon. The professor of natural philosophy was too well acquainted with physical science to suppose that his late president, who had died at Bale... could have found his way back to Berlin in person. He regarded the apparition in no other light than as a phantom produced by some derangement of his own proper organs. M. Gleditsch went about his own business, without stopping longer than to ascertain exactly the appearance of that object...[80]

Thus is recorded the last terrestrial sighting of Pierre Louis Moreau de Maupertuis, some years after his death. This very lack of excite-

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>
> A short time after the death of Maupertuis, M. Gleditsch being obliged to traverse the hall in which the Academy held its sittings, having some arrangements to make in the cabinet of natural history, which was under his charge, and being willing to complete them on the Thursday before the meeting, he perceived, on entering the hall, the apparition of M. de Maupertuis, upright and stationary, in the first angle on his left hand, having his eyes fixed on him. This was about three o'clock in the afternoon. The professor of natural philosophy was too well acquainted with physical science to suppose that his late president, who had died at Bale... could have found his way back to Berlin in person. He regarded the apparition in no other light than as a phantom produced by some derangement of his own proper organs. M. Gleditsch went about his own business, without stopping longer than to ascertain exactly the appearance of that subject...[78]

Thus is recorded the last terrestrial sighting of Pierre Louis Moreau de Maupertuis, some years after his death. This very lack of emotion-ment, even for the ectophasmic remains of Maupertuis, typifies the depths to which his prestige had fallen.

For the most part, the few times that Maupertuis is mentioned by biographers and commentators, in the nineteenth century, he has been treated shabbily. Thus the Biographie Universelle[81] describes Maupertuis as having:

> a disquieting and imperious nature, alienating from himself the greater part of his colleagues... his stay in Paris was not at all according to his likes; there, too many reputations competed with his and tended to eclipse him... The scholars, his natural judges, began to see him as only a geometer of the second rank.[82]

The Grand Encyclopédie of 1896 describes Maupertuis thus:

> A mediocre writer with a stiff and pretentious style, a soul made false by vanity, who, outside of the measurement of the meridian degree of the arc of Tornea, as a scholar, did not produce any work or make any discovery of importance.[83]

A thoroughly unredeeming picture of Maupertuis as a scientist appears in Joseph Bertrand's account of Maupertuis:

> From the first years however, a bold and superficial philosopher appears, ready to solve all questions without being prepared to treat them in any depth... Mind agitated but without consistency, moving but without being active, incapable of competition and of effort, he preserved throughout his life an incomplete and superficial science... he prides himself on literature and philosophy; despite their vast pretentions, these works, as poor in content as they are mediocre in style, do not belong to the history of science... Ready to grasp and use the favors of the great, Maupertuis made his scientific reputation the instrument of his fortune.[84]

The long arm of Voltaire is seen once more, in the following remark made by Le Sueur:

> Voltaire attacked Maupertuis and clearly demolished him through ridicule, in his diatribe of Dr. Akakia. The poor president never recovered from this attack, full of sly

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Some historians of the twentieth century continued to hold Voltaire responsible for Maupertuis' decline and disappearance. Bentley Glass, the geneticist-turned-historian, refers to Maupertuis as "this man, whose great contemporary reputation has been almost completely eclipsed because of the vicious satirical attacks made upon it by Voltaire."[86] The importance of Voltaire's attacks on Maupertuis are also acknowledged and made much of by Jerome Fee and A. O. Lovejoy.

> The present attitude towards Maupertuis, however, can be understood only in the light of this ancient quarrel with Koenig. Voltaire's irony has been more dominant than the supposedly clear and dispassionate record of the scientific historian. The scant-mention, if any, which is granted to Maupertuis usually carries with it a faint but unmistakable note of scorn.[87]

> Maupertuis is usually made to play a somewhat comic role in the literary history of his century, as the rival of Voltaire for the favor of Frederick and as the victim of one of Voltaire's most ferocious satires. Although Frederick took the side of Maupertuis in that famous quarrel and caused the copies of Voltaire's libel to be burned by the hangman in all the public places of Berlin, the satirist has been more successful in gaining the ear of posterity. Immensely famous and respected as a sort of scientific oracle in his own day, Maupertuis seems now to be best known through the misrepresentations of his adversary; there is even reason to fear, from internal evidence, that some learned historians of philosophy, in the little they have to say about the "Native of St. Malo" - as Voltaire always designated him - have depended more upon the "Histoire du Docteur Akakia" than upon a careful examination of Maupertuis' own writings.[88]

Many historians of the twentieth century, however, seem intent on casting aside the legacy of Voltaire and the nineteenth century academicians, prepared to take a new look at Maupertuis. But, it seems as if they are not entirely neutral in their approach to this "maligned" personality. Possibly a bit guilt-ridden by the almost irony, all the more bloody as it was true.[55]

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> ...is it that we, in confronting a superabundance of riches and so varied an originality typical of the eighteenth century, have wrongly forgotten one of its most typical and interesting representatives?... he is one of the most attractive figures of the age of the philosophers, with a constantly questing mind. And by these very qualities, he is particularly representative of this epogue, it also being so attractive and so full of curiosity... There is first and foremost his curiosity and his truly encyclopedic competence, covering domains as diverse as the exact sciences, biology, the philosophy of nature and science, moral philosophy. Next, there is his interest in general ideas, fundamental problems, vast systems of the world and of man, which defines the "philosophic" spirit. There is finally a concern for clarity and precision in thought, a simplicity and rigor in expression...[89]

I have observed that twentieth century historians in their assessments have tended to separate Maupertuis the man from Maupertuis the scientist. In general, emphasis is placed on the scholar rather than on the personality, so that little reference is made to Maupertuis' black humor, jealousies, eccentricities, etc. Maillet is concerned to show us Maupertuis as the well rounded savant:

> Certainly Newton was a better astronomer than he, but were d'Alembert, Euler and Bernoulli better mathematicians? Were Linnaeus, Reaumur and Buffon better naturalists? Descartes and Leibniz better philosphers? Voltaire a better Stylist?... One thing is certain, that is that no one more symbolized the Encyclopedist. Was he not the "homme complet?"... He was also an administrator of quality. The reorganization of the Berlin Academy of Sciences was a recognized success... But he also showed himself to be a great scholar; penetrating in his analysis, he was equally dominant in synthesis and had the visions of the precursor. Geometer, naturalist, astronomer, geographer,

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> he excelled in each of these areas with as much success in one as in the others.[90]

Perhaps the most laudatory statements about Maupertuis are to be found in the article of Bentley Glass, appropriately titled: "Maupertuis, the Forgotten Genius."

> Only now, when the separate strands of genetics, embryology, anthropology and evolution are woven together and the principle of least action is seen to be basic to them all, are we in a position to recognize Maupertuis as one of the greatest luminaries of eighteenth century science. He takes his rightful place at last in the company of Lamarck, Alfred Russell Wallace and Charles Darwin; of Johann Friedrich Blumenbach, the father of anthropology; of Gregor Mendel and Hugo de Vries. A man too far before his time, Maupertuis was the most versatile genius of them all.[91]

Lest I leave the impression that the nineteenth and twentieth centuries had been thoroughly extremist in their views of Maupertuis, let me cite several more objective, less emotional evaluations of Maupertuis that appeared in both centuries. Damiron, a nineteenth-century philosopher, says:

> It is assuredly not necessary to put him in the first rank..., he is not of the order of Descartes or Leibniz or Newton or even of d'Alembert, although, he did closely approach the latter; but nevertheless his place among them is still very honorable.[92]

A similarly even-tempered evaluation is made by the twentieth century philosopher A. O. Lovejoy:

> ...in spite of the touch of vanity which sometimes made him ridiculous and the superficiality of a good deal of his knowledge - his reputation deserves in some measure to be rehabilitated. He was by no means a great scientific investigator; his work in physics and in astronomy, which he professed for his chief specialities, seems to be of decidedly questionable accuracy and value... But in any history of the general movement of scientific thought in his century Maupertuis clearly merits a place of some distinction. For he was the possessor of a wide view of the interrelation of different scientific problems; he was an ingenious and yet often a pretty shrewd

> he excelled in each of these areas with as much success in one as in the others."[30]

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Lest I leave the impression that the nineteenth and twentieth centuries had been thoroughly extremist in their views of Maupertuis, let me cite several more objective, less emotional evaluations of Maupertuis that appeared in both centuries. Damiron, a nineteenth-century philosopher, says:

> It is absolutely not necessary to put him in the first rank...; he is not of the order of Descartes or Leibniz or Newton or even of d'Alembert, although he did scarcely approach the latter; but nevertheless his place among them is still very honorable.[32]

A similarly even-tempered evaluation is made by the twentieth century philosopher A. O. Lovejoy:

> ...In spite of the points of vanity which sometimes made him ridiculous and the superficiality of a good deal of his thinking – [illegible] – Maupertuis [illegible] scientific [illegible] of his work in physics and in astronomy [illegible] for his chief contributions [illegible] and values. [illegible] of the general movement of scientific thought [illegible] of the distinction [illegible] of a wide view of the interrelations [illegible] problems; he was an imaginative and yet often a pretty shrewd

> and critical interpreter of the bearing and ulterior consequences of the scientific discoveries of others; and he contributed to more than one branch of science new and important conceptions which during the subsequent century and a half have come into great vogue and in some cases into general acceptance.[93]

Pierre Brunet, the author of the definitive biography of Maupertuis, sums up Maupertuis as follows:

> ...if his reputation has barely survived it is less the result of the ridicule directed at him by Voltaire than because it was a reputation that was difficult to sustain. Maupertuis was not one of the geniuses like Descartes, Newton, or Leibniz, who renewed and transformed the problems he touched, nor even like d'Alembert, Euler or Bernoulli who greatly deepened certain definitive points, or while projecting a fecund light on others, opened the mind to new ways. He distinguished himself by an alert, ready, penetrating intelligence which permitted him to raise problems, devote himself to them, interest others in them, while creating around him an atmosphere of study...[94]

That Maupertuis did disappear from the scientific community is indisputable. Whatever the reason for his decline, unbiased and accurate knowledge of his work was no longer in evidence in the latter part of the eighteenth century, throughout the nineteenth century and the beginning of the twentieth century. During the nineteenth century, little or no credit was given to Maupertuis for his work on the Principle of Least Action. This important mathematical principle was attributed to Euler, La Grange and Hamilton. Mach, in his classical Science of Mechanics, does mention Maupertuis, but it is merely to say that the Principle of Least Action was not very important, and to give an erroneous interpretation of Maupertuis' contribution to it.

Maupertuis did not fare much better among the early historians of evolutionary theory. Thomas Huxley, (1878) makes only a passing refer-and critical interpreter of the hearing and election consequences of the mathematic distribution of objects and he contributed to more than one branch of science new and important conceptions which during the subsequent century and a half have come into great vogue and in some cases into general acceptance.[53]

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Maupertuis did not fare much better among the early historians of evolutionary theory. Thomas Huxley, (1878) makes only a passing reference to Maupertuis' "curious hypothesis as to the causes of variation which he thinks may be sufficient to account for the origin of all animals from a single pair."[95] Quaterfages, Perrier, Clodd, Packard, Nordenskiold, Radl and other such historians ignored him completely. It was not until the publications of Lovejoy[96] and Delage[97] that any mention was made of the positive contributions of Maupertuis to the theory of transformism.

To assert that Voltaire was responsible for the oblivion that engulfed Maupertuis, as a scientist and academician, is to stretch the limits of reason. It is doubtful if a mathematician, physicist or biologist of the nineteenth century would care two pins for what Voltaire had to say about the talents and abilties (or personality) of Maupertuis, much less allow the vituperations of this amateur to influence their readiness to inform themselves about and make use of Maupertuis' work. Maupertuis' contributions were on record, in the memoirs of the Academy of Paris and of Berlin. His collected works went through four separate editions, the last in 1768, nine years after his death. That his work was ignored although available derived not from Voltaire's attacks on Maupertuis' person and scientific reputation but rather from the contents of Maupertuis' work itself. This point will be discussed in a later chapter.

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Nineteenth and twentieth century biographers of Maupertuis have not, I believe, stressed a most important point, and that is the recognition of Maupertuis as an eighteenth century "Renaissance Man", the made to Maupertuis' "curious hypothesis as to the number of variations which he thinks may be sufficient to account for the origin of all animals from a single pair."[65] Quatrefages, Perrier, Goodé, Packard, Nordenskiold, Locy and other such historians ignored him completely. It was not until the publications of Lovejoy[66] and Bridge[67] that any mention was made of the positive contributions of Maupertuis to the theory of trans formism.

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However, among his contemporaries, he was recognized as a man who combined scientific with literary ability.

> To the accomplishments of style, Maupertuis joined the clarity of ideas, the clarity and charm with which he can express the most abstract things and shed light on the most profound secrets of science and which distinguished him, at first, from the crowd of authors and philosophers; and he found in these abilities that which raised him, immediately to the first rank, which so few scholars achieve, and to which place they attain only after long efforts.[98]

Maupertuis' scientific knowledge, style and wit are most eloquently combined in the selections he wrote specifically for the interested, nonscientific audience. The most representative of such pieces are the Lettre sur la Comète (1742) and the Vénus physique (1745), in which he undertook to instruct his audience, in as delightful a way as possible, in subject matter that was profound and abstract.

> Letter from Frederick to Maupertuis (Nov. 1747):
> Your verses are very pretty; and if you had cultivated this talent, you would have been one of the finest poets of your century. I judge less by what you have sent me than by your Vénus physique where you reveal the system of nature in the formation of beings, not in cold, heavy lines like those of Lucretius but with all the ceremony and charm of a prose so poetic that many of our poems are prose by comparison.[99]

And from Fouchy:

> Literature, eloquence and even Poetry are neither unknown nor indifferent to him; one finds in his works the report of a trip that we made while in Lapland in order to see an ancient monument of these people... one day it will perhaps be one of the most important discoveries in Literature; his style was clear and precise, the fine points of our language were well-known to him, he possessed such a precious talent on this point that the French Academy judged him worthy of being admitted into that Sanctuary of the Muse.[100]

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By Maupertuis, the scientist and artist were recognized as being something more than colleagues, rather as "brothers":

> Artists and scientists are brothers; artists are more like metaphysicians and geometers than they realize. How many exact definitions must a man make, how many problems must a man solve, who composes on subjects of imagination and taste? A secret that it is not necessary to point out to the person with a beautiful mind is that the eloquent man, be he poet or orator, is above all a profound reasoner and a most patient geometer.[101]

In the speech given at his reception into the French Academy, Maupertuis once again made very clear the close affiliation that he believed existed between the man of letters and the man of science:

> The only difference, Messieurs, that I find between these two kinds of scholars is that one is enclosed in narrow limits permitting itself the usage of only a small number of ideas which are the most simple, and which strike our minds most uniformly: the other, in a most vast field, exercises his calculations on the most subtle and the most varied of ideas.[102]

> The one exercises a kind of empire over matter, the other dominates the mind; but without doubt, both have rules; and these rules are founded on the same principles. It is not the lines and circles traced by the geometer; it is the correctness of his reasoning that discovers the truths that he seeks: it is not at all the sound of the words nor rigourous syntax; it is the same appropriateness that allows the poet or orator to dispose hearts to his will.[103]

That a talent for writing and a talent for doing scientific investigation were not mutually exclusive abilities is made obvious in the following passages:

> I would have it noticed that the greatest men of antiquity, the Platos, the Aristotles, were at the same time poets, orators, philosophers, geometers...[104]

> After the long night in which letters and science were eclipsed... one sees them suddenly reappear and almost always united in great men.[105]

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* * *

The portrait of Maupertuis that emerges from this cross section of opinions which span two centuries, is that of a dynamic, volatile individual, unafraid to champion unpopular ideas, boldly speculative in a wide range of subjects, and most of all, a true representative of the eighteenth century Enlightenment in his unceasing quest for knowledge of the seen and unseen world around him.

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NOTES

1. P. de la Condamine, "La vie ardente et tourmentee de Maupertuis", Miroir H, 1958, N. 106.

2. Angliviel de la Beaumelle, La vie de Maupertuis, (Paris, 1856) contains the unpublished letters and notes exchanged between the king of Prussia (Frederick II) and Maupertuis. La Beaumelle was a contemporary of Maupertuis and one of his most active defenders in the literary quarrel that Voltaire waged against him. The biography was written just after the death of Maupertuis. However, the ill health of the author prevented the book from being published in his lifetime. It was not until 1856 that the book appeared in print. The most notable item in the book is the collection of letters between the King of Prussia and Maupertuis, since, as was mentioned, few letters written by Maupertuis have survived. The book was reviewed by Sainte-Beuve, in Causeries du Lundi, 1857, who had a devastating comment to make on the authenticity of the letters written by Frederick to Maupertuis. He noted that he had come across the original collection of Frederick's correspondence and in comparing the letter contained in Beaumelle's biography with the originals, it was apparent that Frederick's letters had been "embellished". Nothing essential had been added to the contents, but themes introduced by the king had been elaborated upon. Sainte-Beuve laid this piece of poetic license on the shoulders of La Beaumelle himself. However, it came to light in Le Sueur's preface to his edition of Maupertuis' correspondence, that the "sinner" was not La Beaumelle at all. Apparently, La Beaumelle had been given permission to use the collection of Letters being held

NOTES

1. P. de la Condamine, "La vie ardente et tourmentée de Maupertuis", Miroir H, 1956, N. 108.

2. Angliviel de la Beaumelle, La vie de Maupertuis, (Paris, 1856) contains the unpublished letters and notes exchanged between the King of Prussia (Frederick II) and Maupertuis. La Beaumelle was a contemporary of Maupertuis and one of his most active defenders in the literary quarrel that Voltaire waged against him. The biography was written just after the death of Maupertuis. However, the ill health of the author prevented the book from being published in his lifetime. It was not until 1856 that the book appeared in print. The most notable item in the book is the collection of letters between the King of Prussia and Maupertuis, since, as was mentioned, few letters written by Maupertuis have survived. The book was reviewed by Sainte-Beuve, in Causeries du Lundi, 1857, who had a devastating comment to make on the authenticity of the letters written by Frederick to Maupertuis. He noted that he had come across the original collection of Frederick's correspondence and in comparing the letter contained in Beaumelle's biography with the originals, it was apparent that Frederick's letters had been "embellished". Nothing essential had been added to the contents, but themes introduced by the King had been elaborated upon. Sainte-Beuve laid this piece of poetic license on the shoulders of La Beaumelle himself. However, it came to light in Le Sueur's preface to his edition of Maupertuis' correspondence, that the "sinner" was not La Beaumelle at all. Apparently, La Beaumelle had been given permission to use the collection of letters being held

by La Condamine. La Beaumelle, however, was too ill to carry out this task. It was delegated to a woman (no information is given about her) who took these liberties in the copies that she made for La Beaumelle from the Condamine collection.

3. ibid., p. 216.

4. Grandjean de Fouchy, "Éloge de M. de Maupertuis", Histoire de l'Académie Royale des Sciences, 1759, p. 262.

5. All references to the collected works of Maupertuis refer to the 1768 edition of Maupertuis' Oeuvres, reproduced by Georg Olms, publishers, 1965.

6. Fouchy, op. cit. p. 270. It is of interest to note that this éloge was written with considerable restraint, and the reason for it becomes apparent in the latter part of the passage. Fouchy is obviously offended that Maupertuis, a Frenchman, upon whom France had bestowed so much, should not only consider, but actually accept the position offered to him by the King of Prussia. That this acceptance rankled is revealed in a later statement made by Fouchy: "he would have undoubtedly done better to continue to render to the king and his country the services for which he was recognized, honored and compensated; and the Academy is too well informed of the duties of a subject towards his Prince, and of a citizen towards his country to suggest his conduct as a model to imitate."

7. ibid., p. 275.

8. Samuel Formey, "Éloge de Monsieur de Maupertuis", Histoire de l'Académie Royale des Sciences et Belles Lettres, (Berlin, 1759), pp. 464-512.

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3. Ibid., p. 226.

4. Gran Jean de Fouchy, "Eloge de M. de Maupertuis", Histoire de l'Académie Royale des Sciences, 1759, p. 262.

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8. Samuel Formey, "Eloge de Monsieur de Maupertuis", Histoire de l'Académie Royale des Sciences et Belles Lettres, (Berlin, 1759), pp. 464-512.

9. ibid., p. 13.

10. ibid., p. 506.

11. ibid., p. 507.

12. ibid., p. 509.

13. This question was taken from Outhier's Journal d'une voyage au Nord, cited by Leon Velluz in Maupertuis (Paris, Hachette), 1969, p. 53.

14. Collé's statements are cited by Abbé Le Sueur, Maupertuis et ses correspondents, lettres inédits, (Paris, 1897), p. 13

15. ibid., p. 13.

16. This quote of d'Argens comes from his Histoire de l'esprit humain, vol. IV, pp. 352-353. It was cited by Velluz, op. cit. p. 13.

17. The story of the legacy of La Condamine, and of the recovery of the remaining letters in Maupertuis' correspondence, is told by Abbé Le Sueur in the preface to his book, op. cit.

18. Formey, the secretary of the Berlin Academy, recalls a letter sent to him by Mme. de Maupertuis after the death of Maupertuis in which she wrote: "I am writing today to M. Bernoulli to ask him if he found your letters among the papers of my late husband; I doubt it, because while at Basle, M. Bernoulli told me that he had been obliged, two weeks before the death of my husband, to destroy a quantity of letters and particularly those which he had received from his friends in Berlin." This letter is part of the Souvenirs d'un citoyen, (Paris, Barez), 1797, p. 201.

19. La Beaumelle, op. cit. p. 449.

20. ibid., p. 251.

9. Ibid., p. 13.

10. Ibid., p. 506.

11. Ibid., p. 507.

12. Ibid., p. 509.

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14. Collé's statements are cited by Abbé Le Sueur, Maupertuis et ses correspondants, lettres inédites, (Paris, 1897), p. 13

15. Ibid., p. 11.

16. This quote of d'Argens comes from his Histoire de l'esprit humain, vol. IV, pp. 352-353. It was cited by Velluz, op. cit. p. 10.

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19. La Beaumelle, op. cit., p. 449.

20. Ibid., p. 251.

21. The letter was cited in P. Damiron, Mémoires pour servir à l'histoire de la philosophie au XVIIIe siecle, (Paris, Librairie Philosophique de Ladrange, 1864), p. 43.

22. Maupertuis, Oeuvres, vol. II, Réponse aux objections de M. Diderot, p. 185.

23. Damiron, op. cit. p. 95.

24. Maupertuis, Oeuvres, vol. II, Lettre Première, p. 221.

25. The phrase was used by Maupertuis in a conversation that he had with Samuel Formey. It is recorded by Formey in his Souvenirs, op. cit. p. 220.

26. The dispute involved the Principle of Least Action. Koenig claimed that Leibniz had expressed the essence of the principle, prior to Maupertuis. Further details about the dispute and the ensuing scandal will be presented later in the chapter.

27. Letter from Maupertuis to Formey, dated March 13, 1759. It is contained in the Souvenirs, op. cit. p. 191.

28. Maupertuis, op. cit. vol. II, p. 221.

29. The memoir entitled, "Observations et expériences sur une des espèces de salamandre", appeared in the Mémoires de l'Académie Royale des Sciences, 1727.

30. ibid., p. 29.

30*a*. Maupertuis, Oeuvres, vol. II, Vénus physique, pp. 3-133.

31. Maupertuis, Oeuvres, vol. I, Essai de philosophie morale, pp. 173-252.

32. Maupertuis, Oeuvres, vol. I, Essai de cosmologie, pp. 3-78.

33. Maupertuis, op. cit. vol. II, Système de la Nature, pp. 139-184.

21. The letter was cited in P. Damiron, *Mémoires pour servir à l'histoire de la philosophie au XVIIIe siècle*, (Paris, Librairie Philosophique de Ladrange, 1858), p. 41.

22. Maupertuis, *Oeuvres*, vol. II, *Réponse aux objections de M. Diderot*, p. 185.

23. Damiron, op. cit. p. 95.

24. Maupertuis, *Oeuvres*, vol. II, *Lettre Dixième*, p. 221.

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27. Letter from Maupertuis to Formey, dated March 19, 1753. It is mentioned in the *Souvenirs*, op. cit. p. 221.

28. Maupertuis, op. cit. vol. II, p. 221.

29. The memoir entitled, "Observations et expériences sur une des espèces de salamandre", appeared in the *Mémoires de l'Académie Royale des Sciences*, 1727.

30. Ibid., p. 29.

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31. Maupertuis, *Oeuvres*, vol. I, *Essai de philosophie morale*, pp. 173-252.

32. Maupertuis, *Oeuvres*, vol. I, *Essai de cosmologie*, pp. 3-78.

33. Maupertuis, op. cit. vol. II, *Système de la Nature*, pp. 139-184.

34. ibid., p. 137.

35. P. Maziere, "Traité des petite toubillons de la matière subtile", (1726); Jean Bernoulli, "Sur le systèm de M. Descartes et la manière d'en déduire les orbites et les aphelies des planètes." (1730). Both pieces were cited by Pierre Brunet, Maupertuis, (Paris, Blanchard, 1929), p. 21.

36. Several examples of such works inspired by Cartesian physics are cited by Brunet, op. cit. p. 21, footnote 4: "Explications physique et mécanique du choc des corps à ressort"; "Lois generales du mouvement dans le tourbillon spherique"; "Problème physique mathematique, dont la solution tend à servir de réponse à une des objections de M. Newton contra la possibilité des tourbillons célestes."

37. A. R. Hall, in his article, "Newton in France: After View.", History of Science, XIII, 1975, pp. 233-250, cites the work of Henry Guerlac who has shown that Malbranche made a careful study of Newton's Opticks as early as the summer of 1707, and that in his Éclaircissement (1712) Malebranche had even suggested that "it is necessary to see the experiments that one will find in the excellent work of M. Newton." p. 242.

38. ibid., p. 242.

39. Louville's article appeared in the Mémoire de l'Académie Royale des Sciences, (1720), pp. 35-84. Cited by Hall, op. cit. p. 240.

40. Hall, op. cit. p. 241.

41. ibid., p. 247.

42. Voltaire, Philosophical Letters, translated by E. Dilworth, (New York, Bobbs Merrill Co., 1961), p. 60.

34. Ibid., p. 237.

35. P. Mazière, "Traité des petits tourbillons de la matière subtile", (1726); Jean Bernoulli, "Sur le système de M. Descartes et la manière d'en déduire les orbites et les aphélies des planètes," (1730). Both pieces were cited by Pierre Brunet, Maupertuis, (Paris, Blanchard, 1929), p. 21.

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38. Ibid., p. 243.

39. Louville's article appeared in the Mémoire de l'Académie Royale des Sciences, (1720), pp. 35-55. Cited by Hall, op. cit. p. 240.

40. Hall, op. cit., p. 244.

41. Ibid., p. 247.

42. Voltaire, Philosophical Letters, translated by E. Dilworth, (New York, Bobbs Merrill Co., 1961), p. 60.

43. Brunet, op. cit. p. 15.

44. Harcourt Brown, "From London to Lapland and Berlin", Science and the Human Comedy. (Toronto, University of Toronto Press, 1976), pp. 167-206.

45. ibid., p. 169.

46. Maupertuis, "Sur les loix de l'attraction", Mémoires de l'Académie Royale des Sciences, 1732, pp. 343-362.

47. Maupertuis, Oeuvres, vol. I, Discours sur les differentes figures des astres, pp. 81-170.

48. La Beaumelle, op. cit. p. 24.

49. The quote was taken from D'Alembert's Discours préliminaire de l'Encyclopédie, cited by Brunet op. cit. p. 22.

50. Maupertuis, Oeuvres, vol. II, Lettre XII, pp. 284-289.

51. ibid., p. 284.

52. Maupertuis, Oeuvres, vol. III, Éloge de M. de Montesquieu, pp. 383-433.

53. H. Brown, op. cit. p. 169.

54. A brief discussion of the dispute over the shape of the earth is contained in the Preface to Maupertuis' Relation du Voyage au Cercle Polaire, vol. III, pp. 71-87.

55. Maupertuis, Oeuvres, vol. III, Lettre XIII, pp. 295-296.

56. Letter 1360 from Voltaire to Maupertuis, dated Jan. 10, 1738. This letter is found in the Correspondence of Voltaire, gathered together by Theodore Besterman, (Geneve, Institut et musée Voltaire), 1953.

57. The surrender followed upon the repetition made by Cassini-fils

43. Brunet, op. cit. p. 15.

44. Harcourt Brown, "From London to Lapland and Berlin", Science and the Human Comedy. (Toronto, University of Toronto Press, 1976), pp. 167-205.

45. Ibid., p. 169.

46. Maupertuis, "Sur les lois de l'attraction", Mémoires de l'Académie Royale des Sciences, 1732, pp. 343-362.

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51. Ibid., p. 285.

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55. Maupertuis, Oeuvres, vol. III, Lettre XIII, pp. 291-295.

56. Letter 1380 from Voltaire to Maupertuis, dated Jan. 10, 1738. This letter is found in the Correspondence of Voltaire, gathered together by Theodore Besterman, (Geneve, Institute et musée Voltaire), 1953.

57. The surrender followed upon the expedition made by Cassini-fils

of former measurements made in France; and upon the arrival of data from La Condamine, unequivocally supported Maupertuis' findings.

58. This was written by Maupertuis in his Lettre d'un horloger anglais, pp. 50-52. This is a very rare work, a very limited number of copies were made. Brunet cites it in his work, p. 84.

59. Letter 1445, Voltaire to Maupertuis, May 22, 1738, Besterman, op. cit. vol. 7 p. 188.

60. "Accord de la differentes loix de la Nature," Oeuvres, vol. IV, pp. 3-28, read before the Paris Academy of Science in 1744; "Recherche des lois du mouvement", op. cit. vol. IV, pp. 31-42, read before the Paris Academy in 1740. Maupertuis recognized that this first paper on statics dealt with a particular case of the Principle of Least Action. The Principle will be discussed in a later chapter.

61. Maupertuis, Oeuvres, vol. I, Essai de Cosmologie, pp. 3-78.

62. Formey, op. cit. p. 497.

63. Cited by Brunet, op. cit. p. 142.

64. Cited by Brunet, op. cit. p. 147.

65. Cited by Maillet, op. cit. p. 26.

66. Besterman, op. cit. Letter 515, vol. 2, p. 379.

67. Voltaire is referring to the Philosophical Letters, which had been published in 1732 and which was in 1734 still receiving such unremitting opposition that Voltaire was forced to leave Paris.

68. Besterman, op. cit. Letter 708, vol. 3, p. 235.

69. Besterman, op. cit. Letter 2333, vol. 11, p. 118.

70. This passage is from Thiebulat's Frederick le Grand, cited by Brunet op. cit. p. 130.

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68. Besterman, op. cit. Letter 709, vol. 3, p. 225.

69. Besterman, op. cit. Letter 2233, vol. 11, p. 218.

70. This passage is from Thiebault's Frederick le Grand, cited by Brunet op. cit. p. 130.

71. Sainte-Beuve, op. cit. quoted this letter of Buffon in a footnote, p. 92.

72. The piece Dr. Akakia is taken from the collected works of Voltaire in translation: The Works of Voltaire with notes by T. Smollett, (London, Dumont), forty volumes. Dr. Akakia appears in vol. 37, pp. 183-199.

73. Voltaire, op. cit. p. 183.

74. ibid., p. 189.

75. ibid., p. 198.

76. This quotation comes from D'Alembert's article "Cosmologie" which appeared in the Encyclopédie. Brunet, op. cit. cites it on p. 143.

77. Letters from Frederick to Maupertuis, cited by La Beaumelle, op. cit. p. 171.

78. ibid., p. 279.

80. Sir Walter Scott, Demonology and Witchcraft: Letters addressed to J. G. Lockhart, Esq., (New York, Bell Publishing Co.), 1952, p. 34.

81. Biographie Universelle, (Paris, Michaud), 1820, vol. 27, pp. 529-537.

82. ibid., p. 533.

83. Cited by P. L. Maillet in "Pierre Louis Moreau de Maupertuis pour le bicentenaire de sa mort," Les Conférences du Palais de la Découverte, Apr. 1960, Serie D, no. 69, p. 5.

84. Joseph Bertrand, L'Académie des Sciences et les Académiciens de 1666 à 1793, (Paris), 1869, p. 286.

85. Le Sueur, op. cit. p. 25.

71. Sainte-Beuve, op. cit. quoted this letter of Buffon in a footnote, p. 96.

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79. Ibid., p. 229.

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81. Histoire de l'Académie, (Paris, Pissot), 1759, vol. 27, pp. 529-532.

82. Ibid., p. 530.

83. Cited by J.-L. Fischer in "Pierre Louis Moreau de Maupertuis pour le bicentenaire de sa mort," Les Conférences du Palais de la Découverte, Apr. 1959, Série D, no. 60, p. 5.

84. Joseph Bertrand, L'Académie des Sciences et les Académiciens de 1666 à 1793, (Paris), 1869, p. 298.

85. La Beaume, op. cit. p. 29.

86. Bentley Glass, "Maupertuis and the Beginnings of Genetics", Quarterly Review of Biology, 22, no. 3, Sept. 1947, p. 196.

87. J. Fee, "Maupertuis and the Principle of Least Action", The Scientific Monthly, vol. 52, 1941, p. 502.

88. A. O. Lovejoy, "Some eighteenth century Evolutionists", Popular Science Monthly, vol. 65, 1904, p. 240.

89. E. Callot, La philosophie de la vie au XVIIIe siècle, (Paris, 1965), p. 149.

90. Maillet, op. cit. p. 31, 32.

91. H. B. Glass, "Maupertuis, a forgotten genius", Scientific American, vol. 193, Oct. 1955, p. 110.

92. P. Damiron, op. cit. p. 4.

93. A. O. Lovejoy, op. cit. p. 240.

94. Pierre Brunet, op. cit. p. 194.

95. Quote from Huxley, cited by Glass, Quarterly Review, op. cit. p. 208.

96. Lovejoy, op. cit.

97. Ives Delage, L'Hérédité et les Grands Problèmes de la Biologie Générale, (Paris, Reinwald, 1896).

98. Formey, Éloge, op. cit. p. 474.

99. Letter from Frederick to Maupertuis, (Nov. 1747), in the collection of La Beaumelle, op. cit. p. 361.

100. Fouchy, op. cit. p. 270.

101. Letter from Maupertuis to Frederick, La Beaumelle, op. cit. p. 295.

102. Maupertuis, Oeuvres, vol. III, Harangue prononcée par M. de Maupertuis dans l'Académie Francaise, p. 261.

86. Bentley Glass, "Maupertuis and the Beginnings of Genetics", Quarterly Review of Biology, 22, no. 3, Sept. 1947, p. 196.

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90. Hoeller, op. cit. p. 33, 35.

91. H. B. Glass, "Maupertuis, a forgotten genius", Scientific American, vol. 193, Oct. 1955, p. 110.

92. P. Dastrou, op. cit. p. 9.

93. A. O. Lovejoy, op. cit. p. 280.

94. Pierre Brunet, op. cit. p. 154.

95. Quote from Huxley, cited by Glass, Quarterly Review, op. cit., p. 205.

96. Lovejoy, op. cit.

97. Jean Rostand, L'Hérédité et les grands problèmes de la biologie générale, (Paris, Gallimard, 1950).

98. Forerunners, Glass, op. cit. p. 424.

99. Letter from Frederick to Maupertuis, (Nov. 1747), in the collection of La Beaumelle, op. cit. p. 361.

100. Fouchy, op. cit. p. 270.

101. Letter from Maupertuis to Frederick, La Beaumelle, op. cit. p. 390.

102. Maupertuis, Oeuvres, vol. III, Discours prononcé par M. de Maupertuis dans l'Académie Française, p. 261.

103. ibid., p. 262.

104. ibid., p. 263.

105. ibid., p. 264.

CHAPTER TWO

The Philosophy of Biology of Maupertuis

Bentley Glass, in several papers about Maupertuis, chooses to portray him as a figure "out of his time", more akin to biologists of the nineteenth than his own contemporary scientists of the eighteenth century.

> Here was a man who argued on genetic grounds against preformation fifteen years before the work of Caspar Friedrich Wolff which was eventually to dispose of the encasement theory of preformation; who investigated human heredity in a manner calculated to draw the admiration of any geneticist of the present day, and who applied the mathematical theory of probability to genetics over a century before Mendel; who undertook experiments in animal breeding to throw light on his theories; who formulated a theory of heredity that was particulate and involved the mutual attraction of analogous particles provided by each parent, and that implied segregation, dominance and independent assortment... . Surely he ranks above his contemporaries in Biology. Instead, we must compare him with the mighty figures of a later time.
>
> Thus in the company of Lamarck, of Karl Ernst von Baer, who eventually disposed of the preformation theory, of Blumenbach, the father of anthropology and of Darwin and Wallace, Mendel and Hugo de Vries, Maupertuis at last takes his rightful place. A man, too far before his time, he was the most many-sided genius of them all.[1]

Can we agree that Maupertuis was such a misfit? Before this question can be answered, Maupertuis' work needs to be evaluated on two levels; Glass himself restricts consideration of Maupertuis' "precocity" chiefly to his biological work, which is essentially a non-experimental, highly speculative offering. Whether or not this presumed precocity is a valid assessment of Maupertuis' work on generation and heredity will be discussed in a later chapter. What is of interest in this chapter is the second level at which one can evaluate

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> Thus in the company of Lamarck, of Karl Ernst von Baer, who eventually disposed of the recapitulation theory of Meckel, the father of embryology and of Darwin, and Galton, Mendel and Hugo de Vries, irrespective of what these men rightly placed. I rank him not before his time, he was the most many-sided genius of them all.[1]

Can we agree that Maupertuis was such a misfit? Before this question can be answered, Maupertuis' work needs to be evaluated on two levels. Glass himself restricts consideration of Maupertuis' "precocity" chiefly to his biological work, which is essentially a non-experimental, highly speculative offering. Whether or not this presumed precocity is a valid assessment of Maupertuis' work on generation and heredity will be discussed in a later chapter. What is of interest in this chapter is the second level at which one can evaluate

Maupertuis' precocity -- namely considering the philosophical and metaphysical tenets upon which he based his biological speculations. Was he also "ahead of his time" with respect to these ideas? To ascertain this, one would have to compare his philosophical beliefs with those of his contemporaries who also interested themselves in the speculative aspects of the same areas of biology. These include some of the most illustrious figures of the eighteenth century: Buffon, La Mettrie, Diderot, D'Holbach. Therefore, in this chapter, I shall compare the philosophical and religious ideas of these four savants with those of Maupertuis in order to determine whether Maupertuis was indeed a man "too far before his time."

1. Biological Materialism -- The Biological Revolution of the Eighteenth Century

or

the exorcism of the ghost from the machine

> Above all, there must be no dualism, no ghost in the machine. Matter of itself needs no soul or principle of motion to set it going; rather motion is a natural property of all matter and all motion comes from moving matter.[2]

The universe of the eighteenth was viewed, for the most part, in a thoroughly mechanistic way:

> The physics of Newton and physico-mathematical science in general, had since the time of Spinoza interpreted the physical universe as nothing more than a well-regulated machine. Its seeming mysteries were explainable by the mathematical laws and mechanical principles employed in its construction by the supreme "Intelligence" or "Architect".[3]

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This view was the cornerstone of the Cartesian doctrine of biological mechanism:

> The crux of Descartes' endeavor in his Treatise on Man was the interpretation of physiological function in terms of matter in motion. Of matter he acknowledged three kinds, or elements, distinguished by the respective shapes, sizes and motions of the particles they comprise. As for motion God distributed a certain quantity of it at the time of Creation; thereafter it was transferred from body to body without change in amount. Descartes asserted that bodies moving rectilinearly continue to do so unless something happens to deflect them. In applying physics to physiology, Descartes places special emphasis on the heat that every physiologist of the period attributed to the heart. He viewed man's body as a constellation of corpuscularly constituted, mechanically interacting parts. The cardinal tenet in Descartes' physiology was its assumption that the body is so arranged that every part can be activated by the transfer to it of motion that is ultimately derived from the heat of the heart.[4]

In general, matter was held to be completely inert, thoroughly obedient to the then-known laws of impulsion and attraction. An excellent summary of the state of science in the last half of the seventeenth century (which proves to be equally applicable to the first decades of the eighteenth century) is given by Paolo Casini:

> In the second half of the seventeenth century the universe appeared, both to the followers of Descartes or Gassendi, and to those of Hobbes or Newton, like a machine, composed of inanimate matter and functioning according to a calculable system of mathematical laws. It is well-known that the Cartesian and Newtonian schools -- separated by profound differences as to the nature of the laws operating in the cosmos -- shared an atomic, quantitative conception of matter. In opposition to the qualitative physics of Aristotle, there was this return to the corpuscular physics of Democritus and Epicurus that better served the demands of contemporary experimentation. Whether the world was formed in a full plenum, according to the complex system of vortices and collisions, espoused by Descartes in his work Le Monde; or whether the celestial bodies and elementary particles gravitated towards one another in a Newtonian vacuum according to the laws of universal gravitation, it was agreed to define matter as an aggregate of inert atoms

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> or particles. In both cases, movement and attraction of masses were considered to be extrinsic properties induced in matter by God.[5]

Although these were the prevalent ideas, the early eighteenth century also harbored a growing dissatisfaction with existing explanations. It was rapidly becoming obvious that an unmodified machine analogy, though useful hitherto, was not sufficiently sensitive to provide explanations or direct continued investigations of organic phenomena. First of all, the human and animal machine regularly performed operations that were completely beyond the capacities of any ordinary machine -- such as, self-repair, growth, movement, reproduction. La Mettrie called the human body "a machine that rewinds its own springs -- the living image of perpetual motion."[6] Secondly, the laws that governed the movements of inanimate celestial bodies and terrestrial objects were inadequate to describe the movements of various body parts in their day-to-day functions. Living matter moved from a state of simplicity to one of complexity. During the lifetime of the organism, elementary components needed by the body were constantly being assimilated and organized into highly specialized parts of it. Instead of increasing disintegration, the biological system exhibited increased organization.

In addition to a growing uneasiness about accepting the machine-analogy as a way to understanding living entities, it was also becoming evident that matter was not inert. There had been early speculations about an inherent activity in matter. Toland in his fourth Letter to Serena states:

> I hold that Motion is essential to Matter, that is to say,

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> as inseparable from its Nature as Impenetrability or Extension and that it ought to make a part of its definition... . I deny that Matter is or ever was an inactive, dead lump in absolute repose, a lazy and unwieldly thing... .[7]

That matter has an internal activity was also postulated by Leibniz in his Monadology (1714). In conceiving of the world as an assemblage of elemental, immaterial monads which are impervious to all outside forces, Leibniz invested the monad with all that was necessary to maintain itself autonomously.

