Engels

Dialectics of Nature

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Translated from the German by ***Clemens Dutt***

ФРИДРИХ ЭНГЕЛЬС

ДИАЛЕКТИКА ПРИРОДЫ

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Preface

Dialectics of Nature is one of the more important works of Frederick Engels. It gives a dialectical materialist generalisation of the principal achievements of the natural sciences in the mid-nineteenth century, develops materialist dialectics, and criticises metaphysical and idealist conceptions in natural science.

In the last century, over several decades, the development of the capitalist mode of production and the productive forces of capitalism made for rapid progress in technology and the natural sciences, particularly those sciences that were linked more or less intimately with industry.

The beginning, and still more the middle, of the nineteenth century witnessed a whole series of discoveries and achievements in mathematics, astronomy, physics, chemistry and biology. New facts and natural laws were established, new theories and hypotheses conceived and new branches of science brought into being.

Engels showed the three outstanding advances in that triumphant march of natural science to be the discovery of the organic cell, the discovery of the law of conservation and transformation of energy, and Darwinism. In 1838 and 1839 M. J. Schleiden and T. Schwann established the identity of vegetable and animal cells; they proved that the cell is the basic structural unit of living organisms, and created an integral cell theory of the structure of organisms. Thereby they demonstrated the unity of the organic world. Between 1842 and 1847, J. R. Mayer, J. P. Joule, W. R. Grove, L. A. Colding and H. Helmholtz discovered and substantiated the law of conservation and transformation of energy. As a result, nature presented itself as a continuous process of one form of the universal motion of matter changing into another. In 1859 Charles Darwin published his fundamental work, *On the Origin of Species by Means of Natural Selection*, which completed the development of evolutionary ideas over a whole century and formed the basis for modern biology. The philosophical significance of these discoveries was that they revealed the dialectical character of natural developments in a particularly succinct form.

From the mid-nineteenth century onwards scientific progress assumed the character of a veritable revolution. It was hampered, however, by the contradiction between the dialectical character of the new data obtained by natural science and the metaphysical method used by scientists.

It was indispensable to generalise the main scientific achievements of the second third of the nineteenth century from the standpoint of philosophy and elaborate the dialectical materialist conception of nature.

Marx being fully absorbed in his cardinal work, *Capital*, it was Engels who tackled the new theoretical problems posed by scientific progress. Engels was able to begin this work after relinquishing his job in a Manchester firm and moving to London. Still, the Franco-Prussian war, the Paris Commune and his own activity in the International prevented him from concentrating on theoretical research before early 1873.

The interest which Marx and Engels took in scientific problems was neither accidental nor fleeting. Marx steadily expanded his scientific knowledge He began his scientific studies in youth, as can be seen from a letter he wrote to his father, and carried them on to the closing years of his life, when he wrote independent treatises on mathematics. Engels went through much the same evolution.

To create an integral world outlook, the founders of Marxism did not limit themselves to a critical revision of the earlier achievements of philosophy, political economy, and socialist and communist doctrines. They had to generalise the main achievements of contemporary natural science if materialism was to be given a new, dialectical form. "Marx and I," wrote Engels in his "Preface" to the second edition of *Anti-Dühring*, "were pretty well the only people to rescue conscious dialectics from German idealist philosophy and apply it in the materialist conception of nature and history. But a knowledge of mathematics and natural science is essential to a conception of nature which is dialectical and at the same time materialist." (F. Engels, *Anti-Dühring*, Moscow, 1959, p. 16.)

Marx stressed the role of the natural sciences by pointing out, in his preparatory work for *Capital* in 1863, that natural science "underlies all knowledge".

Marx and Engels were equally interested in science, but there existed a kind of division of labour between them. Marx was better versed in mathematics, the history of technology, and agricultural chemistry. Besides, he studied physics, chemistry, biology, geology, anatomy and physiology. Unlike Engels, he gave more of his time to mathematics and the applied sciences. Engels, on the other hand, had a more intimate knowledge of physics and biology; he also studied mathematics, astronomy, chemistry, anatomy and physiology and devoted greater attention to theoretical natural science than Marx did.

As early as the period of formation of Marxism, that is, before 1848, Marx and Engels cited in their writings numerous facts indicating their keen interest in scientific and technological progress. But they had not yet begun their special studies in natural science.