> There is no conceivable way in which a monad could be inwardly altered or changed by some other being than itself. We cannot alter anything in it, nor conceive any internal movement in it which can be excited, directed, increased or diminished by us. Such an externally induced change is only possible in composites where the parts interchange among themselves. The monads have no windows by which anything can enter in or go out. Accidents are not detachable from substances nor able to walk away on their own account as the sensible species of the scholastics were supposed to do. Neither substance nor accident therefore can enter a monad from outside.[8]

> It follows that the natural changes of the monads depend on an inner principle, because an external cause can produce no effect on the inner being of the monad.[9]

Leibniz not only suggested inherent dynamism in matter, he also focused attention on the unit nature of matter. Very possibly Leibniz's metaphysical monad would have remained only a topic for philosophical discussion, with few implications for the "real" world, had there not developed, simultaneously, an expanding interest in microscopy.

> The microscopic observations showed concretely, that the biological mechanical system of Descartes was false. The microscopic observations of animal and plant tissues, the study of protozoa, made great progress in the last decades of the seventeenth century: the fine structure of these living beings which had appeared to Descartes as compact aggregates of homogeneous and inert matter, made active by a radically distinct substance, the res cognitans, now

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revealed unexpected complexity, activity and dynamism.[10]

The discovery of these active microscopic units reinforced Leibniz's speculations about the existence of the monads, but with one important difference. Leibniz's immaterial monads were now endowed not only with internal activity, but they had been assigned a physical materiality.

To make matters even more interesting, the period of the 1740's saw a series of discoveries that excited further belief in the inherent activity of living matter. The most startling was the discovery of the fresh water polyp in 1740, by Abraham Trembley. His investigations were written up and published as the Mémoires pour servir à l'histoire d'un genre de polypes d'eau douce à bras en ferme de cornes in 1744. The most astonishing feature about this incredible organism was it ability to completely regenerate itself from whatever number of pieces it was divided into. This meant that the capacity to produce more living matter like itself, was diffused throughout the material, or rather, it was a property of matter.

But this was not all. The entire process of budding (an asexual form of reproduction that involves formation of a daughter cell from the parental cell by a protuberance which grows larger and eventually separates itself from the parent), seen in microorganisms, such as the polyp, also bore witness to the fact that living matter could organize itself, spontaneously, to produce new life.

At a higher level, Haller investigated the behavior of muscles, isolated from the body and noted that these muscles could react to direct stimulation, without the intervention of nerves. This would revealed unexpected complexity, activity and dynamism.[19]

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In toto, it was becoming increasingly difficult to maintain that matter was a passive lump. There was just too much evidence to indicate that the opposite was true.

What did the convergence of all these discoveries mean? Briefly, it meant that a new model was now available to more accurately represent the way in which organic bodies behave, which could possibly inspire new investigations into the study of organic phenomena. The machine-analogy and the inert atom could be rejected, and its place taken by a material corpuscle that was active, creative, sensitive, and provided with an internal source of movement and an internal set of regulations. This new model was immediately taken up by a group of scholars whom I shall call the Biological Materialists.[11] Although it was variously termed the organic molecule (Buffon), the sensitive fiber (Diderot) or the elementary particle (Maupertuis), it became the basis upon which the eighteenth century materialists chose to interpret and explain organic phenomena, and, in the process, they brought into existence the Biological Revolution.

* * *

The group of savants who came to be called materialists held to certain common propositions which Maurice Mandelbaum defines thusly:

> ...we would class as a materialist anyone who accepts all of the following: that there is an independently existing world; that human beings, like all other objects, are material entities; that the human mind does not exist as an entity distinct from the human body; and that there is no God (nor any other non-human being) whose mode of existence is not that of material entities.[12]

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Essentially then, the materialist would say a) there is a real world, external to me, with which I interact; but its existence does not depend on my existence; b) there are only material entities in this world; therefore one summarily rejected all immaterial agents, including God; c) there is only one kind of substance in the world, possessing both physical properties, such as impenetrability and extension (which had formerly been attributed only to matter or body) and psychic properties, such as will, memory, thought, etc. (which had been the exclusive features of the immaterial substance or soul). There was a group of individuals, who accepted the tenets of materialism, but then proceeded beyond this fundamental substructure to consider particular problems in the life sciences. Whether they realized it or not, these biological materialists found themselves dealing with the same set of problems in very much the same way: such problems as the cause of movement in animate matter, the source of the laws governing this movement, the spontaneity of living matter and the autonomy of their vital functions that has produced such a startling re-interpretation of the nature of matter.

One of the first areas of interest to the biological materialist was the question of movement, as so well expressed by Maupertuis:

> The greatest phenomenon of Nature, the most marvelous, is movement: without it everything would be plunged into eternal death, or in a uniformity, worse yet than chaos; it is movement which carries action and life everywhere.[13]

The movements of particular interest to the biological materialist were the internal movements of plants, animals, and man. These involved such vital processes as growth, development, reproduction, Essentially then, the materialist would say a) there is a real world, external to me, with which I interact; but its existence does not depend on my existence; b) there are only material entities in this world; therefore one summarily rejected all immaterial agents, including God; c) there is only one kind of substance in the world, possessing both physical properties, such as impenetrability and extension (which had formerly been attributed only to matter or body) and psychic properties, such as will, memory, thought, etc. (which had been the exclusive features of the immaterial substance or soul). There was a group of individuals, who accepted the tenets of materialism, but then proceeded beyond them (sometimes unknowingly) to consider particular problems in the life sciences. Whether they realized it or not, these biological materialists found themselves dealing with the same set of problems in very much the same way; such problems as the cause of movement in organic matter, the source of the laws governing this movement, the spontaneity of living matter and the autonomy of their vital functions that had produced such a startling re-interpretation of the nature of matter.

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Moreover, the movements were not only internally induced, but were regulated by some mechanism inherent in matter.

They recognized that the laws which governed organic phenomena were not the ordinary laws of motion. Indeed, biological processes appeared to be too complex to be amenable to the mathematical manipulations understood in the eighteenth century, but the biological materialists agreed that the laws governing organic phenomena must be derived from the nature of matter itself.

Biological materialism espouses a number of extraordinary notions: living matter is active, creative, self-regulating, spontaneous. It is responsible only to itself in its day to day operations. Gone is the need for <u>any external agent</u>, <u>material or immaterial</u>, in determining how matter functions. There is a measure of determinism in vital phenomena, but this too is a product of the nature of matter; it is a self-determinism. As a consequence of these characteristics of matter, biological materialism leads inevitably to a conclusion of enormous, if not damning consequences. There is no role for God or his divine agents, or for any spirit whatsoever, in the ordinary activities of matter. There is no need for supernatural causes or the assumption of divine purpose in the material universe. The properties of matter are such that nothing beyond the material is and such physiological functions as circulation, digestion, and respiration. One and all, the biological materialists realized that such internal movements were the products of internal causes, i.e., neither external force, nor external agent was involved in initiating digestion or circulation or growth. Seek the cause within matter itself!

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The strong stand taken by the materialists in their elimination of God as an element of scientific analysis led to their being classed as atheists. In the eighteenth century, the two terms "materialists" and "atheists" were often regarded as synonymous. In the article Atheism in the 1779 edition of the Encyclopédie we read:

> One can regard as a tru atheist only the one who rejects the idea of an intelligence which governs with a certain design... . The materialists are true atheists, not so much because they consider bodies only, as because they recognize no intelligence which moves and governs them.[14]

The break with traditional teleology had been made. To the biological materialists, God may be in the Heavens, but whether He is or not, all is still right with the world.

2. The Biological Materialists: La Mettrie, Buffon, Diderot, and D'Holbach

The common bonds linking the biological materialists will become apparent in the discussion of their work which follows. In general, they were in remarkable accord on several points:

a) there is an independent world; b) there is only one substance in this real, material world; c) there is no room for God in this world.

Julien Offray de La Mettrie:

> I reduce to two the philosophical systems on the soul of man. The first, and the most ancient, is the system of materialism; the second is that of spiritualism. Metaphysicians who have insinuated that matter could indeed have the faculty of thinking, have not lost their reason... .[15]
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> nature is absolutely unknown to us? Descartes and all the Cartesians, among whom one can include the Malebranchists, have made the same mistake. They have admitted two distinct substances in man, as if they have well and truly seen them.[16]

So convinced was La Mettrie about the "singleness" of substance in the universe, that he concluded that Descartes himself was probably a monist also, and merely spoke of two distinct substances as a means of placating the theologians:

> ... whatever he says on the distinction of two substances, it is apparent that it is only a piece of slight of hand, a trick of style, to make the theologians swallow a poison hidden in the shadow of an analogy which strikes everybody but is not seen by them.[17]

After all, La Mettrie notes, it was Descartes who "recognized the animal nature; he was the first to demonstrate that animals were pure machines."[18]

> To be a machine, to feel, to think, to be able to distinguish good from evil as one does blue from yellow, in a word to be born with intelligence and a sure instinct for morality and to be only an animal, are things no more contradictory than to be a monkey or a parrot, and to be able to experience pleasure... I believe that thought is so compatible with organized matter, that it seems to be as much a property as electricity, the faculty of motion, impenetrability, extension, etc.[19]

From L'Homme Machine, La Mettrie's final thoughts are:

> Let us boldly conclude that man is a machine; and that there is in all the universe only one substance diversely modified.[20]

Of utmost importance to the material-monist, is the need to show that the "spiritual" is in fact material, in other words, that the entity "soul" can in fact be identified with a part of the body.

> I wish to speak of this stimulating, impetuous principle — the Soul. This principle exists and has its seat in the brain at the origin of the nerves through which it exerts its dominion over the rest of the body.[21]

Moreover, the faculties of the soul must in turn be identified with

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Moreover, the faculties of the soul must in turn be identified with the corpuscular arrangement of the brain:

> We have explained the memory, the imagination and the passions: faculties of the soul which clearly depend on the simple disposition of the sensorium, which is only a purely mechanical arrangement of the parts which form the soft substance of the brain.[22]

> The soul is only a principle of movement, or a material part of the brain, that one can without fear of error, regard as the principle fiber of the whole body which has a visible influence on all the others... .[23]

To speak of a monistic world meant necessarily that the "stuff" of nature embodied the power of self-motion. To La Mettrie, the inherent motion of matter was regarded as an undeniable statement of fact:

> At present it has been clearly demonstrated against the Cartesians, the Stahlians, the Malebranchists and the theologians little worthy of being placed here, that matter moves by itself, not only when it is organized, as in the whole heart, for example, but even when this organization is destroyed... .[24]

> ...each little fiber or part of the organized body moves by a principle which is proper to it and whose action does not depend at all on nerves as do voluntary movements... .[25]

> If the body possesses the smallest principle of movement, the living body will have all that is necessary for it to move itself, feel, think, repent, conduct itself in other words in the physical and moral world.[26]

> If one asks me now what is the seat of this innate force in our body; I answer that it resides very clearly in what the ancients have called Parenchyme -- that is, in the substance proper of the body parts, taken from the veins, arteries, nerves, in a word from the organization of the whole body; and consequently each part contains in itself the elastic fibers more or less alive according to the need each part has of it. Let us go into some detail on these fibers of the human machine. All the movements -- vital, animal, natural and automatic are made by their action. Is it not mechanically that the body withdraws from an unexpected precipice, stricken with terror? that the eyelids lower at the threat of a blow... that the heart, arteries, muscles shrink during sleep as during waking hours?[27]

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The full consequences of giving the power of self-movement to matter culminates in the ability of living beings to generate anew other organized beings of the same kind -- indeed, one is witness to the phenomenon hitherto reserved to God alone -- organized beings creating in their own image more organized beings.

Although La Mettrie believed that the sperm contributed the essentials to the embryo (the egg providing nourishment alone), he did not subscribe to the animalculism of the preformationists who asserted that the embryo was already preformed in the sperm, requiring nutrition to attain to its full growth. Rather he has given a very clear picture of the gradual (epigenetic) formation of the organs in the developing fetus.

> Let us observe man inside and outside its shell;[28] let us examine with a microscope the youngest embryos at four, six, eight and fifteen days; after this time they can be observed with the naked eye. What does one see? Only the head; a small round egg with two dark points that are the eyes. Before this time everything being more shapeless, one only perceived a medullary pulp which is the brain in which are first formed the origin of the nerves or the principle of feeling and the heart which has already, by itself in this pulp, the faculty of beating... . Afterwards, little by little, one sees the head elongate to the neck which has expanded to form the chest where the heart has already descended... .[29]

How the appropriate parts come together was beyond the range of observation and La Mettrie says, "I will not assume anything regarding that which does not strike my senses."[30] But he does add an interesting comment:

> That is about all that one knows about generation. That the parts which attract one another, which are made to unite with each other and to occupy such and such a place, unite according to their Nature; and thus form the eyes, heart, stomach and finally the whole body... .[31]

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> Let us observe the chick and puncture its shell;[28] let us examine with a microscope the prodigious embryos of four, five, eight and fifteen days; after this time they can be observed with the naked eye. What does one see? Only the head; a small round egg with two dark points that are the eyes. Before this time everything being more shapeless, one only perceived a medullary pulp which is the brain in which are first formed the origin of the nerves or the principle of feeling and the heart which has already, by itself in this pulp, the faculty of beating.... ; afterwards, little by little, one sees the head elongate to the neck which was expanded to form the chest where the heart has already descended... .[29]

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> That is about all that one knows about generation. That the parts which attract one another, which are made to unite with each other and to occupy such and such a place, unite according to their natures and thus form the eyes, heart, stomach and finally the whole body... .[31]

What struck La Mettrie was that the elemental fib rs composing the body parts operated according to the essence or nature of the fibers. Moveover, he noted:

> Such is the motive principle of the whole body or of body parts, that it does not produce disordered movements, as one believed, but very regular movements and that occurs in warm blooded, perfect animals as well as in the cold, imperfect animals.[32]

In other words, it was observed that the activites of the body parts were regulated and that laws governing the functioning of the animal body could be derived from the essential nature of matter, not from the presumed will of God.

It is a recurring theme -- given self-movement in matter, one is led to postulate and then observe self-regulation and the apparent following out of a design that is inherent in living matter. Gone then is the need for recourse to God and his purposes. An explanation of biological phenomena could be confined to the conclusions drawn from experiments and observations.

> I have revealed the viciousness of the reasoning of M. Pluche in order ...to shelter from attack the method of those who would follow the way that I have opened to them, that of interpreting supernatural things, incomprehensible in themselves, by the light that each receives from nature... . Experience and observation alone ought to guide us here... .[33]

La Mettrie expressed the opinion that not only should one rely on experiment and observation, but one should recognize that the need for God is purely arbitrary:

> ...it is absolutely impossible to go back to the origin of things. It is all the same for our peace of mind whether matter be eternal or created, whether there be a God or not.[34]

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However, La Mettrie did not stop there. He asserted an unequivocal terms that "l'univers ne sera jamais heureux, à moins qu'il ne soit Athée..."[35]

La Mettrie attacked the mainstay of the Deist argument -- that the presence of intelligence in nature requires that the maker also be intelligent:

> Nature has made in the machine of man another machine which is suitable for retaining ideas and creating new ones... . Having made, without seeing, eyes that see, she (Nature) has made, without thinking, a machine which thinks.[36]

> The faculty of thinking having the same source as that of seeing, hearing, speaking, reproducing, I do not think that it is ridiculous to have an intelligent being produced by a blind cause.[37]

La Mettrie does not say anything specific about there being a material, independent world. Rather, La Mettrie regarded such a world as a "given" fact, and this is implicit in many of his statements. He urges that man in order to understand himself better, compare his anatomy with that of the other animals;[38] "in general, the form and composition of the brain of quadrupeds is almost the same as that of man."[39]

> Nature has created us all only to be happy; yes, all from the worm which crawls to the eagle which loses itself in the skies. That is why she has given to all animals some part of the natural law... .[40]

This whole hearted, unquestioning acceptance of an external, material world is part and parcel of La Mettrie's overall materialism.

Georges Louis Leclerc de Buffon

As nonchalantly as La Mettrie treated the question of the existence of an independent material world, Buffon, as an active phenomenalist, places great emphasis on the interaction between our senses terms that "l'univers ne sera jamais heureux, à moins qu'il ne soit Athée...."[35]

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As nonchalantly as La Mettrie treated the question of the existence of an independent material world, Buffon, as an active phenomenalist, placed great emphasis on the interaction between our senses and those objects external to us which incite reactions:

> Because this inanimate matter, this stone, this mud which is beneath our feet, has several properties: its existence alone supposes a very great number of properties... . We will not say, as do several philosophes, that matter, in whatever form it is, knows its own existence and its relative faculties: this opinion involves a metaphysical question that we do not propose to treat here; it suffices for us to make known that, since we do not have knowledge of all the relations which we can have with external objects, we must not doubt that inanimate matter has infinitely less of this knowledge, and moreover, our sensations do not resemble in any way the objects which cause them.[41]

> This order of ideas, this sequence of thoughts which exist within ourselves, although very different from the objects which cause them... do give us some relation with the external objects and we can regard these relations as real since they are invariable and always the same relative to us.[42]

There is in this material world a kind of matter that Buffon calls organic matter -- the organic molecules:

> We will see that there exists in nature an infinity of living organic particles, that organized beings are composed of these organic particles... thus the matter that the animal or plant assimilates to its substance is organic matter which is of the same nature as that of the animal or plant...[43]

The living organized beings are characterized by an internal form (or forms) which Buffon called the moule intérieur: Growth occurs via the assimilation of organic molecules by the moule which shapes them into the appropriate parts of the body. Aiding the process of assimilation are penetrating forces which Buffon notes are similar to gravity:

> ...which are relative to the interior of matter and which have no relations with the external qualities of the body, but which act on the most intimate parts and which penetrate at all points.[44]

The growth and development and reproduction of the organism were attributed to the combined functioning of the moule and the and those objects external to us which incite reactions:

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> We will see that there exists in nature an infinity of living organic particles, that organized beings are composed of these organic particles. . . that the nutrition for the animal or plant assimilates to its substance an organic matter which is of the same nature as that of the animal or plant. . .[13]

The living organized beings are characterized by an internal form (or force) which Buffon called the moule intérieure. Growth occurs via the assimilation of organic molecules by the moule which shapes them into the appropriate parts of the body. Aiding the process of assimilation are penetrating forces which Buffon notes are similar to gravity:

> . . .which are relative to the interior of matter and which have no relations with the external qualities of the body, but which act on the most intimate parts and which penetrate to all points.[14]

The growth and development and reproduction of the organism were attributed to the combined functioning of the moule and the penetrating forces.[45] What is of importance here is that Buffon was convinced that the organic functions of the organized body were totally explicable by matter and its own motions.

> I have admitted, in my explanation of development and reproduction, first the traditional mechanical principles, followed by the inclusion of the penetrating force of gravity which one is obliged to accept, and by analogy, I believed that I could speak of other penetrating forces which function in the organized body, as experiments assure us I have shown by these facts that matter tends to organize itself.[46]

In accepting the presence in organic bodies of internal penetrating forces, Buffon recognized that the ordinary laws of movement were not sufficient to account for organic phenomena:

> ...to wish to explain the animal economy and the different movements of the human body, be it the circulation of the blood or the movements of the muscles, etc., only by the mechanical principles which the moderns wish to limit philosophy, is precisely the same thing as if a man, in trying to give an account of a picture, closed his eyes and told us all about the picture with his sense of touch; because it is evident that neither the circulation of the blood, nor the movement of the muscles, nor the animal functions can be explained by impulsion or the other laws of ordinary mechanics; it is also evident that nutrition, development and reproduction are the products of other laws.[47]

And if Buffon was attempting to deduce such laws, he would undoubtedly seek to extract them from the behavior of matter (the <u>moule intérieur</u>) and the penetrating forces of the body. In other words, like La Mettrie, Buffon would derive the laws of organic phenomena from the nature of organic matter and not have recourse to teleology.

<u>Denis Diderot</u>

"It is of nature that I am going to write."[48] Thus opens Diderot's <u>De l'interprétation de la Nature</u>; and the Nature that he speaks of is the composite of all the material elements in the universe beyond penetrating forces.[63] What is of importance here is that Buffon was convinced that the organic functions of the organized body were totally explicable by matter and its own motions.

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"It is of nature that I am going to write."[66] Thus opens Diderot's *De l'interprétation de la nature* and the nature that he speaks of is the composite of all the material elements in the universe beyond which there is nothing:

> I shall then call elements the different heterogeneous matter necessary for the general production of the phenomena of nature; and I shall call Nature, the actual, general result or the general successive combinations of the elements.[49]

Diderot does inject a note of caution with respect to accepting the reality of that world of Nature. Mindful of the precepts of Berkeley, which emphasized that since we are aware only of the ideas of things and not the things in themselves, we can conclude that the world does not exist outside our mind, Diderot asserts:

> There is a moment of delirium when the sensitive harpsichord thinks that it is the only harpsichord that there is in the world, and that all the harmony of the universe is produced by it.[50]

But this is, for Diderot, only a momentary hesitation, for he immediately continues that the conclusions drawn about the world are not drawn by us at all:

> ...they are all drawn by nature. We only make the statement that phenomena are joined, that their connection is either necessary or contingent... .[51]

Diderot urges that we further accept the reality of this world of nature:

> Be a good scientist and admit that an effect has indeed happened when you have seen it happen even though you cannot explain the relationship between cause and effect.[52]

Moreover, in this real, material universe:

> There is no more than one substance in the universe, in man, in animals. The bird-organ is of wood, the man is of flesh. The canary is of flesh, the musician is of flesh differently organized; but both have the same origin, the same formation, the same functions, and the same purpose.[53]

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In the Conversation between D'Alembert and Diderot, Diderot clearly depicts the discomfort engendered in D'Alembert at the mere suggestion that matter should not be thought inert. Rather than accept sensitivity in matter, D'Alembert would prefer to maintain a belief in God that is almost as difficult to accept:

> I grant you that a Being who exists somewhere but corresponds to no one point in space, a Being with no dimensions yet occupying space, who is complete in himself at every point in this space, who differs in essence from matter but is one with matter, who is moved by matter and moves matter but never moves himself, who acts upon matter yet undergoes all its changes, a Being of whom I have no conception whatever, so contradictory is he by nature, is difficult to accept. But other difficulties lie in wait for anyone who rejects him, for after all, if this sensitivity that you substitute for him is a general and essential property of nature, then stone must feel.
>
> Answers Diderot: Why not?[54]

Diderot continues to reply to D'Alembert:

> Just listen to your own arguments and you will feel how pitiful they are. You will come to feel that by refusing to entertain a simple hypothesis that explains everything -- sensitivity as a property common to all matter or as a result of the organization of matter -- you are flying in the face of common sense and plunging into a chasm of mysteries, contradictions and absurdities.[55]

Diderot argues strongly against the prevalent concept of inert matter:

> The body, according to some philosophers, is, by itself, without action and without force; it is a terrible falsehood, quite contrary to all good physics, to all good chemistry; by itself by the nature of its essential qualities, either considered as individual molecules or in a body, it is full of action and force.[56]
>
> Each form has its own sort of happiness and unhappiness. From the elephant down to the flea... from the flea down to the sensitive and living molecule which is the origin of all, there is not a speck in the whole of nature that does not feel pain or pleasure.[57]

Diderot, like the other biological materialists, was much concerned with movement, particularly with internal movement, within either the depicts the discomfort engendered in D'Alembert at the mere suggestion that matter should not be thought inert. Rather than accept sensitivity in matter, D'Alembert would prefer to maintain a belief in God that is almost as difficult to accept:

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Diderot, like the other biological materialists, was much concerned with movement, particularly with internal movement, within either the organized being or the individual molecule:

> In order that matter be moved, an action or force is necessary; yes, either external to the molecule or inherent, essential, intimate to the molecule... [58]

That there was something special about the inherent movements of matter was recognized by Diderot:

> The force which acts on the molecule exhausts itself; the intimate force of the molecule does not exhaust itself at all. It is immutable, eternal.[59]

This internal movement is translated into a variety of organic activities, one of the most complex and mysterious being the epigenetic development of the newly formed fetus:

> In the beginning you were an imperceptible speck, made of even smaller particles dispersed in the blood and lymph of your father and mother. This speck became a fine thread, then a bundle of threads. So far not the slightest suggestion of the attractive form you now have: your eyes, those lovely eyes, were no more like eyes than the tip of a sea-anemone's claw is like an anemone. Each thread in the bundle evolved, simply by being fed and because of its special structure, into a particular organ -- except those organs formed by a complete metamorphosis of certain threads in the bundle.[60]

Diderot seeks to explain all organic phenomena through material factors alone:

> Here is the general formula in a few words: eat, digest, distil in vasci licit et fiat homo secundum artem. And anyone lecturing to the Academy on the stages in the formation of a man or animal need refer only to material factors, the successive stages of which would be an inert body, a sentient being, a thinking being and then a being who can resolve the problem of the precession of the equinoxes, a sublime being, a miraculous being, one who ages, grows infirm, dies, decomposes and returns to humus.[61]

In treating living beings in this entirely materialistic manner, the role of God is naturally diminished; scientific explanation can and ought to omit all reference to God and God's design.

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This internal movement is translated into a variety of organic activities, one of the most complex and mysterious being the ontogenetic development of the newly formed fetus:

> In the beginning you were an imperceptible point, made of even smaller particles dispersed in the blood and lymph of your father and mother. This point became a loose thread, then a bundle of threads. Up to now not the slightest suggestion of the attractive form you now have; your eyes, those lovely eyes, were no more like eyes than the tip of a sea-anemone's claw is like an anemone. Each thread in the bundle evolved, simply by being fed and because of its special structure, into a particular organ -- except those organs formed by a complete metamorphosis of certain threads in the bundle.[60]

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In creating living beings in this entirely materialistic manner, the role of God is naturally diminished; scientific explanation can and ought to omit all reference to God and God's design.

Diderot, speaking through the blind mathematician Saunderson in Lettre d'un Aveugle, states that what cannot be explained by natural causes remains a problem to be explained by natural causes. There are no problems that can be explained otherwise:

> Couldn't we have a little less pride and a little more philosophy in our discussion? If nature offers us a difficult knot to untie, let us leave it for what it is, and let us not, in order to untie it, use the hand of a being who will then become himself a new known for us, more irresoluble than the first... My friend, confess your ignorance and don't bother me with your elephant and your tortoise...[62]

In the last analysis, Diderot rejects final causes:

> The physicist, whose profession is to instruct and not to system build, will abandon the "why" and only concern himself with the "how". The "how" is derived from beings; the "why" from our understanding; it holds on to systems; it depends on the progress of our knowledge. How many absurd ideas, how many false suppositions, how many fanciful notions are there, in the hymns that several rash defenders of final causes have dared to compose in honor of the Creator?[63]

and rejects God:

> The supposition of any being whatever, placed outside of the material universe, is impossible. It is necesary that one never make such suppositions because one can never infer anything from them.[64]

And thus Diderot joins La Mettrie and Buffon in repudiating God and final causes, and takes with them a step towards scientific explanation as we know it today.

Paul Heinrich Dietrich, Baron von Holbach

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Diderot, speaking through the blind mathematician Saunderson in Lettre d'un Aveugle, states that what cannot be explained by natural causes remains a problem to be explained by natural causes. There are no problems that can be explained otherwise:

> Couldn't we have a little less pride and a little more philosophy in our discussion. If nature offers us a difficult knot to untie, let us leave it for what it is, and let us not, in order to untie it, use the hand of a being who will then become himself a new knot for us, more irresolvable than the first.... My friend, confess your ignorance and don't bother me with your elephant and your tortoise....

In the last analysis, Diderot rejects final causes:

> The physicist, whose profession is to instruct and not to system build, will abandon the "why" and only concern himself with the "how". The "how" is derived from beings; the "why" from our understanding; it holds on to systems, it depends on the progress of our knowledge. How many absurd ideas, how many false suppositions, how many fanciful notions are there, in the hymns that several rash defenders of final causes have dared to compose in honor of the Creator![69]

and rejects God:

> The supposition of any being whatever, placed outside of the material universe, is impossible. It is necessary that one never make such suppositions because one can never infer anything from them.[70]

And thus Diderot joins La Mettrie and Buffon in repudiating God and final causes, and takes with them a step towards scientific explanation as we know it today.

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Not one of the materialists mentioned so far, is as enthusiastic as D'Holbach in his efforts to remove from Nature any vestige of the supernatural and the spiritual. To delve into his Système de la Nature is to find oneself plunged into a completely deterministic world where nothing exists but matter and motion:

> The Universe, this vast assemblage of everything that exists offers us everywhere only matter and movement: the ensemble shows us only an immense and uninterruped chain of causes and effects... .[65]

The objective reality of the universe is thoroughly accepted; this is made evident in his statement about how bodies external to us can affect us:

> We do not know the elements of the bodies, but we do know some of their properties or qualities and we distinguish the different matters by the effects or changes which they produce on our senses, that is to say, but the different movements which their presence produces in us.[66]

D'Holbach is most emphatic in his rejection of dualism and his assertion that there is indeed only one substance in the universe:

> Man distinguishes two substances in himself; one visibly submissive to the influence of material beings, and composed of gross and inert matter, was called body; the other, that was supposed to be simple, of very pure essence, was regarded as acting by itself and giving movement to the body with which it found itself so miraculously united; this latter was called soul or spirit; the functions of one were called physical, corporeal, material; the functions of the other were called spiritual and intellectual...[67]

> Experience will show us that in ourselves, as well as in all objects which act on us, there is always only matter endowed with different properties, diversely combined, diversely modified, and which acts by reason of its properties. In a word, man is an organized whole, composed of different matters, and like all the other productions of nature, he follows general and known laws, as well as those laws or ways of acting which are specific for him and not known.[68]

This one substance subsumes both corporal and psychic properties:

> The more that we think about it, the more we are convinced that the soul, far from having to be distinguished from body, is only the body itself seen with respect to some of its functions... . Thus the soul is man considered from the faculty of feeling, thinking and of acting in a manner resulting from its own nature... .[69]

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This one substance embraces both corporeal and psychic phenomena:

> The more that we think about it, the more we are convinced that the soul, far from needing to be distinguished from body, is only the body itself seen with respect to some of its functions. . . . Thus the soul is the body considered from the faculty of feeling, thinking and of acting, in a manner resulting from its own mechanism. . . .[60]

> As a matter of fact the brain is the common center in which all the nerves scattered throughout the body terminate and mingle: it is by means of this internal organ that all of the operations attributed to the soul are performed; these are the impressions, changes, movements, communicated to the nerves which modify the brain; consequently, the brain reacts, putting into operation the organs of the body, or the brain acts on itself and becomes capable of producing within its own surroundings a great variety of movements which have been designated by the name of intellectual faculties.[70]

Once again, as with the other biological materialists, emphasis is placed on movement:

> All is movement in the universe. The essence of nature is to act and if we attentively consider its parts we will see that there is not one part of it that enjoys absolute rest... .[71]

> If one asks from whence comes movement in matter, we will answer ...that movement is a necessary consequence of the existence of matter, a consequence of its essence and its primitive properties, such as extension, gravity, impenetrability, shape. Because of these essential properties, constituent and inherent in all matter, and without which it is impossible to form an idea of it, the different matters of which the universe is composed, have through all eternity attracted each other, gravitated towards a center, collided with each other, been attracted and repelled, combined and separated, in a word, acted and moved in different ways, following the essence and the energy approriate to each kind of matter.[72]

To D'Holbach, and to the biological materialists as a group, it must have been a glorious experience -- to recognize conceptually and experimentally, that living matter could regulate its own activities without any help from "a ghost in the machine":

> ... one will recognize that it is to movement alone that are due the changes, the combinations, the forms, in a word all the modifications of matter. It is by movement that all exists comes into being, deteriorates, increases and is destroyed...[73]

> Our senses show us that in general there are two kinds of movements in beings which surround us: one is the movement of mass, by which a whole body is transferred from one place to another; the movement of this kind is sensible for us... . The other

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is internal and hidden, a movement which depends on the energy appropriate to a body, that-is-to-say, from the essence, from the combination, from the action and reaction of insensible molecules of matter of which the body is composed: this movement is not apparent to us; we know it only by the alterations or changes that we observe at the end of a period of time, on the body or on the mixture... such as the imperceptible movements by which we see a plant or animal grow, without our eyes being able to follow the progressive movements of the causes which produce these effects. Finally there are the internal movements which occur in man which we have named intellectual faculties, his thoughts, his passions, his wishes... . We call spontaneous the movements excited in a body which encloses within itself the cause of the changes that we see operate in it; then we say that the body acts and moves by its own energy.[74]

D'Holbach's world is a deterministic world, where nothing is left to chance; where all things that happen must necessarily have so happened, because of the nature of matter:

> ... it is necesary to conclude that all movements or all the ways of acting by living beings are due to certain causes, and these causes can only act and move according to their manner of being or their essential properties; it is necessary to conclude that all phenomena are necessary and that each being of nature, in particular circumstances and according to given properties, can act only as it does.[75]

A vivid example of the rigid sort of determinism that D'Holbach applies to matter is illustrated in his discussion of the behavior of a piece of dust blown by the wind:

> Confusion appears to our eyes in the whirls of dust raised by an impetuous wind and in the waves raised by opposing winds in a frightful storm, but there is no a single molecule of dust or water which is placed by chance, which does not have sufficient cause to occupy the place in which it is found or which does not act rigorously in the manner in which it ought to act. A geometer who knew exactly the different forces which act in both cases, and the properties of the molecules which are moved, would show that according to the given causes, each molecule acts precisely as it must act and can act in no other way.[76]

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The laws that govern the internal behavior of things are not the ordinary laws of motion; rather they are directly derived from the properties of matter:

> Whatever is the nature and combination of beings, their movements always have one direction or tendency: without direction we could have no idea of movement: this direction is regulated by the properties of each being: as soon as it has been given properties, it necessarily acts, that-is-to-say, it follows the law invariably determined by these same properties which constitute the essence of the being.[77]

In thus eliminating final causation as a factor to be considered in the explanation of organic phenomena, D'Holbach returns scientific research to the strictly material world of experiment and natural causes:

> It is then to physics and experiment that man ought to have recourse in all his research. Nature acts by simple, uniform, invariable laws that experiment enables us to know; it is by our senses that we are tied to universal nature; it is by our senses that we are able to perform the experiments and discover its secrets; as soon as we leave the domain of experiment, we fall into the void, led astray by our imagination.[78]

> Many things are, without doubt, beyond our conception; but everything that happens in the world is natural and can be most simply attributed to this same nature, rather than an agent of whom we have no idea.[79]

> If in the chain of these causes, several obstacles occur which oppose our research, we must try to overcome them, and if we cannot succeed we never have the right to conclude that the chain is broken, or that the cause which acts is supernatural... .[80]

For D'Holbach, rejection is complete: there is no searching after supernatural agents, final causes or even God:

> Few men have the courage to examine the God that everyone agrees to recognize; there is almost no one who dares to doubt his existence... each one receives in his infancy, without examination, the vague name of God which his father has transmiteed to him... however, each one modifies Him, in his manner... .[81]

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> All men agree on the objects that they have submitted to experiment; we do not see disputes on the principles of Geometry... . But we only find disputes, uncertainty and variation in all the systems which have God for their object... .[82]

> These disputes and perpetual variations ought at least to convince us that the ideas of the Divinity have neither the evidence nor certitude that one attributes to them and it can be permitted to doubt the reality of a being whom men see so diversely... . In spite of all the efforts and the subtleties of the most ardent defenders, the existence of God is not even probable, and even if it would be (probable), can all the probabilities of the world acquire the force of a demonstration?[83]

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To summarize then, these are the main links that hold together the various philosophers of the biological materialists: there does exist a real, material world whose parameters are described in terms of matter and motion; matter is active and self-regulative, requiring as explanation only natural causes, revealed through experiment and observation, derived from the very nature of matter itself.

3. Maupertuis and Biological Materialism:

The question that initiated this chapter asked -- how do Maupertuis' philosophical ideas fit into the eighteenth century scientific and intellectual milieu? The purpose of this section is to present Maupertuis' philosophic ideas about organic phenomena and compare his thoughts to the major tenets of biological materialism. We will see that Maupertuis is, in the main, a biological materialist, but he differs from mainstream biological materialism in two respects: he is a firm believer in final causation; he maintains that movement is not an essential attribute of matter, and that the laws of movement

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Of primary consideration then, is Maupertuis' attitude towards a real, external, material world:

> Our perceptions enter our soul through the senses -- odor, sound, taste, touch and sight. Each one causes us to have different perceptions; and all of them can deceive us if we do not take care.
>
> A flower grows in my garden: it produces subtle particles which come to strike the nerves of my nose and I experience the feeling that I call odor. But to what does this feeling belong? To my soul, no doubt. The shock of several bodies can well be the cause of occasion, but it is evident that the physics of this phenomenon has nothing in common with the feeling of odor... .
>
> I will say the same about the fruit that I eat: the movement of its particles against the nerves of my mouth assuredly do not at all resemble the sense of taste. The senses of which I just spoke about scarcely deceive us: they only do so to the least attentive among the vulgar who, without examination, say that the odor is in the flower... the taste is in the fruit. But if one questions such people one will see that their ideas do not differ much from ours; and it will be easy to teach them not to confuse what, on these occasions belongs to the external body and that which belongs to us.[84]
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> Extension, like the other properties is only a perception of my soul transported to an external object, without there being anything in the object which can resemble what my soul perceives... considering then that there is no resemblance, no relation between our perceptions and the external objects, one will agree that all those objects are only simple phenomena... . But what produces these phenomena? how are they perceived? To say that it is by corporal particles is to advance nothing, since these particles themselves are only phenomena. It is necessary that our perceptions be caused by other beings which have a force or a power to excite them.
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> Thus we have it: we live in a world where nothing that we perceive resembles what we perceive. Unknown beings excite all the feelings in our soul, all the sensations that it feels; and without resembling any of the things that we perceive, we represent them all.[85]

This line of reasoning follows the philosophy of John Locke; it is the philosophy of phenomenalism, which made such an impact upon are derived from God.

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This line of reasoning follows the philosophy of John Locke, it is the philosophy of phenomenalism, which ends much as Kant's does the intellectuals of the late seventeenth and eighteenth centuries. Based on the premise that man, being the creature that he is, can never know the essence of an object, phenomenalism still provided one positive note, that there was indeed an object out there to be known.

Maupertuis was not always convinced of the existential reality of an external world. At one time, convinced that one can never know the external object itself, Maupertuis began to question the very existence of an external world, a world that was apparent to us only through our perceptions. This skepticism is obvious in his Reflexions Philosophiques which appeared in 1748. In it, Maupertuis takes the Berkeleyian position that all we can know are the ideas in our minds; therefore, ideas alone constitute reality. Thus, the endowment of existence itself comes from the man thinking about an object:

> I experience a perception composed of the repetition of preceding perceptions and the association of several circumstances which give it greater force, and seem to give it more reality: I have the perception "I saw a tree", joined to the perception, "I was in a certain place"; I have the perception "I returned to this place, I saw this tree; I returned again to the same place, I saw the same tree", etc. This repetition and the circumstances which accompany it, form a new perception, "I will see a tree all the times that I will go to this place": finally THERE IS A TREE.[86]

> This last perception carries, so to speak, its reality to its object and forms a proposition about the existence of the tree as something independent of me.[87]

> It seems that in spite of his extreme cleverness he (Maupertuis is speaking of a critic, M. Boindin) has not followed or entirely understood the sense of the proposition "there is"; and he remains at the point where all the other philosophes remain when, after being convinced that it would be possible that all the objects that we consider as extant, have no other existence except that which our perception gives them, they distinguish this kind of intelligible existence from another material

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> existence outside of us and independent of us: a distinction void of sense and which one would know could not take place, if one has properly understood us.[88]

This attitude did not remain unchanged. As we have seen from the previous quotations taken from his Letter IV written in 1752, Maupertuis returned to his Lockean stance and even rejected the Berkeleyian view:

> Finally, to reduce everything to the simple perceptions of my soul; to say that its existence is such, it (the soul) experiences by itself, a series of modifications by which it attributes existence to beings which do not exist at all; to remain alone in the Universe, it is an idea that is sad indeed.[89]

Reiteration of the rejection of this Berkeleyian view appears in 1756, in one of the final pieces that Maupertuis wrote:

> ... to say that in mathematics the mind forms the object that it considers, is to say nothing or to say something very false: our Mind can create nothing, it receives impressions of objects through the senses; it can call some of them ideas, and give the name sensations to the others; it can join them and separate them in a thousand different ways, but it can not create a single new object, it can not create a single new perception.[90]

Having established the existence of an external world, Maupertuis then considered the composition of this world. It was a world essentially akin to that of the biological materialists -- a world of matter and motion.

> I call "elements" the smallest parts of matter in which division is possible, without entering into the question if matter is divisible to infinity or if it is not.[91]

For Maupertuis, these "elements" or primitive bodies are inflexible and also possess other specific properties:

> Far from all bodies being elastic, one could well maintain that all bodies are hard: that is to say, that the primitive bodies are inflexible; and that the elasticity that one

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> For from all bodies being elastic, one would only conclude that all bodies are hard; that is to say, that the primitive bodies are inflexible; and that the elasticity that one

> observes in some bodies is only the effect of the arrangement of the parts of such bodies and of a particular organization.[92]

> It is in these elementary bodies that it is necessary to seek out the general properties of matter; the composite bodies disguise from us. In some of them (the composite bodies) dented parts remain dented; and one calls such a body soft: in some other bodies the dented parts are restored; and one calls such bodies elastic. But both are only systems or assemblages of inflexible bodies attached to one another. Impenetrability, solidity, inflexibility, hardness -- it is only the same property attached to the primitive body.[93]

It should be emphasized that for Maupertuis, the properties of the primitive bodies are real, and "the more phenomena one has to explain, the more necessary it is to laden matter with properties".[94]

In these statements, Maupertuis is referring to matter in general; to the primitive, elementary particles that formed the building blocks of inanimate and animate Nature. However, like the other biological materialists, he found himself drawn to the still mystifying phenomena that distinguished the animate from the inanimate. It is interesting to note that Maupertuis maintained a modified Cartesian outlook, with respect to the animal and human body, in that he regarded such organized beings as machines:

> Leaving aside the influence that the soul, on rather rare occasions, seems to have on the animal economy, one can truly say that our body is a pure machine, in which everything occurs according to the laws of ordinary mechanics: but what a marvelous machine! what a number, what a comlexity of parts![95]

At the same time that Maupertuis recognizes the machine-like qualities of the animate body, he is very much aware that the machine he is dealing with is no ordinary machine:

> The first idea that presents itself is that in as much as

> observed in some bodies is only the effect of the arrangement of the parts of such bodies and of a particular organization.[52]

> It is in those elementary bodies that it is necessary to seek out the general properties of matter, the composite bodies disguise them to. In some of them (the composite bodies) dented parts remain dented, and one calls such a body soft; in some other bodies the dented parts are restored, and one calls such bodies elastic. But both are only systems or assemblages of indivisible bodies attached to one another. Impenetrability, mobility, inflexibility, hardness — it is only the same property attached to the primitive body.[53]

It should be emphasized that for Maupertuis, the properties of the primitive bodies are real, and "the more phenomena one has to explain, the more necessary it is to laden matter with properties".[54]

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At the same time that Maupertuis recognizes the machine-like qualities of the animate body, he is very much aware that the machine he is dealing with is no ordinary machine:

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> the human body is a true machine, activity consumes it imperceptibly, that is to say, that a certain quantity of movement destroys it. However, if one remembers that these disorders which occur repair themselves, one can no longer compare the body to ordinary machines. It is a growing machine, that is to say, its parts are susceptible to development and increase in size; and which, when once put into motion, tends continually to a certain point of maturity.[96]

Like the biological materialists, Maupertuis recognized that the traditional mechanical explanation of organic phenomena was not wholly adequate. Matter and the laws of motion, for example, could not provide a satisfying account of the formation of new organized beings (generation).