Marx began those studies in 1851, when he resumed his research into political economy and went into the history of technology and agricultural chemistry with the express aim of familiarising himself thoroughly with these branches of knowledge. Afterwards he used the results of his studies in the chapter of Volume I of *Capital* on machines and in developing his theory of ground rent in Volume III of the same work. Engels likewise began to study various scientific problems in the fifties.

While writing the original version of *Capital*, Marx came to the conclusion that he must make a special study of mathematics. In 1858 he began to study algebra and then analytical geometry and differential and integral calculus. Subsequently these studies assumed an independent character. During the same period Engels began to study physics and physiology in order to draw on the achievements of these sciences, specifically the cell theory and the theory of transformation of energy, in elaborating dialectics. Darwin's *Origin of Species,* which appeared at the end of 1859, gave further impetus to scientific studies of Marx and Engels. Engels read Darwin's book as soon as it was published. Marx, who read it late in 1860, gave a classical definition of the significance which Darwin's great discovery would have for Marxism. "This is the book which provides the natural historic basis for our concept," he wrote to Engels on December 19, 1860. In later years Marx and Engels considerably extended the range of their scientific studies. They studied biology, anatomy, physiology, astronomy, physics, chemistry and other sciences.

A highly important stage in those studies began in 1873 and lasted till Marx's death in 1883. During that period Marx and Engels proceeded to write independent treatises as they expanded their investigations in the natural sciences. Marx wrote the most important part of his mathematical manuscripts, in which he set out to substantiate the differential calculus in terms of dialectics. But it was Engels who played the decisive role in the sphere of natural science by his writings, above all *Dialectics of Nature.*

Dialectics of Nature was the culmination of profound scientific studies by Engels over many years. Originally (about January 1873—see pp. 202-07 of this edition) he planned to set out the results of his research in the form of a polemical work criticising L. Büchner, a vulgar materialist. Later on he decided to set himself a more comprehensive task. In a letter he wrote from London to Marx in Manchester on May 30, 1873, he informed Marx of his intention to write *Dialectics of Nature.* Marx showed the letter to K. Schorlemmer, a prominent chemist. The original of that letter shows comments by Schorlemmer, who approved of the main points of Engels's plan. In the years that followed Engels did a colossal amount of work in line with his plan, but he was unable to carry it through to the end.

Engels wrote the items which are included in *Dialectics of Nature* from 1873 to 1886. During this period he studied a vast amount of source material on major problems of natural science and wrote, in more or less complete form, 10 articles and chapters and over 170 notes and fragments.

Engels's work on *Dialectics of Nature* may be divided into two important periods: from the conception of the book to the beginning of the work on *Anti-Dühring* (May 1873-May 1876), and from the completion of *Anti-Dühring* to Marx's death (July 1878-March 1883). In the former period Engels was chiefly busy collecting data, and wrote most of the fragments and the "Introduction". During the latter period, he drew up a specific plan for his future book and wrote a good deal of new fragments and almost all the chapters. Upon Marx's death, being fully taken up with the job of completing the publication of *Capital* and leading the international working-class movement, Engels could no longer pursue his scientific studies methodically and had virtually to discontinue his work on *Dialectics of Nature,* which remained unfinished. However, he used both the results of his previous investigations and new scientific data in a number of works written in the latter period.

The task which Engels set himself in writing *Dialectics of Nature* is stated in his "Preface" to the second edition of *Anti-Dühring* as follows: "It goes without saying that my recapitulation of mathematics and the natural sciences was undertaken in order to convince myself also in detail of what in general I was not in doubt—that in nature, amid the welter of innumerable changes, the same dialectical laws of motion force their way through as those which in history govern the apparent fortuitousness of events.... To me there could be no question of building the laws of dialectics into nature, but of discovering them in it and evolving them from it." (F. Engels, *Dialectics of Nature*, Moscow, 1959, pp. 17 and 19.) The task was, therefore, to reveal the objective dialectics of nature and thereby prove the necessity for conscious materialist dialectics in natural science, expel idealism, metaphysics, agnosticism and vulgar materialism from science, generalise the main results of scientific progress from the standpoint of dialectical materialism and so demonstrate the universal character of the basic laws of materialist dialectics.

Engels mustered a wealth of factual data to that end. Altogether he used about a hundred works by noted scientists, including C. Bossut (mathematics), J. H. Mädler and A. Secchi (astronomy), J. R. Mayer, H. Helmholtz, W. R. Grove, W. Thomson, R. Clausius, J. C. Maxwell, G. Wiedemann and T. Thomson (physics), A. Naumann, H. E. Roscoe and K. Schorlemmer (chemistry), Charles Darwin, Ernst Hæckel and H. A. Nicholson (biology), as well as the periodical *Nature*. Unfortunately, for a number of reasons, Engels was unable to use such works, less known at the time but no less valuable historically, as those of Lomonosov, Lobachevsky, Riemann and Butlerov, or Maxwell's works on the theory of the electromagnetic field.

Although it was not finished and some of its components are in the nature of preliminary sketches and fragmentary notes, *Dialectics of Nature* is a connected whole, united by common fundamental ideas and a single well-composed plan.

In *Dialectics of Nature*, using ample evidence from the history of natural science, particularly from the Renaissance to the middle of the nineteenth century, Engels shows that the development of natural science is determined in the final analysis by practical needs, by production. For the first time in the history of Marxism, he dealt thoroughly with the problem of the relationship between philosophy and natural science, established their interdependence, proved that "the metaphysical outlook has become impossible in natural science owing to the very development of the latter", that "the return to dialectics takes place unconsciously, hence contradictorily and slowly" and that, divested of Hegelian mysticism, dialectics "becomes an absolute necessity for natural science" (see pp. 17, 208 of this edition), and called on scientists to learn to use the dialectical method consciously.

Engels elaborated the fundamental postulates of dialectical materialism on matter and motion, on time and space. He gave a specific definition of dialectics, formulated the three fundamental laws of dialectics and showed that "the dialectical laws are real laws of development of nature, and therefore are valid also for theoretical natural science". (Ibid., p. 64.)

The pivotal idea of *Dialectics of Nature* is the classification of the forms of motion of matter and, accordingly, the classification of the sciences which treat of these forms. A pure change of place is the lowest form of motion, while thought is the highest. The mechanical, physical, chemical and biological forms of motion are the main forms dealt with by the natural sciences. Each lower form of motion changes into a higher form by a dialectical leap. Each higher form of motion contains, but does not come down to, a lower form as a subordinate element. On the basis of this theory of the forms of motion of matter, Engels builds the dialectical materialist classification of the natural sciences, each of which "analyses a single form of motion, or a series of forms of motion that belong together and pass into one another". (Ibid., p. 252.)

In keeping with this pivotal idea, Engels consistently examines the dialectical content of mathematics, mechanics, physics, chemistry and biology. In mathematics he singles out the problem of the seeming apriority of mathematical abstractions, in astronomy the problem of the origin and development of the solar system, in physics the theory of the transformation of energy, in chemistry the problem of atomistics, in biology the problem of the origin and essence of life, the cell theory, and Darwinism. The labour theory of the origin of man, which Engels formulates in the book, constitutes a transition from natural science to the history of society.

As he considers all these problems Engels does not confine himself to a simple registration of this or that scientific discovery but uses the dialectical materialist method to interpret the more important achievements of natural science in a new way. Speaking of the significance of the discovery made by J. R. Mayer and other scientists, who established the law of conservation of energy, Engels stresses that what was specifically new in this discovery was the formulation of the absolute law of nature according to which any form of motion can and must change into any other form of motion. Engels contributes to the understanding of the law of conservation of energy by advancing the proposition that energy is indestructible either quantitatively or qualitatively and that no form of motion in the infinite universe, changing into other forms of motion, can disappear altogether as such. Or, speaking of the historic significance of Darwin's discovery, Engels points out, on the other hand, that Darwin disregarded the causes of mutability of species. He criticises the one-sided notion which makes an absolute of the struggle for existence, and emphasises the role of the environment in the development of organisms and the role of metabolism as a function determining them.

Using the dialectical materialist method, Engels solves a number of problems of contemporary natural science, forecasts the further trend of scientific progress and anticipates some of the subsequent achievements of science. For instance, he solves the problem of the twofold measure of motion; analysing the contradictions of the contemporary theory of electricity, he anticipates the theory of electrolytic dissociation.