> Descartes, like the Ancients, believed that man was formed from the mixing of the liquors which were shed by the two sexes. This great philosopher in his Traité de l'homme, believed it possible to explain how, with only the laws of movement and fermentation, there can be formed a heart, a brain, a nose, eyes, etc.[97]

Such a purely mechanistic outlook is rejected by Maupertuis:

> Several philosophers have been rash enough to undertake explaining all mechanics with just the laws of motion, even the first formation: give us, they have said, matter and movement, and we can form the world such as it is. What a truly extravagant enterprise![98]

Maupertuis turned away from the purely mechanistic Cartesian model of nature. His change in attitude can best be viewed in his works concerned with generation:

> Although I greatly respect Descartes and I believe, like him, that the fetus is formed from the mixing of the two semen, I cannot believe that anyone is satisfied with the explanation he has given of it...[99]

From the reports of several chemical experiments, Maupertuis is led to consider other forces which could possibly provide an answer to the formation of new organized beings:

the human body is a true machine, activity consumes it imperceptibly, that is to say, that a certain quantity of movement destroys it. However, if one considers that these disorders which occur repair themselves, one can no longer compare the body to ordinary machines. It is a growing machine, that is to say, its parts are susceptible to development and increase in size; and which, when once put into motion, tends continually to a certain point of maturity.[21]

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From the reports of several chemical experiments, Maupertuis is led to consider other forces which could possibly provide an answer to the formation of new organized beings.

> When one mixes silver and nitric acid with mercury and water, the particles of matter come to arrange themselves in the form of a body so similar to a tree that one has called it the Tree of Diana... . Since the discovery of this admirable formation, one has found several others... .
>
> Although these formations appear less organized than the bodies of most animals, would they not depend on the same mechanisms, on similar laws? Do the ordinary laws suffice or would it be necessary to call on new forces for help?
>
> These forces, incomprehensible as they are, seemed to have penetrated the Academy of Science of Paris. One of the most illustrious members of this company (Geoffroy) has felt the difficulty in reducing the secrets of Nature to the operations of the common laws of movement and has been obliged to have recourse to forces which he believed one would receive more favorably under the name of "rapports", but rapports which are such that all the time that two substances have this disposition to join one another, will find themselves united; if they encounter a third with a greater rapport for one of the other two, it will unite with it, freeing the other... I cannot prevent myself from warning here that these forces and rapports are only another thing that other and bolder philosophers have called attraction... . Astronomers were among the first to feel the need for a new principle to explain the movements of celestial bodies... . Chemistry has since recognized the necessity; and the most famous chemists today admit attraction and extend it even further than the astonomers have done. Why, if this force exists in Nature, does it not occur in the formation of the bodies of animals? That there is in each of the semens, particles destined to form the heart, the head, the entrails, the arms, the legs; these parts each have a greater rapport for union with that particle which must be its neighbor in the formation of the animal, than with any other; the fetus is formed; and if it were still a thousand times more organized than it is, it will still be formed.[100]

These speculations, expressed by Maupertuis in the Vénus physique (1745) placed Maupertuis clearly in line with the biological materialists. Dissatisfied with the Cartesian mechanistic approach to the life sciences, Maupertuis turned to a "new" force to explain a very old phenomenon -- the force of attraction or affinity. Maupertuis' model for generation was still a purely physical one. The particles

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Between 1745, the year of publication of the Vénus physique and 1751, the first appearance of his Système de la Nature[101] a change occurred in Maupertuis' speculations. He is no longer satisfied with the model of generation that he had proposed in the Vénus physique:[102]

> Some philosophes have believed that with matter and movement they could explain all Nature: and to make the explanation simpler yet, they have cautioned that by matter they understand only extension. Others, feeling the insufficiency of this simplicity, believed that it was necessary to add to extension, impenetrability, mobility, inertia; and finally even attraction was included, a force by which all the particles of matter tend towards one another in a direct ratio of their mass and in a reciprocal ratio of their distance.[103]
>
> However, if one carefully examines things, one will see that although those people who have introduced these properties into matter have explained successfully enough several phenomena, these properties are not yet sufficient to explain several others. The more that one delves into the study of Nature, the more one sees that impenetrability, mobility, inertia, even attraction, are insufficient to explain a number of phenomena. The simplest operations of chemistry could not be explained by the law of attraction that serves to explain the movement of the celestial spheres. It is necessary to suppose attractive forces that follow other laws.
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> But even with these attractive forces... one is still far from explaining the formation of a plant or an animal.[104]

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> Some philosophers have believed that with matter and movement they could explain all Nature; and to make the explanation simpler yet, some have considered that by matter they understand only extension. Others, feeling the insufficiency of this simplicity, believed that it was necessary to add to extension, impenetrability, mobility, inertia, and finally even attraction; but indeed, a force by which all the particles of matter tend towards one another in a direct ratio of their mass and in a reciprocal ratio of their distance.
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> But even with these attractive forces, one is still far from explaining the formation of a plant or an animal.[103]

But while rejecting Cartesian mechanism once again, and its forces of attraction, Maupertuis did not shift to the opposing school of vitalism to account for the phenomenon of generation.

> Some have imagined Plastic Natures, which are without intelligence and without matter, produced in the Universe everything that matter and intelligence could do. Others have introduced intelligent substances such as Genii and Demons, to move the stars and provide for the production of animals and plants and all organized bodies.[105]

> Experience teaches us, that although we cannot know how a thing is produced, that entities in which intelligence and matter occur, can act on bodies; but experience does not teach us at all, and one can never comprehend, how immaterial substances, without the immediate cooperation of an all-powerful being, could do it. The matter becomes even more incomprehensible if one understands that these immaterial substances are deprived of intelligence.[106]

It is at this point that Maupertuis, again following the line of reasoning of the biological materialists, incorporates into matter properties that had traditionally been withheld from matter. For the biological materialist this "vitalistic" property was denoting sensitivity or irritability; for Maupertuis it is the principle of intelligence, that shall enable brute matter to do everything that the vital spirit formerly supplied.

> A uniform, blind attraction scattered throughout all the particles of matter, cannot serve to explain how the particles are arranged to form a body, even whose organization is of the most simple. If all particles have the same tendency, the same force to unite one to another, why do they not all unite in a hasty, confused manner? If one wants to speculate on the matter, a speculation serving as an analogy, it is necessary to have recourse to some principle of intelligence, to something similar to what we call desire, aversion, memory.[107]

Maupertuis clearly recognizes the daring statement he has made. He realizes that he is about to topple one of the major shibboleths of the still predominant Cartesians -- the idea that there is a complete attraction, Maupertuis did not shift to the opposite school of vitalism to account for the phenomenon of generation.

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> Experience teaches us, that although we cannot know how a thing is produced, that entities in which intelligence and matter occur, can not be denied; but experience does not teach us at all, and one can never comprehend, how immaterial substances, without the immediate cooperation of an all-powerful being, could do it. And matter becomes even more incomprehensible if one understands that these immaterial substances are deprived of intelligence.'[74]

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Maupertuis clearly recognizes the daring statement he has made. He realizes that he is about to topple one of the major strongholds of the still predominant Cartesians -- the idea that there is a complete separation between material (corporeal) and immaterial (psychic) properties. To soften the blow he attempts to call into alliance the powerful forces of religion:

> There is no need to be alarmed by the statements I have just given: one should not believe that I wish to establish a dangerous opinion here. Already I hear murmurs from all those who take for pious zeal, a stubbornness of their feelings, a difficulty that they have in receiving new ideas. They are going to see that all is lost if one admits thought into matter.[108]

> The most orthodox theologians, and even theologians of the earliest times, have granted intelligence to animals. And if some of them have used the term "sensitive soul", they have always believed that animals do see, hear, want, fear, remember.[109]

> Now, if in these large collections of matter which are the bodies of animals, one admits the principle of intelligence, without peril, what greater peril will one find in attributing it to the smallest particles of matter? If one says that organization has made the difference, can one conceive that organization which is only an arrangement of parts, can ever produce a thought? But that is not the question here; it is only the question of examining if there is a danger in supposing some degree of intelligence in matter. The danger, if it exists, would be as great in admitting intelligence into the body of an elephant or a monkey as it would be in admitting it into a grain of sand.[110]

> Now not only is there no danger in granting to matter some degree of intelligence, of desire, of aversion, of memory; not only have the earliest fathers of our religion not refused intelligence to animals; but they have even made this intelligence material... .[111]

Maupertuis attacks the traditional dualism held by many of the philosophes of the eighteenth century and offers in its stead material monism:

> The latter (the dualists) regard thought as the proper essence of the soul, and extension as the proper essence of the body; and not finding in their concept of the soul any properties which belong to the body, nor finding in the body any properties suitable to the soul, they believe that they have assured themselves not only of the distinction between these two sub-

stances, but also the impossibility that they have any properties in common.[112]

If it were true that the essence of the soul was only thought, and that the essence of the body was only extension, the reasoning of these philosophes would be correct; because there is nothing that one can see more clearly than the difference between extension and thought. But if both are only properties, they can both belong to a common subject whose essence is unknown to us; all the reasoning of the Philosophes crumbles and the coexistence of thought with extension does not appear impossible any longer.[113]

Until now, Maupertuis has presented us with the typical arguments and outlook of the biological materialist, but, in his application of his material monism, in the Système de la Nature, the first major breach is revealed: namely, that God, and the intentions of God determine all operations in the Universe. To begin with:

Religion forbids us from believing that the bodies we see owe their primary origin solely to the laws of Nature and to the properties of matter. The holy scriptures teach us how all bodies were created from nothing... .[114]

Maupertuis argues that at the time of the Creation:

...he (God) endowed each particle of matter, each element, with the property similar to what we call in us, desire, aversion, memory; the formation of the first individuals was miraculous, those which followed them were no more than the effects of these properties. Elements appropriate for each body, finding themselves in sufficient quantity and within distances from where they could exercise their action, will unite with each other in order to continually repair the losses of the universe.[115]

The elements appropriate to form the fetus swim in the semen of the male and female animals: but each extract of the part resembles that part it must form; it preserves a kind of memory of its former situation; and will return there each time it is able to, in order to form the same part in the fetus.[116]

But must the system which we have proposed be limited to animals? Why so limit it? Plants, minerals, even metals, are they not of similar origins? Doesn't their production stances, but also the impossibility that they have any properties in common.[112]

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> lead us to other organized bodies? Do we not see with our own eyes something similar to that which occurs in the germs of plants and in the matrix of animals; when the most subtle particles of a salt, are scattered in some fluid which permits them to move and unite, don't they, in effect, unite and form regular bodies, cubes, pyramids, etc. which is appropriate to the nature of each salt?[117]

Maupertuis, in a sincere attempt at objectivity, enumerates the three general systems that have been suggested to account for the formation of organized bodies (animal, plant and mineral):

> 1. That one in which brute, unintelligent elements, meeting by chance encounters, will have formed the Universe.[118]

But in a previous paragraph, Maupertuis has already made known what he thinks of a system which:

> ...only admits as principle in the Universe only eternal atoms, without feeling and without intelligence; whose chance meetings have formed all things. To topple such a system, it will suffice to ask those who support it how it would be possible that atoms without intelligence produce an intelligence.[119]

The second system, according to Maupertuis, is:

> 2. That one in which the Supreme Being or his subordinate agents, distinct from matter, would have used the elements, like an architect uses stones in the construction of buildings.[120]

Maupertuis has already brought to our attention the impossibility of immaterial beings operating on material beings. We are thus left with the third system, which, not unexpectedly, echoes Maupertuis' own speculations on the system of Nature. It is:

> 3. That one in which the elements themselves endowed with intelligence, dispose of themselves and unite in order to fulfill the purposes of God.[121]

That this is the choice of Maupertuis is obvious:

> God, in creating the world, endowed each part of matter with this property (intelligence), by which he wished

lead us to other organized bodies? Do we not see with our own eyes something similar to that which occurs in the germs of plants and in the matrix of animals; when the most subtle particles of a salt, are scattered in some fluid which permits them to move and unite, don't they, in effect, unite and form regular bodies, cubes, pyramids, etc. which is appropriate to the nature of each salt?[117]

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God, in creating the world, endowed each part of matter with this property (intelligence), by which He wished

> that the individuals he had formed would reproduce themselves. And since intelligence is necessary for the formation of organized bodies, it appears more magnificent and more worthy of God that the bodies are formed by means of the properties that he distributed to the elements at that first time; it is as if at each time, these bodies were immediate productions of his power.[122]

In comparing Maupertuis with the biological materialists, we are still struck by the tenacity with which they all (Maupertuis and the materialists) cling to the concept of active, spontaneous matter; matter which regulates itself; matter which creates itself anew. But whereas the biological materialists maintain that the self-regulation of matter is a consequence of internal directives which are constitutive to matter, Maupertuis maintains that these inner directives are not inherent in matter, but rather are the arbitrary endowments of God given to matter so that some purpose of His could be fulfilled.

The biological materialists used the property of self-regulation in matter as a means of removing God as a factor in explanation. Maupertuis, on the other hand, places God at the core of all phenomena. Indeed, Maupertuis says, "One cannot doubt that all things are regulated by a Supreme Being."[123] As a matter of fact, in order to understand fully the causes of physical events, not only is it necessary to determine the properties of the bodies under observation, but it is also necessary to determine the final causes involved:

> In order to give our research both breadth and certainty, it is necessary to employ both of these means. Let us determine the movements of the bodies, but let us also consult the intentions of the Intelligence which makes them move.[124]

The second breach between Maupertuis and the biological materialists involves the phenomenon of movement and the laws of motion.

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The second breach between Maupertuis and the biological materialists involves the phenomenon of movement and the laws of motion.

The materialists were uniformly of the opinion that movement was an essential part of matter and that the laws governing the movement of matter were necessarily derived from the nature of matter. However, according to Maupertuis:

> We see some parts of matter in motion, we see others at rest: therefore, movement is not an essential property of matter; it is a state in which matter can be or not be, and we can not see that matter can procure movement by itself. The parts of matter which move have thus received their movement from some mysterious cause which until now is unknown to me.[125]

Maupertuis did not remain hesitant about defining the source of movement for the entire universe:

> Movement and force are such realities of Nature, that one cannot easily conceive that they can be produced or destroyed. Moreover, the duration of the world and the perseverance of motion can cause one to think that movement or force always remains in the universe, always able to preserve or reproduce the same effects.
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> Newton, more attentive to observing Nature than in building systems, seeing that in the collision of different particles of matter, movement was more often destroyed than augmented, believed that in the long run, motion would be annihilated, if God did not, from time to time, impress new forces on the world-machine.[126]

In a thorough break with the ideas of Descartes and Leibniz on the conservation of motion, Maupertuis endorsed the view that:

> ...these movements are neither eternal nor independent; they are obedient to a power which produces and augments them, diminishes and destroys them, in the most economical and most wise manner.[127]

But not only was God the source of all motion in the universe, he was also the source of all laws governing motion:

> But when one realizes that all the laws of movement are based on the principle of the best, one will no longer doubt that they owe their establishment to an all-powerful, all-wise Being... .[128]

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But not only was God the source of all motion in the universe, he was also the source of all laws governing motion:

> But when one realizes that all the laws of movement are based on the principle of the best, one will no longer doubt that they owe their establishment to an all-powerful, all-wise Being.... [132]

This point is I believe the most fundamental difference between Maupertuis and the materialists. Unlike the materialists who sought to establish the laws of movement from their understanding of the essential properties of matter, Maupertuis asserted that such material necessity had no place in the establishment of laws. Rather, laws were the products of the completely unfettered will of God, who could (and did) bring into operation any law he chose.

> I believe it is more certain and useful to deduce these laws (of movement) from the attributes of an all wise, all powerful Being. If the ones I find in this way are the same as those observed in the Universe, is that not the strongest proof that this Being exists, and that he is the author of these laws.
>
> But could one not say that although the laws of movement have, until now, only been demonstrated by hypotheses and experiments, they are perhaps the necessary consequences of the nature of bodies; there not being anything arbitrary in their establishment, you attribute to Providence what is only the effect of necessity.
>
> If it is true that the laws of movement are the indispensable consequences of the nature of bodies, even that still proves the perfection of the Supreme Being: it is that all things are so ordained, that a blind and necessary mathematics can perform what the most enlightened and most free intelligence has prescribed.[129]

* * *

One cannot deny that these breaches with materialism are of major dimensions. Can we then maintain that Maupertuis was a biological materialist: Before we posit an answer, it might be enlightening to see how Maupertuis assessed himself.:

> All the philosophes of today form two sects. There are those who would wish to submit Nature to a purely material order, excluding every intelligent principle; or at least they wish that in the explanation of phenomena, one never had recourse to this principle; that one entirely banished final causes.[130]

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> If it is true that the laws of movement are the indispensable consequences of the nature of bodies, even that still proves the perfection of the Supreme Being; it is that all things are so ordered, that a blind and necessary mathematics can perform that the most enlightened and most free intelligence has prescribed.[128]

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> ...they believe that a blind mechanism is able to form the most organized bodies among the plants and animals, and to bring about all of the marvels that we see in the Universe.[131]

> The others on the contrary, make continual usage of final causes, discovering throughout all Nature the purposes of the Creator, seeing his designs in the smallest of phenomena.[132]

> In order to not refer to examples of a most indecent sort, which would be too common, I shall only speak of those who find God in the folds of a rhinoceros; because this animal being covered with such a tough skin could not move without those folds. Is this not to commit a wrong to the greatest of truths, in wishing to prove it by such arguments?[133]

> According to the first group, the Universe could do without God: at least the most magnificent marvels that one observes does not show the necessity for God at all. According to the latter, the smallest parts of the Universe can offer demonstrations of God: his power, his wisdom and his goodness are painted on the wings of butterflies and in the webs of spiders.[134]

Maupertuis cannot identify himself completely with either of these philosophic sects, because, "One group sees the Supreme Intelligence everywhere; the other sees it nowhere."[135] We know that Maupertuis has already rejected a completely mechanistic universe. Similarly, in discussing the petty arguments of the believers in final causes, Maupertuis says, "Let us leave these trifles to those who are unaware of the frivolity of such arguments."[136]

Maupertuis finds himself in the difficult position of not conforming to either group, and hence being denounced by them both:

> As there are today almost no philosophes who have not sided with one or the other of these two manners of reasoning, I can scarcely fail to displease both of them.[137]

> I have been attacked by both kinds of philosophers, by those who have found that I place too much value on final causes, and by those who have believed that I have not made enough use of them.[138]

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> In order to not enter an examination of a very tedious sort, which would be too extensive, I shall only speak of those who find God in the folds of a rhinoceros, because that animal being covered with such a tough skin could not move without those folds. Is this not to cause a wrong to the greatest of truths, in wishing to prove it by such arguments?[143]
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> According to the first group, the Universe could do without God: at least the most magnificent marvels that one observes does not prove the necessity for God at all. According to the latter, the smallest parts of the Universe are other demonstrations of God: His power, His wisdom and His goodness are depicted in the wings of butterflies and in the webs of spiders.[144]

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Therefore, Maupertuis must have used elements of both schools. But if I were required to determine which of the schools seemed to exert a greater influence on Maupertuis, I would have to choose the finalists.

Maupertuis himself recognizes the dangers involved in the use of final causation:

> I know the repugnance that several mathematicians have for the application of final causes to physics, and I agree to a certain point; I confess that it is not without danger that one introduces them: the error into which men such as Fermat have fallen, in using such causes only show too well how dangerous their usage can be.[139]

But on the whole he asserts:

> One cannot doubt that all things are regulated by a Supreme Being who while he has impressed forces on matter which denote his power, has destined matter to perform such actions in order to mark his wisdom... .[140]

* * *

What definitive statements can be made about Maupertuis' philosophical doctrine? The world for Maupertuis is a material one; the primitive elements are real particles bearing real properties, obeying specific laws. It is an ordered, mathematical world. But, behind the facade of "blind mechanism" there is a principle of intelligence at work and the source of this intelligence is the Supreme Being. It is to this all powerful, all wise Deity that, says Maupertuis, we owe the miracle of Creation; and it is from this same Deity that the laws governing his creation must be derived.

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For the biological materialist, explanation begins and ends with the properties of matter. The investigator confines his statements to his observations of matter and to deductions derived from such observations. But basic to all his research and/or system building, is that the roots of his science are firmly grounded in matter.

Maupertuis would agree that explanation ought to depend on observations of the properties of matter, but this gives us only a partial explanation. In order to give the complete picture, a scientific study must include a statement about the purpose for which an object does what it does or is what it is; and it must be recognized that the behavior of such objects is not rooted in its material composition, but rather depends upon the will of God.

> We have, I believe, shown that the greatest philosophers have not been able to deduce the laws of movement from the original idea that they had of the essence of bodies.
> We have also shown that those who added inertia to this original idea (extension) were able to obtain these laws only by means of precarious hypotheses or facts drawn from experiment... If after all that, someone persists in saying: the idea of extension only comes to you by experiment, through your senses; more experiments cause you to add impenetrability and inertia: still more experiments will cause you to discover other properties. And if you are able to finally obtain a notion of the complete body, who knows if you will not see that all the laws of movement are connected by an absolute necessity?
>
> If someone, I say, persists in reasoning in this way, I do not believe that one can demonstrate to him the impossibility of his supposition; but I repeat to him and he can be assured, that there is nothing in the world which can be sheltered from such reasoning, nothing in Nature which can not be suspected of necessity.[141]
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> In denying to all these laws the claimed prerogative of mathematical necessity, one can discover another (prerogative), much more precious; it is the nature of choice by an intelligent and free being: it is to bear the imprint of the wisdom and the power of the one who established the laws.[142]

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If, in Maupertuis' own eyes, he was not a materialist, to some of his contemporaries, he did warrant the label "materialist".

Paul Vernière, in his study on Spinozism in eighteenth century France, discusses the practice indulged in by various abbots of France, that is, buying up what was regarded by the Church as dangerous, impious publications and manuscripts. Included among these heterodox works were those of Maupertuis.[143]

Diderot, in response to the ideas postulated by Maupertuis in his Dissertatio, asserts that Maupertuis, in his guise of Dr. Baumann, uses the divine principle of intelligence as a property of matter only to avoid being labelled an atheist or a materialist. Otherwise, he would probably not have resorted to it.[144]

How do twentieth century commentators view Maupertuis?

In discussing Maupertuis' doctrine of particles endowed with intelligence and memory, Cassirer describes it as a sublimated form of materialism.[145]

Glass describes Maupertuis as "A mathematician trained in Cartesian views, an early convert to Newton's teachings; Maupertuis belies the remark made by Driesch that all epigenesists were vitalists, for Maupertuis was a consistent mechanist.[146]

According to Wartofsky, Maupertuis took the first steps in the materialization of the Leibnizian monad[147] and hence can be called a materialist; but Copleston is not so certain:

> The truth of the matter seems to be that though Maupertuis' writings contributed to the growth of materialism, his position is too equivocal to warrant our classing him without qualification with the materialistic prilosophers of the French Enlightenment.[148]

Vartanian assesses Maupertuis' position as a materialist by comparing him to Diderot:

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Vartanian assesses Maupertuis' position as a materialist by comparing him to Diderot:

Diderot's position was at the heart of Enlightenment's materialist science: that of Maupertuis, torn between the equally insistent demands of the old teleology and of the new vitalist current, remained on its periphery.[149]

Maupertuis, strictly speaking, does not belong to Diderot's faction. His leading concern in natural philosophy was to effect, on the example of Leibniz, some sort of compromise between finalistic theology and mechanistic science. This did not prevent Maupertuis from participating indirectly in the growth of scientific naturalism, by virtue of his speculations on vitalist phenomena and transformist process. Maupertuis did not succeed in resolving the conflicts, so clearly perceived and described by him, that sprang from the coexistence in the eighteenth century of the Newtonian teleological scheme and the naturalistic purport of biology in the 1740's. Instead, his discussions of the subject seemed only to strengthen each of the two viewpoints which continued to remain separate and incompatible. The principle value for us of Maupertuis' thought consists in the bright light it throws on the issues basic to the appearance of the philosophe's materialism.[150]

To return to our opening question: Was Maupertuis a man "out of his time", one could be persuaded to answer that he was indeed a most appropriate representative of the eighteenth century, combining as he did the avant-garde ideas of the eighteenth century French materialists and the still deeply entrenched traditional beliefs in a teleological universe.

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NOTES

1. Bentley Glass, "Maupertuis, Pioneer of Genetics and Evolution", Forerunners of Darwin, edited by B. Glass, O. Temkin, Wm. Straus (Baltimore, Johns Hopkins Press, 1968), p. 82.

2. John Herman Randall, Jr., The Career of Philosophy (New York, Columbia University Press, 1966), p. 896.

3. Aram Vartanian, "From Deist to Atheist, Diderot's Philosophical Orientation 1746 - 1749", Diderot Studies, vol. 1, 1949, p. 47.

4. René Descartes, Treatise of Man, translated by T. S. Hall (Cambridge, Harvard University Press, 1972), p. XXXV.

5. Paolo Casini, "Il Concetto di Molecola Organica nella Filosofia Naturale del Settecento," Giornale critico della Filosofia Italiana, XXXVII, 3, 1958, p. 359.

6. La Mettrie, Oeuvres philosophiques, vol. 111, p. 12, cited by A. Vartanian in Diderot and Descartes: A Study of Scientific Naturalism in the Enlightenment (Princeton, Princeton University Press, 1953), p. 268.

7. John Toland, Letters to Serena (London, 1704), Letter IV, p. 158.

8. G. W. Leibniz, The Monadology, taken from the collection, Leibniz Selections, edited by Philip Wiener (New York, Charles Scribner's Sons, 1951), point 7, p. 533.

9. Ibid, point 11, p. 534.

10. Casini, op. cit. p. 361.

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6. La Mettrie, Oeuvres philosophiques, vol. III, p. 92, cited by A. Vartanian in Diderot and Descartes: A Study of Scientific Naturalism in the Enlightenment (Princeton, Princeton University Press, 1953), p. 255.

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12. Maurice Mandelbaum, History, Man and Reason - A Study in Nineteenth Century Thought (Baltimore, Johns Hopkins Press, 1971), p. 22.

13. P.L. M. de Maupertuis, Oeuvres (Hildesheim, New York, Georg Olms Verlag, 1974), vol. 1, p. 26.

14. Encyclopédie - ou dictionaire raisonné des sciences (1779 edition), Article, Atheisme, p. 806.

15. Julien Offray de La Mettrie, L'Homme Machine, in Oeuvres philosophiques (Berlin, 1774), vol. 1, p. 285.

16. Ibid., p. 286.

17. La Mettrie, L'Homme Machine, a critical edition with an introductory monograph and notes by Aram Vartanian (New Jersey, Princeton University Press, 1960), p. 191.

18. Ibid.

19. Ibid., p. 192.

20. Ibid., p. 197.

21. La Mettrie, L'Homme Machine (Oeuvres), op. cit. p. 335.

22. La Mettrie, Traité de l'Ame (Oeuvres), op. cit. p. 113.

23. La Mettrie, L'Homme Machine (Oeuvres), op. cit. p. 339.

24. La Mettrie, L'Homme Machine, (Vartanian's edition), op. cit.,

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22. La Mettrie, Traité de l'Ame (Oeuvres), op. cit. p. 113.

23. La Mettrie, L'Homme Machine (Oeuvres), op. cit. p. 209.

24. La Mettrie, L'Homme Machine, (Vartanian's edition), op. cit.,

p. 188.

25. La Mettrie, L'Homme Machine, (Oeuvres), op. cit., p. 333.

26. Ibid., p. 331.

27. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 182.

28. La Mettrie likened the amniotic enclosure of mammalian fetuses to eggs lacking the hardened shells of birds, L'Homme Machine, (Vartanian), p. 193.

29. Ibid.

30. Ibid., p. 194.

31. Ibid.

32. La Mettrie, L'Homme Machine, (Oeuvres), op. cit., p. 334.

33. Ibid., p. 288.

34. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 176.

35. Ibid., p. 179.

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37. Ibid. XXVIII.

38. La Mettrie, L'Homme Machine (Oeuvres), op. cit., p. 298.

39. Ibid.

40. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 175.

41. Georges Louis Leclerc de Buffon, Oeuvres Complètes de Buffon (Paris, Librairie Abel Pilon), vol. 4, p. 144.

42. Ibid., p. 145.

43. Ibid., p. 169.

44. Ibid., p. 170.

45. For a detailed discussion of the functions of the moule intérieur,

p. 189.

25. La Mettrie, L'Homme Machine, (Oeuvres), op. cit., p. 300.

26. Ibid., p. 301.

27. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 192.

28. La Mettrie likened the amniotic enclosure of gestating fetuses to eggs lacking the hardened shells of birds, L'Homme Machine, (Vartanian), p. 193.

29. Ibid.

30. Ibid., p. 194.

31. Ibid.

32. La Mettrie, L'Homme Machine, (Oeuvres), op. cit., p. 304.

33. Ibid., p. 305.

34. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 186.

35. Ibid., p. 179.

36. La Mettrie, Système d'Épicure, (Oeuvres), op. cit., p. 370, XXVII.

37. Ibid. XXVIII.

38. La Mettrie, L'Homme Machine (Oeuvres), op. cit., p. 296.

39. Ibid.

40. La Mettrie, L'Homme Machine, (Vartanian), op. cit., p. 173.

41. Georges Louis Leclerc de Buffon, Oeuvres Complètes de Buffon (Paris, Librairie Abel Pilon), vol. 4, p. 164.

42. Ibid., p. 165.

43. Ibid., p. 169.

44. Ibid., p. 170.

45. For a detailed discussion of the functions of the moule intérieur,

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46. Buffon, op. cit., p. 175.

47. Ibid., p. 180.

48. Denis Diderot, Oeuvres Complètes de Diderot (Paris, Garnier Frères, 1875), vol. 2, De l'Interprétation de la Nature, p. 9.

49. Ibid., p. 56.

50. Diderot, op. cit. Entretien entre d'Alembert et Diderot, p. 118.

51. Ibid.

52. Diderot, Conversation between D'Alembert and Diderot (Penguin edition, 1966), p. 160.

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56. Diderot, Principes Philosophiques (Oeuvres), op. cit., p. 65.

57. Diderot, D'Alembert's Dream, Penguin edition, op. cit., p. 182.

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61. Diderot, Conversation, op. cit., p. 153.

62. Diderot, Lettre d'un Aveugle, (Oeuvres), op. cit., vol. 1, p. 308.

63. Diderot, De l'Interprétation de la Nature, op. cit., p. 54.

64. Diderot, Principes, op. cit., p. 69.

65. Paul Henrich Dietrich, Baron von Holbach, Système de la Nature (London, 1777), p. 8.

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52. Diderot, Conversation between d'Alembert and Diderot (Penguin edition, 1966), p. 160.

53. Diderot, Entretien (Oeuvres), op. cit. p. 112.

54. Ibid., p. 159.

55. Diderot, Principes Philosophiques (Oeuvres), op. cit., p. 65.

57. Diderot, D'Alembert's Dream, Penguin edition, op. cit., p. 163.

58. Diderot, Principes (Oeuvres), op. cit., p. 68.

59. Ibid.

60. Diderot, D'Alembert's Dream, op. cit., p. 165.

61. Diderot, Conversation, op. cit., p. 157.

62. Diderot, Lettre sur les Aveugles (Oeuvres), op. cit., vol. 1, p. 309.

63. Diderot, De l'Interprétation de la Nature, op. cit., p. 34.

64. Diderot, Principes, op. cit., p. 69.

65. Paul Heinrich Dietrich, Baron von Holbach, Système de la Nature (London, 1770), p. 8.

66. Ibid., p. 25.

67. Ibid., p. 61.

68. Ibid., p. 62.

69. Ibid., p. 78.

70. Ibid.

71. Ibid., p. 13.

72. Ibid., p. 21.

73. Ibid., p. 26.

74. Ibid., p. 11.

75. Ibid., p. 39.

76. Ibid., p. 40.

77. Ibid., p. 37.

78. Ibid., p. 4.

79. Ibid., p. 469.

80. Ibid., p. 34.

81. Ibid., p. 440.

82. Ibid., p. 441.

83. Ibid., p. 442.

84. Maupertuis, Oeuvres, vol. 11, Lettre IV, pp. 228 - 230.

85. Ibid., pp. 232, 233, 234.

86. Maupertuis, Oeuvres, vol. 1, Reflexions philosophiques, p. 278, XXIV.

87. Ibid., p. 279, XXV.

88. Ibid., p. 302.

89. Maupertuis, vol. 11, Lettre IV, p. 236.

90. Maupertuis, vol. 1, Examen philosophique, p. 393.

91. Maupertuis, vol. 11, Système de la Nature, p. 157, footnote a.

92. Maupertuis, vol. 11, Lettre X, p. 272.

93. Maupertui , vol. 11, Lettre IX, p. 266.

94. Maupertuis, vol. 11, Système de la Nature, p. 154.

95. Maupertuis, vol. 11, Lettre XV, p. 315.

96. Maupertuis, vol. 11, Lettre XIX, p. 342.

97. Maupertuis, vol. 11, Vénus physique, p. 67.

98. Maupertuis, op. cit., vol. 1, Essaie de Cosmologie, p. 45.

99. Maupertuis, op. cit., vol. 11, Vénus physique, p. 85.

100. Ibid., pp. 86 - 89.

101. The Système de la Nature, was first issued as a pseudonymous publication, in Latin, bearing the title Dissertatio inauguralis metaphysica de universali naturae systemate by Dr. Baumann. When Maupertuis admitted to the writing of the work it was re-issued in French, in 1754, with the title: Système de la Nature.

102. Maupertuis, vol. 11, Système, p. 139, 1.

103. A possible explanation for this change is suggested in the next chapter.

104. Maupertuis, vol. II, Système de la Nature, p. 140, 111 and p. 141, IV.

105. Ibid., p. 141, VI.

106. Ibid., p. 142, VIII.

107. Ibid., p. 146, XIV.

108. Ibid., p. 147, XV.

109. Ibid., p. 148, XVII.

110. Ibid., p. 149, XVIII.

91. Maupertuis, vol. II, Système de la Nature, p. 157, footnote a.

92. Maupertuis, vol. II, Lettre X, p. 272.

93. Maupertuis, vol. II, Lettre IX, p. 266.

94. Maupertuis, vol. II, Système de la Nature, p. 159.

95. Maupertuis, vol. II, Lettre IX, p. 275.

96. Maupertuis, vol. II, Lettre XIV, p. 343.

97. Maupertuis, vol. II, Vénus physique, p. 67.

98. Maupertuis, op. cit., vol. I, Essais de Cosmologie, p. 45.

99. Maupertuis, op. cit., vol. II, Vénus physique, p. 69.

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102. Maupertuis, vol. II, Système, p. 139, i.

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104. Maupertuis, vol. II, Système de la Nature, p. 140, III and p. 143, IV.

105. Ibid., p. 141, VI.

106. Ibid., p. 142, XIII.

107. Ibid., p. 146, XIV.

108. Ibid., p. 147, XV.

109. Ibid., p. 148, XVII.

110. Ibid., p. 149, XVIII.

111. Ibid., p. 149, XIX.

112. Ibid., p. 151, XXI.

113. Ibid., p. 151, XXII.

114. Ibid., p. 154, XXVII.

115. Ibid., p. 157, XXXI.

116. Ibid., p. 158, XXXIII.

117. Ibid., p. 166, XLVII.

118. Ibid., p. 184.

119. Ibid., p. 182.

120. Ibid., p. 184.

121. Ibid.

122. Ibid., p. 183.

123. Maupertuis, vol. IV, <u>Accord des Loix de la Nature</u>, p. 21.

124. Ibid., p. 22.

125. Maupertuis, vol. 1, <u>Essai de Cosmologie</u>, p. 32.

126. Maupertuis, vol. 11, <u>Lettre X</u>, p. 271.

127. Ibid., p. 274.

128. Maupertuis, vol. 1, <u>Essai de Cosmologie</u>, p. 34.

129. Ibid., p. 24.

130. Ibid., p. XII.

131. Ibid., p. 13.

132. Ibid., p. XIII.

133. Ibid., p. 12.

134. Ibid., p. XIII.

135. Ibid., p. 13

136. Ibid., p. 12.

137. Ibid., p. XIII.

138. Ibid., p. XIV.

139. Maupertuis, vol. IV, Accord des Lois, p. 20.

140. Ibid., p. 21.

141. Maupertuis, vol. 1, Examen philosophique, p. 424, LXXI.

142. Ibid., LXX.

143. Paul Vernière, Spinoza et la Pensée Francaise avant la Révolution (Paris, Presses Universitaires de France, 1954), p. 415.

144. Diderot, op. cit., p. 46.

145. Ernst Cassirer, The Philosophy of the Enlightenment (Boston, Beacon Press, 1966), p. 90.

146. Glass, "Maupertuis and the Beginning of Genetics", Quarterly Review of Biology, vol. 22, no. 3, Sept. 1947, p. 200.

147. Marx W. Wartofsky, "Diderot and the Development of Materialist Monism", Diderot Studies, vol. 2, 1952, p. 290.

148. Frederick Copleston, A History of Philosophy, Part One, The French Enlightenment to Kant (New York, Doubleday, 1964), vol. 6, p. 31.

149. Vartanian, Diderot and Descartes, op. cit., p. 272.

150. Ibid., p. 306.

137. Ibid., p. XXII.

138. Ibid., p. XIV.

139. Hemsterhuis, vol. IV, Accord des Idées, p. 20.

140. Ibid., p. 21.

141. Hemsterhuis, vol. I, Examen philosophique, p. 423, LXII.

142. Ibid., LXX.

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148. Frederick Copleston, A History of Philosophy, Part One, The French Enlightenment to Kant (New York, Doubleday, 1960), vol. 6, p. 51.

149. Vartanian, Diderot and Descartes, op. cit., p. 292.

150. Ibid., p. 306.

CHAPTER THREE

The influence of theology on Maupertuis; the importance of Maupertuis' theological beliefs to his science

In Chapter Two, I discussed the significance of final causation in the scientific explanations offered by Maupertuis. In this chapter, I shall continue to explore the role of theology in the scientific career of Maupertuis, seeking to demonstrate that, as far as Maupertuis was concerned, science continued to retain strong roots in a theological substructure.

Maupertuis' intense feelings about God and religion lavishly colored all aspects of his life. Consequently, a more enriched understanding of Maupertuis as a scientist can be obtained, if first, one attempts to understand Maupertuis, the believer.

Part One: Maupertuis, the believer

Samuel Formey, Maupertuis' close friend, remarked in his Éloge to Maupertuis:

> M. de Maupertuis had deep feelings about religion; and they increased with the approach of death. ...I have already mentioned that one will not find the slightest trace of impiety in the writings of M. de Maupertuis: and that, in this century, is a distinction as rare as it is real.[1]

For Maupertuis, religion was the core of his existence:

> Here is the most important thing of all, that for which we give such little attention in comparison to the magnitude of its object. I speak of Religion, which some ridicule without understanding it, which others worship without having studied it, and of which only a small number observe its true precepts.[2]

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So important was religion to Maupertuis that he readily broke his personal vow of not publicly defending his positions on various issues, in order to speak out against Diderot's attempt to brand him an "atheist":

> When I allowed the publication of some of my thoughts, I promised myself that in case someone attacked me, I would not waste my time defending things which perhaps did not deserve to be defended... . Neither the injustice of the critics, nor the case that I could have made against them, have made me change my resolution. There is only one class of objections to which one is obliged to respond, and for which silence would be a mistake either against society or against oneself; they are those which would give erroneous impressions of our religion or of our customs.[3]

Whether or not Maupertuis was a regular church-goer or even a devout Catholic, is not at issue here. What does matter is the fact that Maupertuis was a staunch believer in God; and his God was not some vague, shadowy, behind-the-scene figure, but rather a sharply defined entity, omnipotent and active in the world of his creati n:

> God is of an eternal order, the Creator of the Universe, a Being all-powerful, all wise, all good.[4]

The role that Maupertuis has assigned to God is scarcely the "Dieu faineant" of Descartes or the Legislative God of Leibniz. The part that God plays in the world is explicitly described in a passage taken from a letter (dated Apr. 24, 1750) from Maupertuis to Frederick II,

> ... I admire the poetry of the piece that I have been honored to have addressed to me, but I am not at all impressed by the reasons you quote to me which remove an area of dominion from the all-powerful Being and allow him to be only an inspector-general. Take care, Sire; from this system to the atheism that you abhor is but a step... . I feel that it is easier to conceive of a being who directs everything immediately and unceasingly than to conceive of a God who abandons the machine to the laws of movement which he has impressed on it, a God capable of creating everything and incapable of conducting anything. or, if one wishes, active enough to operate the most difficult marvels and lazy enough to neglect them; such is the god of Epicurus, but it is not mine, nor dare I say, is it

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yours, Your Majesty.[5]

Maupertuis was not only a firm believer in God, but he also asserted that man had an immortal soul:

> Man is the work of God, composed of a body which must perish and a soul which will endure eternally.[6]

Does this pronouncement contradict the "single substance" theory that Maupertuis went to such great lengths to make known and have accepted? (Maupertuis' material-monism was discussed in Chapter Two.) Not really, since Maupertuis still maintains that man, like all the animals, plants and other organized entities, is composed of a single substance that has both the physical properties that had been associated with matter and the psychic properties that had characterized spirit. However, to man and man alone has been added a special feature -- a moral principle which is responsible for lifting man to an order above the other entities of earth; a principle which enables man to know God and his duties to God:

> Until now, speaking as philosophers, we have considered intelligence necessary for the formation of bodies; it is what man has in common with the animals, plants and in some way with all organized beings. But man has another principle which renders his condition quite different from theirs, which enables him to know God, and in which he finds the moral notions of his duties... . I do not undertake to explain the relationship between the moral principle and the intelligence [an intelligence] which results from the united perceptions of the elements (the particles composing the body): it suffices that we know that we have an indivisible, immortal soul that is entirely distinct from the body and capable of deserving eternal punishment or reward.[7]

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* * *

The strength and sincerity of Maupertuis' theological beliefs are evident and for practical purposes, beyond question. What is of interest here is to notice just how influential were Maupertuis' theological beliefs on his own activities as a scientist.