Unlike most of the scientists of his day, Engels defends and carries forward the idea of the complexity of the atom. "Atoms, however, are in no wise regarded as simple or in general as the smallest known particles of matter," he writes (see this volume, p. 270). He foresaw the existence of particles that are the analogues of mathematical infinitesimals of different orders. The present-day theory of the structure of matter has borne out, and continues to bear out, Engels's views on the complexity and inexhaustibility of the atom. Elaborating the conception of matter as the unity of attraction and repulsion, Engels pointed to the possibility of existence of such matter as has no rest mass, to use a phrase of contemporary physics, and was borne out by twentieth-century discoveries.

In *Dialectics of Nature*, Engels gives his definition of life. "Life is the mode of existence of protein bodies," he writes (see this volume, p. 301). This definition served as the starting point in investigating the problem of the origin and essence of life.

Especial credit is due to Engels for advancing the labour theory of the origin of man. In his brilliant essay, "The Part Played by Labour in the Transition from Ape to Man", he elucidates the decisive role of labour, of the fashioning of implements, in the formation of man's physical type and of human society. He shows how man's simian ancestor developed into man, a qualitatively distinct being, through a long evolution.

Engels supports, brings to the fore and develops progressive views and theories in every branch of science. In particular, he commends the great achievement of D. I. Mendeleyev, the Russian chemist, who created the periodic table. At the same time he combated notions that no longer accorded with the latest achievements of science and hampered further progress in research. For instance, he denounced the hypothesis of death of the universe through loss of heat, put forward by R. Clausius, W. Thomson and J. Loschmidt. He showed that this fashionable hypothesis ran counter to the rightly conceived law of conservation and transformation of energy. His fundamental tenets on the quantitative as well as qualitative indestructibility of motion and on the resultant impossibility of death of the universe through loss of heat foreshadowed the road which progressive natural science took subsequently.

Throughout his book, revealing the dialectics of nature, Engels battles against various unscientific trends among natural scientists, such as vulgar materialism, metaphysics, idealism, agnosticism, one-sided empiricism and mechanicism, spiritualism and other manifestations of religious ideology.

Needless to say certain particulars of *Dialectics of Nature*, primarily the factual data used by the author, have become obsolete during the past decades of rapid and revolutionary progress in the natural sciences. For example, the Kant-Laplace theory of cosmogony is outdated now. The mechanical hypothesis of ether has been completely rejected. It has been established that the velocity of electric current cannot exceed that of light. But none of these particulars affects the substance of the work. The general method and conception of the book remain, and will always remain, valid.

The important thing in *Dialectics of Nature* is its method, namely, materialist dialectics. The author forcefully brings out the role of theoretical thought, of method, in cognising the world. "Indeed, dialectics cannot be despised with impunity", for without theoretical thought "one cannot bring two natural facts into relation with each other, or understand the connection existing between them", and, as it happens, dialectics is precisely "the sole method of thought appropriate in the highest degree" to the contemporary stage in the development of the natural sciences. (See this volume, pp. 60, 213.)

Dialectics of Nature deals more fully than any other work by the founders of Marxism with such problems and categories of dialectics as causality, necessity and chance, classification of the forms of judgement, the relationship of induction and deduction, the role of hypothesis as a form of development of natural science, and many more.

Even though unfinished, this outstanding work is amazing for its rich and profound theoretical content. It is a new stage in the development of dialectical materialism. It made a substantial contribution to materialism and dialectics and showed the way to the solution of the main problems of contemporary natural science.

It has been said that Engels was unable to finish and print *Dialectics of Nature*. Nevertheless, certain of its propositions became known to the general reader as early as the last quarter of the nineteenth century because Engels used them in several of his published works, first and foremost in *Anti-Dühring*, *Ludwig Feuerbach and the End of Classical German Philosophy*, and the "Introduction" to the English edition of *Socialism: Utopian and Scientific*.