One of the most interesting and exciting aspects of the work of the scientist, is developing a theory, an hypothesis, which, he believes, could explain a particular set of phenomena. For Maupertuis, this aspect of his science was all-important because he did little experimental work; most of his scientific activities remained at the speculative level. Yet, so important to Maupertuis were his religious beliefs that he could claim that any conflict between his belief as a Christian and his scientific hypothesis would readily result in the dissolution of the hypothesis:

> M. Diderot has, perhaps, not rendered justice to my work (the Système de la Nature), but he has dealt justly with my sentiments when he said: "It is necessary to read his [Maupertuis'] work to learn how to reconcile the most daring philosophical ideas with the most profound respect for Religion." Indeed, I am so filled with respect, that I would never hesitate to sacrifice my hypothesis, even a thousand such hypotheses, if I knew that they contained anything which was opposed to the truths of the Faith, or if this authority, to which all Christians must submit, disapproved of the hypotheses.[8]

Maupertuis' strong theological feelings also determined his views on what he believed to be the appropriate goals of scientists in general. To Maupertuis, the scientist must recognize that in serving science he was in reality serving two masters -- science and theology. Science had as its objective, not only the amassing of information to explain the mysteries of the world, but also a goal of another order entirely, -- the study of God through his works and the spreading of this knowledge to unbelievers. In his discussion of the duties of the are evident and for practical purposes, beyond question. What is of interest here is to notice just how influential were Maupertuis' theological beliefs on his own activities as a scientist.

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> I have here examined the different sciences to which we apply ourselves and have not spoken at all of one of the principal objects that this company (the Berlin Academy of Science) has had from its establishment.
>
> The first regulation of the Royal Society declares: that one of these classes (experimental philosophy, mathematics, speculative philosophy, literature) apply itself to the study of religion and to the conversion of the infidels: an article so very peculiar in the way it was presented, that it was ineffective. Our modern regulation does not change any particular class with this occupation: but can one not say that each class has this duty?
>
> Doesn't one find in the study of the marvels of Nature, proofs of the existence of a Supreme Being?
>
> Doesn't speculative philosophy cause us to recognize the necessity of his existence?
>
> Finally, the study of these facts teach us that God has made himself known to men in a way that is even more decisive; he has required worship from them and has so ordained it.[9]

So far, we have been occupied with Maupertuis' views of the way in which theology affects the attitudes of the scientist who is also a believing Christian. But from the perspective of Maupertuis the relationship between science and theology reveals even more dramatic and powerful ties. According to Maupertuis, theology was important to the basic structure of science -- to its philosophy, its methodology, and its system of explanation. From Maupertuis' own account, it will be seen that the relationship between science and theology is not a simple one way street, with science being completely dependent upon theology. Rather, one soon realizes that there is a strong interdependence between theology and science, and it is this tie that I propose to examine in the remaining part of this chapter.

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A. Science as a tool for theology:

The central objective of theology is by definition a demonstration of the existence of God, and therefore, it is not too surprising that Maupertuis devotes a lengthy work, the Essaie de Cosmologie, to the study of those proofs concerned with demonstrating the existence of God. What is interesting for us, however, is Maupertuis' outspoken dismissal of the time-honored paths that theologians and metaphysicians had following in pursuing this end.

> I have warned, from the outset, that the study that I have made of the proofs of the existence of God did not depend at all on those that metaphysicians furnished.[10]

> I shall not examine at all the arguments that one finds in the idea of an infinite Being; in this idea that is so immense that we can not seek it within ourselves, or from within any other finite being, and which appears to prove that a perfect, infinite Being exists.[11]

> ... I shall not stress at all that one can conclude from the intelligence that we find in ourselves, from the sparks of wisdom and power which we see scattered among finite beings, that one can suppose an immense and eternal source from whence is drawn this intelligence, wisdom and power.[12]

> I shall not dwell on the proofs of the existence of a Supreme Being which the Ancients drew on, from the Beauty, Order and Arrangement of the Universe.[13]

> All of these arguments are very strong: but they are not the kind that I shall examine.[14]

The difference between Maupertuis and the theologians that came before him was that Maupertuis, as a scientist, intends to use new concepts in the rational science of the 18th century to demonstrate the existence of God.

> From all times those who have applied themselves to the contemplation of the Universe have found the marks of the wisdom and power of Him who governs it. The more the study of physics has progressed, the more the proofs have multiplied.[15]

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The difference between Maupertuis and the theologians that came before him was that Maupertuis, as a scientist, intended to use new concepts in the natural science of the 18th century to demonstrate the existence of God.

> From all times those who have applied themselves to the contemplation of the Universe have found the marks of the wisdom and power of Him who governs it. The more the study of physics has progressed, the more the proofs have multiplied.[15]

It would appear from this quotation that Maupertuis merely intended to add more illustrations of the argument from design. In the eighteenth century, it was still customary to demonstrate the existence of God through a study of "the marvels of Nature". This is the proclaimed argument from design, which is based on the logical assumption that if, for example, one is presented with a complex, delicately constructed mechanism such as a watch, there must have been a watch-maker; similarly, given the marvelously orchestrated system of the Universe or the complex mechanisms of the living organisms, there must have been a highly intelligent, skillful creator at work. The existence of these marvels is not to be attributed to chance. Is this how Maupertuis intends to use science? Perhaps the best answer to this question is to be found in Maupertuis' own analysis of Newton's argument from design:

> Newton appeared to have been more affected by the proofs to be found in the contemplation of the universe than by all the others that he could have drawn from the reaches of his mind. This great man believed that the movements of the celestial bodies were quite sufficient to demonstrate the existence of the one who governed them. ... All of them (the planets), move in the same direction and describe orbits that are nearly concentric. ... Newton believed that such uniformity could only be the effect of the will of a Supreme Being... The uniformity observed in the construction of animals, their organization, so marvelous and so useful, were for him convincing proofs of the existence of an all-powerful, all-wise Creator.[16]

Maupertuis, however, was not inclined to indulge in the use of such arguments. He believed that the arguments from design can prevent one from seeing other natural explanations which do not require the assumption of a creator. The same phenomena could perhaps be explained by a different theory which would make unnecesssary the acceptance of an intelligence at work. Or, perhaps, chance really could account for

It would appear from this quotation that Maupertuis merely intended to add more illustrations of the argument from design. In the eighteenth century, it was still customary to demonstrate the existence of God through a study of "the marvels of Nature". This is the proclaimed argument from design, which is based on the logical assumption that if, for example, one is presented with a complex, delicately constructed mechanism such as a watch, there must have been a watch-maker; similarly, given the marvellously orchestrated system of the universe or the complex mechanisms of the living organisms, there must have been a highly intelligent, skilled creator at work. The existence of these marvels is not to be attributed to chance. Is this how Maupertuis intends to use evidence? Perhaps the best answer to this question is to be found in Hanoverstadt's own analysis of Newton's argument from design:

> Newton appeared to have been more affected by the proofs to be found in the contemplation of the universe than by all the others that he could have drawn from the reaches of his mind. This great man believed that the movements of the celestial bodies were quite sufficient to demonstrate the existence of the one who governed them. ... All of them (the planets), move in the same direction and describe orbits that are nearly concentric. ... Newton believed that such uniformity could only be the effect of the will of a Supreme Being... The uniformity observed in the construction of animals, their organization, so marvelous and so useful, were for him convincing proofs of the existence of an all-powerful, all-wise Creator.19

Maupertuis, however, was not inclined to indulge in the use of such arguments. He believed that the arguments from design can prevent one from seeking other natural explanations which do not require the assumption of a creator. The same phenomena could perhaps be explained by a different theory which would make unnecessary the acceptance of an intelligence at work. Or, perhaps, chance really could account for the production of a particular phenomenon.

> Let us not conceal the weakness of some of their reasoning: and to better understand the abuse that one has made of the proofs of the existence of God, let us examine the ones which appeared to be so strong to Newton.
>
> Uniformity, he said, of the movement of the planets necessarily shows a choice. It is not possible that blind chance can make them all move in the same direction and in orbits that are almost concentric.
>
> Newton could add to the uniform movement of the planets, the fact that they move in almost the same plane, the zone in which all the orbits are contained is only about one-seventeenth par of the surface of the sphere. If one then takes the orbit of the Earth as the plane to which the others relate, and one regards their position as the effect of chance, the probability that these five other orbits ought not be enclosed in this zone is 17^5:1, that is, 1,419,856 to 1.
>
> If one believes, as did Newton, that all the celestial bodies which were attracted towards the sun move in a void, it is true that it is scarcely probable that chance caused them to move in the plane in which they do move. There remains, however, some probability and consequently one cannot say that this uniformity was the necessary effect of a choice.
>
> But there is more: the alternative between choice or an extreme probability is based only on the inability of Newton to give a physical cause to this uniformity. For other philosophers who have the planets moving in a fluid which carries them along, or which only moderates their movement, the uniformity of their course is not at all inexplicable: it supposes neither chance nor choice.[17]

Similarly Maupertuis attacks Newton's argument from design, as applied to the construction of animals and to the conformity between the structure of a part of a body and its use:

> I do not know if the argument that Newton derives from the construction of the animals is much stronger. If the uniformity that one observed in several kinds was a proof, would not this proof be denied by the infinite variety that is observed in several other kinds? ...Indeed, other philosophers seek to find proof of the existence of God in the variety of forms and I do not know which of the proofs is

the prediction of a particular phenomenon.

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> The argument derived from the fitness of the different parts of the animal to their needs appeared more solid. Are not their feet made to walk, their wings to fly, their eyes to see, their mouths to eat, other parts to reproduce themselves? Is not all that the mark of an intelligence and of a plan which have presided over their construction?
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> This argument had struck the Ancients as it did Newton: and it was in vain that the greatest enemy of Providence (Lucretius) answered them, [pointing out] that use had not been the aim but the result of the construction of the parts of an animal; that chance had formed the eyes, the ears, the tongue, and they had been used to hear and to speak.
>
> But could not one say that in the fortuitous arrangement of the productions of Nature, since only those which displayed a suitable relation of parts could survive, is it not a wonder that this fitness is found in all species which exist at present? Chance, one would say, had produced innumerable quantities of individuals; a small number were constructed in such a manner that the parts of the animal could satisfy its needs; in a much greater number, there was neither suitability, nor order; all these latter perished... the only ones that remained were those in which order and suitability were found; and these species which we see today are only a small part of those that a blind destiny had produced.[18]

If we are not to search for proofs of God in the spectacle of the Universe, where are we to seek him? Unhesitatingly, Maupertuis urges that we seek God in the universal phenomena of Nature, and in the primary laws that govern Nature:

> It is not at all in the insignificant details or in the parts of the Universe which we cannot relate to the whole, that we must seek the Supreme Being; ...it is necessary to seek him in the phenomena whose universality allows no exceptions and whose simplicity is completely exposed to our sight.[19]
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> Let us not be stopped by speculations on the marvels of Nature. The organization of animals, the number of insects and the infinitesmal size of their parts, the immensity of celestial bodies, their distances and revolutions, are more appropriate to astonish rather than inform the mind. The Supreme Being is everywhere; but he is not equally visible

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> everywhere. We will see him best in the simplest objects: seek him out in the primary laws that he has imposed on Nature; in the universal rules according to which movement is conserved, distributed or destroyed... .[20]

> I shall devote myself [to a study of] the primary laws of Nature, those laws which we see constantly observed in all phenomena; those laws which we cannot doubt are the ones that the Supreme Being put forth during the formation of the Universe. These are the laws I seek to discover; these are the laws I seek to derive from the infinite source of wisdom whence they emanate.[21]

The answer for Maupertuis lies, then, in the study of universal phenomena and the principles governing these phenomena. But, in what way is the study of the principles governing the phenomena of Nature more appropriate and satisfying to Maupertuis than those demonstrations drawn from the argument from design? In Maupertuis' opinion, the argument from design merely established the existence of a planner and a plan, without saying anything about the purpose of the plan:

> On a thousand occasions, this Universe has presented us with results... that only show intelligence and design: it is in the purpose of these designs that it is necessary to seek wisdom.[22]

For Maupertuis this was a serious defect because in his mind, the idea of the existence of God was identified with the wisdom of God and the power of God,[23] i.e., God's existence implied the existence of infinite Wisdom and infinite Power. And it was Maupertuis' self-appointed task to make those attributes of God known to man.

The universal phenomena studied by Maupertuis are those of movement and generation. The principles associated with these phenomena are, respectively, the Principle of Least Action and the Principle of Intelligence.

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The universal phenomena studied by Maupertuis are those of movement and generation. The principles associated with these phenomena are, respectively, the Principle of Least Action and the Principle of Intelligence.

The Principle of Least Action

> Let us speak now of the principle which I regard as one of the strongest arguments that the Universe offers us, in order to make known to us the wisdom and power of its sovereign author. It is a metaphysical principle upon which all the laws of movement are based. It is that when any change occurs in Nature, the quantity of action employed for this change is always the smallest possible; the action being a product of the mass of the body multiplied by its speed and the distance it covers.[24]

> It is the principle that I call the le st quantity of action... which extends equally to hard and elastic bodies; and on which depends the movements of all corporal substances.[25]

The first statement of the principle of least action was given by Maupertuis in an address to the members of the Paris Royal Academy of Science in 1744. It was a triumph of sorts for Maupertuis because it meant that he was now able to bring under the aegis of one basic law the seemingly disparate behavior patterns of particles in motion in a variety of circumstances. Maupertuis had made a study of the paths taken by particles of light as they a) traversed a uniform medium, b) were reflected from an opaque surface, and c) traversed media of differing densities.[26] He noted that the ancient philosophers were familiar with two of the laws governing the behavior of light particles:

1. In a uniform medium, light moves in a straight line.
2. When light encounters an object that it cannot penetrate, it is reflected; the angle of reflection is equal to the angle of incidence.

The first of these laws was recognized as common to light particles and to other bodies -- i.e., a body will move in a straight line in

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2. When light encounters an object that it cannot penetrate, it is reflected; the angle of reflection is equal to the angle of incidence.

The first of these laws was recognized as common to light particles and to other bodies -- i.e., a body will move in a straight line in a uniform medium until deflected by an outside force. The second law applied equally to an elastic body when bounced off a firm surface and to the incidence of light particles on a reflecting surface; i.e., when an elastic body hit the surface of a firm body it was bounced off by an angle equal to that with which it hit the surface.

In the seventeenth century however, Snellius and Descartes discovered the phenomenon of refraction of light, and set up the law of refraction to describe the path taken by light as it passes from one medium to another, each of a different density. The behavior of a body, such as a ball, traversing two different media did not follow the law of refraction of light. The question that Maupertuis asked was how to reconcile the differences between the laws governing the reflection and refraction of light with those governing the motion of other bodies. After examining the various explanations for the reflection and refraction of light that had been given, he grouped them into three categories: the first class included those explanations based upon the simple and ordinary principles of mechanics; the second class included explanations which added the property of attraction to the principles of mechanics; "finally the third class included those explanations which were derived from metaphysical principles only; from those laws to which Nature herself appears to be subjected by a superior intelligence."[27] It was this latter class to which Maupertuis was drawn, attracted by the metaphysical principle that Nature, in the production of her effects, acts always by the simplest means. But Maupertuis saw that the refracted light did not obey this simple principle. He, therefore, abandoned it for another metaphysia uniform motion until deflected by an outside force. The second law applied equally to an elastic body when bounced off a firm surface and to the incidence of light particles on a reflecting surface; i.e., when an elastic body hit the surface of a firm body it was bounced off by an angle equal to that with which it hit the surface.

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> Not only does this principle fulfill the idea that we have of the Supreme Being, in as much as it is always acting in the wisest way, but also in so far as it must always keep everything dependent on it.[30]

The Principle of Least Action seemed to be entirely different from Newton's laws of motion, but it gave the same results. Newton's laws describe the motion of bodies under the influence of forces. These forces are efficient causes determining the change of motion at the time that the forces are applied. The Principle of Least Action is a minimum principle, and is expressed in terms of final causes. The moving particle or light ray will follow the path by which it will consume the least amount of action. It appears that the path must be chosen before the particle begins to move! Thus the Principle of Least Action reveals a purposiveness in the most fundamental laws of nature.

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The Principle of Intelligence

The principle of least action is chiefly associated with the activities of inanimate particles in a mechanical world. But what of the animate world? How does God regulate this domain? This question proved to be of great interest to Maupertuis:

> ...once this world was formed, what laws preserved it? what were the means by which the Creator destined individuals, who perish, to reproduce themselves?[31]

Speculation as to what these means of reproduction (i.e., the problem of generation) could be resulted in Maupertuis' eventual recourse to the principle of intelligence. He came upon it in a way that parallels his approach to the principle of least action. Just as Maupertuis had grouped the explanations governing motion into three classes: simple mechanics, attractive forces, and metaphysical principles, so too does he classify the systems governing the process of generation. And just as he rejected explanations based on simple mechanics or attractive forces, so too does he reject such systems of generation:

> Some philosophers believed that with matter and motion they could explain all of Nature: and to make this [explanation] even simpler, they advised that by matter one should understand only extension.[32]

> Never can one explain the formation of an organized body by just the physical properties of matter... .[33]

> A blind, uniform attraction scattered throughout all the particles of matter cannot be used to explain how these particles are arranged to form a body with even the simplest organization.[34]

Maupertuis finally concludes that in seeking to explain how a new body is organized:

> ... it is necessary to have recourse to some principle of intelligence, to something similar to what we call desire, aversion, memory.[35]

This principle has a dual function: it provides the motive force for the process of generation and consequently fulfills its teleological obligation, that of preserving God's creations. But it is as the "Engine" for the process of generation that the principle of intelligence is most fascinating. This intelligence, manifested as "memory" in each particle of matter, is a God-given property:

> ... God has endowed each of the smallest particles of matter, each element, with that property similar to what we call in us desire, aversion, memory; the formation of the first individuals was a miracle, but the succeeding productions are the effects of this property.[36]

Maupertuis' system of generation involves the hypothesized model of pangenesis. Pangenesis refers to the formation of a newly organized body by the mingling of seminal liquor from each of the two contributing parents. The seminal liquor is composed of particles taken from each part of the parental body. Only when the parental liquors intermingle and the appropriate male and female particles can combine, does the new organism form. For Maupertuis, the motivating force allowing particles to come together to form a fetus is this principle of intelligence, displayed in the particle as "memory":

> The elements appropriate to form the fetus swim in the semen of the male and female parental animals: each particulate extract resembles the part from whence it is derived, the part that it must form. It retains a memory of its former position and will go there each time that it is able to.[37]

A comparison of the principle of least action and the principle of intelligence allows us to see the two different ways in which Maupertuis defines the term "principle". The principle of least action is a descriptive statement; it provides the physicist with a mathematical relationship between the mass of a body, its speed and

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A comparison of the principle of least action and the principle of intelligence allows us to see the two different ways in which Maupertuis defines the term "principle". The principle of least action is a descriptive statement; it provides the physicist with a mathematical relationship between the mass of a body, its speed and the distance it travels; it provides the philosopher with a reaffirmed belief in final causes. The principle of intelligence does have its teleological aspects also, but what makes it differ significantly from the principle of least action is that the principle of intelligence is not a descriptive statement at all. It is "principle" operating as an active agent, as the directing force of a universal phenomenon. For Maupertuis, the combination of both principles reveals to mortals a vivid demonstration of God. We are made aware of the wisdom of God through the principle of least action; we are made aware of his power through the principle of intelligence.

B. Theology -- its role in the structure of Science.

Maupertuis' deep-seated theological beliefs affected more than his attitude towards the goals of science; they became an integral part of the discipline through the shaping of his ideas about scientific procedure and philosophy.

1. The dependency of the world on its Creator:

Perhaps one can get some indication about the importance of Maupertuis' theological beliefs to science by examining just how heavily dependent his world, as the object of scientific investigation, was upon God.

It goes without saying that Maupertuis was a staunch believer in Genesis:

> Our religion forbids us to believe that the bodies which we see owe their origins to only the laws of Nature and the properties of matter. The divine scriptures teach us how all bodies were, at first, formed from nothing; and I am very far from having the least doubt about any of the circumstances of this tale.[38]

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But more than being a mere Creator of the Universe, Maupertuis' God was a zealous administrator of his creation:

> One can not doubt that all things are ruled by a Supreme Being... .[39]

> My principle (the principle of least action) most consistent with the ideas which we ought to have of things, leaves the world in continual need of the power of the Creator.[40]

Maupertuis speaks out against Descartes and Leibniz because of their attempts to withdraw the world from the dominion of God. The universe must remain completely dependent on the power and wisdom of God.

> In vain did Descartes imagine a world which could do without the hands of the Creator: in vain did Leibniz have the same plan, based on another principle: no force, no quantity that one can regard as causal in the distribution of movement, subsists unchanged. But there is one (force) which produced afresh, and created, so to speak, at each instant, is always created with the greatest economy that is possible. By that, the Universe annouces its dependence and need of the presence of its author; and make known that this author is as wise as he is powerful. This force is that which I have called action: it is the principle from which I have deduced all the laws of movement. ...[41]

Maupertuis realizes that the long duration of the world and the perseverance of movement in that world have caused us to believe that motion and force are always present, always conserved, always able to produce the same effects. But this is not the case:

> Newton, more concerned with observing Nature than in building systems, seeing that by the collision of different parts of matter, movement is destroyed more often than it is augmented, believed that ultimately motion would be destroyed if God did not impress new forces on the machine of the world, from time to time. This idea had little philosophic appeal to those who wished to withdraw the world from the domain of God... . The Leibnizians especially mocked the idea... .[42]

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> eternal nor independent; they are obedient to a power which produces and augments them, diminishes and destroys them, in the most economical and most wise way.[43]

2. The role of God in method

As a mathematician, Maupertuis thought very highly of the use of mathematics in scientific procedures.

> ... we are able to borrow the help of a trustworthy guide, in the progress of research... Until now, it has not always turned its steps in the direction which we wish to go. Until now, mathematics has had as its aim only the common needs of the physical or the useless speculations of the mind: one has scarcely thought to use it to demonstrate or discover other truths such as those which refer to number or extent.[44]

Maupertuis praises Huygens highly for approaching the study of the laws of motion from a mathematical point of view, rather than from the Leibnizian metaphysical one.

> One sees how little Huygens believed in the possibility of deducing the laws of communication of movement from the essence of the body; what was necessary to attain these laws was a rigorous sequence of propositions.[45]

And, Maupertuis also sees the importance of experiment in science:

> Wasn't it necessary to have thousands of repeated experiments on the fall of bodies in order to give confidence to the doctrine of Galileo? and wasn't it necessary for Newton to affirm by experiment all of the movements of the celestial bodies?
>
> When Huygens, Wren and Wallis found these laws [of movement] at the same time and without being in each others confidence; in spite of the agreement among them, wasn't it still necessary for them to be confirmed by experiments done by the Royal Society of London?[46]

But, Maupertuis does not confine his scientific method to the usual two avenues of pragmatic experiment and mathematical theory. He believed that a scientific statement would bear a greater measure of certainty if, instead of depending on mathematics and experimental obeternal nor independent; they are obedient to a power which produces and augments them, diminishes and destroys them, in the most economical and most wise way."[43]

7. The role of God in method

As a mathematician, Maupertuis thought very highly of the use of mathematics in a scientific procedure:

... we are able to borrow the help of a trustworthy guide, in the progress of research.... Until now, it has not always turned its steps in the direction which we wish to go. Until now, mathematics has had as its aim only the rough needs of the physical or the useless, abstractions of the mind; one has scarcely thought to use it to demonstrate or discover other truths such as those which refer to modes of nature.[44]

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But, Maupertuis does not confine his scientific method to the usual two avenues of pragmatic experiment and mathematical theory. He believed that a scientific statement would have a greater measure of certainty if, instead of depending on mathematics and experimental observations, it were derived immediately from the attributes of God:

> I could start from those laws which are formulated mathematically and confirmed by experiment; and from there seek out the characters of the wisdom and power of the Supreme Being; it is more certain and more useful to deduce these laws from the attributes of an all-powerful, all-wise Being.[47]

3. <u>The Role of God in explanation</u>

To understand the "nature" of an object was not, for Maupertuis, accomplished by a simple physical or even mathematical description. As a phenomenalist, he recognized that we can not attain to an understanding of the essence of the thing:

> ... there is nothing that one sees more clearly than the difference between extension and thought. But if both are only properties, they can both belong to a subject whose own essence is unknown to us.[48]

but, he believed, in the time-honored way of all Aristotelians, that final purpose was a part of causation and hence was to be incorporated into explanation. Thus it was possible to obtain a deeper understanding of something if its purpose could be determined. In the God oriented world of Maupertuis, the purpose of anything was determined by the Creator; therefore if we wish to comprehend the "Why" of a thing, we must have recourse to God:

> ... if attraction does occur in Nautre, to the eyes of one who completely understands the essence of bodies, attraction was a necessary consequence of this essence; but for us, so far, if this property exists in matter, and we wish to know <u>why</u>, it is necessary that we have immediate recourse to the will of the Creator.[49]

Maupertuis explicitly cites the use of observation and teleology in the examination of the laws of nature:

> In order to combine quantity of information with a measure of certainty, it is necessary to employ the two means. Let

extensions, it were derived immediately from the attributes of God:

> I could start from those laws which are formulated axiomatically and confirmed by experience and from there seek out the characters of the wisdom and power of the Supreme Being; it is more certain and more useful to deduce their laws from the attributes of an all-powerful, all-wise Being."[48]

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But, he believed, in the time-honored way of all Aristotelians, that final purpose was a part of existence and hence was to be incorporated into explanation. Thus it was possible to attain a deeper understanding of something if its purpose could be determined. In the God ordered world of Maupertuis, the purpose of anything was determined by the Creator; therefore if we wish to comprehend the "why" of a thing, we must have recourse to God:

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Maupertuis explicitly cites the use of observation and teleology in the examination of the laws of nature:

> In order to combine quantity of information with a measure of certainty, it is necessary to employ the two means. Let

> us determine the movements of bodies (observation), but let us also consult the purposes of the Intelligence which has caused them to move.[50]

There is an additional, practical use that can be derived from an understanding of the intentions of God. Since the God of Maupertuis is described as an intelligence "la plus éclairée et la plus libre",[51] his movements, creations and operations are, therefore, not restricted by an overriding principle such as the principle of the good, or the principle of completion or the principle of sufficient reason. God creates any law he arbitrarily chooses. In the case of the law of attraction, for example, the relation between the distance and force can be given by a variety of ratios, all equally possible, in the eyes of the scientist. Because God is not confined by any principle whatsoever, the investigator is faced with a myriad of possible solutions unless he can determine God's purpose in establishing such a law. Once this reason is known, the circumstances under which the law is operational can be defined and hence limited. Maupertuis notes:

> ... if God wished to establish a law of attraction in Nature, why does this law follow a particular proportion? why does attraction obey the inverse square law? In this infinity of different proportions, which appear to be equally usable in nature, is there a reason for the preference of one over the other?[52]
>
> Suppose that God wished to establish a law of attraction in matter, all of the laws do not appear equally alike to him.[53]
>
> Indeed, if he has made a choice, there would undoubtedly have been some reason for this choice.[54]
>
> Once the metaphysical reason for preference has been posed, mathematical necessity immediately excludes an infinite number of systems which can no longer take place.[55]

Thus, recourse to God's will can provide some practical advantages, in

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Thus, attention to God's will can provide some practical advantages. In the fact that much time and effort could be saved the investigator (an example of the principle of least action operating on the intellectual level).

4. The science of God or the science of Man

Perhaps as old as science itself, is the question that investigators ask about the "absoluteness" of their findings. How close to the "Truth" have they come? How eternal are the truths they have discovered; how dependent are they on the senses of the scientists seeking them?

> If the materials from which the edifice of our sciences is build, have fallen from the heavens: if, as several philosophers have claimed, our ideas are the eternal archetypes of things...; if this system was true, our sciences would have the most solid of foundations, and a reality which did not depend either on the manner of perception or even on our existence.[56]
>
> But if it were true that all our knowledge depended only on the first impressions that objects made on our senses. ... then our science would no longer have any quality of the absolute, it would only be a property belonging to our species; an extra sense in a superior creature would produce a new, more extended science to which we would never be able to attain; one sense less in the human species would restrict our knowledge to even more narrow limits than they have now.[57]
>
> The lack of agreement that we see among philosophers would indeed cause one to think that this last supposition is the true one: that our science is founded only on principles which partake of nothing of the absolute; principles appropriate to the human species, sometimes even to just some sect of philosophers.[58]

Maupertuis finally comes to the alternative offered:

> ... is our science a universal science of the minds, a view of eternal truths, a part of the science of God? or is it only the result of the combination of our sensations, our own work, a property solely of our species?[59]

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> ... is our science a universal science of the world, a view of eternal truths, a part of the science of God? or is it only the result of the combination of our sensations, our own work, a property solely of our species?[60]

Although Maupertuis realizes that there are

> ... sciences which develop from objects which only strike our senses and of which we have only confused or imperfect ideas which leave us in doubt and uncertainty.[60]

Maupertuis believes that ultimately our sciences are grounded upon the "solid foundation" of eternal truths, i.e., they are part of the science of God. And more exciting still is Maupertuis' declaration that these eternal truths are accessible to men through several avenues: by means of the evidence derived from geometry and arithmetic, and by the derivation from the attributes of God.

With respect to Geometry and its relation to God, Maupertuis agrees with the ancient Greek philosophers:

> when they say that Geometry was the occupation of God; they undoubtedly understood that this science compares the works of his powers with the aims of his wisdom.[61]

of the evidence derived from mathematics, Maupertuis said:

> If some thing can persuade us that our sciences are founded on eternal and unchangeable ideas, it is the evidence that one finds in some sciences, and this universal agreement among all those who consider the same proposition. This evidence and this harmony with truth is only found in the mathematical sciences: while all the other parts of our knowledge are subject to eternal dispute, in geometry, everyone is agreed; this science convinces the most uncertain skeptic, convinces the most stubborn mind.[62]

What especially is there about the sciences of mathematics which enable them to yield such certain, such unassailable evidence?

> It is not in the imaginary privilege of being able to create our own ideas; nor because the ideas represent essence whereas others deal with just the properties of the body: ... these ideas have another distinctive character responsible for the kind of evidence they bring to science: it is replicability.[63]

This quality "replicability" is a characteristic of two properties: extension and number.

I find in the ideas of extension the same distinctive char-

> ... sciences which develop from objects which only strike our senses and of which we have only confused or imperfect ideas which leave us in doubt and uncertainty.[89]

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This quality "replicability" is a characteristic of two properties: extension and number.

> I find in the ideas of extension the same distinctive char-

> acter that I observed in number, replicability: I can add one area to an equal area, and thereby double the range, or triple it, etc. It is so clear an idea that I see it immediately: I can cut it in half or in thirds and I still have an equally clear idea of half an area, or a third of it; finally, I see that extension, like number, can be increased or diminished at will and the parts are always equal to each other: this is a character which belongs to no other property of the body.[64]

> ... in the mathematical sciences where the objects, number and extension are exactly replicable, one obtains results upon which everyone agrees; ... it is this which produces such evidence and certainty.[65]

The next step is obvious. Transfer this property that can produce clear and certain evidence from the domain of pure mathematics to the everyday world of physical objects. The catch lies in the fact that not all of the objects with which the scientist deals, possesses replicable properties. The important thing therefore, is to determine which properties do avail themselves of the quality of replicability and measure these properties with caution and precision:

> Between the purely mathematical objects and the objects of metaphysics or morals, there is a certain area in which perfect replicability is not found, but from which it is not entirely excluded: I speak of physical objects; in which, aside from extension and number, one considers some other ideas which can be reduced to replicability: the speed, for example, of bodies in motion, the time needed to travel certain distances -- these have a natural rapport with extension and number, in that these ideas become as replicable as those of number and extension.[66]

> Thus, if in dynamics, one does not always find results which yield the same kind of evidence as those from arithmetic and geometry, it, nevertheless, participates in the evidence and certitude which reigns in these two sciences; and is not inferior to them, if treated with precaution and wisdom.[67]

Now the evidence that is made available through the mathematical sciences, while indications of the absolute and certain qualities of God, and representative of the eternal truths of the science of God,

> sector that I observed in number, replicability; I can add one area to an equal area, and thereby double the range, or triple it, etc. It is as clear an idea that I see it immediately; I can cut it in half or in thirds and I still have an equally clear idea of half an area, or a third of it; finally, I see that extension, like number, can be increased or diminished at will and the parts are always equal to each other: this is a character which belongs to no other property of the body.[64]

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> Thus, if in dynamics, one does not always find results which yield the same kind of evidence as those from arithmetic and geometry, it, nevertheless, participates in the evidence and certitude which reigns in these two sciences, and is not inferior to them, if treated with precaution and wisdom.[67]

But the evidence that is made available through the mathematical sciences, while indications of the absolute and certain qualities of God, and representative of the eternal truths of the science of God, do not involve God directly. The second avenue of approach to the "clear and simple" truths of the science of God depends directly on Maupertuis' unquestioned belief in the existence of God and in his explicit use of the attributes of God.

We have already seen how essential to the principle of least action were God's attributes: wisdom and power. These universal principles, in turn, take on an importance to science, which is quite distinct from their functional, scientific value. Since it is in the nature of the principle to reflect the enduring and unchanging attributes of God, these principles bring to science this same absolute order of qualities. Thus the foundations of science, as expressed in the clear and distinct truths of universal principles, reveal that our science is indeed a part of the science of God.

That Maupertuis sees the structure of science as resting on a substructure of simple and clear principles (the eternal truths of God) is clearly expressed by Maupertuis in his description of the two levels of science:

> If the sciences are founded on certain principles, simple and clear from the very outset, and upon which depend all the truths which are the object of science, there are still other principles, less simple truths, often difficult to discover... . The primary principles have scarcely any need of demonstration because of the evidence they present as soon as the mind examines them; the latter cannot have a general demonstration because it is impossible to cover all the cases in which they operate.[68]

Obviously to Maupertuis, the ties between theology and science are strong and close. Science has become a forceful instrument for proving the existence of God; theology remains an intrinsic part of science. But whereas theology could do without science, science, by do not involve God directly. The second avenue of approach to the "clear and simple" truths of the science of God depends directly on Maupertuis' unquestioned belief in the existence of God and in his explicit use of the attributes of God.

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NOTES

1. Samuel Formey, "Éloge de Monsieur de Maupertuis", Histoire de l'Academie Royale des Sciences et Belles Lettres (Berlin, 1759), p. 505.

2. Pierre Louis Moreau de Maupertuis, Oeuvres, volumes I -IV (Hildesheim; Georg Olms, 1965), volume II, Lettre XVII, Sur la Religion, p. 326.

3. Ibid., p. 185.

4. Maupertuis, vol. I, Essai de Philosophie Morale, p. 235.

5. Angliviel de la Beaumelle, La vie de Maupertuis (Paris, 1856), p. 442.

6. Maupertuis, op. cit. vol. I, Essai de Philosophie Morale, p. 235.

7. Maupertuis, vol. II, Système de la Nature, p. 175, LVII.

8. Maupertuis, vol. II, Réponse aux objections de M. Diderot, p. 216.

9. Maupertuis, vol. III, Des Devoirs de l'Academicien, p. 301.

10. Maupertuis, vol. I, Essai de Cosmologie, p. XVII.

11. Ibid., p. 4.

12. Ibid., p. 5.

13. Ibid., p. 6.

14. Ibid., p. 5.

15. Ibid.

16. Ibid., p. 6.

17. Ibid., p. 8.

18. Ibid., p. 10.

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3. Ibid., p. 181.

4. Maupertuis, vol. I, Essai de Philosophie Morale, p. 235.

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7. Maupertuis, vol. II, Système de la Nature, p. 175, LVIII.

8. Maupertuis, vol. II, Réponse aux objections de M. Diderot, p. 216.

9. Maupertuis, vol. III, Des Devoirs de l'Académicien, p. 302.

10. Maupertuis, vol. I, Essai de Cosmologie, p. XVII.

11. Ibid., p. 4.

12. Ibid., p. 5.

13. Ibid., p. 6.

14. Ibid., p. 5.

15. Ibid.

16. Ibid., p. 8.

17. Ibid., p. 8.

18. Ibid., p. 10.

19. Ibid., p. 21.

20. Ibid., p. 23.

21. Ibid., p. XII.

22. Ibid., p. 19.

23. The whole _Essai de Cosmologie_ is devoted to establishing this identity.

24. Maupertuis, vol. II, _Essai de Cosmologie_, p. XXI.

25. Ibid., p. 42.

26. Maupertuis discusses the behavior of light in the _Accord des différentes lois de la Nature_, vol. IV, pp. 3 - 28.

27. Ibid., p. 8.

28. Ibid., p. 17. The expression "quantity of action" was defined by Maupertuis as the product of the mass of the body, the distance it travels, and the speed at which it travels.

29. Maupertuis, vol. I, _Essai de Cosmologie_, p. 42.

30. Ibid., p. 43.

31. Maupertuis, vol. II, _Système de la Nature_, p. 155.

32. Ibid., p. 139, l.

33. Ibid., p. 154, XXVII.

34. Ibid., p. 146, XIV.

35. Ibid., p. 147.

36. Ibid., p. 157, XXXIII.

38. Ibid., p. 154, XXVII.

39. Maupertuis, vol. IV, _Accord des Lois_, p. 21.

40. Maupertuis, vol. I, _Essai de Cosmologie_, p. 44.

41. Ibid., p. XXVI.

19. Ibid., p. 21.

20. Ibid., p. 22.

21. Ibid., p. XII.

22. Ibid., p. 19.

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24. Maupertuis, vol. II, Essai de Cosmologie, p. XXX.

25. Ibid., p. XXI.

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27. Ibid., p. 6.

28. Ibid., p. 17. The expression "quantity of action" was defined by Maupertuis as the product of the mass of the body, the distance it travels, and the speed at which it travels.

29. Maupertuis, vol. I, Essai de Cosmologie, p. 42.

30. Ibid., p. 42.

31. Maupertuis, vol. II, Système de la Nature, p. 145.

32. Ibid., p. 139, I.

33. Ibid., p. 156, XXVII.

34. Ibid., p. 146, XIV.

35. Ibid., p. 147.

36. Ibid., p. 157, XXXIII.

38. Ibid., p. 154, XXVII.

39. Maupertuis, vol. IV, Accord des lois, p. 23.

40. Maupertuis, vol. I, Essai de Cosmologie, p. 44.

41. Ibid., p. XXVI.

42. Maupertuis, vol. II, Lettre X, Sur les lois du mouvement, p. 271.

43. Ibid., p. 274.

44. Maupertuis, vol. I, Essai de Cosmologie, p. 21.

45. Maupertuis, vol. I, Examen philosophique de la preuve de l'existence de Dieu, p. 420, LII.

46. Ibid., p. 422, LX, LXII.

47. Maupertuis, vol. I, Essai de Cosmologie, p. 23.

48. Maupertuis, vol. II, Système de la Nature, p. 151, XXII.

49. Maupertuis, vol. I, Figure des astres, p. 161.

50. Maupertuis, vol. IV, Accord des Lois, p. 22.

51. Maupertuis, vol. I, Essai de Cosmologie, p. 25.

52. Maupertuis, "Sur les lois de l'attraction," Mémoires de l'Academie Royale des Sciences (Paris, 1732), p. 346.

53. Ibid., p. 347.

54. Ibid., p. 348.

55. Ibid., p. 347.

56. Maupertuis, vol. I, Examen, p. 391, IV.

57. Ibid., V.

58. Ibid., VI.

59. Ibid., VII.

60. Ibid., p. 393, X.

61. Maupertuis, vol. IV, Accord des Lois, p. 22.

62. Maupertuis, vol. I, Examen, p. 392, IX.

63. Ibid., p. 394, XIII.

42. Maupertuis, vol. II, Lettre X, Sur les lois du mouvement, p. 272.

43. Ibid., p. 274.

44. Maupertuis, vol. I, Essai de Cosmologie, p. 21.

45. Maupertuis, vol. I, Examen philosophique de la preuve de l'existence de Dieu, p. 420, XII.

46. Ibid., p. 427, IX, XXII.

47. Maupertuis, vol. I, Essai de Cosmologie, p. 23.

48. Maupertuis, vol. II, Système de la Nature, p. 152, XXII.

49. Maupertuis, vol. I, Figure des astres, p. 101.

50. Maupertuis, vol. IV, Accord des lois, p. 22.

51. Maupertuis, vol. I, Essai de Cosmologie, p. 25.

52. Maupertuis, "Sur les lois de l'attraction," Mémoires de l'Académie Royale des Sciences (Paris, 1732), p. 346.

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59. Ibid., VII.

60. Ibid., p. 392, X.

61. Maupertuis, vol. IV, Accord des lois, p. 22.

62. Maupertuis, vol. I, Examen, p. 393, XX.

63. Ibid., p. 394, XXII.

CHAPTER FOUR

The Precursor

Part One: Out of Oblivion

It has already been noted, in Chapter One, that Maupertuis, though well-known and acclaimed in his own life time, had fallen into disrepute before the end of the eighteenth century. From the time of his death, in 1759, until well into the twentieth century, Maupertuis' scientific work was pointedly neglected.

So outrageous was this state of neglect that H. B. Glass saw fit to entitle his 1955 paper, "Maupertuis - a Forgotten Genius".[1] Elaborating on a theme which he had presented in a 1947 paper,[2] Glass observed:

> Pre-eminent among the scientists of the mid-18th century was a man whose name one must hunt assiduously today to find more than mentioned in histories of science. He was Pierre-Louis Moreau de Maupertuis.[3]

Paul Ostoya, writing in 1954, says:

> The biological works of Maupertuis have, in general, not yet engaged the attention that they deserve... . Paul Brunet, in his book devoted to the work of Maupertuis has not emphasized sufficiently the fact that Maupertuis was the first to have expressed, in 1751, the hypothesis of the evolution of species, in all its generality. In an era in which one loves commemorations, perhaps to excess, no one has thought to celebrate the 200th anniversary of the idea which dominates all of modern biology.[4]

This negligence is not confined to Maupertuis' work in biology; in physics also, few people are aware of his extraordinary discovery -- the principle of least action:

> The author of this principle, Maupertuis, was one of the scientific leaders of the eighteenth century. His own

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The Present

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> The author of this principle, Maupertuis, was one of the scientific leaders of the eighteenth century. His own

> peculiar genius and remarkable energy, combined with a dramatic environment, gave his career a contemporary fame which has seldom been equalled. Today, he is practically unknown, or is remembered only as an object of ridicule and contempt. If the principle which he discovered has waited overlong for recognition, there is a striking parallel in the fate of the author.[5]

As late as 1964, Jean Rostand, in his preface to Emile Callot's book Maupertuis, la savant et le philosophe, was still able to say, with justification:

> Despite the efforts of some historians of science, from Delages to Glass, who have devoted themselves to restoring recognition to the exceptional importance of Maupertuis' work, I do not think that Maupertuis has yet achieved the eminent place which is rightfully his.[6]

Why had Maupertuis' work been so neglected? Are there any cogent reasons that could explain the almost complete disappearance of Maupertuis' name from the science of the eighteenth, nineteenth, and early twentieth century?

One of the most obvious and dramatic causes for Maupertuis' decline has been tied to the long, bitter and scandalous quarrel that flared between Maupertuis and Voltaire, over Voltaire's defense of Koenig, who had raised the issue of priorities in the discovery of the principle of least action. (This has been discussed at length in Chapter One.)

That Voltaire was a powerful and unrelenting adversary is a statement that shall not be challenged here. Macaulay said, "of all the intellectual weapons which have ever been wielded by man, the most terrible was the mockery of Voltaire".[7] And even today, many historians attribute to Voltaire the lion's share of responsibility for the scientific demise of Maupertuis:

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> The present attitude towards Maupertuis, however, can be understood only in the light of this ancient quarrel with Koenig. Voltaire's irony has been more dominant than the supposedly clear and dispassionate record of the scientific historian. The scant mention - if any - which is granted to Maupertuis usually carries with it a faint but unmistakable note of scorn.[8]

This sentiment is echoed by Glass:

> Among the natural philosophers of the time was the then renowned head of Frederick the Great's Academy of Sciences in Berlin. This man, whose great contemporary reputation has been almost completely eclipsed because of the vicious satirical attacks made upon it by Voltaire, was Pierre-Louis de Maupertuis.[9]

and Rostand:

> In general, Maupertuis is regarded as a mind of the second, if not the third order, as a presumptuous, busybody, having left behind no solid piece of work in any area; and this error in appreciation is due, at least in part, to the persistent influence of the slanderous attacks that Voltaire directed against him.[10]

However, I do not believe that historians have as yet properly evaluated the other factors involved in the decline of Maupertuis' reputation and the neglect of his work. However resourceful and implacable Voltaire may have been as an enemy of Maupertuis, I do not believe that the verbal attacks of Voltaire, a scientific Lilliputian, would have been sufficient to topple the career of a scientific Gulliver such as Maupertuis. Rather, we should examine Maupertuis' position in scientific circles; and we must look to Maupertuis' works themselves and see what they in fact offered to his contemporaries and successors. The reasons for his eclipse, lie, I suggest, in these areas.

Just how well was Maupertuis' principle of least action received by his contemporaries? Both Dugas[11] and Bachelard[12] note that his

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Just how well was Maupertuis' principle of least action received by his contemporaries? Both Dugas[11] and Bachelard[12] note that his principle was regarded by noted mathematicians as being too vague, too general, too metaphysical, to offer a contribution of real consequence. Lagrange remarked that Maupertuis' applications of the principle "are too vague and too arbitrary which can only produce uncertainty in the consequences that can be drawn from the principle... ."[13]

Jacques Roger recalls that the life sciences during this period (i.e., the first half of the eighteenth century in France) had been invaded by "outsiders", who, with the boldness born from the ignorance of and irreverance for the accepted, well-entrenched biological ideas, dared to advocate shockingly new concepts, which paid scant heed to the dicta of the professional high priests:

> It is not without interest to note that the scholars and philosophers who were to give a new orientation to the life sciences, most often, did not have the training appropriate for a naturalist or biologist. Maupertuis and Buffon were mathematicians, at first. ... La Mettrie was a physician and philosopher and Diderot remained a philosopher... . These men had come from the outside to revolutionize biology and the natural sciences, to the great scandal of the "professionals", Reaumur, Haller or Spallanzani, shaken from their accustomed ideas by amateurs and rightly exasperated by the inexperience and pretentions of the newcomers.[14]

Thus, Maupertuis' amateur status as a naturalist prevented him from securing for his biological speculations any enduring authority. Ostoya recognizes this lack of authority when he describes the reactions of the first eighteenth century transformists to Maupertuis' pronouncements on transformism:

> ... none of the first transformists cited him. Not even Diderot when, several years after his controversy with Maupertuis, he returned to embrace the hypothesis (of change). It is because Maupertuis was an authority recognized only in mathematics. His writings in biology were, without doubt, considered to be the work of an

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> amateur, and his Système de la nature was thought to be a work more metaphysical than scientific.[15]

This inability to command the serious attention of professionals would not only mean that Maupertuis' contributions to contemporary science were minimal, but would also make it difficult for later researchers to know and appreciate the ideas of Maupertuis.

There is however, another factor that could have been instrumental in the downfall of Maupertuis, namely the actual contents of Maupertuis' work and their interaction with the works of his contemporaries. I suggest that the seeds of Maupertuis' downfall reside in his own work.

Lagrange argued that Maupertuis' principle of least action was ineffective because the applications were too vague. As detrimental as this might have been, there was also the fact that Euler, a loyal follower of Maupertuis, took up where Maupertuis left off and provided the principle of least action with a solid mathematical basis. This work of Euler, which essentially confirmed the principle of Maupertuis, also unwittingly enabled Euler to unseat Maupertuis as the founder of the principle. Mathematicians, and physicists, undertaking research in this field, would automatically refer to the proofs of Euler whose own work was expanded upon by Lagrange and Hamilton. It is thus that the names associated with the principle of least action are those of Euler, Lagrange and Hamilton, and not Maupertuis.

In the area of the life sciences, not only was Maupertuis an amateur at the mercy of professionals, but he was also espousing a theory of epigenesis to account for embryo formation; a theory in

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In the area of the life sciences, not only was Maupertuis an amateur at the mercy of professionals, but he was also proposing a theory of epigenesis to account for embryo formation, a theory in flagrant opposition to the prevailing theory of preformation. For a long time, certainly well over half a century, biologists had followed the preformationist argument that no life was formed de novo; everything that will be, had already been pre-formed at the time of Creation. Few people were comfortable with Maupertuis' epigenetic contention that new formations could and did occur; that the embryo was a new product formed by the contributions of both parents.

Interestingly enough, those few who did oppose preformation found themselves turning away from Maupertuis' approach (i.e., attacking the preformationist argument of embryo development by urging belief in epigenesis as the method of organization). To these few anti-preformationists, the way to counter the preformationist doctrine was through experimental studies on regeneration and spontaneous generation, both of which dramatised the occurrence of new organizations of living things.

> It is significant that the objections of Maupertuis, which would have led biologists away from preformation, were not followed up. Instead, 18th century French biologists engaged in a debate on regeneration. This happened because ferment theorists were committed to establishing spontaneous generation, which would give standing to their science and would at the same time demolish the preformationist position. The philosophic interests of the scientists were allowed to triumph over their sciences.[16]

Thus, Maupertuis' work in biology seemed not to have attracted many adherents among his contemporaries. By the beginning of the 19th century, epigenesis was starting to triumph over preformation theory. However, even then, should Maupertuis' work have surfaced, it still would not have received a very appreciative audience because Maupertuis, while fostering the theory of epigenesis, also maintained flagrant opposition to the prevailing theory of preformation. For a long time, certainly well over half a century, biologists had followed the preformationist argument that no life was formed de novo; everything that will be, had already been pre-formed at the time of Creation. Few people were comfortable with Maupertuis' epigenetic contention that new formations could and did occur; that the embryo was a new product formed by the contributions of both parents.

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Probably as a consequence of all of these factors acting synergistically, Maupertuis' ideas were lost to posterity for almost two hundred years. We have seen however that that particular state of neglect appears to be ending. As early as 1904 Lovejoy spoke of the need to rehabilitate the reputation of Maupertuis.[18] But 20th century historians of science have not stopped at simply redressing the wrong done to Maupertuis in allowing his work to slip into oblivion. There are movements now directed towards portraying Maupertuis as the originator, innovator and precursor of some of the most important concepts of modern science.

Jerome Fee concludes his paper with the unqualified statement that the principle of least action so closely associated with Euler, Lagrange and Hamilton is essentially the principle that Maupertuis disclosed to the Paris Academy of Science in 1744.

> It is uncommon to find a modern author who recognizes the importance of Maupertuis' analysis. One of the few who have done so is Richtmyer, who writes in his "Introduction to Modern Physics": "Nearly two centuries ago, by a line of reasoning which would have done credit to the Greeks, Maupertuis proposed the law of least action."
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> We read of Euler's principle of least action; of Lagrange's; of Hamilton's; and - perhaps the very latest - of Fermat's principle of least action. Fortunately they are all the same. There is only one and that is the one of which Maupertuis wrote.[19]

Guyenot places Maupertuis among the most astute of the forerunners of evolution theory:

> Geneticist of the first order, Maupertuis outlined a conception of transformism based on heredity, on the fortuitous production of variations, on a prophetic vision of the phenomenon of selection and pre-adaptation. We feel him to be infintely closer to us than to the great theoreticians of transformism. ... He was one of the founders of evolution and appears to us as the most remarkable precursors of contemporary mutationism.[20]

And not to be outdone in this lavishing of praise is Glasses' tribute to Maupertuis as precursor to Mendel and modern genetics:

> May we not agree, in conclusion, that this man who argued on genetic grounds against preformation fifteen years before that work of Kaspar Wolff which was eventually to dispose of the encasement theory of preformation; who two hundred years ago investigated human heredity in a manner calculated to draw the admiration of any geneticist of the present day, and who applied the mathematical theory of probability to genetics over a century before Mendel; who undertook experiments in animal breeding to throw light on his theories; who formulated a theory of heredity that was particulate and involved the mutual attraction of analogous particles provided by each parent, and that implied segregation, dominance, and independent assortment; and who finally, formed a theory of organic evolution based upon mutation, natural selection and geographic isolation; - that this man, Pierre Louis Moreau de Maupertuis, not only deserves to be ranked as a greater than his contemporaries in biology, but stands out as one of the greatest figures in history of science.[21]

If we step back, for a moment, from the perspective of the historian and his view of Maupertuis as a precursor, and turn to the scientists in the areas of physics and biology, we see a rather different picture. As has been noted, the mathematicians who interested

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> May we not agree, in conclusion, that this man who argued so gently yet so soundly against preformation fifty years before that work of Caspar Wolff, which was destined to dispose of the preformation theory of development; that two hundred years ago investigated human heredity in a manner calculated to draw the attention of any geneticist of the present day and who applied the mathematical theory of probability to genetics over a century before Mendel; who undertook experiments in animal breeding to throw light on his theories; who formulated a theory of heredity that was particulate and involved the mutual attraction of analogous particles provided by each parent, and that implied segregation, dominance, and independent assortment; and who finally formed a theory of organic evolution based upon mutation, natural selection and geographic isolation - that this man, Pierre Louis Moreau de Maupertuis, not only deserves to be ranked as a greater than his contemporaries in biology, but stands out as one of the greatest figures in history of science.[21]

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Was Maupertuis a precursor, as historians claim, despite his being a non-entity to the actual practitioners in the various fields? Why is there a discrepancy between historians and scientists in their judgements about who is or is not a precursor? What, in fact, do we mean by the term "precursor"?

Part two of this chapter is concerned with a general analysis of that label, "the precursor", in an effort to better understand what the term involves and how to make use of it. I hope, then, to be able to make a specific analysis of Maupertuis as a precursor to Mendel.

Part Two: The Nature of the Precursor

> "I doubt if any of the great discoveries ought properly to be considered as altogether individual achievements..."
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Concomittant with the notion of progress in science, is the widely accepted assumption that each step forward depends upon the work of predecessors. Consequently there has accumulated, in both themselves in the principle of least action rarely looked to Maupertuis for guidance or reference; his work was put down as being too vague and general. Among the evolutionists, down to and including Darwin, no mention at all, is made of Maupertuis or his ideas; similarly, no reference is given to Maupertuis' ideas and analyses by pre and post Mendelians, including Mendel himself.

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Concomitant with the notion of progress in science, is the widely accepted assumption that each step forward depends upon the work of predecessors. Consequently there has accumulated, in both science and the history of science, a long list of names to whom the title "precursor" is applied.

From an examination of a variety of statements made about precursors, by scientists and historians, is it possible to abstract a single entity to which the label precursor can be applied?

A perusal of any of the scientific journals reveals that the characteristic way of beginning a paper is to acknowledge briefly the work done by predecessors in the field -- work that is immediately relevant to the problem under discussion. The emergent picture of the precursor in these circumstances is, unsurprisingly, an individual who made an active contribution to a field of study and whose work has been absorbed into the scientific edifice. As a typical example, consider the opening paragraph of a 1952 paper by Joshua and Esther Lederberg:

> It has been repeatedly questioned,... whether a selective environment may not only select but also direct adaptive heritable changes. In accord with similar discussion in evolutionary biology (Huxley, 1942), we may dénote the concepts of spontaneous mutation and natural selection in contrast to specific induction as "preadaptation" and "directed mutation", respectively. Many lines of evidence have been adduced in support of preadaptation in a variety of systems (Luria and Delbruck, 1943; Lea and Coulson, 1949; Burnet, 1929; Newcombe, 1949; Lewis, 1934; Kristensen, 1944; Novick and Szilard, 1950; Ryan and Schneider, 1949; Demerec, 1949; Welsch, 1950; also reviewed: Braun, 1947; Luria, 1949; Lederberg, 1948, 1949).[22]

However, several of the precursors which Charles Darwin acknowledges in The Origin of Species[23] exhibit characteristics which do not conform to the picture of the precursor as presented in the usual scientific papers. Consider the following two passages in which Darwin refers to the contributions of Thomas Malthus and Karl Ernest science and the history of science, a long list of names to whom the title "precursor" is applied.

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However, several of the precursors which Charles Darwin acknowledges in *The Origin of Species*[27] exhibit characteristics which do not conform to the picture of the precursor as presented in the usual scientific papers. Consider the following two passages in which Darwin refers to the contributions of Thomas Malthus and Karl Ernst von Baer:

> ... as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms...[24]

> ... it has been shown that generally embryos of the most distinct species belonging to the same class are closely similar, but become, when fully developed, widely dissimilar. A better proof of this latter fact cannot be given than the statement by von Baer that "embryos of the mammalia, of birds, lizards and snakes, probably also of chelonia are in their earliest states exceedingly like one another, both as a whole and in mode of development of their parts; so much so, in fact, that we can often distinguish the embryos only by their size...[25]

What is different here from the case cited earlier is that Malthus was not a biologist writing on organic evolution, but an economist concerned with the growth pattern of human populations. Yet for Darwin, the economic speculations of Malthus became a pivotal point in his theory of evolution by natural selection.

In the instance of von Baer, we come upon the paradox of a man designated a precursor of a concept to which he was explicitly opposed. Jane Oppenheimer, in her paper "An Embryological Enigma in the Origin of Species" states:

> Von Baer expressed himself as strongly opposed to Darwin in later years, although he knew that he was somehow involved as one of his precursors. In his essay, "Uber Darwin Lehre", published in 1876, von Baer confessed his belief that he had "supplied some material for the foundation of (Darwin's doctrine), even though time and Darwin himself have erected on the fundament a structure to which I feel myself alien.[26]

Nor is the portrait of the precursor made less murky by the assessment offered by the geneticist cum historian of science, von Baers

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How is the portrait of the precursor made less murky by the assessment offered by the geneticist qua historian of science.

Bentley Glass, in his article "Maupertuis, Pioneer of Genetics and Evolution":

> Eminent as were these contributions to physical science and to philosophy, it is in his biological ideas that Maupertuis was most clearly gifted with prevision... In short, virtually every idea of the Mendelian mechanism of heredity and the classical Darwinian reasoning from natural selection and geographic isolation is here combined, together with De Vries' theory of mutations as the origin of species, in a synthesis of such genius that it is not surprising that no contemporary of its author had a true appreciation of it.[27]

The problem in this case is that Maupertuis' biological studies were made between the years 1745 and 1754. Not long after his death, his work went out of fashion, not to be resurrected until the twentieth century. In this period of almost two hundred years, both the fields of Genetics and Evolution took root and flourished -- without making use of anything that Maupertuis had written. Yet, Glass designates Maupertuis a precursor of both Mendel and Darwin.

It is obvious from the examples given, that no single, uniform picture of a precursor can be drawn; instead we are presented with a composite. We find that the precursor a) may or may not have worked in that area in which he is a precursor; b) he may or may not have been aware of the final construct which incorporated his work, and if aware, he may or may not have been an advocate of that construct; and c) his contribution may or may not have influenced the development of the particular area of investigation to which he is a precursor.

The major difficulty with the definition of the word "precursor" is that it provides us with no quality intrinsic to a scientist which enables us to determine if he is a precursor or not. The definition tells us only that the precursor is "one who or that which precedes

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The major difficulty with the definition of the word "precursor" is that it provides us with no quality intrinsic to a scientist which enables us to determine if he is a precursor or not. The definition tells us only that the precursor is "one who or that which precedes a person or event." Thus, if one is faced with an entity completely isolated from anything or anyone else, there would be no quality internal to the entity which would reveal that he or it is a precursor. Recognition of a precursor requires the presence of an external agent that uses whatever it was that was provided by the putative precursor; only then can the prior person or event be designated a precursor. In other words, the precursor as an anticipator is comprehensible only in connection with that which comes after; the precursor is thus part of a necessarily bonded association.

Obviously then, the definition of a precursor as simply a person or thing who comes before is inadequate; it is more appropriate to recognize the term as defining a relationship between an active subject -- the precursor, who does something which will be of value to later comers and an active predicate -- the follower, who makes use of the earlier work. But even now the picture is incomplete because of the implication of a unidirectional current flowing only from the precursor to the follower. In fact, in addition to the action of the precursor on the predicate, there is a requirement for a reaction of the predicate on the precursor. This reaction is the predicate's acknowledgement of the worth of the work of the precursor, thus giving a sort of "official" recognition to the precursor. In other words, the unilateral activity of the precursor is not sufficient to make him a precursor. His status is achieved only after the precursor's work has been duly appreciated and made use of by the predicate.
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It is relatively easy to retain the narrower definition of the term precursor, continuing to regard it as a simple class noun, and thereby failing to see the relationship inherent in the word. For this reason it is suggested that the word be defined as a category which would explicitly indicate the interaction between the precursor and predicate. Three categories are immediately apparent:

Category I: - active precursor ⇄ predicate. The active precursor plays an active role in a particular field; his contributions (data, hypotheses, models, etc.) are directly used by the followers. These may be described as positive contributions. Such precursors are those explicitly cited by scientists in research papers. However, the active precursor can also produce "negative" contributions, in the sense that, while possibly hindering advancement for the moment, they ultimately stimulate followers to refute the obstacle and thus advance the discipline. For example, the geneticist R. Goldschmidt held that evolution could not take place by the accumulation of small changes in form and function; he championed saltatory evolution. Many evolutionists set up whole programs of research in efforts to refute this thesis. Pierre Brunet takes special note of the importance of erroneous concepts to the advancement of science in the following passage taken from his introduction to Les Physiciens Hollandais au XVIII siècle:[29]

> ... certain discoveries, if they do not originate directly from errors at least owe their point of departure and initial impetus to such errors. Such is the case, for example, for the phlogiston theory which was for Lavoisier the occasion of fruitful research and an important discovery.

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The active precursor thus contributes to his followers, but equally, the followers, because they recognize the merit and make use of the work of the forerunner, contribute in a real sense to the precursor. While, of course, these effects cannot be quantified, at least qualitatively, it seems reasonable to say that the value to their successors of the precursors' information is about matched by the value to the precursor of the successors' use of this information and in their acknowledgement of the worth of the contribution.

<u>Category II</u>: - passive precursor $\overset{\longleftarrow}{\longrightarrow}$ predicate. The passive precursor does not intentionally provide a discipline with information. He may participate in the development of his own field, but his work has been abstracted and modified to apply to a different discipline, or he may promulgate an idea that comes to be used in a manner completely unintended by him. Thus, while information flows from precursor to predicate, with respect to the study of precursors, the activity of greater significance is that of the predicate who recognizes the importance of the precursor's work in a context unimagined by him. Two prominent examples of the "unintentional" precursor come to mind -- Spinoza, often cited as a precursor to the doctrine of materialism, and Plato, whose principle of plentitude became an essential ingredient in the idea of a chain of being.

A chief characteristic of Spinoza's philosophy is his assertion that there is but one substance in the Universe. Consequently, the attributes -- extension and thought are regarded as merely two aspects of this single substance, properly identified as God or Nature. Paul Vernière[30] notes that the neo-Spinozists of the eighteenth century

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> There remained only matter wherein are reunited the properties of movement and sensibility, that is to say of life: one moving, feeling, thinking universal substance, the essence henceforth of a fruitful materialism...[31]

> ...this interpretation is that of all the thinkers of the epoque, traditionalists or not; spinozism is for them a hylozoism where God is assimilated to matter, becoming a useless outgrowth... Towards 1750, the pantheism of Spinoza appeared in the eyes of all the materialists as an alluring foreshadowing.[32]

Stuart Hampshire[33] recalls that in the nineteenth century:

> Spinoza was sometimes celebrated and much more often abominated as a precursor of materialism; but his was a materialism with a difference, if only because the word "matter" normally suggests something solid and inert and no such notion of matter is to be found in his writing.

In seeking to determine the logical ground for the existence of this world, Plato was led to postulate that inherent in the Idea of the Good was the concept of a Self-Transcending Fecundity.

> A timeless and incorporeal One became the logical ground as well as the dynamic source of the existence of a temporal and material and extremely multiple and variegated universe.[34]

> This expansiveness of fecundity of the Good, moreover, as Plato clearly implies, is not the consequence of any free and arbitrary act of choice of the personal Creator in the myth; it is a dialectical necessity. The Idea of the Good is a necessary reality; it cannot be other than what its essence implies; and it therefore must, by virtue of its own nature, necessarily engender finite existents... the Absolute would not be what it is if it gave rise to anything less than a complete world in which the "model", i.e., the totality of ideal Forms, is translated into concrete reality.[35]

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The "fecundity of the Good" or as it is more commonly termed, the principle of plentitude, became one of the fundamental theorems in a conception of the world known as the Great Chain of Being. From the Middle Ages down to the late 18th century, most philosophers and men of science accepted this view of the world without question. Indeed, Lovejoy remarks:

> No history of the biological sciences in the eighteenth century can be adequate which fails to keep in view the fact that, for most men of science throughout that period, the theorems implicit in the conception of the Chain of Being continued to constitute essential presuppositions in the framing of scientific hypotheses... we shall briefly note three aspects of eighteenth-century biological theory in which it was either affected by the general acceptance of the principles of continuity and plentitude, or in its turn tended to bring about a new interpretation of those principles.[36]

The re-interpretation of Plato's logically necessitated principle of plentitude as a guding biological principle, is a development quite unintentioned by Plato.

Category III: - active precursor ←—— no immediate follower. In this category the precursor has no influence on the development of the field in which he is called precursor. This occurs when the contributions of the precursor are forgotten or unavailable, so that the discipline develops without his work. Such precursors, although having no direct influence, are held in high regard because of their singular anticipations of future developments. Consider the recognition given to Michael Servetus as a precursor of the concept of pulmonary circulation of the blood -- even though his work appeared in a book Cristianismi Restitutio which was condemned and burned in 1553. Only four copies of his book escaped destruction. It was unknown to other researchers concerned with the problem of the circulation of principle of plenitude, became one of the fundamental theses in a conception of the world known as the Great Chain of Being. From the Middle Ages down to the late 18th century, most philosophers and men of science accepted this view of the world without question. Indeed, Lovejoy remarks:

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the blood. In this category the predicate is necessarily the historian who discovers the existence of the forgotten work and the flow of activity is entirely from the historian to the precursor.

Perhaps the historian of science is most excited by this category because the study of such precursors satisfies a strictly academic curiosity. Interest in such a precursor is generated not by any demonstrable importance of the precursor to the fully developed scientific issue, but rather by the mere existence of a work in which the future was anticipated.

The Predicate Factor

> Ma quando tu sarai nel dolce mondo,
> priegoti ch'a la mente altrui mi
> rechi.
> (But when thou shalt be in the sweet
> world, I pray thee recall me to the
> memory of man.)
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The responsibility of the predicate to the precursor is the explicit recognition of the work accomplished by the precursor. However, this act of recognition is more than mere advertisement; by it the predicate links the work of the precursor with the larger entity in which the earlier contribution was but a single element. The value, therefore, of the predicate to the precursor is the predicate's capacity to extract from the anticipatory work an importance that transcends its intrinsic value. Indeed, fundamentally one can say that the full value of the work of the precursor can only be known after the work has been used, interpreted, and often reworked by the predicate as he incorporates it into a more encompassing entity.

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The selection of precursors by historians and scientists is not made in a random manner. The predicate, as practicing scientist or historian, asks specific things of his precursors. Just what these requirements are depends upon the demands of the discipline to which the predicate belongs. Because the demands of science and history differ, it is not surprising that precursors selected by historians are often not even thought of by scientists.

The scientist as predicate: A science has been likened to an edifice in which each contribution becomes a building block in the structure. Therefore, before making his own contribution, a scientist must know what others in the field have already done. He makes direct use of the data and models provided by those who preceded him. Thus the scientist views the precursor in a narrow, pragmatic way. He is concerned only with extracting from the precursor information that is specifically relevant to his problem. He seems always to be asking of the precursor -- will your ideas or your data be useful to me in obtaining an answer to my problem. The precursor is, in twentieth century science, most often a contemporary of his predicate. The working scientist has neither the time, nor, evidently, the inclination to consider work that is not essential or not of immediate use to his particular problem.

The manner in which the scientist sees the development of his science (i.e., as a continuous, cumulative process) and the part that he feels he plays in this development combine to influence how and whom he selects as a precursor. A scientist about to begin a particular experiment is au courant of the present state of knowledge in the

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> When it repudiates a past paradigm, a scientific community simultaneously renounces as a fit subject for professional scrutiny most of the books and articles in which that paradigm had been embodied. Scientific education makes use of no equivalent for the art museum or the library of classics, and the result is a sometimes drastic distortion in the scientists' perception of his discipline's present vantage. In short, he comes to see it as progress. No alternative is available to him while he remains in the field.[37]

> ... science textbooks (and too many of the older histories of science) refer only to that part of the work of past scientists that can easily be viewed as contributions to the statement and solution of the texts' paradigm problems. Partly by selection and partly by distortion, the scientists of earlier ages are implicitly represented as having worked upon the same set of fixed problems and in accordance with the same set of fixed canons that the most recent revolution in scientific theory and method has made seem scientific.[38]

The working scientist has little appreciation of discarded theories or the workers who produced them. Thus J. B. Cohen, in Franklin and Newton notes that:

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> ... having witnessed the overthrow of the fluid theory of heat, or caloric theory and the establishment of the theory of heat "as a mode of motion," the men of the nineteenth century were unable to find any virtue in the older theory, or to see how it had served nobly in the advance of science. Even at the middle of the twentieth century one can find reference being made to the caloric theory as a "now discredited" theory of heat, although such an attitude is less common today than it was a hundred years ago.[39]

Perhaps Kuhn comes close to explaining this distrust of history on the part of working scientists when he writes:

> More historical detail, whether of science's present or of its past, or more responsibility to the historical details that are presented, could only give artificial status to human idic ncrasy, error and confusion. Why dignify what science's best and most persistent efforts have made it possible to discard? The depreciation of historical fact is deeply and probably functionally, ingrained in the idiology of the scientific profession, and the same profession that places the highest of all values upon factual details of other sorts. Whitehead caught the unhistorical spirit of the scientific community when he wrote, "A science that hesitates to forget its founders is lost."[40]

The historian as predicate: Among the primary interests of the historian of science is the coherent reconstruction of the origins, growth and development of science. In such a narrative, the historians' choice of precursors is essentially the same as that of the scientists. However, there is another, and more encompassing responsibility charged to the historian of science -- the fulfillment of the aims of history. Herodotus put it succinctly in the opening paragraph to his first book of the History of the Greek and Persian War:

> This is an account of the researches of Herodotus of Halicarnasus, which he publishes in the hope of preserving from decay the remembrance of what men have done, and of preventing the great and wonderful actions of the Greeks and the barbarians from losing their due meed of glory; and above all to put on record the reason why they fought with one another.[41]

> ... having witnessed the overthrow of the fluid theory of heat, or caloric theory and the establishment of the theory of heat "as a mode of motion," the men of the nineteenth century were unable to find any virtue in the older theory, or to see how it had served nobly in the advance of science. Even at the middle of the twentieth century one can find reference being made to the caloric theory as a "now discredited" theory of heat, although such an attitude is less common today than it was a hundred years ago.[39]

Perhaps Kuhn comes closer to explaining this disinterest of history on the part of working scientists when he writes:

> More historical detail, whether of science's present or of its past, or more responsibility to the historical details that are presented, could only give artificial status to human idiosyncrasy, error and confusion. Why dignify what science's best and most persistent efforts have made it possible to discard? The depreciation of historical fact is deeply and probably functionally, ingrained in the ideology of the scientific profession, the same profession that places the highest of all values upon factual details of other sorts. Whitehead caught the unhistorical spirit of the scientific community when he wrote, "A science that hesitates to forget its founders is lost."[40]

The historian as preserver: Among the primary interests of the historian of science is the coherent reconstruction of the origins, growth and development of science. In such a narrative, the historians' choice of procedure is essentially the same as that of the scientists. However, there is another, and more encompassing responsibility charged to the historian of science -- the fulfillment of the aims of history. Herodotus put it elegantly in the opening paragraph to his first book of the *History of the Greek and Persian Wars*:

> This is an account of the researches of Herodotus of Halicarnassus, which he publishes in the hope of preserving from decay the remembrance of what men have done, and of preventing the great and wonderful actions of the Greeks and the barbarians from losing their due meed of glory; and above all to set on record the reason why they fought with one another.[41]

The contemporary historian of science is still obligated by these injunctions. He must record the work done by scientists in the past so as to prevent its falling into oblivion (thus perhaps especially recalling work that has been forgotten). In addition, the historian must organize past works into a coherent picture, which is essentially to recognize and acknowledge researchers as precursors. Finally he must record the reasons for individuals having done the work they did.

The fulfillment of these obligations results in the compilation of a group of precursors quite different from the group selected by the scientists. Thus, important among the precursors cited by the historian of science are men who were once influential in their respective fields, but whose work is not now useful in research. For example, physiologists and anatomists function today quite unmindful of the investigations, speculations, and often, even the names of Alphonso Borelli and Fabricius ab Aquapendente. Yet for the historian of science an understanding of the mechanization of the world view would be incomplete without reference to the works and influence of Borelli; the study of the development of Harvey's theory of the circulation of the blood would be lacking an important building block if the work of Fabricius were omitted. The accordance of praise to such predecessors is in keeping with the injunction of Herodotus to prevent the loss of "due meed of glory" owing to these figures from the past.

Despite the eclipse from glory of the aforementioned precursors, they, at one time, had been acknowledged as important contributors to their disciplines. But what of those investigators whose work had no apparent effect on the development of science? Can one be a precursor

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Despite the eclipse from glory of the aforementioned precursors, they, at one time, had been acknowledged as important contributors to their disciplines. But what of those investigators whose work had no apparent effect on the development of science? Can one be a precursor if his work is unknown to later practitioners? It is precisely this group of precursors that displays most clearly the difference in thinking between scientists and historians. For the historian, the criteria of use and influence are not the principal factors in determining who a precursor is. If an individual has clearly anticipated a concept, process or explanation, at length and in some detail (and not merely as casual or idle speculation), the historian will regard him as a precursor. The historian will do so in part because it forms a segment (albeit a neglected segment) of science and therefore tells us something about what a science was like at a particular moment in the past, and in part for the value derived from comparing a science of the period in which the first heralds of a new idea appeared and the later period when the idea reappeared and was appreciated. Were there relevant factors common to both periods? Why did the idea not take root the first time it was enunciated?

Thus while the scientist views the historical development of his discipline as basically a stepwise progression of experiments and data leading to a more detailed explanation of some phenomenon, process, etc., and therefore eschews the inclusion of outmoded or erroneous theories in the study of its development, these apparent deviations from the path to the "true" explanation are precisely the points of interest for the historian. It is in examining these discarded theories that the historian can come to understand what constituted a problem for a scientist in an earlier time; what were the concepts that led to his formuation of a particular hypothesis; what were the means available to the scientist to allow him to test his hypothesis.

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And it is in examining these cast-off theories and forgotten works that the historian may uncover the first glimmerings of theories which were to be more fully developed by later workers. As a by-product of these studies, the historian is also able to reveal the very non-linear pattern of scientific advancement -- a pattern that is made obvious only when a detailed record is kept of all the starts and stops, misinterpretations, errors and dead-ends.

Put in Kuhn's terminology, the historian's work is that of preserving as part of the scientific memory the existence of paradigms no longer in use. For the historian, the supplanted paradigm, the replacement paradigm and all the individuals who contributed to either of them merit attention because each of these elements form a part of a unified history. For the scientist, the only precursors worth considering are those responsible for the development of the most current paradigm. And this most recent paradigm, effectively wipes out all traces of the now defunct paradigm.

> ... both the layman's and the practitioner's knowledge of science is based on textbooks and a few other types of literature derived from them. Textbooks, however, being pedagogic vehicles for the perpetuation of normal science, have to be rewritten in whole or in part whenever the language, problem-structure or standards of normal science change. In short, they have to be rewritten in the aftermath of each scientific revolution, and once rewritten, they inevitably disguise not only the role but the very existence of the revolutions that produced them. Unless he has personally experienced a revolution in his own lifetime, the historical sense either of the working scientist or of the lay reader of textbook literature extends only to the outcome of the most recent revolutions in the field.[42]

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Working scientists, as a group, are not especially concerned with the antiquities of their science. Their experiments are performed and analyzed without reference to philosophical or epistemological aspects of the work. Although they are obviously not unaffected by the social and cultural developments around them, they do not consciously allow these factors to influence their experimentation or scientific thinking. In general, the attitude of the scientist to his work is one of concentrated preoccupation with his particular field of study and closely related areas. There is little inclination to investigate areas outside his discipline. The historian of science, however, must be responsive to two demanding disciplines; he must seek to understand and describe the aims and procedures of science, while simultaneously discharging his obligations to history.

> It is obvious that to be a good historian of science it is not enough to be a scientist. In the first place one must have the will to give oneself up to history, that is, to have a taste for it; one must cultivate the historical sense within oneself, which is a sense entirely different from the scientific; and finally one must master a number of special skills which are indispensable aids to the historian while they are of absolutely no value to the scientist who is concerned only for the progress of science.[43]

Because the historian of science is, in this sense an interdisciplinary figure, he is sensitive to interactions among disciplines. For this reason the historian is not at all adverse to searching for precursors and influences in areas far afield from the sciences. It is openly acknowledged among historians that the thoughts of scientists (particularly scientists of the 16th, 17th, and 18th centuries when science was very much a part of natural philosophy) have been shown to have been moulded by philosophical and religious principles.

Many of the arguments of William Harvey were drawn from Aristotle -- particularly Aristotle's doctrine of the supremacy of the heart and analyzed without reference to philosophical or epistemological aspects of the work. Although they are obviously not unaffected by the social and cultural developments around them, they do not consciously allow these factors to influence their experimentation or scientific thinking. In general, the attitude of the scientist to his work is one of concentrated preoccupation with his particular field of study and closely related areas. There is little inclination to investigate areas outside his discipline. The historian of science, however, must be responsive to two demanding disciplines; he must seek to understand and describe the aims and procedures of science, while simultaneously discharging his obligations to history.

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and his emphasis on circular motion. The conception of pulmonary circulation by Michael Servetus resulted from his interpretation of the Scriptures.

> Convinced of the identity of air, the spirit of God and Holy Ghost, he accepted the literal truth of the statement in Genesis, that God breathed His spirit into the heart of Adam. He accepted, too, the Old Testament that, "life is the blood." These beliefs led him (Servetus) to search for the site of the formation of the vital spirit or breath of life, in man... For Servetus the pulmonary circulation served theological theory.[44]

This turning to areas outside of science leads the historian to an appreciation of precursors not at all acknowledged by the working scientists.[45] Here the historian can find precursors who, to all intents and purposes, do not provide answers to scientific problems but who, nevertheless, can lay claim to the title "precursor" through their activities in making possible the success and accomplishments of working scientists. This group of precursors I have called "peripheral precursors" and they constitute a category separate from the three categories already mentioned. While precursors of this group are derived from a variety of disciplines -- philosophy, theology, economics, literature -- it is not this characteristic that distinguishes them from the precursors of the other categories. Their claim to distinction rests precisely on the fact that they <u>do not</u> provide scientists with answers to problems. Their activities are peripheral to developments taking place <u>in</u> the sciences.

Precursors of this category are often responsible for recognizing and advertising the existence of a problem. Although a step removed from the doing of science, they are deeply involved in espousing and

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Precursors of this category are often responsible for recognizing and advertising the existence of a problem. Although a step removed from the doing of science, they are deeply involved in exposing and transmitting new scientific theories via the media of letters. Thus, for example, prior to the appearance of Darwin's Origin of Species (1859), a number of figures from non-scientific disciplines were involved in discussing the theory of evolution and its importance to biological explanation. Schopenhauer, in his The Will in Nature (1854), declared that he favored the theory of evolution because it was the only possible explanation of the homologies found in vertebrate skeletons.[46] Tennyson, in his In Memoriam (1833-1850), began his poem as a lament over the death of his friend, A. Hallam, but ended the poem with various speculations concerning evolution and the immortality of the soul.[47] It is with little effort that one can compile a list of the novelists, poets and essayists who, in the years before 1859, upheld the theory of evolution and incorporated it as a theme central to their stories and poems.[48]

Peripheral precursors have another important function -- namely, "preparing the mind" for acceptance of a new theory. The glib use of the phrase "preparing the mind" should not obscure the tangible results arising from the persistent and widespread diffusion of new theories via the works of the peripheral precursors. It is in their constant reiteration of new theories and concepts, in stories, reviews and critiques, that the novelty is worn off and a certain familiarity is created which helps to eliminate the threatening qualities of the new ideas.

The role of the peripheral precursor emerges more clearly when one examines the circumstances under which a new (or resurrected) theory is finally accepted. To begin with, a new theory is frequently transmitting new scientific theories via the media of letters. Thus, for example, prior to the appearance of Darwin's Origin of Species (1859), a number of figures from non-scientific disciplines were involved in discussing the theory of evolution and its importance to biological explanation. Schopenhauer, in his The Will in Nature (1854), declared that he favored the theory of evolution because it was the only possible explanation of the homologies found in vertebrate skeletons.[54] Tennyson, in his In Memoriam (1833-1850), began his poem as a lament over the death of his friend, A. Hallam, but ended the poem with various speculations concerning evolution and the immortality of the soul.[55] It is with little effort that one can compile a list of the novelists, poets and essayists who, in the years before 1859, upheld the theory of evolution and incorporated it as a theme central to their novels and poems.[56]

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The role of the peripheral precursor emerges more clearly when one examines the circumstances under which a new (or resurrected) theory is finally accepted. To begin with, a new theory is frequently accepted on the basis of but a little evidence and a lot of belief in a particular metaphysical principle which finds expression in the new theory. One would, therefore, probably agree with the observation made by Owsei Temkin: "The appeal of an idea does not, after all, necessarily rest on its logical strength and supporting facts."[49] As a case in point, Temkin refers to Unger -- a botanist at the University of Vienna (1852):

> ... it is hard to decide whether even Unger was led to accept descent as a purely logical consequence of his paleontological and geographical research, or postulated it under the influence of metaphysical predilections. The form he gave to it indicates that his general views on man, the world and their progress played a considerable part.[50]

And there are cases in which a great deal of evidence is available favoring the theory, yet, despite the evidence, the theory is rejected on non-logical considerations. In his essay "The Argument for Organic Evolution", Lovejoy notes:

> The inquiry will also be found, I think, to throw a somewhat instructive light upon the psychology of belief and show how far, even in the minds of acute and professedly unprejudiced men of science, the emotion of conviction may lag behind the presentation of proof.[51]

Later in the same essay, Lovejoy refers to the hesitancy of Huxley to accept the theory of evolution before the publication of the Origin of Species -- despite the fact that the evidence available to him in 1859 was substantially the same as that published in the twenty-year period before 1859.

> The truth is -- as the evidence to be adduced will make clear -- that Huxley's strongly emotional and highly pugnacious nature was held back in his earlier years by certain wholly non-logical influences from accepting a hypothesis for which the evidence was practically as cogent for over a decade before he accepted it as it was at the time of his conversion. These influences

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> did not in Huxley's case, as they did in so many others, proceed from religious tradition or temperamental conservatism. But Huxley had unquestionably been strongly repelled by the Vestiges.[52]

Thus acceptance of a new theory often involves emotional and psychological factors, factors that cannot be discounted in assessing whether or not a theory will be accepted or rejected. It is in precisely this intangible area that peripheral precursors may do much to sway hesitant or recalcitrant minds towards the new viewpoint. Continued exposure to the new concept may produce sufficient familiarity with it so as to overcome scientific timidity. In addition, the stature of some of these peripheral precursors can be sufficiently authoritative as to influence undecided minds in favor of a new idea. Millhauer, in Just Before Darwin, discusses the transformist ideas expressed in Kant:

> Immanuel Kant, in the Critique of Judgment, finds that "the agreement of so many genera of animals in a certain common scheme ... strengthens our suspicions of an actual relationship between them in their production from a common parent"; and though like other philosophers, he (Kant) gives this stupendous suggestion no more than a page or two, still he is Kant, writing at the height of his career and of his intellectual power.[53]

Finally, peripheral precursors function to keep extant a theory in a hostile climate. Continual exposure of the scientific and interested lay community to an as yet unaccepted idea serves to maintain interest in it. While doing this, the peripheral precursors are buying time for the scientific supporters of the theory. While they persist in circulating the new idea, the scientists can continue to investigate and gather evidence in support of it -- and in the last analysis, it is the scientific evidence which is of vital importance did not in Huxley's case, as they did in so many others, proceed from religious tradition or temperamental conservatism. But Huxley had emphatically been strongly repelled by the Vestiges.[52]

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In summary, it should be recognized that while peripheral precursors remain peripheral to the solution of the problem to which they are precursor, their significance lies in their capacity to focus attention on the existence of the problem. Rather than bring contributions to the development of a concept, they serve as adherents at a time vital to the gestation of the theory. These precursors are dependent for their historical recognition on the predicate-historian. Indeed, many peripheral precursors were minor figures in their time with the consequence that they and their written works were forgotten or lost. The recovery and evaluation of such works provide the predicate-historian with an enormous measure of satisfaction -- not to mention a better and more detailed picture of the establishment of theories in the sciences.

Idea as Precursor

A common reason for historians to disagree on who qualifies as a precursor is that the writings of putative precursors are often ambiguous. Thus, Charles Darwin, in the opening of the Origin of Species included a section called "An Historical Sketch", in which he discussed the work of naturalists on transformation of species prior to his own work. Among the naturalists included is Buffon. Darwin states:

> Some few naturalists, on the other hand, have believed that species undergo modification and that the existing forms of life are the descendants by true generation of pre-existing forms. Passing over allusions to the subject in the classi-

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> cal writers, the first author who in modern times has treated it in a scientific spirit was Buffon. But as his opinions fluctuated greatly at different periods, and as he does not enter on the causes or means of the transformation of species, I need not here enter on details.[54]

Is, therefore, Buffon a precursor of evolutionary thought? It is difficult to know and the matter still generates disagreement among historians of science.