The ideas of *Dialectics of Nature* were developed further in Lenin's *Materialism and Empirio-criticism*, a brilliant work furnishing a philosophical generalisation of the vast scientific data accumulated by the beginning of the twentieth century. Lenin elaborated these ideas in *Philosophical Notebooks* and his programme article, "On the Significance of Militant Materialism". He was unfamiliar with *Dialectics of Nature* (which was first published after his death), but with the aid of Marx's and Engels's dialectical materialism he arrived, on a number of fundamental questions, to the same conclusions as Engels did in *Dialectics of Nature*, and carried forward Engels's theses.

Scientific achievement in the twentieth century confirmed and contributed to Marx's and Engels's dialectical materialist conception of nature. In physics, the discoveries made by Max Planck, Niels Bohr and Louis de Broglie scientifically proved the dialectical postulate on the unity of the discreteness and continuity of matter. Albert Einstein's theory of relativity concretised Engels's theses on matter, motion, time and space. The modern theory of elementary particles fully bears out Engels's and Lenin's propositions on the inexhaustibility of the atom and the electron. The conclusions of dialectical materialism in the field of biology have been borne out as well. Cybernetics and many other new sciences, such as physical chemistry, biochemistry, geophysics, space biology, etc., have confirmed, and continue to confirm, Engels's prediction that the greatest achievements should be expected where different sciences meet.

Such are the results of the historical verification of dialectical materialism, the Marxist method. The past decades have shown the profundity of Engels's and Lenin's idea of the necessity for an alliance of philosophy and natural science, of philosophers and scientists. The future will no doubt bring further proof of the significance of this idea.

The theoretical content of *Dialectics of Nature* has been confirmed by the course of history over almost a century and is being continuously enriched as a result of further successes in science and technology. The immortal ideas of this work will continue to light science's way in this age of atomic energy, cybernetic machines, the application of the laws of organic nature, and space exploration—the great age of communism.

* * *

Dialectics of Nature has come down to us in the form of four folders into which Engels divided, shortly before his death, all the articles and notes relating to this work. He gave the folders the following headings: (1) "Dialectics and Natural Science", (2) "The Investigation of Nature and Dialectics", (3) "Dialectics of Nature", and (4) "Mathematics and Natural Science. Miscellaneous." Only two of the folders—the second and the third—have tables of contents made by the author. It is from these tables that we know exactly of the material which Engels assigned to the second and third folders and of the order of its arrangement in the folders. As for the first and fourth folders, we are not certain that their various sheets are arranged exactly as Engels wanted them to be.

The first folder ("Dialectics and Natural Science") is made up of two parts: (1) Notes written on 11 double sheets numbered by the author, each sheet being entitled "Dialectics of Nature". These notes, which are separated from one another by dividing lines, date from the period between 1873 and 1876. They were written in the chronological order in which they were arranged on the numbered sheets of the manuscript. (2) Twenty unnumbered sheets, each containing one longer note or several shorter ones separated by dividing lines. Very few of these notes contain data enabling us to date them.

The second folder ("The Investigation of Nature and Dialectics") comprises three large notes: "On the Prototypes of the Mathematical Infinite in the Real World", "On the 'Mechanical' Conception of Nature", "On Nägeli's Incapacity To Know the Infinite", "Old Preface to *Anti-Dühring*. On Dialectics", the article "The Part Played by Labour in the Transition from Ape to Man" and a large fragment entitled "Omitted from *Feuerbach*". The table of contents made by Engels for this folder indicates that originally it included two more articles: "Basic Forms of Motion" and "Natural Science in the Spirit World". Subsequently Engels crossed the headings of these articles out of the table of contents of the second folder and transferred them to the third folder, in which he incorporated the more completed components of his unfinished work.

The third folder ("Dialectics of Nature") contains six articles which are the most completed: "Basic Forms of Motion", "The Measure of Motion.—Work", "Electricity", "Natural Science in the Spirit World", "Introduction" and "Tidal Friction".

The fourth folder ("Mathematics and Natural Science. Miscellaneous") consists of two unfinished chapters: "Dialectics" and "Heat", eighteen unnumbered sheets each of which contains one longer note or several shorter ones separated by a dividing line, and several sheets with mathematical calculations. Among the notes in the fourth folder are two plan outlines of *Dialectics of Nature*. The dates of these notes can be established only in a very few cases.

Detailed indexes of the contents of the folders and the chronology of the chapters and fragments of *Dialectics of Nature* will be found at the end of this volume (pp. 350).