> Judgements on Buffon's service to the theory of evolution have varied widely. Guyenot calls him "un des fondateurs du transformisme"; Perrier makes the rather startling claim, "Buffon a donc une claire conception de la lutte pour la vie et de la selection naturelle qui en est consequence," though he adds, "Seulement il ne developpe pas cette idee fondamentale"; Osborn says, more reasonably, "He may be said to have asked all the questions which were to be answered in the course of the succeeding century"; finally Rostand writes, "Buffon, dont le role de presurseur nous parait... assez surestime..."[55]

From J. S. Wilkie's discussion of the ideas of Buffon (in a series of three papers[56]), it is evident that Buffon as a precursor is difficult to evaluate because Buffon's opinion does indeed, as Darwin said, fluctuate over the years. Thus, in the article De l'Ane (1753) Buffon is described by Wilkie as being indifferent or hostile to the theory of evolution. In a later article, De la degeneration des animaux (1766), he admitted to evolution in the origin of species. However, it is Wilkie's contention that:

> From the whole of this study it appears that Buffon was in fact very much a man of his own age. Like many other great men he prepared the way for future developments which he could not himself foresee. His most valuable contribution relating to the theory of evolution was his appreciation of the significance of the geographical distribution of animals, but the theory of evolution itself seems to have remained foreign to his thought, and he was never more respectable as a scientist than in his refusal to elaborate a general theory of this kind upon the facts available to him.[57]

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Whatever the final summing-up, Buffon did express an idea about evolution at one period of his life. Though Buffon, the man, changed his mind several times, the pro-transormist article was available to Darwin and was thus able to influence his thoughts (and the thoughts of the early evolutionists) to a favoring of transformism. Therefore, in instances of this kind, much of the difficulty in assessing whether or not an individual is a precursor can be eliminated if the historian separates the author from the idea and uses the idea. In these cases, it should be the career of the idea that is followed, with the person's name used as a convenience.

The same principle applies when the ideas of an author are used in ways that are unexpected and often unacceptable to him. Consider the "uniformitarian principle" formulated by Lyell. Huxley, in a paper entitled "Science and Pseudo-Science" (1887) says:

> I cannot but believe that Lyell was, for others, as for myself, the chief agent in smoothing the road for Darwin. For consistent uniformitarianism postulates evolution as much in the organic as the inorganic world.[58]

Despite the importance that the principle of uniformity had for Darwin in his formulation of the concept of organic evolution, Lyell remained for a very long time, a staunch supporter of the doctrine of special creation. However, whatever Lyell thought, his ideas were certainly precursors of Darwin's evolutionary thought.

Another case in point is the use made by evolutionists of the Linnaean system of classification. The theory of evolution simply appropriated this system and asserted that it was not an arbitrary construct, but represented the natural relationships among groups in

Whatever the final summing-up, Butler did express an idea about evolution at one period of his life. Though Butler, the man, changed his mind several times, the pro-transformist article was available to Darwin and was thus able to influence his thoughts (and the thoughts of the early evolutionists) to a favoring of transformism. Therefore, in instances of this kind, much of the difficulty in assessing whether or not an individual is a precursor can be eliminated if the historian separates the author from the book and uses the ideas. In these cases, it should be the course of the idea that is followed, with the person's name used as a convenience.

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IV

Whiggism - a methodology for the historian of science?

> It is part and parcel of the whig interpretation of history that it studies the past with reference to the present... . On this system the historian is bound to construe his function as demanding him to be vigilant for likeness between past and present instead of being vigilant for unlikeness; so that he will find it easy to say that he has seen the present in the past, he will imagine that he has discovered a "root" or an "anticipation" of the twentieth century when in reality he is in a world of different connotations altogether... The total result of this method is to impose a certain form upon the whole historical story and to produce a scheme of general history which is bound to converge beautifully upon the present.[59]

In general, this approach to history is to be avoided. However, I would like to suggest that there are special investigations in history which ought to make use of the whig interpretation. Let it be recalled that the precursor has been defined as "a person or thing that goes before and indicates the approach of someone or something, paving the way for the accomplishment or success of another." It is, therefore, implicit in the definition that the precursor presages something that is larger, more developed, and more complete than that which came before, and, moreover, that this later development was made possible because of some activity of the precursor. It is natural and necessary, then, to look for a precursor of a particular concept while making constant reference to the developed concept the plant and animal kingdoms. But, however valuable Linnaeus' system was to the concept of evolution it is clear that Linnaeus was not an evolutionist. Nevertheless, Linnaean classification was an important precursor of Darwinian evolution.

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To prevent the analysis of a putative precursor from succumbing to the pitfalls of whiggism, the historian should examine the work of the precursor in the context of its own period -- being especially attentive to the contemporary implications of all the terms used. If the historian neglects this step, he could easily conclude that likeness and anticipations exist where in fact they do not. Thus Lovejoy in his article, "Buffon and the Concept of Species" considers the term "continuity":

> But the idea of continuity as generally held in the time of Buffon had no reference to temporal sequences and by no means involved, in the minds of those who accepted it, any definite belief in the descent of what are commonly called species from other species... This fact has often been overlooked by interpreters of eighteenth century writers. When we find such a writing saying that "nature passes from one species to another by gradual and almost imperceptible transitions," it is by no means safe to assume that the phrase contains any reference to genealogical transitions or that the writer meant by his words to affirm the transformation of species through the summation of some slight individual variations. Misapprehension upon this point has caused some eighteenth century authors to be quite undeservedly set down as evolutionists.[60]

It is obvious however, that at this point, the historian has recorded an essentially static picture. In seeking out a precursor, it is not enough to describe the status quo of the science in the period in question. Although this is a necessary step in determining whether a person was a precursor or not, it is not sufficient. The statement of the theme given in vacuo, as it were, provides no affirmation of its precursory value. The status of a possible precursor (which is equivalent to the whig present). Indeed, it is impossible to speak of a precursor, for example, of the theory of evolution without reference to the theory of evolution.

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The historian thus asks himself two questions: (1) Does the content of the theme in the earlier work approximate in essence the final statement of the same theme? (2) Was there something in the earlier work vital to the formulation of the later concept? If the answer to either of these questions is in the affirmative, then the historian can conclude that he has discovered a valid precursor. In obtaining these answers, however, the historian has had to make reference to the fully-formed concept; it is here that the present state of knowledge intrudes into the past.

It should be noted that this final step in our scheme does more than merely confirm or deny the status of a precursor. It also serves to realize the potential of the contribution of the precursor by returning it to the larger study of the development of the final scientific construct, so that we can observe how the work of the precursor was incorporated into the whole. The growth of a concept, by the assimilation of hypotheses and evidence of prior individuals, imposes an order on the components of the concept. Whereas it is not a strictly linear arrangement (i.e., the work of one precursor does not necessarily, or even usually, emerge from that of another), the works of precursors necessarily converge to a single focus -- namely, the fully-formed concept. It is therefore not surprising that the exposition of the development of a concept has the whiggish characteristic of being "the story of an ascent to a splendid and virtuous climax."[61]

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NOTES

1. H. B. Glass, "Maupertuis, a Forgotten Genius", Scientific American, 193, 1955, 100 - 110.

2. H. B. Glass, "Maupertuis and the beginnings of Genetics", Quarterly Review of Biology, vol. 22, 1947, 196 - 210.

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4. Paul Ostoya, "Maupertuis et la biologie", Revue d'Histoire des Sciences, vol. 7, 1954, p. 60.

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6. Jean Rostand, Preface to the book, Maupertuis, le savant et le philosophe, by Emile Callot (Paris, Marcel Rivière et Cie, 1964), p. 7.

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Ibid., 51 - 83.

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CHAPTER FIVE

Maupertuis and Mendel - is theirs a precursor-predicate relationship?

Introduction to Chapter Five

The purpose of this chapter is to determine if Maupertuis can be considered a precursor to Mendel. The procedure to be followed is the one which I have suggested in the preceding discussion on the precursor. Fundamentally, what is involved is a comparison between Maupertuis' work on generation and Mendel's principles of heredity.

Part one of this chapter is a straightforward examination of Maupertuis' work in natural history. Part two is devoted to a discussion of Mendel's work in heredity. In part three, the two protagonists are brought together through posing the following question. What is there in Maupertuis' system of generation - in his conclusions, explanations and speculations, that could have been of use to Mendel in his formulation of the principles of heredity, or reveal any anticipations of Mendel's principles of heredity?

However, to determine if Maupertuis is a precursor of Mendel, one cannot be satisfied with just a comparison of their work. If Maupertuis were a precursor of Mendel, he would fit into the type three category; i.e., he would be a precursor who, while contributing actively to a field of study, has no immediate followers because his work has been neglected or is unavailable. Such a precursor becomes a "creation" of the historian, in the sense that the precursor's value to a discipline depends on the historian's interpretation of the precursor's work. To reduce hindsight to a minimum, it is necessary

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Now, what do I mean by "context of the times"? I am referring to those circumstances surrounding the work of a particular individual, to the "speculative interests, beliefs or broad theoretical options of the time",[1] to the assumptions that were basic to the development of explanatory or speculative systems,[2] to the scientific issues that had excited the imagination and curiosity of the men of the period and the questions that were raised in response to the study of these issues. Therefore, in my comparison of the work of Maupertuis and Mendel, I shall not only examine the content of their work, but also the context of their work (i.e., the intellectual framework within which the work was conceived and pursued). Thus part three will not only compare Maupertuis' work on generation and Mendel's work in genetics, but will take note of the basic assumptions that defined and confined the work of each; the systems and models available to both of them; the questions that directed their scientific studies. Should the type three precursor be evaluated on the basis of just the content of his work, and not the context, it is possible that the presumed similarities and anticipations could be spurious.

Part One: The Biological Work of Maupertuis

The Issues and the Solutions

From the earliest period of recorded history, one of the most fascinating subjects to excite man's interest involved his own origins and development. Up through the eighteenth century, this material, that the historian examine the presumptive precursor's work in the context of the precursor's own time.

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Part One: The Historical Work of Maupertuis

The Issues and the Solutions

From the earliest period of recorded history, one of the most fascinating subjects to excite man's interest involved his own origins and development. Up through the eighteenth century, this material, which involved the processes of fertilization, inheritance and embryology, were all grouped together under the term "generation". And if one examines the papers and monographs on generation written during the eighteenth century[3] and compares them with the treatises that had appeared in fifth century B.C. Greece, the first century A.D. Rome, throughout the Middle Ages and on through the seventeenth century, one discovers that the very same questions continue to be asked, pointing up the continuing interest in these areas and emphasizing the difficulties in formulating conclusive, satisfying answers.

Among the questions most commonly asked were those that concerned the source of the generative material[4]: Which of the two parents provided the genetic material? Was it a contribution of the male parent alone? the female parent alone? or did both parents contribute (the two semen theory)? How did the embryo develop? Did it develop <u>de novo</u> from an unformed, homogeneous substrate (epigenesis) or was it already preformed in the generative material, merely requiring an increase in size (preformation)? Where did the generative material come from? Was it the product of particular organs of the body -- the blood? or the brain? or was it the result of contributions provided by all the body parts (pangenesis)?

Of equal interest, was the early recognition that offspring resembled their parents. On a more general plane, this fact of resemblance was expressed as an awareness of the constancy of species. The first book of Genesis comments on this phenomenon of like begetting like:[5]

And God said, "Let the earth bring forth living creatures

> according to their kinds: cattle and creeping things and beasts of the earth according to their kinds." And it was so.
> And God made the beasts of the earth according to their kinds and the cattle according to their kinds, and everything that creeps upon the ground according to its kind. And God saw that it was good.

One of the earliest explanations that man devised to account for this phenomenon of constancy was the mechanism of pangenesis. The advantage offered by pangenesis was that it could explain the resemblance of progeny to their forebears because, as Hippocrates pointed out, in 400 B.C., the semen that constituted the material of the embryo came from all parts of both parents.[6] So useful was this vehicle for explaining the processes of generation that it survived as a functioning doctrine for over 2300 years,[7] Darwin being the latest of the biologists to propose pangenesis as the mechanism of reproduction.[8]

Other problems presented themselves to the curious: how did one account for the appearance of offspring which resembled neither of the parents, but instead showed a likeness to one of the parental ancestors? Especially prominent in the eighteenth century were questions having to do with the formation of hybrids and the reason for the prevalent sterility exhibited by these hybrids. And certainly, one of the most dramatic enigmas was the frequent appearance of "monsters".[9] All of these questions were by-products of the process of generation.

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Maupertuis' interest in genetics[10] was first aroused by the sight of the celebrated "negre-blanc", an African albino, who had been brought to Paris in 1744 and put on display before an audience of gaping Parisians. According to Maupertuis' account:

> He was a child of four or five years who had all the features of the Negro, but whose skin was very pale and white, which only served to augment his ugliness. His head was covered with a sandy wool: his eyes were a clear blue which seemed to be hurt by sunlight: his hands were large and poorly formed, resembling more the paws of an animal than the hands of a man. I have been assured that he was born of an African mother and father, both very black.[10]

What piqued Maupertuis' interest was the information that such occurrences (i.e., the birth of "white-skinned" children to black parents) was not at all rare; that in Senegal, he had been assured, one could find many black families having white-skinned members.[11] What was most impressive was that the trait seemed to be passed on from one generation to another, and moreover it appeared to be able to establish itself within a few generations, and just as easily disappear.[12]

His conclusion that the feature was an inherited one did, in effect, bring him to speculate about the general process of generation, which involved not only heredity but the whole problem of embryonic formation. The purpose of the Vénus physique was to examine the various systems that had been proposed to account for the embryo formation.[13] But Maupertuis did not limit himself to just speculation on fetal development. He expanded his study to such other phenomena as "the resemblance of the child to both the mother and father; the formation of the animal hybrid resulting from the cross of two different species; the formation of monsters... ."[14]

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The dominant system to explain generation in the eighteenth century was preformation. The doctrine of preformation asserted that the embryo existed already completely developed within the egg or the sperm. If the egg were the source of the embryo (ovism), the sperm merely provided the mechanical trigger to the embryo, causing it to increase in size. If the sperm housed the embryo, the function of the egg was merely to provide nourishment for the growth of the embryo. Whether the source of the preformed embryo was the sperm or the egg, it was clear that only one parent was the source of the generative material.

However, Maupertuis argued against preformation as the correct explanation. Evidence from many independent sources indicated that not one, but both parents were involved in the production of the embryo.

> Some very powerful reasons cause us to see that each of the sexes contributes to the formation of the animal. A child is born sometimes with the traits of the father, sometimes with the traits of the mother; he is born with their defects and habits... . Although these resemblances are not always observed, they appear too often to be attributed to chance.
>
> In the cross of different species these resemblances to both parents are more obvious. When a black man marries a white woman, it seems that the two colors are mixed; the child is born olive colored, and is mid-way between the traits of the mother and father. ... The donkey and the mare form an animal which is neither horse nor donkey, but is visibly a composite of the two... .[15]
>
> If all the animals of one species were already formed and contained only in the father or only in the mother... would one observe resemblance to both?[16]
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> ... since the child does resemble them both, I believe one can conclude that both of them participate in its formation.[17]

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But it seemed that for every observation made in favor of such a role for the egg, other anatomists came up with observations which seemed to deny such a part. Some even regarded the egg as a chimera. And in the light of these contradictory observations, Maupertuis was inclined to dismiss the egg as an element in embryo formation.[18]

Evidence against the participation of the sperm came from the well known experiments of Harvey, who examined the cervix of does just after copulation. In no case did he see evidence of sperm.[19]

In the light of the evidence that had been gathered by others, which denied that only one parent was involved in generation and in the light of the evidence which seemed to deny any function of sperm and egg in the process of reproduction, Maupertuis was inclined to reject preformation. The final stroke that turned him most emphatically against preformation was his own study of the Ruhe family of Berlin.[20] It had been observed that some members of the Ruhe family had been born with extra digits on each of their hands and feet (a condition now termed polydactyly -- a dominant single gene trait). Maupertuis traced the appearance of this condition back through three generations. On the basis of probability computations (which I shall discuss later), Maupertuis concluded that the appearance of the trait in three consecutive generations ruled out the possibility of this being a "chance" happening. On the contrary, the trait was inherited, and it was seen to be transmitted by the mother to her son in one generation, and by that afflicted son to his progeny in the next generation.

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What could Maupertuis do after having rejected preformation, and indeed any explanation which involved the egg and sperm? His choice was to return to the ancient, venerable system that Descartes also had made use of -- the two semen theory. Each sex was believed to produce a fluid, called the seminal liquor. An embryo was formed by the mixing of the seminal liquors from both parents.[22] The two-semen theory, by requiring material contributions from both parents, could provide the mechanism for explaining how offspring could resemble both parents. However, it did not answer the question: where did the seminal liquor originate? To deal with this problem, Maupertuis turned once again to theories of antiquity; he revivified the doctrine of pangenesis. Like the Ancients, Maupertuis believed that the seminal liquor contained all of the parts (in germ form) needed to form a new being. The proper assemblage of these particles would form a new being of the same species as the animals that provided the liquors. The elementary particles were derived from each organ of the parental body and became part of that same organ in the newly organized body.[23]

Maupertuis' model has so far provided us with the material of generation, but as yet it has not given us an explanation as to how, from a mixture of parental seminal liquors, an embryo could be organized. What causes this "sorting out" of particles? How are they "properly assembled"?

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one could be satisfied with an explanation that depended solely on matter and its motion.[24] Something more than simple mechanics was needed. Maupertuis was to find this special mechanism in the work of a fellow Academician, Geoffroy l'Aîné, who studied the attractive forces acting between substances. Geoffroy emphasized the action of attractive forces in the union of two substances. If two substances had a "disposition" or "rapport" for each other, they would unite. This union would remain intact until a third substance came along which showed a greater affinity for one of the members of the pair. The "intruder" would oust the substance that now had less "rapport" with its partner. Maupertuis decided to be absolutely frank with his readers and he admitted that the forces he was talking about were attractive forces; he did not want to hide behind the facade of such epithets as "dispositions" or "rapports", even though he knew that the term "attractive forces" often led many of his compeers to think of a resurrection of occult powers.[25] In an effort to pacify such people, and make them realize that attractive forces were natural and not supernatural agencies, Maupertuis recalled how important their use had been in astronomy, to explain the movement of celestial bodies, and in chemistry, to explain the formation of chemical compounds. When he had sufficiently wooed and calmed his reader, he then asked: "Why, if this force exists in nature, would it not operate in the formation of the bodies of animals?"[26]

How would these forces of attraction operate in the organization of the embryo?

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> destined to form the heart, the head, the entrails, the arms, the legs; in the formation of the animal, these parts have a greater affinity with that particle which must be its neighbor, than for any other. ... once the two particles which must touch are united, then a third which would have been able to make the same union, no longer has a place and remains useless. It is thus, by these repeated operations, that the child is formed from the particles of the father and the mother, and often bears visible signs that it shares in traits from both parents.[27]

On the basis of this model, which makes use of attractive forces between neighboring particles, Maupertuis could offer an explanation for the formation of the embryo and indicate why it is that offspring resemble their parents. Should something happen to interfere with the affinity of the two particles for each other, then irregularities would arise in the arrangement of the particles, and these irregularities produced monsters:

> If each particle is united to that particle which must be its neighbor, and that is all, then the child is born perfectly formed. If some particles are too far away from each other, or if they are placed inconveniently or if the attraction between them is too weak to unite to each other those particles which ought to be united, then a defective monster is born (monsters par defaut). But if it happens that some superfluous particles are there, and they join with two particles that are already united, then a monster with extra parts is formed (monster par excès).[28]

Maupertuis had succeeded in achieving the goals he set himself in the <u>Vénus physique</u> (1745). He had examined the various systems of generation and on the basis of the available evidence was able to discard preformation, and he had been able to set up his own model of generation, which, by means of attractive forces, was able to provide explanations for some of the most enigmatic questions that man had ever posed.

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Between 1745 (the year in which the Vénus physique was published) and 1751 (the year in which the original Latin version of the Système de la Nature appeared -- Dissertatio inauguralis metaphysica de universale naturae systemate), something may have happened to intensify Maupertuis' theological inclinations.[29] I am not certain as to what it could have been; possibly his health was becoming more precarious. (His health had become delicate after his voyage to Lapland. This weakness may have led to his developing tuberculosis, the disease from which he died in 1759.) In any event, a sharp contrast can be drawn between the mood and contents of the Vénus physique and the Système de la Nature. The Vénus physique was a sparkling, chatty, almost gay, popularization of a scientific subject. The explanation that Maupertuis had given for the processes of generation were dependent upon such physical factors as matter, motion, forces of attraction. There was no mention of God; there were no theological or teleological overtones. This was all changed in the Système de la Nature. Although Maupertuis dealt with much the same material as had been treated in the Vénus physique, there was now a strong difference in mood. The light, delicate touch of the Vénus physique had been replaced by a heavy, somber tone. There had been a shift away from explanations based on physical causes, to dogmatic statements which attributed the phenomena of generation to metaphysical principles. The hand of God was everywhere, and the purpose of God had become the reason for all things.

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The change in Maupertuis' approach to the study of generation could also have been the result of more extensive studies by Maupertuis of work done on embryo formation. We have statements made by Maupertuis which disclose his greater awareness of, and appreciation for, the complexities involved in the organization of the embryo, and his assertion that the more one studied natural phenomena, the more one realized that such properties of matter as impenetrability, motion, inertia, even attraction, are not sufficient to explain many natural occurrences. Once again Maupertuis turned to chemistry, noting this time, however, that even the simplest operations in chemistry can not be explained by the same forces of attraction that apply to celestial motion. Therefore, it was not surprising to Maupertus that forces of attraction were still far from explaining the formation of a plant or animal.[30] His 1745 model of generation, which had been operationally dependent on forces of attraction, was now not enough to produce the delicate, complex structures that characterized living things. "Something more" was needed, and this time in his need Maupertuis transcended the material world and reached into the realm of metaphysics, hoping that there he would find the motive force for his model of generation:

> A uniform, blind force of attraction, scattered throughout all the particles of matter, cannot be used to explain how the particles are arranged to form even the most simple body. If all the particles have the same tendency, the same force, to explain the union of particles, why do these form the eye? why do those form the ear? why this marvelous arrangement? why don't they unite in a random fashion? ... it is necessary to have recourse to some principle of intelligence, to something similar to what we call design, aversion, memory.[31]

By resorting to intelligence, an intelligence that was inherent <u>in</u> matter, Maupertuis was challenging the long accepted belief that matter of work done on embryo formation. We have statements made by Maupertuis which disclose his greater awareness of, and appreciation for, the complexities involved in the organization of the embryo, and his assertion that the more one studied natural phenomena, the more one realized that such properties of matter as impenetrability, motion, inertia, even attraction, are not sufficient to explain many natural occurrences. Once again Maupertuis turned to chemistry, noting this time, however, that even the simplest operations in chemistry can not be explained by the same forces of attraction that apply to celestial motion. Therefore, it was not surprising to Maupertuis that forces of attraction were still far from explaining the formation of a plant or animal.[39] His 1745 model of generation, which had been operationally dependent on forces of attraction, was now not enough to produce the delicate, complex structures that characterized living things. "Something more" was needed, and this time in his mind Maupertuis transcended the material world and reached into the realm of metaphysics, hoping that there he would find the motive force for his model of generation:

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By resorting to intelligence, an intelligence that was inherent in matter, Maupertuis was challenging the long accepted belief that matter and mind were two completely separate realms. The properties of matter included extension, hardness, impenetrability, but not thought. By insisting that intelligence was a property of matter, Maupertuis was effectively aligning himself with the notorious materialists of the eighteenth century (see chapter two for a more extensive discussion of Maupertuis and the eighteenth century materialists), and he knew that he was stirring up a furor because he went to great lengths to show that all was not lost by attributing thought to matter. On the contrary, the most orthodox of theologians recognized that animals were intelligent. "Now if, in the large masses of matter, such as the bodies of animals, one allows without peril some principle of intelligence, what greater risk can one encounter by attributing it to the smallest particles of matter?"[32] The properties of extension and thought were, according to Maupertuis, two distinct properties of the same subject and the study of the phenomena of Nature should tell us if this is so. Maupertuis hastens to add, however, that in explaining the phenomena of Nature we ought to employ the fewest number of principles, and the simplest principles possible. Hence, if it were possible to explain all the phenomena of Nature without admitting thought to matter, one should do so: "but if, with all its properties, Nature remains inexplicable, one does not depart from the rule we have established by admitting new properties."[33] Specifically, if it were not possible to explain the formation of organized bodies by means of the physical properties of matter "it will be necessary to admit new ones, or rather recognize properties which are there."[34] From Maupertuis' point of view, it has become necessary to grant to and mind were two completely separate realms. The properties of matter included extension, hardness, impenetrability, but not thought. By insisting that intelligence was a property of matter, Maupertuis was effectively allying himself with the notorious materialists of the eighteenth century (see chapter two for a more extensive discussion of Maupertuis and the eighteenth century materialists), and he knew that he was stirring up a furor because he went to great lengths to show that all was not lost by attributing thought to matter. On the contrary, the most orthodox of theologians recognized that animals were intelligent. "Now if, in the large masses of matter, such as the bodies of animals, one allows without peril some principle of intelligence, what greater risk can one encounter by attributing it to the smallest particles of matter?"[57] The properties of extension and thought were, according to Maupertuis, two distinct properties of the same subject and the study of the phenomena of Nature should tell us if this is so. Maupertuis hastens to add, however, that in explaining the phenomena of Nature we ought to employ the fewest number of principles, and the simplest principles possible. Hence, if it were possible to explain all the phenomena of Nature without admitting thought to matter, one should do so; that is, with all the properties, Nature remains inexplicable, one does not depart from the rule we have established by admitting new properties."[58] Specifically, if it were not possible to explain the formation of organized bodies by means of the physical properties of matter "it will be necessary to admit new ones, or rather recognize properties which are there."[59] From Maupertuis' point of view, it has become necessary to grant to to matter the property of intelligence because "one will never explain the formation of any organized body solely by the physical properties of matter."[35] Maupertuis has been led by the facts, as he saw them, to espouse a principle of intelligence as essential to the explanation of generation. (The principle of intelligence has been discussed in chapters two and three.) Let us just note several salient features of this principle. It was Maupertuis' belief that intelligence was a special property endowed by God to all matter. In the elementary particles, from which all organized bodies were formed, this intelligence was manifested as desire, aversion, memory. The function of this intelligence/memory fulfilled a definite purpose of God; it prevented the eventual loss of God's living creations by allowing them to affect their own generation.[36]

In asserting that matter had the property of intelligence, Maupertuis was able to create a second model of generation, now dependent on the intelligence/memory of the elementary particles of the seminal liquor. Whereas in the earlier model the guiding force was attraction, in his newer mode, elementary particles were guided to their appropriate places in the developing embryo by memories they retained of their former positions in the organism which formed the seminal liquor.

> The elements appropriate to form the fetus swim in the semen of the male and female animals: but each extract of the part similar to that which it must form, preserves a kind of memory of its former situation; and will return to it every time that it is able to, in order to form the same part of the fetus.[37]

> Thus from the ordinary manner in which the elements behave, one can explain the conservation of the species and the re-

to matter the property of intelligence because "one will never explain the formation of any organized body solely by the physical properties of matter."[55] Maupertuis has been led by the facts, as he saw them, to espouse a principle of intelligence as essential to the explanation of generation. (The principle of intelligence has been discussed in chapters two and three.) Let us just note several salient features of this principle. It was Maupertuis' belief that intelligence was a special property endowed by God to all matter. In the elementary particles, from which all organized bodies were formed, this intelligence was manifested as desire, aversion, memory. The function of this intelligence/memory fulfilled a definite purpose of God, to preserve the eventual form of God's living creations by allowing them to effect their own generation.[56]

In asserting that matter had the property of intelligence, Maupertuis was able to create a second model of generation, one dependent on the intelligence/memory of the elementary particles of the seminal liquor. Whereas in the earlier model the guiding force was attraction, in his newer mode, elementary particles were guided to their appropriate places in the developing embryo by memories they retained of their former positions in the organism which formed the seminal liquor.

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semblance to the parents.[38]

This model was also able to explain those other phenomena of generation that Maupertuis inquired after. Monsters were still produced by the presence of extra elementary particles or by the absence of some particles.[39] Hybrids between two species revealed characteristics of both parental species because the particles from each parent retained memories of their former positions and returned to those positions once more, even though there had been a mixing of the seminal liquors of the two species.[40]

* * *

<u>The arrangement of particles</u>

In discussing Maupertuis' two models of generation (i.e., Model I being dependent on forces of attraction; Model II being dependent on the principle of intelligence), one might be led to believe that the differences between them outweighed their similarities. Actually, the two models should not be looked upon as alternatives to each other; rather model II is an evolved form of model I, having subsumed all of the properties of model I. What the principle of intelligence does for each of the particles is to permit each element to approach the position it is to occupy in the developing fetus. When the elements are close enough to each other, then the forces of attraction between neighboring particles can operate and a close union of the particles ensues.[41] Thus what Maupertuis has finally developed is a delicate, relatively sophisticated model that allows a body of organized matter to reproduce itself into similar organized bodies without semblance to the parents.[38]

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Whether Maupertuis interpreted the phenomena of generation according to his first or second model, there was one requirement they had in common -- the need to provide for the proper assemblage of particles, so as to produce progeny similar in form to the parents. The proper (or improper) arrangement of particles was the pivotal element in Maupertuis' system of generation. As we have seen, the proper arrangement of particles was necessary to form normal offspring similar to the parents; an improper arrangement of particles, caused by the irregular union of too many or too few particles, produced monsters; the hybrid offspring between two species displayed characteristics of both species because the elementary particles assumed an arrangement appropriate to the parental species from which it was derived. But this was not the full extent to which the phenomena of generation proved to be a function of the arrangement of particles. The sterility of matings between two very different species was attributed to the complete lack of rapport between particles coming from each of the parents. Under these circumstances, the elements could not assume or preserve any kind of suitable arrangement with each other and reproduction became impossible.[42] The spontaneous generation of living forms (such as the formation of eels from decomposing flour) was likewise a product of arrangement; in this case, the elements were described as being too susceptible to arrangements or of possessing confused memories. As a consequence, the arrangement of particles occurred with the greatest ease, and all kinds of life forms emerged.[43] But the intervention of outside physical forces, plastic natures, omens, genii or other agents of Nature.

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Maupertuis stated that if, for some reason, there was a scarcity of parental particles in the mixed seminal fluids, the original assemblage of particles, which had prevailed in each of the parents, could not be reproduced, and therefore a different arrangement occurred. Under such circumstances "one would see a white child born to black parents or even a black child born to white parents."[44] According to Maupertuis, then, a specific trait was not thought to be inherent in the particle, but was the expression of the external arrangement of the particles.

From all of these explanations of the various phenomena of generation, there emerges one general characteristic of the model. It provides us with a geometrical explanation of the basic life processes. It is an explanation that is a function of the spatial arrangement of the particles; it is an explanation that does not concern itself with the inner composition or internal functions of the particles; instead, the important factors are such quantitative parameters as the number of particles present, the degree of affinity between the particles, the strength of the memory of each particle.[45]

* * *

Atavism

One of the phenomena of generation that Maupertuis prided himself on being able to explain was "atavism", the resemblance of offspring

to more remote ancestors rather than to the immediate parents.[46] How did this come about? Let us first recall Maupertuis' description of how the parental forms reappear in the offspring. The seminal liquors of the male and female contain many particles, but ordinarily the greatest number of particles are those that have been derived from each of the parents. These male and female particles are analogous to each other and possess a great affinity for each other; therefore, they will be the ones to unite with each other to form an embryo which resembles the parents.[47]

It sometimes happened that the particles that had originated in the ancestor were able to retain very strong memories of their ancestral arrangement, and the passage of time seemed to enhance these memories. Sometimes the forces of attraction between the ancestral particles were stronger than those between the parental particles.[48] Occasionally something happened to decrease the number of parental particles in the seminal liquor. If any of these circumstances prevailed, "the original particles from the ancestors would assume the upper hand; and the child, instead of resembling the mother and father, would resemble their more distant ancestors.[49]

From this explanation of atavism, two very important ideas emerged. First, we are to understand that the seminal liquor did not only contain particles derived from the parental generation, but also maintained a population of particles that had originated in the ancestors. Therefore, Maupertuis must have believed in a material continuity from one generation to the next. Second, the phenomenon of atavism demonstrates that an individual could carry ancestral particles but need to more remote ancestors rather than to the immediate parents.[36] How did this come about? Let us first recall Maupertuis' description of how the parental forms reappear in the offspring. The seminal liquors of the male and female contain many particles, but ordinarily the greatest number of particles are those that have been derived from each of the parents. These male and female particles are analogous to each other and possess a great affinity for each other; therefore, they will be the ones to unite with each other to form an embryo which resembles the parents.[37]

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The Transformism of Maupertuis

Maupertuis had, so far, applied his model of generation to questions that had been asked for centuries. But his inquiring mind (and possibly his sense of the dramatic) led him far from the traditional areas of investigation. With his typical boldness, he dared to support a belief that was, in his day, not only unpopular, but defintely iconoclastic. Maupertuis dared to state that species had changed; that the number of species had increased since the Creation, and in fact continued to do so. He was, in effect, flying in the face of a widely accepted concept, the belief in the fixity of species.

The arguments favoring this concept of immutable species were drawn from several sources: the religious argument which maintained that the act of Creation was a unique event and therefore the species as initially formed were permanent entities; the metaphysical argument drawn from the doctrine of the Chain of Being, which held that all the species that could be formed by God, had already been formed; the not exhibit the ancestral trait. Under appropriate conditions, however, the ancestral trait could reappear in the descendants, and in an unchanged state. These factors, the presence of a trait which is unseen, the transmission of the trait from one generation to the next, the unchanged reappearance of that trait, define the genetic concept known as recessivity (to be discussed later in this chapter). Therefore, although Maupertuis did not call a trait recessive, he did have a feeling for the concept of recessivity.

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Maupertuis was undaunted by these arguments. As we have seen in chapter two, Maupertuis was one of the early biological materialists who believed that matter was active and capable of organizing itself and directing its own activities. In addition, Maupertuis saw what appeared to him to be the formation of new species.[50]

What constituted a species according to Maupertuis? First of all, at no time did he attempt to define a "species" on the basis of a fundamental system of anatomical structures; that is, he did not take a particular organ system such as the reproductive system and use it as the key group of structures to which individuals could be compared to see if they were members of the species. Instead, if an individual showed a change in <u>any part</u> of the organism, this alteration could serve as the distinctive feature of a new species. Perhaps Maupertuis' concept of species could best be understood by tracing the steps which Maupertuis believed led to the formation of a new species. First of all, a variation of a trait occurred in an individual, completely by chance. Thus, for example, in a population of black crows, several white plumed crows appeared. By selected matings between just white individuals, over a series of generations, a group of crows would be philosophic belief that Nature (or matter) was passive and, therefore, no new creation was possible; and the pragmatic argument which contended that the evidence from biblical sources and other ancient manuscripts which gave descriptions of plants and animals, as well as the evidence from wall paintings of ancient tombs and temples, revealed that there was little or no difference between ancient and contemporary species.

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The following passage in which Maupertuis describes the appearance of so many diverse species, reveals several important points: the versatility of his model of generation, the significance of "arrangement" in the formation of a new species and the relative ease with which a new species could be formed and propagated, even in Nature, without the interference of man and his program of selective breeding:

> There can occur such tenacious arrangements (of particles) that from their first appearance, they dominate over all the preceding arrangements and obliterate them.[54]

> Could one not explain by that (i.e., the tenacious arrangements) how from only two individuals, the multiplication of the most dissimilar species would have been possible. They would have owed their primary appearance to several fortuitous productions, in which the elementary particles would not have retained the order that they had in the parental animals: each degree of error would have made a new species: and by means of repeated deviations would come the infinite diversity of animals that we see today.[55]

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When Maupertuis first enunciated his belief (in the *Vénus physique*) that species were not immutable, he did not set the new species on an equal footing with the original species. He distinguished between the original species or "the works of Nature", and the more transient species or "the digressions of Nature":

> That which is most certain, is that all the variations which could have characterized new species of animals and of plants tend to disappear: they are digressions of Nature... . Her works always tend to take the upper hand.[56]

Perhaps at this time Maupertuis still saw something special about God's original creations. It is evident that the means of preservation of the new species depended initially on selective mating between like individuals. And even if the new trait were to be established in the population, there was no certainty that the new arrangement of particles would prevail indefinitely. The new trait was retained as long as "the particles which produced the original traits were less numerous in each generation."[57] But the possibility remained that by chance the original particles could once again increase in number, organize into the old pattern and prevail over the new arrangement. As Maupertuis said, this was not only possible, but highly probable.

However, by 1751 (in the Système de la Nature) Maupertuis' attitude about the transience of the new species had changed. As we have seen, he later maintained that the prevalence of the new arrangement of particles was no longer threatened by the original arrangement, because right from the start, the new arrangement was dominant to the old. Moreover, Maupertuis had not only commented that there were present so many different species, but also "the number of species will perhaps increase even more with time."[58]

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I do not believe that anyone should (or could) deny that Maupertuis was a believer in the formation of new species. However, it is interesting that Maupertuis' belief in species formation was based more on his ignorance of contemporary taxonomy and heredity than on what he did know. Because he was not a taxonomist, he was not bound by the criteria that defined the species. Hence he was easily convinced that the appearance of a single new trait in a group of organisms (e.g., the appearance of variegated colors in plants,[59] white crows among black,[60] six-digited individuals within a population of five-digited individuals[61]) heralded the appearance of a new species.[62]

Because he did not know anything about the actual mechanism of heredity (and he cannot be faulted for this), Maupertuis could not be expected to realize that what he was actually seeing when he spoke of species formation, was either one of two processes: homozygosis of a recessive gene and the establishment, by selective crossing, of a pure line, or the appearance and selection of a dominant gene. (The definitions of these terms will be given in the section dealing with Mendel's laws.) Thus, in the absence of this information, Maupertuis was able to take a bold step away from the traditional belief in the fixity of species and towards a theory of evolution.

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I cannot conclude this section on the transformation theory of Maupertuis without bringing up one of the more recent views taken of

Maupertuis as a precursor to Darwin. I have already mentioned how enthusiastic was the movement, in the first half of the twentieth century, towards recognizing in the works of Maupertuis anticipations of the theory of evolution. The bandwagon effect of this movement was slowed down considerably by the adverse comments by the Nobel prizewinning Geneticist, F. Jacob, in his book La logique du vivant (1970). And at present, a definite negative reaction has set in against considering Maupertuis to be a precursor to Darwin, as evinced in a paper read at the Journée d'étude sur Pierre Louis Moreau de Maupertuis, by Anne Fagot[63] and from the discussion which followed it. According to Mlle. Fagot:

> It is evident that one can make Maupertuis an anticipator of the theory of evolution only through a biased reading of his work... one can have the pleasure of attributing to Maupertuis all the key explanatory elements of the theory of evolution of species (such as chance and selection) while forgetting that he lacked the essential concept of evolution itself.[64]

The essence of the concept of evolution calls for the gradual accumulation of changes within a species eventually producing such a divergence between the new species and the original one, that cross-breeding between the true forms becomes impossible and so one must acknowledge that two separate species exist where only one had originally. Did Maupertuis have such a concept? There are passages which seem to suggest that Maupertuis may have had an idea about the real transformation of one species into another.[65] (This is discussed at length in note 61.) But even if Maupertuis did not have any conception of the idea of evolution, can he summarily be dismissed as a precursor to the theory of evolution? Is the function of the precursor

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* * *

Maupertuis' biological investigations sought answers to a variety of old, ever-recurring questions. Have Maupertuis' answers succeeded in settling any of the issues of his day? The answer must be no, because in the Vénus physique Maupertuis himself says:

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> I do not expect that the outline of the system which I have proposed to explain the formation of animals, will please everybody: I am not even very satisfied myself.[68]

Even at the conclusion of his later work, the Système de la Nature, Maupertuis could not offer the reader a definitive explanation of generation. He felt that three systems were possible: one dependent on the chance collisions between unintelligent particles, a second which attributed the formation of organized bodies to God or to his subordinate agents, and the third which assigned formation to the elementary particles themselves, which, having been endowed with intelligence, could organize themselves so as to fulfill God's purpose.[69] (Maupertuis' choice is obvious.)

Thus, in the year 1751, we are faced with much the same situation that had prevailed in 1651, in 1351, in 551 B.C. The same questions were still being asked; and the answers continued to lack conviction or bring satisfaction. No solid foundation for future research work had been laid; and the cycle prepared to start anew in the nineteenth century.

Part Two: Mendel - a man alone

> Change occurs not only by continuous improvement in knowledge but also by the cutting off of whole problems as irrelevant or uninteresting. John Dewey once noted that: "intellectual progress usually occurs through sheer abandonment of questions, together with both of the alternatives they assume -- an abandonment that results from their decreasing vitality and a change of urgent interest. We do not solve them: we get over them. Old questions are solved by disappearing, evaporation, while new questions... take their place.[70]

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Not only may there be a complete change in the questions asked, but there can also be a change in method and a new way of analyzing and dence; consider, for example, the progress made in embryology:

> With the advent of developmental mechanics, many old questions were left behind while new ones took on central importance. Entire methodologies and modes of explanation and evidence were substituted for older ones in which it had become a new type of embryology.[71]

These changes in questions, method and analysis constitute a change in context; a contextual change such as occurred in the study of heredity in the middle of the nineteenth century. The events involved in the realization of this particular change constitute one of the most extraordinary episodes in the history of biology, because the entire endeavor was literally the work of one man, an Augustinian monk named Gregor Mendel (1822 - 1884).

* * *

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The study of heredity proceeded along two different lines: the practical, applied efforts of the breeders and the theoretical work of the hybridizers. The differences in their approach are sharply revealed by the issues that occupied each group and by their totally dissimilar methods of investigation.

The nineteenth century breeder, like his eighteenth century predecessor, was principally concerned with improving the agronomic dence; consider, for example, the progress made in embryology:

> With the advent of developmental mechanics, many old questions were left behind while new ones took on central importance. Entire methodologies and modes of explanation and evidence were substituted for older ones to which it had become a new type of embryology.[71]

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qualities of livestock or crop plant. His classic method was simplicity itself: select the organisms that showed the desired trait and use them as progenitors of the next generation. Examination of the progeny of such a cross was generally limited to a search for those individuals that carried the desired factor in this next generation, although some observations of the other progeny were also made. But, the recording of the observations was the most that happened. The breeder showed little interest in trying to draw any general conclusions from the observations; certainly, there was no effort to count the different kinds of individuals. An experimental mating was judged successful if the breeder obtained individuals who themselves carried and could transmit the trait in question.

The theoretical hybridist was primarily interested in the same question that had plagued many natural historians of the eighteenth century, namely, what is the origin of species? In general, the hybridizer tried to generate new species by crossing two established species. However, all the theoretician could do was offer sweeping speculations about inheritance since he was really unaware of the basic element of heredity, that is, the individual trait. For the theorist, an organism was regarded as a "whole" unit which resembled either the mother or father. Little notice was taken of the specific traits involved in the resemblance, and this omission was a direct consequence of the general attitude adopted by theoreticians who thought in terms of essences. They saw species as the product of "specific essences" and the constitution of the species was viewed as a nebulous confusion of these essences. There was nothing definite that could be qualities of livestock or crop plant. His classic method was simplicity itself: select the organisms that showed the desired trait and use them as progenitors of the next generation. Examination of the progeny of such a cross was generally limited to a search for those individuals that carried the desired factor in this next generation, although some observations of the other progeny were also made. But, the recording of the observations was the most that happened. The breeder showed little interest in trying to draw any general conclusions from the observations; certainly, there was no effort to count the different kinds of individuals. An experimental mating was judged successful if the breeder obtained individuals who themselves carried and could transmit the trait in question.

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Both the breeders and theoreticians looked upon the results of hybrid breeding experiments as studies in confusion. The full extent of this confusion was well illustrated in the authoritative compendium of hybrid experiments collected by Gartner (1849). In it, he described experiments that involved many different plant species and the only conclusive thing that he was able to say about the offspring of hybrid parents was that the offspring were variable.[72] It is not difficult to appreciate the bewilderment of both groups: the breeders, in following traits from the original parental (called the P_1 generation to the first hybrid (labelled the F_1) generation to the progeny of the hybrid parents (the F_2 generation), were overwhelmingly struck by the observation that the homogeneous hybrids of the F_1 generation never "bred true". Their progeny (the F_2 generation) always showed some reversion toward the parental forms. No attempt was made to develop an explanation for the extreme variability of the F_1 hybrids. The theorists, who might have attempted an explanation for the phenomena, did not pay attention to the individual traits and hence missed the regularity with which the parental and hybrid forms appeared in the F_2 generation. They saw only vague resemblances between offspring and parents.

It is at this point, amidst this clutter of uninterpretable information, that Mendel came upon the scene. His attempts to deal with the genetic riddles of the breeders and hybridists was akin to Alexander's solution to the Gordian knot. He just sliced through the confusion by ignoring the old questions and the old methods, replacing them with new issues and new means of explanations.

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Mendel's Aims

That we are dealing with a person whose scientific outlook differed completely from his contemporaries is revealed in the very first page of Mendel's opus Versuche über Pflanzen-Hybriden.[73] Whereas his contemporaries were aware only of chaos in their experiments, Mendel's initial experiments on ornamental plants allowed him to state:

> The striking regularity with which the same hybrid forms always reappeared whenever fertilization between like species took place suggested further experiments whose task it was to follow the development of hybrids in their progeny.[74]

It was this regularity in the appearance of hybrid forms that caused Mendel to believe that a law could be found descriptive of the phenomenon of hybrid formation. Mendel's specific aim was to formulate such a law; and he recognized readily that his aim and the means needed to achieve it were innovations in the field of heredity.

> That no generally applicable law of the formation and development of hybrids has yet been successfully formulated can hardly astonish anyone who is acquainted with the extent of the task and who can appreciate the difficulties with which experiments of this kind have to contend. A final decision can be reached only when the results of detailed experiments from the most diverse plant families are available. Whoever surveys the work in this field will come to the conviction that among the numerous experiments not one has been carried out to an extent or in a manner that would make it possible to determine the number of different forms in which hybrid progeny appear, permit classification of these forms in each generation with certainty, and ascertain their numerical interrelationships. It requires a good deal of courage indeed to undertake such a far-reaching task; however, this seems to be the one correct way of finally reaching the solution to a question whose significance for the evolutionary history of organic forms must not be underestimated.[75]

Mendel's Method

Mendel did not immediately plunge into his projected experiments on hybrid formation. He appreciated the fact that certain preliminary steps had to be taken before he could even attempt to understand the regularities of hybrid development and the causes of these regularities.

> The value and validity of any experiment are determined by the suitability of the means used as well as by the way they are applied. In the present case as well, it can not be unimportant which plant species were chosen for the experiments and how these were carried out.[76]

The plant species he required was one that was not easily fertilized by foreign pollen, was able to form a fertile hybrid in varietal crosses, possessed constant, differing traits.[77] A twentieth century geneticist can not help but be amazed at Mendel's penetrating insight into his subject. Mendel stressed the need for constant traits (he understood the importance of using only pure lines so that the composition of the parents and progeny would be know at all times during the course of the experiments); he stressed the importance of discontinuous traits (the traits had to be definite and clear. Differences could not rest on "more or less" criteria which were difficult to define: "such traits were not usable for individual experiments; these had to be limited to characteristics which stand out clearly and decisively in the plants."[78]); he stressed the need for traits that were alternate forms of each other rather than intermediate or transitional forms between the two (the plant was tall or short; the seeds were round or wrinkled). What is most incredible about Mendel's choice of criteria, besides being absolutely novel to the breeder and hybridizer, is the still mystifying question: How did Mendel come

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In the preliminary process of testing out which of the traits was suitable for study in the chosen plant (the pea plant, *Pisum sativum*), Mendel demonstrated and defined the dominance/recessive relationship between traits:

> Each of the seven hybrid traits either resembles so closely one of the two parental traits that the other escapes detection, or is so similar to it that no certain distinction can be made. This is of great importance to the definition and classification of the forms in which the offspring of hybrids appear. In the following discussion those traits that pass into hybrid association entirely or almost entirely unchanged, thus themselves representing the traits of the hybrid, are termed dominating, and those that become latent in the association, recessive. The word "recessive" was chosen because the traits so designated recede or disappear entirely in the hybrids, but reappear unchanged in their progeny, as will be demonstrated later.[80]

Knowledge of the dominant:recessive relationship was very important because, as we shall see below, Mendel's method depends entirely on being able to distinguish all of the various kinds of progeny produced by hybrid parents (observing their outward appearance or phenotype and also testing their internal composition or genotype) and being able to determine the numerical relationships between the to realize that the traits that could provide him with the information that he needed about hybrid development were traits that were constant, discontinuous and manifested only one of several alternate forms. It must be emphasized that Mendel knew to choose these criteria before he had begun his eight year series of experiments and even before his preliminary steps were taken to select the appropriate organism. This means that Mendel essentially had to have at the very least understood the nature of the answers years before he had even begun the experiments on the pea plant.[79]

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Knowledge of the dominant/recessive relationship was very important because, as we shall see below, Mendel's method depends entirely on being able to distinguish all of the various kinds of progeny produced by hybrid parents (observing their outward appearance or *phenotype* and also testing their internal composition or *genotype*) and being able to determine the numerical relationships between the hybrid forms.

Now, what precisely was Mendel's method? How did it differ from the standard artificial fertilization techniques used by plant breeders? Both Mendel and the plant breeders started their experiments by crossing parental lines which manifested particular traits. But, the breeders were not certain that their parental strains would always produce offspring manifesting the trait. Mendel worked with established, pure lines, i.e., lines of known composition. His crosses were therefore controlled crosses and the products of such crosses were known to house a representative trait from each of the parents (the theory for this statement will be discussed later). They were designated hybrids. These hybrids (or F_1 generation) resembled the dominant form of the parental pair. The hybrids were then interbred so that the F_2 progeny could be obtained. In this generation, both parental types appeared. Now, the breeders had often gone as far as this in their breeding experiments, but for them the re-emergence of both parental types signalled the end of the experiment. The re-appearance of both forms was the familiar sign of defeat and frustration because the F_1 hybrid had broken down; no new species had been formed. For Mendel, the excitement of the experiment had just begun. Now was the time to observe the classes of progeny present. But this was not all. Not only were all the classes described, but the individuals of each class were counted, and note was taken of the frequency of appearance of each of the classes, expressed in the form of a ratio.

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There cannot be too much emphasis placed on the arithmetic method used by Mendel in his analysis of F_2 progeny.[81] And the most important aspect of that arithmetic method was the use of the numerical relationship. The first time that such ratios appeared in Mendel's paper was in his discussion of the results obtained from the cross of hybrids for each of the seven traits used in his study of the pea plant.

> The numerical proportions obtained for each pair of differing traits are as follows:
>
> Experiment 1. Seed shape. From 253 hybrids 7324 seeds were obtained in the second experimental year. Of them, 5474 were round or roundish and 1850 angular wrinkled. This gives the ratio 2.96:1.
>
> Experiment 2. Albumen coloration. 258 plants yielded 8023 seeds, 6022 yellow and 2001 green; their ratio, therefore, is 3.01:1.[82]

If it were possible to preface a written statement with a musical fanfare, this first mention of the 3:1 ratio would be the most appropriate place. In this casual mention of numerical proportions, Mendel has introduced the most significant factor in his experimental and analytic procedure.

The Use of the Ratio in Mendel's Method

The most obvious use of the numerical ratio was, of course, the ease with which Mendel could make a quantitative statement about the composition of a population. (See the quotation given above.) More important, the use of ratios made it possible for Mendel to make a general statement about any population of hybrid progeny that manifested dominant/recessive traits:

> In this generation, along with the dominating traits, the recessive ones also reappear, their individuality fully revealed, and they do so in the decisively expressed average proportion

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> 3:1, so that among each four plants of this generation three receive the dominating and one the recessive characteristic. This is true, without exception, of all traits included in the experiment.[83]

And then, the ratio, in combination with the appropriate symbols, enabled Mendel to achieve an extraordinary degree of abstraction and generalization in his discussion of heritable traits. Let us first consider Mendel's unique use of symbols. From his analysis of the F_1 hybrid Mendel knew that both dominant and recessive factors were present in the same plant. Instead of confining himself to particular pairs of traits characteristic of a particular plant, Mendel chose to abstract the trait from the organism, give it a symbol and regard it as a mathematical element. Thus he denoted the dominant constant trait A and the recessive trait a. When considering the composition of the organism with respect to a single pair of traits, Mendel designated the individual by two letters: A A if both factors were dominant; a a if both factors were recessive (these are the homozygous forms, i.e., both factors are the same); Aa when both factors are present in the hybrid (this is the heterozygous form, in which the traits differ from each other).[84]

Mendel's analysis of the 3:1 ratio revealed that the dominant forms were really of two types: the homozygous dominant form and the heterozygous dominant, in a 1:2 ratio with each other. Therefore the actual composition of the population of organisms showing a 3:1 ratio was 1 homozygous dominant to 2 heterozygotes to 1 homozygous recessive or 1AA : 2Aa : 1aa. Mendel recognized this 1:2:1 ratio as the distribution of a binomial series, and the binomial series provided Mendel

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Mendel considered the case of progeny formed from dihybrid parents (parents differing by two pairs of traits). What could he say about them? First of all, he could express each pair of traits as a binomial: If A,a and B,b are the traits of the dihybrid, their binomial expressions are: AA + Aa + aa; BB + Bb + bb. Each of the members of the first series was then combined term by term with members of the second series. The following expressions were obtained: AB + Ab + aB + ab + 2ABb + 2aBb + 2aBb + 2AaB + 2Aab + 4AaBb. From this expression, Mendel determined all the kinds of progeny that the dihybrids produced and their frequencies.[85] The value of such expressions lies in the fact that they are abstract, independent of organism, independent of the kind of trait being considered; yet a researcher who had never worked with the organism could know before the experiment was performed just what kind of progeny to expect and what the numerical relationship was between them. The following passage illustrates quite graphically the degree of abstractness Mendel had achieved with the binomial ratio and the great amount of information that could be derived from the combination series:

> If n designates the number of characteristic differences in the two parental plants, the 3^n is the number of terms in the combination series, 4^n the number of individuals that belong to the series, and 2^n the number of combinations that remain constant. For instance, when the parental types differ in four traits the series contains $3^4 = 81$ terms, $4^4 = 256$ individuals, and $2^4 = 16$ constant forms; stated differently,

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> among each 256 offspring of hybrids there are 81 different combinations, 16 of which are constant.[86]

The predictive aspect of these combination expressions became a most important part of Mendel's method, enablin: Mendel to achieve in biology a level of sophistication and elegance that heretofore had been reserved for physics and astronomy. A simple example can demonstrate the u e Mendel made of predictive ratios in his own work. Mendel was concerned with trying to determine if the gametes (or reproductive cells) of the dihybrid plant were produced with equal frequency.[87] He had noted that in Pisum hybrids constant forms appeared among the progeny of hybrids and that they do so in all combinations of associated traits (for example, in the dihybrid the constant forms would be AABB, AAbb, aaBB, aabb). This meant that when the dihybrid plant AaBb formed its gametes, A and a always separated from each other, and that A combined with B and b; likewise a combined with B and b. The array of gametes was: AB, Ab, aB, ab. If, as Mendel hypothesized, these classes of gametes were produced equally frequently, then the cross between the dihybrid plant and a plant recessive for both traits would produce the following progeny classes with equal frequency: AaBb, Aabb, aaBb, aabb. The ratio among the classes should therefore be 1:1:1:1. Mendel carried out the cross of the dihybrid to the double recessive and obtained these results (gathered from two separate experiments):[88]

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	Exp. 2	Exp. 4
AaBb	31	24
Aabb	26	25
aaBb	27	22
aabb	26	27

Mendel's conclusion: "In all experiments, therefore, all forms postulated by the preceding hypothesis appeared, and did so in nearly equal numbers."[89] Therefore the gametes were produced by the dihybrid with equal frequency. As we have seen from the experiment given above, Mendel postulated that the classes of progeny that appeared should do so in nearly equal numbers. After performing the experiment, Mendel was satisfied that the array of numbers that he obtained, 31, 26, 27, 26 and 24, 25, 22, 27 did represent classes of equal frequency. If the classes of the first experiment are to be nearly equal, the total number in each class should be 27; the total number of individuals in each class of the second experiment should be 24. Now it is obvious that each of the classes did not all register the same number. Why did Mendel believe that the observed deviations from the expected did not constitute a significant deviation? In other words, how did he know that the observed data fit the expected numbers? Fisher observed that the test of significance of deviations from expectation in a binomial series had been familiar to mathematicians at least since the middle of the eighteenth century. He suggests that even though Mendel's mathematical studies in Vienna may have paid little attention to the theory of probability --

> he (Mendel) was engaged in other researches of a statistical character, in meteorology, and in connection with sun-spots, so that it is scarcely conceivable, had the matter caused

> any anxiety, that he knew of no book or friend that would enable him to examine objectively whether or not the observed deviations from e pectation confirmed with the laws of chance.[90]

Even though Mendel did not explicitly show his calculations on the fit of his observed to the expect d data, it is obvious that he did make use of such statistical analyses. They were, indeed, a fundamental part of his experimental procedure.

* * *

The Mendelian method is characterized by several definitive steps: 1) construction of lines pure for a particular trait, 2) formation of the hybrid and the subsequent breeding within the F_1 progeny, 3) determination of the types of classes to be expected in the F_2 generation, determination of the numerical relationships among these classes, 4) counting of the progeny, 5) comparison of the expected results with the observed results to see if a fit obtains. These steps, first outlined and performed by Mendel between 1858 and 1865 remain the cornerstone and fundamental method of classical genetics.

<u>Mendel's Laws of Heredity; the role of the ratio in the formulation of the laws.</u>

Mendel's purpose in studying the progeny of hybrid crosses was to ascertain the law(s) applicable to the formation and development of hybrids. Consequently Mendel constructed hybrids for each of the seven pairs of traits that he had selected. The parental forms <u>AA</u> and <u>aa</u> were crossed in order to produce the F_1 hybrid <u>Aa</u>. As was noted in the discussion on the dominant/recessive relationship between traits, all the members of the F_1 were homozygous in appearance,

> any anxiety, that he knew of no book or friend that would enable him to examine objectively whether or not the observed deviations from a prediction conflicted with the laws of chance.[39]

Even though Mendel did not explicitly show his calculations on the fit of his observed to the expected data, it is obvious that he did make use of such statistical analyses. They were, indeed, a fundamental part of his experimental procedure.

* * *

The Mendelian method is characterized by several definitive steps: 1) construction of lines pure for a particular trait, 2) formation of the hybrid and the subsequent breeding within the F_1 progeny, 3) determination of the types of classes to be expected in the F_2 generation, determination of the numerical relationships among these classes, 4) counting of the progeny, 5) comparison of the expected results with the observed results to see if a fit obtains. These steps, first outlined and performed by Mendel between 1856 and 1865 remain the cornerstone and fundamental method of classical genetics.

<u>Mendel's Laws of Heredity: the role of the ratio in the formulation of the laws</u>

Mendel's purpose in studying the progeny of hybrid crosses was to ascertain the law(s) applicable to the formation and development of hybrids. Consequently Mendel constructed hybrids for each of the seven pairs of traits that he had selected. The parental forms AA and aa were crossed in order to produce the F_1 hybrid Aa. As was noted in the discussion on the dominant/recessive relationship between traits, all the members of the F_1 were homozygous in appearance, resembling the dominant parental strain. When the F_1 hybrids were interbred, the recessive trait, which had been marked by its absence in the hybrid, now reappeared, so that 1/4 of all the F_2 progeny displayed the recessive trait. In the remaining 3/4 of the F_2 progeny, all of which showed the dominant trait, one third continued to produce dominant individuals only, while two thirds produced dominant and recessive forms. In Mendel's words:

> it now becomes apparent that of the seeds formed by the hybrids with one pair of differing traits, one half again develop the hybrid form while the other half yield plants that remain constant and receive the dominating and the recessive character in equal shares.[91]

In modern terminology, this principle is referred to as the Law of Segregation, and it applies to the reappearance of the pure forms of the dominant trait and recessive trait in the progeny of the hybrid as a consequence of the segregation (or sorting out) of the paired traits in the hybrid parent.

Mendel discovered that if he formed hybrids for two or three different traits, and followed each pair of traits through the F_1 and F_2 generations, it was apparent from the ratios of the progeny classes that each pair of traits behaved independently of the others. Thus in a dihybrid AaBb, the separation of A from a and the appearance of each in the F_2 progeny would not be affected by the separation of B from b and the emergence of both traits in the F_2 offspring.

> there can be no doubt that for all traits included in the experiment this statement is valid: The progeny of hybrids in which several essentially different traits are united represent the terms of a combination series in which the series for each pair of differing traits are combined. This also shows at the same time that the behavior of each pair of differing traits in a hybrid association is independent

resembling the dominant parental strain. When the F_1 hybrids were inbred, the recessive trait, which had been masked by its absence in the hybrid, now reappeared, so that 1/4 of all the F_2 progeny displayed the recessive trait. In the remaining 3/4 of the F_2 progeny, all of which showed the dominant trait, one third continued to produce dominant individuals only, while two thirds produced dominant and recessive forms. In Mendel's words:

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of all other differences in the two parental plants.[92]
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* * *

These concepts: the Dominance:Recessive relationship, the Law of Segregation and the Law of Independent Assortment, constitute the foundation of the science of Genetics. We, in the twentieth century, know how general they are in describing the phenomena of heredity. What is so astounding however is that Mendel, after working on just two plant species, Pisum and Phaseolus, was equally convinced that these laws were applicable to hybrid formation in any organism.

> The object of further experiments will be to determine whether the law of development discovered for Pisum is also valid for hybrids of other plants. Several experiments were started quite recently for this purpose. I have completed two fairly small experiments with species of Phaseolus, which might be mentioned here.[93]

> Despite the many obstacles with which the observations had to contend, this experiment still establishes that development of hybrids follows the same law as in Pisum with respect to those traits concerned with the shape of the plant.[94]

> Whether variable hybrids of other plant species show complete agreement in behavior (with Pisum) also remains to be decided experimentally; one might assume, however, that no basic difference could exist in important matters since unity in the plan of development of organic life is beyond doubt.[95]

Mendel's conviction that his laws of hybrid development were the functional laws which did govern and explain the phenomena of heredity, were strengthened as a result of Mendel's application of his laws to the enigmatic results which had been obtained by breeders for years. Mendel called attention to one of the most unstable traits of ornamenof all other differences in the two parental plants."[71]

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Mendel also applied his laws to the experimental results obtained by Kolreuter and Gartner, the two recognized authorities in the breeding field. "With respect to the features of hybrids and their regular development, consistency with the observations made on Pisum is unmistakable."[97]

* * *

The Laws of Dominance, Segregation and Independent Assortment were formulated by directly observing and counting the individuals which belonged to an array of classes distinguished from each other by discontinuous, easily identifiable traits. Therefore, one can say that Mendel's principles were the direct outgrowth of his observations. But, the formulation of these laws was made possible only by Mendel's astute recognition of regularly occurring F_2 classes and of the numerical relationships exhibited by them. Thus one would have to acknowledge that the discovery of the principles of heredity was dependent on these calculable ratios, being in fact verbalizations of tal plants — its coloration. Coloration was often referred to as the model of instability. However, Mendel analyzed the observations made on the variations in color of the _Dianthus_ plant. The colors and patterns (stripes of color) spanned the range from white to red to striped, in the progeny, but if the plants were studied in the light of Mendel's principles one "cannot easily escape the conviction that here, too, development proceeds according to a certain law which possibly finds its expression through the combination of several independent color traits."[96]

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He crossed two hybrids: AaBb x AaBb. From the nine classes that were produced four of them were constant for both traits and were symbolized: AABB, AAbb, aaBB, aabb. Now, such constant lines were the products of identical gametes:

> In our experience we find everywhere confirmation that constant progeny can be formed only when germinal cells and fertilizing pollen are alike, both endowed with the potential for creating identical individuals, as in normal fertilization of pure strains. Therefore, we must conside it inevitable that in a hybrid plant also identical factors are acting together in the production of constant forms.[98]

In order to have formed these constant types, the dihybrid had to have produced these gametes: AB, Ab, aB, ab.[99] Mendel observed that the classes of F_2 progeny contained all the possible combinations of the two traits:

> Since the different constant forms are produced in a single plant, even in just a single flower, it seems logical to conclude that in the ovaries of hybrids as many germinal cells and in the anthers as many kinds of pollen cells are formed as there are possibilities for constant combination forms and that these germinal and pollen cells correspond in their internal make-up to the individual forms.[100]

The cross of the dihybrid to the double recessive (the discussion appears in the section on method) AaBb x aabb, revealed that the gametes of the dihybrid, were produced in the same frequency. Hence, Mendel was able to make the statement that:

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> pea hybrids form germinal and pollen cells that in their composition correspond in equal numbers to all the constand forms resulting from the combination of traits united through fertilization.[101]

From this succinct statement several very important inferences can be drawn. When the germ cells (or gametes) are being formed, the paired members of the trait separate from each other, so that A and a do not end up in the same cell. However, A can find itself in the same cells as B or b; likewise a can be teamed with B or b; all the possible combinations of A with B and b, and a with B and b are possible and do form. Therefore, the separation of members of a pair of traits at the cell level is reflected in the law of segregation; and the various combinations of traits which come together to form the gametes are revealed in the law of independent assortment.

As important as these inferences are, they still give us just a glimpse of the extraordinary insights of Mendel. We know from his paper that he had an accurate picture of the process of fertilization.

> It is presumably beyond doubt that in Pisum a complete union of elements from both fertilizing cells has to take place for the formation of a new embryo. How else could one explain that both parental types recur in equal numbers and with all their characteristics in the offspring of hybrids?[102]

Mendel symbolized the union of the elements from both parents (represented by the new embryo or zygote) by the double notation AA or Aa or aa. We would call this the 2n or diploid state. In the gametes, only one member of the pair was represented. Mendel designated the composition of such cells by only single letters. We would refer to such cells as being in the n or haploid state. If we put these inferences of Mendel's together, we can come up with a very startling picture:

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1) the 2n organism, by definition, has each trait represented twice in its cells. 2) in the formation of the gametes there is a separation of the paired factors. 3) the gametes carry only one factor from each pair. Thus, without naming it, Mendel has definitely described the process of meiosis, the basic mechanism that keeps the chromosome number constant in sexually reproducing organisms; a process, by the way, that was not directly observed until the late 1870's.

The role of chance in heredity

Mendel's principles of heredity brought order and stability to an area of study that had formerly been characterised by chaos and instability. But an interesting paradox arose. Though one could at last predict the frequency of appearance of a trait in a population, the predictability was a consequence of the laws of chance operating on a large population of equivalent elements. Thus the physical composition of a gamete depended on the random (or chance) assortment of factors as the paired members of a trait segregated from each other in the formation of the gamete. And the physical union of the gametes themselves (i.e., the process of fertilization) was also a function of chance:

> It is entirely a matter of chance which of the two kinds of pollen combines with each single germinal cell. However, according to the laws of probability, in an average of many cases it will always happen that every pollen form A and a will unite equally often with every germinal cell form A and a; therefore, in fertilization, one of the two pollen cells A will meet a germinal cell a, and equally, one pollen cell a will become associated with a germinal cell A, the other with a.[103]

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The 1:2:1 ratio of the classes observed in the F_2 generation was a direct result of the chance fertilization of the pollen and germinal cells.

Mendel was appreciative of both aspects of chance: as an inherent part of the meiotic process and the process of fertilization, and thus subject to the regularization of the laws of chance; and chance as an unpredictable occurrence which caused deviations from the expected results:

> The true ratios can be given only by the mean calculated from the sum of as many separate values as possible; the larger their number the more likely it is that mere chance effects will be eliminated.[104]

* * *

Mendel's contributions to the scientific community were overwhelming in their breadth and depth. He did more than formulate the laws of hybrid development. He established the principles upon which the whole new science was to develop. He gave us the method of investigation that is still in use today. And he showed us how powerful a tool genetics could be -- allowing us to bridge the gap between the macroscopic world of observed data to the microscopic, speculative world of cellular mechanism.

At the beginning of his paper, Mendel placed the judgment of his accomplishments in the hands of his reader:

> Whether the plan by which the individual experiments were set up and carried out was adequate to the assigned task should be decided by a benevolent judgment.[105]

May we not answer that Mendel has far surpassed his initial goals; and the least benevolent of judgments would have to acknowledge that: "Gregor Mendel's short treatise is one of the triumphs of the human direct result of the chance fertilization of the pollen and germinal cells.

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Part Three: A comparison of the biological ideas of Maupertuis and the Mendelian principles of heredity

The Scientist views the Presumptive Precursor

The purpose of this section is to examine Maupertuis' biological works in order to determine if Maupertuis can be considered a precursor to Mendel. Since Maupertuis did not have any following that we know of, we cannot know how useful his work could have been to scientists who came after him. But we can indulge in that ever-tempting pastime, so popular with historians, the exercise of "what - if", and ask: What would have happened if Mendel had read Maupertuis' works prior to the formulation of his own laws of heredity? Would Mendel have discovered any information or ideas that might have been of value to him?

We must remember that Mendel lived almost a century after Maupertuis, a century in which biology was established as a scientific discipline and during which time great strides had been taken in the area, methodologically, factually and conceptually. Mendel, as a product of a nineteenth century scientific education, would therefore have brought to his study of Maupertuis certain ideas and knowledge through which would filter Maupertuis' own contributions, and by which Maupertuis' contributions would be judged and accepted or rejected.

It is possible that if Mendel had come across Maupertuis' Vénus physique (it had been translated into German in 1788) and the Système mind."156

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It is possible that if Mendel had ever come across Maupertuis' *Vénus physique* (it had been translated into German in 1755) and the *Système* de la nature (originally written in Latin in 1751, translated into German in 1767), he might have been wary of finding in them anything of use to him, as a scientist, because the proposed reasons for which the books had been written were decidedly antiquated by now. The Vénus physique was written to protest the acceptance of preformation as the system of generation, and to postulate that the embryo was the product of contributions from the two parents. By Mendel's time, there had been a definite shift to epigenesis and acceptance of the biparental role in generation. The Système de la nature was concerned with establishing matter as intelligent, active and internally motivated. To biologists of the nineteenth century, the physiological studies of living matter would have rendered the subject obsolete.

But let us assume that Mendel was not turned away by the outdated reasons for which the books had been written. How would he have reacted to their contents? As we have seen, Mendel accepted that fertilization was "initiated by the union of one germinal (female) and one pollen (male) cell into a single cell."[107] He therefore would have agreed with Maupertuis that both parents were responsible for the formation of the embryo. However, he would have immediately rejected Maupertuis' belief that the male and female seminal liquors were the agents of fertilization rather than the egg and sperm cells.

The central propositions of the cell theory, namely that the cell is the unit of structure and function of all living things, had already been sharply defined by 1840, and by the late 1840's it was recognized that living cells could arise only through the division of

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The central propositions of the cell theory, namely that the cell is the unit of structure and function of all living things, had already been sharply defined by 1860, and by the mid 1850's it was recognized that living cells could arise only through the division of previously existing cells. During Mendel's period at the University of Vienna, 1851-1853, he would undoubtedly have been apprised of these latest developments, and he would have accepted as true the sharp separation between living organisms (animals and plants) and the inanimate world of minerals. Consequently, Mendel would not have agreed with one of Maupertuis' fundamental beliefs, that the elements which were organized to form animals and plants were the same as those that formed metals, minerals and precious stones, except that these latter elements had a very low degree of intelligence, or in the words of Maupertuis, they were "less active".[108]

The concept of dominance was of ancient vintage, well known to farmers, breeders, and any individual observant of the inheritance of familial traits. However, the concept of recessivity is another matter entirely. The recessive trait is a masked trait, and because it does seem to appear only sporadically, it is a more subtle, more difficult trait to follow, than is the dominant character. The concept of recessivity, however, entails more than the sporadic appearance of a masked trait. Essential to the concept are the following factors: it must be recognized that the recessive trait is carried in the individual which does not manifest it; the recessive trait can remain in its hidden or "latent" state for any number of generations; when the recessive trait finally emerges, it is unchanged in nature. All three factors are in evidence in Maupertuis' description of atavism:

> It is common enough to see a child bearing a close resemblance to his ancestors than to his most immediate parents. The ele-

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> ments which form some of the traits can have retained the ancestral organization rather than the paternal arrangement, either because they have been united for a longer time in the ancestral arrangement than in the paternal arrangement, or because they have a greater attractive force between them; in such a case they will be placed in the fetus as they had been in the ancestor.[109]

It is quite possible that if Mendel had read this passage he would have been alerted to the condition of recessivity.

It is also possible that Maupertuis could have provided Mendel with a methodological aid. Mendel, we have seen, was most emphati about carrying out his experiments with hybrids formed within the species Pisum sativum (they are intra-specific hybrids), concentrating on single, obvious traits. Though Maupertuis discussed inter-specific hybrids, most of the crosses that he mentions at length involved distinct, oft dramatic traits that appeared in crosses betwen races or varieties within the same species. One of the most significant experiments that he mentioned (significant because he himself performed it) was the crossing of Icelandic dogs of various color patterns to obtain a specific color arrangement.[110] The most famous cross that he discussed was the genealogy of the Ruhe family, in which he traced the appearance of six-digitism through three generations.[111] And of course, there was his extended coverage of albinism as it appeared among black families in Africa and South America.[112]

Since the scientist is free to gather ideas and information from any probable (or improbable) sources, and interpret (or mis-interpret) them, according to his own understanding, it is not at all unlikely that Mendel could have obtained some useful ideas from Maupertuis.

Interestingly enough, had Mendel read Maupertuis after he had

> nents which form some of the traits can have retained the ancestral organization rather than the paternal arrangement, either because they have been united for a longer time in the ancestral arrangement than in the paternal arrangement, or because they have a greater attractive force between them; in such a case they will be placed in the fetus as they had been in the ancestor.[107]

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It is also possible that Maupertuis could have provided Mendel with a methodological aid. Mendel, as have seen, was most modest about carrying out his experiments with hybrids formed within the species Pisum sativum (they are intra-specific hybrids), concentrating on single, obvious traits. Though Maupertuis discussed inter-specific hybrids, most of the crosses that he mentions at length involved distinct, clear, domestic traits that appeared in crosses between races or varieties within the same species. One of the most significant experiments that he mentioned (significant because he himself performed it) was the crossing of Icelandic dogs of various color patterns to obtain a specific color arrangement.[109] The most famous cross that he discussed was the genealogy of the Ruhe family, in which he traced the appearance of six-digitism through three generations.[111] And of course, there was his extended coverage of albinism as it appeared among black families in Africa and South America.[112]

Since the scientist is free to gather ideas and information from any probable (or improbable) sources, and interpret (or misinterpret) them, according to his own understanding, it is not at all unlikely that Mendel could have obtained some useful ideas from Maupertuis.

Interestingly enough, had Mendel read Maupertuis after he had developed his principles of heredity his analysis of the phenomenon of heredity would have received additional affirmation. Such reinforcement was most forthcoming in Maupertuis' analysis of the Ruhe pedigree.[113] In this family, Maupertuis recorded the appearance of extra digits on the feet and hands of several of its members. He was most disturbed to see that in the second generation, of eight children born to a polydactylous mother and normal father, four were normal and four were affected. This appearance of normal and polydactylous offspring was evident once again in the third generation, resulting from the marriage of a polydactylous father and a normal mother, This time, among six children, four were normal and two were affected. Maupertuis was delighted that the pedigree enforced his belief that both parents were responsible for the formation of the offspring, but he was undeniably disturbed at what appeared to be the gradual disappearance of the anomalous trait. He explained this as the usual effort of Nature to do away with new and unusual forms. Had Mendel seen these data he would have immediately noticed the almost perfect 1:1 ratio, in the second generation, betwen polydactyly and normal offspring, and he would have realized that he was dealing with a dominant trait that was present in heterozygous condition in one of the parents. Maupertuis' analysis would not only have provided Mendel with further confirmation of his laws of heredity, but Mendel would have seen these laws operating in man, as he asserted they should.

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The Historian views the Presumptive Precursor

As speculative as the historian may be in playing the "what - if" game, he must put a careful rein on the freedom he allows himself when interpreting the work of a presumptive precursor. This is especially true when applying the Whig method of investigation to the work of a presumptive class III precursor, because in this kind of analysis, the final decision rests with the historian alone. In following the Whig analysis, I shall seek out the points of similarity between Mendel's laws of heredity and Maupertuis' biological ideas. To determine if these points of similarity are genuine and anticipatory, it will be necessary to discover these factors that were needed by Mendel in his formulation of the laws of heredity and to draw into focus the unspecified assumptions upon which Mendel erected these laws. We will then be in a position to determine if any of Maupertuis' ideas satisfied Mendel's needs. And by examining the assumptions of the nineteenth century scientific milieu of Mendel and the scientific framework of the eighteenth century in which Maupertuis worked, we can assess the boundaries which confined and molded the thoughts of each of them, to see if Maupertuis had at his disposal the conceptual wherewithal to meet the needs of a nineteenth century biologist.

Mendel's Law of Dominance

> ...those traits that pass into hybrid association entirely or almost entirely unchanged, thus themselves representing the traits of the hybrid, are termed dominating, and those that become latent in the association, recessive. The word "recessive" was chosen because the traits so designated recede or disappear entirely in the hybrids, but reappear unchanged in their progeny, as will be demonstrated later.[114]

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The statement of Mendel's law of dominance is clear and straightforward, and one may proceed to make use of the concept without making any further inquiry. But for our purposes, the interesting aspects of the law are the presumptions upon which it is based.

First, the law assumes that the two factors responsible for determining alternate states of the structure occur simultaneously in the diploid (2n) zygote. This presumption, in turn, depends on the accurate description of fertilization which requires the union of a haploid (1n) egg and haploid sperm cell to form the zygote. Mendel's own experiments revealed that the hybrid Aa produced, with equal frequency, germ cells that were pure for A or a.[115] And basic to all this work was the acceptance of the cell theory which asserts that living organisms are composed of cells, each of which must be derived from pre-existing living cells.

Second, it is understood that the two factors interact with each other:

> The distinguishing traits of two plants can, after all, be caused only by differences in the composition and grouping of the elements existing in dynamic interaction in their primordial cells.[116]

The product of this interaction is the phenotype of the structure. As a consequence of this interaction the dominant/recessive relationship is revealed to us.

Third, this dominant/recesive relationship is a constant one, that is, in the same species a recessive trait will always be hidden by the dominant trait whenever the two factors are brought together in the hybrid zygote.

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We have already seen that Maupertuis ascribed the phenomenon of dominance to the arrangement of the particles of the mixed seminal liquors. Dominance was a condition externally impressed upon the particles; it was not a function of the internal activity of the particles. The following passage is most pointed in relating the dominant state to the ordered pattern of particles. In this passage Maupertuis has just been discussing the behavior of particles in species-hybrids, noting how sterility in the hybrid could be the result of particles remaining in a state of equilibrium, not uniting in one way or the other. He then goes on to say:

> On the other hand, there can be such tenacious arrangements (of particles), that from the first generation in which they occur they prevail over all the preceding arrangements, and they eliminate them.[117]

Maupertuis described the arrangement of the particles as a function of the number of parental particles present in the mixed seminal liquor, of the attractive forces between the parental particles and the state of the "memory" of the particles (i.e., clear or confused about their previous positions). Each of these factors could (and did) vary, and the change in any of them could undo what had been the prevailing arrangement. Hence we find that, according to Maupertuis, dominance was not a constant property of one particular trait with respect to its allele (or alternate state); rather dominance was a variable phenomenon that reflected the immediate physical condition of the particles involved in forming a particular structure. Under these circumstances, one could not say that black skin color was dominant to white skin color because should something happen to change the physical para-

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What can we say of Maupertuis' view of the interaction between particles? It is interesting that the only real interaction that Maupertuis' mentions are the attractive forces responsible for bringing the appropriate particles together to form a structure in the new embryo. This point in development was crucial in Mendel's system because at the moment in which the 2n zygote is formed, the two determinants began to function. This was not the case in Maupertuis' system. As soon as the particles were brought together in the newly organized structure, they lost their individuality, giving up to the whole all those properties that characterized the particles as autonomous and free moving. So complete was this absorption that the particles lost all trace of their previous forms:

> It is thus that an army, seen from a certain distance, would look to our eyes like one large animal; it is thus that a swarm of bees, when they have been assembled and united around the branch of a tree, no longer offers to our eyes a body which bears any resemblance to the individuals which have formed it.[119]

Not only did the particles become physically submerged in the larger structure, but they even gave up their very special sense of perception:

> Each element in its union with the others, having merged its perception with theirs, lost the particular sensation of self

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(soi), and with the memory of the early state of the element unavailable to us, our own origin is completely lost to us.[120]

Maupertuis could state that in man (and by analogy in other organized bodies) the perceptions of the individual elements combined to form one very special perception that was stronger and more perfect than any of the elementary perceptions taken singly. So complete was this absorption of the elementary perception to the unique perception, that one could readily compare the loss of the particular soi to the whole, with the merger of the physical form of the particle with the whole organ.[121] Since the particle is lost physically and psychically to the whole organ, it is empty to speak of "interaction between particles".

That Maupertuis could not provide Mendel with the factors needed to develop the Mendelian concept of dominance does not indicate an intellectual incapacity on the part of Maupertuis. Much of the difficulty can be attributed to the fact that the eighteenth century did not possess the Cell Theory. Because of this lack, there was not much effort made to study the contents of the structural units of the organ, nor was there a move to investigate the activities of these units. During the eighteenth century, the naturalists emphasized organs and systems of organs without giving much thought to anything below this level of organization. It is therefore not surprising that Maupertuis did not concentrate on the particles *per se*, but on the process of arrangement that produced the larger organized bodies. After all, Maupertuis' original motivation to study generation was not centered on the structures that were produced, but rather on the (soi), and with the memory of the early state of the element unavailable to us, our own origin is completely lost to us.[120]

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The Law of Segregation

Mendel's careful study of the crosses of two hybrids differing by a single pair of traits allowed him to state categorically that:

> ... of the seeds formed by the hybrids with one pair of differing traits, one half again develop the hybrid form while the other half yield plants that remain constant and receive the dominating and the recessive character in equal shares.[122]

Put into more familiar terminology the law of segregation states that when homogeneous appearing F_1 hybrids are interbred (Aa x Aa) the F_2 progeny do not retain this homogeneous condition. Instead, both parental types reappear, in the ratio of three dominant: 1 recessive. (The genotypic ratio is the 1:2:1 ratio of dominant:hybrid:recessive.)

The law of segregation, at first approximation, seems merely to have given a numerical frequency to a phenomenon that had been observed and commented upon by breeders for many years, namely that the hybrids of the F_1 generation "did not breed true", that their progeny showed a reversion to parental types.

But as we have seen, Mendel's reference to segregation referred not only to the directly observable "separating out" of the parental classes in the F_2 generation, but also to the unseen behavior of the allelic determinants. We know that Mendel recognized fertilization to be "the complete union of elements from both fertilizing cells"[123] to form the new embryo, which he characterized by the use of a double symbol AA, Aa, or aa. Furthermore, we know from his experimental studies of the reproductive cells of hybrids that he was aware that the process that produced them.

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Bentley Glass unhesitatingly asserts that:

> This principle, too, was foreshadowed by Maupertuis. However the particles might previously be combined in each one of the parents, the particles from the two semens, he supposed, would unite separately in accordance with their affinities and since corresponding particles from the mother and the father would be most alike, they would unite two by two and exclude other combinations.[125]

Is this so? Did Maupertuis really anticipate the separation of paired alleles from each other? According to Maupertuis, the seminal liquors contributed by each of the parents contained a sufficient number of particles to form more than one embyro.[126] Indeed, Maupertuis is most definite in his assertion that "the seminal liquor of each kind of animal contains an innumerable number of particles appropriate to form by their assemblage animals of the same species."[127] However, not only does the seminal liquor contain many particles, but the formation of each structure requires a large, but unspecified, number of particles. That just two factors are not responsible for the formation of a body part is made evident by Maupertuis' definition of the monster:

> If some of the particles are too far away from each other, or if they are not appropriately formed, or if the forces of attraction between them are too weak to unite them to each other, then a defective monster (monstre par défaut) is born. But if it happens that too many particles are in

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place... there is formed a monster par excès.[128]

When the seminal liquors of both parents have combined, the particles suitable to form the arms, legs, etc. will be attracted to each other to form the specific structure.[129] If you symbolize the leg particles that are found in the paternal semen as PL_1, PL_2, PL_3 .....PL_n and the maternal leg particles as ML_1, ML_2, ML_3, ...ML_n, the formation of the leg in the embryo will involve the attraction of the particles in the following manner: PL_1 will attract ML_1, PL_2 will attract ML_2, etc. until as many particles have combined to form the leg as are necessary. Glass says that the separation of particles PL_1, PL_2, etc. from the remaining pool of paternal leg particles constitutes the same kind of separation that Mendel referred to in the segregation of the paired alleles from each other. But let us examine the descriptions given of these separations. If Mendel's definition of separation of alleles were applied to Maupertuis' model, PL_1 should separate from some other paternal leg particle, call it PL_a, PL_2 would separate from PL_b, etc. until the required number of paternal leg particles have left it to form the embryo leg. The important point is that one particular paternal leg particle is deliberately pulled away from some other paternal leg particle. But is that what is happening? Not at all. According to Maupertuis, the paternal leg particles are being separated from the remaining pool of paternal leg particles, not by mutual repulsion between the paternal leg particles, but rather by the attraction of one maternal leg particle ML_1 for the paternal leg particle PL_1.

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Maupertuis' model of segregation of particles is based on the mutual attraction between many maternal and paternal particles, coming together to form the embryonic structure. Mendel's law of segregation depends upon the mutual repulsion of the two alleles to form the reproductive cells.

Chance and its Function in the Mendelian System and in Maupertuis Model of Generation

Mendel structured his system of heredity on two fundamental concepts: each trait was the product of a pair of dterminants; which two allelic determinants would be brought together in any particular cell was a matter of chance. In this section we shall concetrate on the importance of chance in the phenomena of heredity.

The role of chance was quite evident to Mendel; "it is entirely a matter of chance which of the two kinds of pollen (from a hybrid plant Aa) combines with each single germinal cell."[130] For Mendel to have said that the union of germ cells was a function of chance was to have made a statement of enormous significance. It acknowledged that chance, so often depicted as a blind or unpredictable force, was behaving in a regular, uniform, predictable manner. But more than saying that chance could be tamed and made subject to regulatory laws, Mendel was making a very basic statement about the nature of his system. He was in effect stating that chance was inherent in the mechanism of heredity; that however much you know of the process of fertilization and the formation of the embryo, this will not change the fact that the union of a single egg and a single sperm cell is a product of chance. We cannot know in advance which particular egg will be fertilized by which particular sperm to produce an individual

of a particular constitution. However, in a large, breeding population of Aa hybrids, one could show that certain classes of progeny appear with stable, regular frequencies and in the long run, you could predict how many individuals of each class could be expected from the inbreeding of hybrids.

The following passage from Mendel's paper deserves to be quoted in full because it gives a startlingly clear picture of a statistically based natural system and of Mendel's own deep understanding of this statistically based system:

> This (the 1:2:1 ratio of AA:Aa:aa offsping) represents the average course of self-fertilization of hybrids when two differing traits are associated in them. In individual flowers and individual plants, however, the ratio in which the members of the series are formed may be subject to not insignificant deviations. Aside from the fact that the numbers in which both kinds of germinal cells occur in the ovary can be considered equal only on the average, it remains purely a matter of chance which of the two kinds of pollen fertilizes each individual germinal cell. Therefore, isolated values must necessarily be subject to fluctuations, and even extreme cases are possible, as mentioned earlier in experiments on seed shape and albumen coloration. The true ratios can be given only by the mean calculated from the sum of as many separate values as possible; the larger their number the more likely it is that mere chance effects will be eliminated.[131]

Several factors ought to be carefully noted, namely: Mendel's use of average values, rather than trusting to isolated values; his awareness of the occurrence of deviations caused by chance; his recognition that these fluctuations could be eliminated by making many observations; his knowing that by eliminating (or reducing) chance fluctuations, the true ratios of expected classes could be obtained. All of these factors are important features of a kind of probability which has been termed aleatory. Aleatory probability is applicable

to those systems that depend on the "objective existence of certain regularities that are characteristic of the systems, regularities which imply that the long run or average behavior in a large aggregate of objects of events is approximately independent of the precise details that determine exactly what will happen in each individual case."[132]

The view that there are natural systems that ought to be described by statistical rather than causal laws was just beginning to be understood by physicists in the second half of the nineteenth century (just when Mendel was studying mathematics and physics at the university of Vienna). For physicists of the first half of the nineteenth century, such as Maxwell, the theory of probability and statistical analysis were merely tools to use in observing whole populations, because observations on individual members of the population were impossible to make (e.g., in the study of gas molecules). However, during the second half of the nineteenth century the outlook changed dramatically. No longer was probability theory an expedient means of obtaining information in otherwise difficult circumstances, "on the contrary, statistical analysis and the theory of probability supplied the rules for the logic of the whole world. Large numbers are studied not so much because it is impossible to investigate the individual units, but mainly because their behavior is of no interest at all."[133]

The reason for the lack of interest in the behavior of individual units was a consequence of a changed view of the natural world:

> Is it not possible that in many instances what nature and experience show us is only the average itself -- our senses and our intellect being too coarse to penetrate to the

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> Is it not possible that in many instances what nature and experience show us is only the average itself -- our senses and our intellect being too coarse to penetrate to the

> numberless individual cases out of which the sum or the average is made up? May not even the simplest phenomenon or thing in nature be in fact an aggregate, a total, and its apparent behavior and properties merely a collective effect?[134]

This conception of the natural world, as one in which only average values have meaning because our senses are too coarse to perceive single events, was a novel consideration of the nineteenth century.[135] Indeed, this is a far cry from the Newtonian view of physics which was based on a rigid determinism.[136]

One might venture to say that the word that best describes the eighteenth century view of the natural world is deterministic. Nothing just happened; all things were part of a chain of cause and effect:

> All events, even those which on account of their insignificance do not seem to follow the great laws of nature, are a result of it just as necessarily as the revolutions of the sun. In ignornace of the ties which unite such events to the entire system of the universe, they have been made to depend upon final causes or upon hazard, according as they occur and are repeated with regularity, or appear without regard to order; but these imaginary causes have gradually receded with the widening bounds of knowledge and dissapear entirely before sound philosophy, whic sees them only as expressions of our ignorance of the true causes.[137]

Given such a philosophical perspective, there was really no roon (or need) for chance as an operative agent. And though events did seem to happen "fortuitiously", "inexplicably", and "unpredictably", chance was just not acceptable as a reasonable explanation. It was generally held that: "When we say that something happens by chance, we reall, mean that the cause is unknown to us, not, as some people inopportunely imagine, that chance itself can be the cause of something."[138]

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Thus an eighteenth century scholar found himself having to resort to chance in describing the occurrence of an event, there was an implied understanding that this was merely a temporary state, sequential to our ignorance. There was always the promise (even if it were a promise destined to be fulfilled in the distant future) that eventually we would gather all the information needed to convert our state of ignorance to one of knowledge and hence cast our chance and substitute it by the "real" cause. And for the avowed pessimists who believed that man might never be intelligent enough to ever know all that had to be known to explain an event deterministically, there was offered the sop that even if man himself could not attain to such an intellectual capacity, in time there could be another intelligence

> which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it -- an intelligence sufficiently vast to submit these data to analysis -- it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes.[139]

But the fact remained that man, as yet, did not have the knowledge to fully explain many natural phenomena.

> Strictly speaking it may even be said that nearly all our knowledge is problematical; and in the small number of things which we are able to know with certainty, even in the mathematical sciences themselves, the principal mans for ascertaining truth -- induction and analogy -- are based on probabilities... [140]

The interpretation of probability in the eighteenth century was a subjective probability. As we have seen, the eighteenth century savant believed that our limited knowledge allowed us to make only incomplete analyses of an event. Because we did not know all of the factors involved, at best our explanatory statements were probability to chance in describing the occurrence of an event, there was an implied understanding that this was merely a temporary stance, sequential to our ignorance. There was always the promise (even if it were a promise destined to be fulfilled in the distant future) that eventually we would gather all the information needed to convert our state of ignorance to one of knowledge and hence cast out chance and substitute it by the "real" cause. And for the avowed pessimist who believed that man might never be intelligent enough to ever know all that had to be known to explain an event deterministically, there was offered the sop that even if man himself could not attain to such an intellectual capacity, in time there could be another intelligence

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The world for Maupertuis was a deterministic one. It will be recalled that at the core of Maupertuis' physics was the principle of least action, a principle that openly acknowledged that the movements of the particles of the universe were already predetermined or known by the particles. Thus, there was no random movement of the particles, rather each moved in a path that required the least amount of action. Similarly, the particles of the seminal liquors did not just scatter haphazardly. Primed by the principle of intelligence, each particle was directed by its specific memory to its appropriate position in the developing embryo.

Maupertuis referred to chance in several of his works, describing it as "blind fate" which produced all the species of animals, of which only a small number were able to survive;[142] attributing to chance the appearance of a new assemblage of particles.[143] Maupertuis associated chance with the unexpected and the arbitrary, not with phenomena that occurred regularly, such as the resemblance of offspring to their parents.[144] As a matter of fact, the only time that Maupertuis did use statements representing this incomplete degree of knowledge. This kind of probability is called "epistemic probability." It is not concerned with existing stable frequencies and average values; that is the domain of aleatory probability. Rather epistemic probability seeks to measure the degree of certainty of a statement, its degree of believability. It is a probability that describes "how likely we think a given inference or conclusion drawn on the basis of incomplete knowledge may be."[181] It is this form of epistemic (or subjective) probability that Maupertuis wrote about.

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According to Glass, this application of mathematics to genetic investigation is like Mendel's. He calls it

> ...the first application of one of the most important of the principles of the mathematics of probability, that of the probability of coincidence of independent items, to genetics. It was this very principle that Mendel applied so effectively in his analysis of segregation, random recombination, and independent assortment.[146]

There is, I believe, a serious rupture here between what Maupertuis wrote and the implication that Glass asks us to derive from the passage. Maupertuis and Mendel did use the same principle, that of multiplying independent probabilities. But the implication that Glass wants us to draw is that Maupertuis and Mendel used the same principle for the same purpose. Actually, Mendel applied the principle in order to obtain an aleatory probability statement.[147] Maupertuis probability calculus was to demonstrate that chance was not operating. This calculation occurred in Lettre XIV, Sur la generation des animaux (1752), in which Maupertuis recorded his investigation of the appearance of polydactyly in the Ruhe family of Berlin.[144] The Ruhe family pedigree revealed that polydactyly had appeared in three consecutive generations. The question that Maupertuis posed was this: What was the probability that chance was not involved in the repeated appearance of the trait for these three generations? From his research, he could assert that polydactylous individuals appeared by chance in one out of 20,000 to 1. The probability that a polydactylous child will not appear by chance in two consecutive generations is $(20,000:1)^2$ or 400000000 to 1. The probability that an affected child will not appear in three consecutive generations is $(20,000:1)^3$ or 8000000000000 to 1.

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> the probability that this singularity will not continue for three successive generations would be 8000000000000 to 1; a number so great that the certitude of the best demonstrated things of physics does not approach to these probabilities.[148]

In other words, Maupertuis could state with almost complete certainty that chance was not operating to produce polydactyly.

Once again, one cannot blame Maupertuis for viewing probability in this epistemic fashion. That was the way the eighteenth century examined probability. It was only in the nineteenth century that an aleatory view was developed.

In summary then, Mendel regards chance as an integral part of the biological system and he uses aleatory probability to describe the behavior of the unit factors as they obey the laws of chance. Maupertuis on the other hand denies chance any role in the study of heredity. For him, the probability calculus provides us with a way of determining the degree of certitude that can be attributed to a conclusion.

* * *

Although there are several points of similarity between Maupertuis and Mendel, it has become obvious that the similarities are few and superficial, whereas the differences are many and vital. I would like to note one more difference, which while not pertaining specifically to the question of the anticipatory nature of Maupertuis' work, nevertheused the principle for an opposite purpose, to determine with what degree of certainty he could assert that chance was not operating to produce polydactylous offspring in three successive generations. Maupertuis had concluded that

> the probability that this singularity will not continue for three successive generations would be 5200000000000 to 1; a number so great that the certitude of the best demonstrated things of physics does not approach to these probabilities.[158]

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less indicates a very basic difference between Maupertuis and Mendel and the kind of model each offers to us.

Maupertuis had been primarily concerned with establishing the point that both parents contributed to the formation of the embryo. With this in mind, he developed a model which demonstrated how seminal contributions of both parents produced the new embryo. At the same time, this model could explain why it was that offspring resembled their parents and, consequently, why species remained constant. But, in order to explain other interesting phenomena of generation, such as the formation of monsters, atavism, or the sterility of hybrids, Maupertuis' model could suffice only if, in some way, it was made to function irregularly. The normal operations of the model could not explain all of the phenomena of generation.

Mendel, however, provided us with a formal mechanism capable of explaining all the aspects of heredity that he was interested in, such as the apparent homogeneity of the F_1 generation, the "reversion" to parental type in the F_2 generation, the complexity of the inheritance of color, the "transformation" of one species into another. Each of these problems had plagued breeders and hybridists for generations, and each of these questions was simply and easily answered through the "normal" functioning of his mechanism. Moreover, phenomena observed by geneticists fifty years later were easily explained by this same system, such as the linkage between traits, the inheritance of sex, the evolution of species. And despite the change of emphasis of genetics, away from the formal to the chemical functioning of genetic entities, in the last analysis, the Mendelian groundwork remains un-have indicated a very basic difference between Maupertuis and Mendel and the kind of model each offers to us.

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Conclusion

I believe that we are now in a position to recognize that the question "Was Maupertuis a precursor of Mendel?" is not a mere matter of identification, nor is it a simple question. As a question, it generates certain basic questions about the nature of the precursor. We need to know if Maupertuis was an active or passive precursor? did he have a following or not? As a matter of identification, it involves not only the designation of the precursor, but also a recognition of the relationship between the precursor and his predicate since it is the predicate who, in effect, creates the position of precursor. Therefore, while we seek to know the identity of the precursor, we must also identify the predicate. If we can assign the presumptive precursor to one of the three categories defining the precursor-predicate relationship, we can effectively answer all of these questions. Therefore, if we want to know if Maupertuis was a precursor of Mendel, we must first properly locate Maupertuis in one of these categories.

The first category applies to those precursors who are active contributors to a field and whose work is (or has been) used in the development of ideas, concepts or models in the field. In other words, the active precursor has an active follower. In this particular category of precursor, the active predicate can be either the scientist who makes direct use of the contributed information in the expansion of his particular field, or the historian who makes use of the contributed information in his study of the origins, growth and

development of a particular field.

Whereas Maupertuis was an active contributor to the study of generation, his ideas were not picked up by any subsequent students of generation. As a matter of fact, few people made any reference to Maupertuis in any of his areas of endeavor. Therefore, we could not assign Maupertuis to category I.

The second category refers to those precursors who have not intentionally sought to provide ideas or data to an area of science. They are the passive precursors whose work has been transplanted from the original area of research to another field by later researchers. Thus the passive precursor could find himself an unexpected forerunner of a concept or model about which he had given no thought, possibly in an area far afield from his own. In this category, the predicate takes the initiative because it is his use of the information that establishes the precursor as precursor. Generally the active predicate of the second category is the scientist, rather than the historian. Clearly, Maupertuis does not fit into category II.

The third group of precursors is composed of those individuals who did make active contributions to a discipline, but who had no following. Whatever ideas or information they could have offered was neglected and forgotten, so that a whole area of research developed without the help of such precursors. Yet, these individuals may have anticipated future theories and concepts, and properly might be called forerunners. The relationship between the precursor and predicate of this third category is rather special. There is no scientific predicate; no investigator had sought to make use of this earlier work.

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Scientists of a much later period would scarcely be concerned with seeking out and evaluating these past works because, by and large, such works were out of date (or possibly erroneous) and hence of no practical use to the modern researcher. The historian however is the active predicate in category III. It is his purpose to cull and bring to light all kinds of past scientific work, whether it be outdated or erroneous. The precursor of this third category is therefore largely dependent on the historian's analysis of this past work, an analysis which seeks to determine if the presumed precursor did foreshadow and influence later developments.

If Maupertuis were a precursor, the third category would be the most appropriate group in which to place him. And the determination of Maupertuis' status as a precursor would rest solely on the historian's interpretation of Maupertuis' work. Since the historian does have free rein, he might attempt to surmise the ways in which Mendel, as a scientific predicate, could have made use of the precursor's work, had it been available. As we have seen, from Mendel's point of view, Maupertuis could have provided him with tantalizing insights into the concept of recessivity, and even have offered some methodological direction. Thus, in answer to the question "Was Maupertuis a precursor to Mendel?", one could answer: Yes, from Mendel's perspective, Maupertuis could have been a precursor. But the question is really one that must be treated by the historian from the perspective of the historian. It has been suggested that the historian ought to make use of the Whig interpretation of history in the analysis of the presumptive precursor because this is one time when the best

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When we apply this method, and its restrictions, to the work of Maupertuis, it becomes evident that the historian would have to answer that: No, Maupertuis was not a precursor to Mendel. The lack of the cell theory in the eighteenth century and the concomitant emphasis on organs, and organ systems prevented Maupertuis from even contemplating the Mendelian concept of dominance and the law of segregation. The belief in a deterministic universe caused Maupertuis to deny the operation of chance as part of the elemental processes of Nature. Maupertuis could not be a precursor to Mendel because he was bound by the body of information of his time, by the theological tenets of his time, by the unmentioned but influential philosophical and intellectual postulates of his time.

But, Maupertuis can not be dismissed too lightly. As I have said, to the scientist he could have been inspirational; to the historian of science he still provides a panoramic view of an exciting and scientifically bountiful era. An appropriate epitaph to approach is the one which deliberately allows the present to obtrude on the past. In the analysis of Maupertuis as a possible precursor to Mendel, it is logical to start with the Mendelian principles of heredity, determine what factors are necessary for the construction of these principles and then examine Maupertuis' work to see if his ideas really did supply any of these factors. The use of this this approach must be tempered by one important injunction, which is that the work of the presumptive precursor be interpreted in context, i.e., according to the philosophical-scientific-intellectual framework of the precursor's own time.

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Maupertuis is this passage from Diderot's Pensées sur l'Interpretation de la Nature:

> Happy is the systematic philosopher to whom nature will have given, as in other times to Epicurus, Lucretius, Aristotle and Plato, a strong imagination, a grand eloquence, the art of presenting his ideas through striking and sublime images! The edifice that he has constructed will fall one day; but his statue will remain standing in the middle of the ruins... .[149]

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NOTES

1. Michel Foucault, The Order of Things (a translation of Les Mots et et les Choses), (New York, Vintage Books edition, Sept. 1973), p. 158. An example of "broad theoretical options" would be the kinds of systems of generation available in the eighteenth century to a person who wished to present a theory and still be understood by his contemporaries working in the same field. In the eighteenth century, Maupertuis' options would have allowed him to choose between preformation, epigenesis and pangenesis.

2. Peter Bowler, "Evolutionism in the Enlightenmen", History of Science, vol. 12, part 3, no. 17, Sept. 1974, p. 174. With specific reference to Maupertuis, these assumptions would be the ones that were basic to his idea of the nature of matter, to the concept of life (the material of chapter two), the role of divine power in nature (discussed in chapter three) and the occurrence of events by chance.

3. An excellent listing of the various papers dealing with generation in the eighteenth century can be found in the bibliography offered in Jacques Roger's Les Sciences de la vie dans la pensée francaise du du XVIII^e siècle (Paris, Colin, 1971), 785-803.

4. Some helpful discussions about generation, the theories that had been formulated and the information available at different periods in the history of generation can be found in the following works:

Hans Stubbe, History of Genetics, from the prehistoric times to the rediscovery of Mendel's Laws (translated by T.R.W. Waters),

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Anthony Preus, "Galen's Criticism of Aristitle's Conception Theory", Journal of the History of Biology, vol. 10, no. 1, Spring 1977, 65-85.

Conway Zirkle, "The inheritance of acquired characters and the provisional hypothesis of pangenesis", American Naturalist, vol LXIX, no. 6, 529-546.

Conway Zirkle, "The early history of the idea of the inheritance of acquired characters and of pangenesis", Transactions of the American Philosophilcal Society (Philadelphia, New Series, 1946), XXXIV.

C. F. Mayer, "Genesis of Genetics", Acta Geneticae et Gemellologiae, vol. 11, no. 3, 237-332.

5. The New Oxford Annotated Bible, Genesis 1, verses 24, 25.

6. This statement from Hippocrates was cited by Zirkle, American Naturalist, op. cit., p. 430.

7. Stubbe, op. cit., p. 66.

Even though the doctrine of pangenesis provided an explanation for the resemblance of offspring to parents, and the general phenomenon of the constancy of species, it apparently was not able to convince all of the naturalists in various periods. It was to receive its greatest challenge, in the seventeenth and eighteenth centuries, from the doctrine of preformation which not only explained the constancy of species but also provided the reason for the apparent observation of preformed parts in as yet unfertilized or newly fertilized eggs and justification for the punishment of all mankind for the

(Cambridge, M.I.T. Press, 1972);

Anthony Preus, "Galen's Criticism of Aristotle's Conception Theory", *Journal of the History of Biology*, vol. 10, no. 1, Spring 1977, 65-85.

Conway Zirkle, "The inheritance of acquired characters and the provisional hypothesis of pangenesis", *American Naturalist*, vol LXIX, no. 6, 417-446.

Conway Zirkle, "The early history of the idea of the inheritance of acquired characters and of pangenesis", *Transactions of the American Philosophical Society* (Philadelphia, New Series, 1946), XXXIV.

C. F. Meyer, "Genesis of Genetics", *Acta Geneticae et Gemellologiae*, vol. 11, no. 3, 237-302.

5. *The New Oxford Annotated Bible*, Genesis 1, verses 24, 25.

6. This statement from Hippocrates was cited by Zirkle, *American Naturalist*, op. cit., p. 420.

7. Stubbe, op. cit., p. 66.

Even though the doctrine of pangenesis provided an explanation for the resemblance of offspring to parents, and the general phenomenon of the constancy of species, it apparently was not able to convince all of the naturalists in various periods. It was to receive its greatest challenge, in the seventeenth and eighteenth centuries, from the doctrine of preformation which not only explained the constancy of species but also provided the reason for the apparent observation of preformed parts in as yet unfertilized or newly fertilized eggs and justification for the punishment of all mankind for the original sin of Adam and Eve.

8. Zirkle, American Naturalist, p. 430.

9. Two lively and informative books dealing with the history of theories of monsters, both mythical and real, are:

Teratogenesis: An inquiry into the causes of monstrosities, by J. W. Ballantyne (Edinburgh, Olive and Boyd, 1897).

The Mystery and Lore of Monsters, by Charles J. S. Thompson (New York, University Books, 1968).

10. Maupertuis, Oeuvres, vol. II, Vénus physique, p. 115.

11. Ibid., p. 117.

12. Ibid.

13. Ibid., p. 5. The Vénus physique was a delightful work written to popularize the work that was being done in generation. It enjoyed great popularity in the various salons of Paris, although it did tend to raise some eyebrows because of the openness of Maupertuis on the subject of reproduction.

14. Ibid., p. 93.

15. Ibid., p. 68.

16. Ibid., p. 70.

17. Ibid., p. 81.

18. Maupertuis' arguments for and against the role of the egg are given in chapter VI of the Vénus physique, pp. 32-35.

19. Maupertuis' discussion of Harvey's experiments are given in chapter VII, pp. 36-44.

20. A detailed discussion of the transmission of this trait is given by Maupertuis in the Système de la Nature, vol. II, p. 160, and in his

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14. Ibid., p. 95.

15. Ibid., p. 60.

16. Ibid., p. 70.

17. Ibid., p. 51.

18. Maupertuis' arguments for and against the role of the egg are given in chapter VI of the Vénus physique, pp. 22-26.

19. Maupertuis' discussion of Harvey's experiments are given in chapter VII, pp. 26-34.

20. A detailed discussion of the transmission of this trait is given by Maupertuis in the Système de la Nature, vol. II, p. 160, and in the

Lettre XIV Sur la génération des animaux, vol. II, 307-308.

21. Maupertuis, vol. II, Lettre XIV, p. 308.

22. Ibid., p. 11.

23. Ibid., p. 120.

24. Vol. II, Vénus physique, p. 85; Système de la Nature, p. 144.

25. Maupertuis, Vénus physique, vol. II, p. 87.

26. Ibid., p. 88, 89.

27. Ibid., p. 89.

28. Ibid., p. 90.

29. If one had read only the biological works of Maupertuis, namely the Vénus physique (1745) and the Système de la Nature (1751), one would be tempted to say that between 1745 and 1751 Maupertuis underwent a religious crisis. This would explain the complete naturalism of the Vénus physique and the heavy emphasis on God's role in nature in the Système de la Nature. However, I believe that Maupertuis always had theological inclinations which often intruded into his scientific work. In his paper Sur les loix de l'attraction, read before the Paris Academy of Science in 1732, Maupertuis concluded that the inverse relationship between distance and the force of gravity as expressed in the law is what it is, because God chose to have it so. The law was an expression of God's absolute freedom of choice. In 1744, in the Accord des Loix, also read before the Paris Academy, Maupertuis publicly proclaimed his principle of least action a teleological principle meant to harmonize the various laws of motion. Even though the Essai de Cosmologie (his attempt to prove the existence of God by demonstration of God's wisdom and power as revealed in the univer-

Lettre XIV Sur la génération des animaux, vol. II, 207-208.

21. Maupertuis, vol. II, Lettre XIV, p. 208.

22. Ibid., p. 11.

23. Ibid., p. 120.

24. Vol. II, *Vénus physique*, p. 83; *Système de la Nature*, p. 144.

25. Maupertuis, *Vénus physique*, vol. II, p. 47.

26. Ibid., p. 88, 89.

27. Ibid., p. 89.

28. Ibid., p. 90.

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sal principles that regulate nature) was published in 1750, it had existed in manuscript form as early as 1740 because in a letter written by Voltaire to Maupertuis, dated August 10, 1741, Voltaire spoke of having just read the manuscript of the Essai that Maupertuis had sent to him. Therefore, I believe that it may be more accurate to say that after 1745 something happened to Maupertuis which intensified his theological feelings but was not responsible for causing them.

30. Système de la Nature, p. 140, III; p. 141, IV.

31. Ibid., p. 146, XIV.

32. Ibid., p. 149, XVIII.

33. Ibid., p. 153, XXIV.

34. Ibid., p. 154, XXVI.

35. Ibid., p. 155, XXVIII.

36. Ibid., p. 157, XXXI.

In asserting that matter should be endowed with perception, Maupertuis seems to be following in the footsteps of Leibniz who asserted in his Monadology that the basic units of the universe were autonomous, metaphysical units, the monads, which manifested the properties of force and perception. Maupertuis addressed himself directly to the issue of the monads in his Lettre VII Sur les systèmes, vol. II, 257-261. His aversion to the system of monads stemmed primarily from two points. Leibniz insisted on retaining a complete separation between matter and mind. To explain the apparent connection between the movements of a body and the perceptions of the mind, Leibniz postulated the existence of a preestablished harmony which accounted for the nal principles that regulate nature) was published in 1750, it had existed in manuscript form as early as 1740 because in a letter written by Voltaire to Maupertuis, dated August 10, 1741, Voltaire spoke of having just read the manuscript of the Essai that Maupertuis had sent to him. Therefore, I believe that it may be more accurate to say that after 1745 something happened to Maupertuis which intensified his theological feelings but was not responsible for causing them.

30. Système de la Nature, p. 140, XIII; p. 143, XV.

31. Ibid., p. 144, XVI.

32. Ibid., p. 145, XVIII.

33. Ibid., p. 153, XXIV.

34. Ibid., p. 156, XXVI.

35. Ibid., p. 155, XXVIII.

36. Ibid., p. 157, XXXI.

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37. Ibid., p. 158, XXXIII.

38. Ibid., p. 159, XXXIV.

39. Ibid., p. 159, XXXV, XXXVI.

40. Ibid., p. 161, XXXVIII.

41. Ibid., p. 157, XXXI.

42. Système de la Nature. p. 161, XXXIV.

43. Ibid., p. 161, XL.

44. Vénus physique, p. 121.

45. One could argue that memory was a part of the composition of the particle. Granted, the memory was inherent, but its activities were not. Its functions were concentrated outside the particle. Its purpose was to guide the element to its appropriate position in the external arrangement of the particle. Nowehere is there given much attention to what goes on within the particle -- its orientation is always directed beyond its boundaries.

46. Système de la Nature, p. 162, XLI.

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42. _Système de la Nature_, p. 161, XXXIX.

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46. _Système de la Nature_, p. 162, XLI.

47. Vénus physique, p. 121.

48. Système de la Nature, p. 162, XLI.

49. Vénus physique, p. 122.

50. It would hardly seem likely that Maupertuis, a staunch defender of Genesis, would act in defiance of the concept of the fixity of species, which interprets God's act of Creation as the first and only occasion for new forms to be produced. Therefore, why did Maupertuis defy this concept? I can only opine that great as his devotion was to God and religious dogma, so was his belief in his own observations of nature; and these observations indicated that change had occurred in species. At no time does he deal with the contradiction between Genesis and his own speculations.

51. Vénus physique, p. 118.

52. Ibid., p. 110.

53. Ibid.

54. Système de la Nature, p. 164, XLIV.

55. Ibid., XLV.

56. Vénus physique, p. 124.

57. Ibid., p. 123.

58. Système de la Nature, p. 164, XLV.
Possibly the reason for this change in attitude, i.e., his willingness to accept the permanent quality of the new species, can be attributed to Maupertuis' greater awareness of variation in Nature. In 1745 he had just begun his work in natural history; by 1751 he had probably made more lobservations, experimented more (he did dabble in breeding experiments of his own, see Lettre XIV), read more -- and from this

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51. Vénus physique, p. 118.

52. Ibid., p. 120.

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54. Système de la Nature, p. 164, XLIV.

55. Ibid., XLV.

56. Vénus physique, p. 124.

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59. Vénus physique, p. 119.

60. Ibid., p. 118.

61. Système de la Nature, p. 160.

62. The belief that a new species can be established in just one step is known as saltation. Maupertuis need not have felt foolish in taking such a position. Over one hundred fifty years later, De Vries, one of the rediscoverers of the Mendelian laws of heredity, remained steadfast in his belief in saltation.

63. Anne Fagot, "Le Transformisme de Maupertuis", Actes de la Journée Maupertuis (Paris Librarie Philosophique, J. Vrin, 1975).

64. Ibid., p. 167.

65. It is impossible for us to know what was in Maupertuis' mind when he wrote these next passages, all of them taken from the Système de la Nature. They are open to various interpretations, but I would like to suggest one that seems to imply that Maupertuis did have an idea about evolution. In paragraph XLV (p. 164) of the Système, Maupertuis stated that new species arose through changes in the arrangement of the elementary particles, so that the parental patterns or organization were no longer followed. Moreover, Maupertuis noted that "each degree of error would make a new species: and by means of repeated deviations have come the infinite diversity of animals that we see today." Now, Maupertuis did not say if the digressions occurred only in the original stock, so that all of the new species would be

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59. Vénus physique, p. 119.

60. Ibid., p. 115.

61. Système de la Nature, p. 170.

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derivatives of it; or if deviations occurred in the original stock and in the new stocks. If this latter were the case, then instead of each species differing from the original species by a single deviation, it would be possible to have an accumulation of errors in the new species. Thus starting from the parental stock "A", a new stock A_1 could arise. A_1 could itself produce a deviant A_{12}, which in turn could produce a new species A_{123}. This interpretation allows for the accumulation of deviations, and there ensues an increasing degree of divergence between the original species A and the most recent species A_{123}. It may well be that even though A and A_{123} are different species, they retain a sufficient similarity between particle arrangements that the mixing of the particles in a cross between the two species could still result in the formation of a viable embryo which is a hybrid between the two species. Let us consider the following passage of Maupertuis' in this light:

> If the elements are derived from animals of different species, but there still reamins sufficient rapport between these elements... the elements will form hybrid animals. (p. 161, XXXVIII)

But it is possible that the accumulation of deviations has become so great that there is no longer any rapport between particles of either species. Under these circumstances there can be no progeny formed; reproduction is impossible and species A_{123} could, with respect to species A, be a completely different species, now called B. Because there is no possibility of crossing the two species, A and B are now isolated from each other. Consider this next passage of Maupertuis with this point in mind:

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> Lastly, if the elements are derived from animals which no longer have sufficient similarity between them, the elements are either not able to assume the suitable arrangement or cannot maintain a suitable arrangement. Generation becomes impossible. (P. 161, XXXIX)

66. Charles Darwin, The Origin of Species (New York, Mentor edition, 1958), p. 17.

67. Vénus physique, p. 123.

68. Ibid., p. 130.

69. Système de la Nature, p. 184.

70. Robert E. Kohler, "The History of Biochemistry: A Survey", Journal of the History of Biology, vol. 8, no. 2, Fall, 1975, p. 279.

71. Scott Gilbert, "The Embryological Origins of the Gene Theory", Journal of the History of Biology, vol. 11, no. 2, Fall 1978, p. 309.

72. Gärtner's work Versuche und Beobachtungen über die Bastardenzeugung in Pflanzenreich, is cited in the paper of Elizabeth Gasking, "Why was Mendel's work ignored?", Journal of the History of Ideas, vol. XX, no. 1, Jan. 1959, 60-84.

73. Mendel's paper, which was first read at the meetings of the local Scientific Society of Brunn, in 1865, was published in Verhandlungen des naturforschenden Vereines in April 1865, pp. 3-47.

74. Gregor Mendel, "Experiments on Plant Hybrids" (translated from Versuche über Pflanzen-Hybriden), The Origin of Genetics: A Mendel Source Book, edited by Curt Stern and Eva R. Sherwood (San Francisco, Freeman and Co., 1966), p. 1.

75. Ibid., p. 2.

76. Ibid., p. 3.

77. Ibid.

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75. Ibid., p. 2.

76. Ibid., p. 3.

77. Ibid.

78. Ibid., p. 6.

79. Zirkle, in his paper "Gregor Mendel and his Precursors", <u>Isis</u>, vol. 42, part 2., no. 128, June 1951, suggests that Mendel may have arrived at some of his theoretical conclusions about heredity as a result of his work with bees. Zirkle reports that Iltis, the authoritative biographer of Mendel, noted that Mendel did work with bees, not so much to obtain their honey, but to study the effects of crossing alien races of bees with native ones. (P. 102).

The belief that Mendel did know the answers to his questions on hybrid formation before undertaking his series of experiments was investigated by two biostatisticians, R. A. Fisher, in his paper, "Has Mendel's Work been rediscovered?", in the <u>Origins of Genetics</u> (op. cit.) pp. 139-172, and Sewell Wright in his paper, "Mendel's Ratios", <u>Origin of Gneetics</u>, pp. 173-175. Both of them have examined Mendel's data and the fit of the data to his theory. In both investigations, it was obvious that the data were closer to theoretical predictions than would have been expected; in other words, the fit of the data was too good. Fisher calculated that the probability of having data fit the appropriate ratios as well as they did, could only occur once in 2,000 times. Fisher states:

> it is very clear, from the form his experiments took, that he knew very surely what to expect, and designed them as a demonstration for others rather than for his own enlightenment. (p. 165).

80. Mendel, op. cit., p. 9.

81. The application of mathematics to data was not generally undertaken by natural historians. Many of these early biologists evaluated

their material through verbal description and often, in these early days, that was the only feasible way to handle the information. But, Mendel was not just the run-of-the-mill breeder/hybrid ·er. His training was in physics and mathematics and he did carry over into his experi·ental work the attitudes and perspective of the physicist and mathematician. The use of abstract statements and general formulae were not alien to him; and he was sufficiently sensitized by his mathematical and physical background to make use of mathematical analyses wherever possible.

82. Mendel, op. cit., p. 11. The full discussion of the results of his F_2 crosses, which encompassed hybrids for each of the seven traits, appears on pp. 10-15.

83. Ibid., p. 10.

84. Ibid., p. 16.

85. Ibid., p. 20.

86. Ibid., p. 22.

87. Mendel's experiments on the composition and frequency of dihybrid gametes are described on pp. 23-27.

88. Mendel, op. cit., p. 27.

89. Ibid.

90. Fisher, Origins of Genetics, op. cit., p. 150.

91. Mendel, op. cit., p. 15.

92. Ibid., p. 22.

93. Ibid., p. 32.

94. Ibid., p. 35.

95. Ibid., p. 43.

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90. Fisher, Origins of Genetics, op. cit., p. 120.

91. Mendel, op. cit., p. 15.

92. Ibid., p. 22.

93. Ibid., p. 32.

94. Ibid., p. 33.

95. Ibid., p. 43.

96. Ibid., p. 38.

97. Ibid., p. 39.

98. Ibid., p. 24.

99. This array of dihybrid gametes accounts not only for the constant types, but also for all the classes produced:

Both the male and female dihybrid gametes are the same and can be represented on a table as follows:

♂ gametes:		AB	Ab	aB	ab
♀ gametes:	AB	AABB	AABb	AaBB	AaBb
	Ab	AABb	AAbb	AaBb	Aabb
	aB	AaBB	AaBb	aaBB	aaBb
	ab	AaBb	Aabb	aaBb	aabb

Mendel saw and counted individuals with these various compositions (p. 19). The line that interests us most is the left to right diagonal, constituting, as it does, the row of constant forms produced by the union of like gametes.

100. Mendel, op. cit., p. 24.

101. Ibid., p. 29.

102. Ibid., p. 41.

103. Ibid., p. 29.

104. Ibid., p. 31.

105. Ibid., p. 2.

106. Curt Stern, Origin of Genetics, op. cit., p. V.

107. Mendel, op. cit., p. 41.

108. Maupertuis, vol. II, Système de la nature, p. 169, XLIX.

96. Ibid., p. 58.

97. Ibid., p. 39.

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aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb

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100. Mendel, op. cit., p. 26.

101. Ibid., p. 29.

102. Ibid., p. 41.

103. Ibid., p. 29.

104. Ibid., p. 31.

105. Ibid., p. 2.

106. Curt Stern, Principles of Genetics, op. cit., p. 9.

107. Mendel, op. cit., p. 41.

108. Maupertuis, vol. II, Système de la nature, p. 169, xxxiv.

109. Ibid., p. 162, XLI.

Even though Mendel may have been apprised of the condition of recessivity through Maupertuis, Maupertuis himself was not the first to formulate the concept. He was quite conversant with Lucretius, as is evidenced by the many footnotes scattered throughout his works, that make direct reference to Lucretius' De rerum naturae. In Book IV of that work, lines 1217-1224, the following lines appear:

> It often happens also that the children may appear like a grandfather and reproduce the looks of a great-grandfather, because the parent often conceal in their bodies many primordia mingled in many ways, which fathers hand on to father received from their stock; from these Venus brings forth forms with varying lot, and reproduces the countenance, the voice, the hair of their ancestor.

All the necessary features are present to make a complete concept of recessivity.

110. Maupertuis, vol. II, Lettre XIV Sur la génération des animaux, p. 310.

111. Ibid., p. 307.

112. The entire second part of the Vénus physique discusses the inheritance of specific traits in the various races of man.

113. Maupertuis, vol. II, Lettre XIV, p. 307-310.

114. Mendel, op. cit., p. 9.

115. Ibid., pp. 23-2[illegible].

116. Ibid., p. 43.

117. Maupertuis, vol. II, Système de la nature, p. 164, XLIV.

118. Maupertuis, vol. II, Vénus physique, p. 122.

119. Maupertuis, vol. II, Système de la nature, p. 170, LI.

120. Ibid., p. 172, LIV.

109. Ibid., p. 162, XLI.

Even though Hendel may have been apprized of the condition of recessivity through Maupertuis, Maupertuis himself was not the first to formulate the concept. He was quite conversant with Lucretius, as is evidenced by the many footnotes scattered throughout his works, that make direct reference to Lucretius' De rerum natura. In Book IV of that work, lines 1217-1224, the following lines appear:

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113. Maupertuis, vol. II, Lettre XIV, p. 307-310.

114. Hendel, op. cit., p. 9.

115. Ibid., pp. 23-25.

116. Ibid., p. 43.

117. Maupertuis, vol. II, Système de la nature, p. 164, XXIV.

118. Maupertuis, vol. II, Vénus physique, p. 123.

119. Maupertuis, vol. II, Système de la nature, p. 170, LI.

120. Ibid., p. 172, LIV.

121. Ibid.

122. Mendel, op. cit., p. 15.

123. Ibid., p. 41, note.

124. Ibid., pp. 23-30.

125. H. Bentley Glass, "Maupertuis and the Beginnings of Genetics", Quarterly Review of Biology, vol. 22, no. 3, Sept. 1947, p. 203.

126. Maupertuis, vol. II, Vénus physique, p. 89.

127. Ibid., p. 120.

128. Ibid., p. 90.

129. Ibid., p. 89.

130. Mendel, op. cit., p. 29.

131. Ibid., p. 31.

132. David Bohm, Causality and Chance in Modern Physics (Philadelphia, University of Pennsylvania Press, 1971), p. 27.

133. Francois Jacob, The Logic of Life, A History of Heredity, translated by Betty E. Spillmann (New York, Vintage Books, 1976), p. 196.

134. John T. Merz, A History of European Scientific Thought in the Nineteenth Century (New York, Dover Publication, 1965), vol. II, p. 589.

135. Ibid., p. 602.

136. F. Jacob, op. cit., p. 197.

137. Pierre Simon, Marquis de LaPlace, A Philosophical Essay on Probabilities, translated from the sixth French edition by F. W. Truscott and F. L. Emory (New York, Dover Publications, 1951), p. 3.

138. Encyclopédie Francaise, cited in the article Hazard (Paris, 1778), vol. 17, p. 126.

139. LaPlace, op. cit., p. 4.

121. Ibid.

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125. H. Bentley Glass, "Maupertuis and the Beginnings of Genetics", Quarterly Review of Biology, vol. 22, no. 3, Sept. 1947, p. 203.

126. Maupertuis, vol. II, Vénus physique, p. 86.

127. Ibid., p. 120.

128. Ibid., p. 90.

129. Ibid., p. 89.

130. Mendel, op. cit., p. 29.

131. Ibid., p. 31.

132. David Bohm, Causality and Chance in Modern Physics (Philadelphia, University of Pennsylvania Press, 1957), p. 27.

133. François Jacob, The Logic of Life, A History of Heredity, translated by Betty E. Spillmann (New York, Vintage Books, 1976), p. 166.

134. John T. Merz, A History of European Scientific Thought in the Nineteenth Century (New York, Dover Publications, 1965), vol. II, p. 589.

135. Ibid., p. 601.

136. F. Jacob, op. cit., p. 197.

137. Pierre Simon, Marquis de Laplace, A Philosophical Essay on Probabilities, translated from the sixth French edition by F. W. Truscott and F. L. Emory (New York, Dover Publications, 1951), p. 4.

138. Encyclopédie Française, cited in the article Hasard (Paris, 1779), vol. 17, p. 228.

139. Laplace, op. cit., p. 6.

140. Ibid., p. 1.

141. Bohm, op. cit., p. 27.

142. Maupertuis, vol. I, Essais de Cosmologie, p. 12.

143. Maupertuis, vol. II, Système de la nature, p. 164, XLV.

144. Ibid., vol. II, Vénus physique, p. 69.

145. Ibid., vol. II, Lettre XIV, pp. 307-310.

146. Glass, op. cit., p. 205.

147. Mendel's use of the principle of multiplying independent probabilities, as used in the cross of two hybrids, Aa x Aa:

		♀ cells	
		1/2A	1/2a
♂ cells	1/2A	1/2A x 1/2A = 1/4A	1/2A x 1/2a = 1/4Aa
	1/2a	1/2a x 1/2A = 1/4Aa	1/2a x 1/2a = 1/4aa

or

1/4 AA : 1/2Aa : 1/4aa = 1AA : 2Aa : laa

148. Maupertuis, vol. II, Lettre XIV, P. 310.

149. Diderot's passage was cited by Paul Ostoya, in Les Theories de l'Evolution (Paris, Payot, 1951), p. 46.

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