An acquaintance with the contents of the four folders shows that Engels included in them not only chapters and preliminary sketches written especially for *Dialectics of Nature*, but also some manuscripts which originally were not intended for it, namely, the "Old Preface to *Anti-Dühring*", two "Notes to *Anti-Dühring*" ("On the Prototypes of the Mathematical Infinite in the Real World" and "On the 'Mechanical' Conception of Nature"), "Omitted from *Feuerbach*", "The Part Played by Labour in the Transition from Ape to Man" and "Natural Science in the Spirit World."

The present edition of *Dialectics of Nature* includes everything contained in Engels's four folders, except for a few pages with fragmentary mathematical calculations not accompanied by any explanatory text, and the following notes, which are obviously unconnected with *Dialectics of Nature*: (1) the original outline of the "Introduction" to *Anti-Dühring* (on modern socialism), (2) a fragment about slavery, (3) extracts from Charles Fourier's book *New Industrial and Social World* (these three notes are part of the preparatory work for *Anti-Dühring*), and (4) a small note with a comment by Engels on the negative view which Philip Pauli, the German chemist, took of the labour theory of value.

Within these bounds, *Dialectics of Nature* consists of 10 articles and chapters, 169 notes and fragments, and two plan outlines—181 components in all.

The material is here arranged by subjects, in keeping with the basic lines of Engels's plan, as indicated in the two plan outlines which have reached us. Both outlines are given at the very beginning of the book. One of them, which is more detailed and embraces the whole of Engels's work, was written, as everything seems to suggest, in August 1878. The other, which covers only a part of the work, was written approximately in 1880. The available material for *Dialectics of Nature*, on which Engels worked intermittently for thirteen years (1873-86), does not fully coincide with the items indicated in the general plan. This is why it has been impossible to follow in every detail the plan made in 1878. Nevertheless, the basic content of the manuscript and the basic lines of the plan of *Dialectics of Nature* fully accord with each other. The arrangement of the material is therefore based on the plan outlines. The demarcation adopted is that indicated by Engels himself, in grouping the materials by folders, between more or less completed chapters, on the one hand, and preparatory notes, on the other. Thus the book is divided into two parts: (1) articles and chapters, and (2) notes and fragments. In each of these two parts, the material is arranged according to an identical guiding pattern conforming to the basic lines of Engels's plan.

These basic lines indicate the following sequence of the parts: (a) historical introduction, (b) general questions of materialist dialectics, (c) classification of the sciences, (d) considerations regarding the dialectical content of individual sciences, (e) examination of some important methodological problems of natural science, (f) transition to social sciences. The last but one part remained almost unelaborated.

The basic lines of the plan account for the following sequence of the articles and chapters of *Dialectics of Nature* constituting the first part of the book:

(1) Introduction (written in 1875-76);
(2) Old Preface to *Anti-Dühring*. On Dialectics (May-June 1878);
(3) Natural Science in the Spirit World (early 1878);
(4) Dialectics (late 1879);
(5) Basic Forms of Motion (1880-81);
(6) The Measure of Motion.—Work (1880-81);
(7) Tidal Friction (1880-81);
(8) Heat (April 1881-November 1882);
(9) Electricity (1882);
(10) The Part Played by Labour in the Transition from Ape to Man (June 1876).

In regard to all these articles and chapters, the order by subjects almost coincides with the chronological order, except for the article "The Part Played by Labour", which forms a transition from the natural to the social sciences. The article "Natural Science in the Spirit World" is not mentioned in Engels's plan outlines. In all probability Engels originally intended to publish it separately, in some magazine, and did not include it in *Dialectics of Nature* until later. Here it appears in the third place among the articles and chapters because, like the two preceding articles, it is of general methodological significance and is fairly closely connected with the "Old Preface to *Anti-Dühring*" as far as its fundamental idea is concerned (the need of theoretical thought for empirical natural science).

As regards the rough drafts, notes and fragments forming the second part of the book, a comparison of the available material with Engels's plan outlines leads to this material being arranged as follows:

(1) From the History of Science;
(2) Natural Science and Philosophy;
(3) Dialectics;
(4) Forms of Motion of Matter. Classification of the Sciences;
(5) Mathematics;
(6) Mechanics and Astronomy;
(7) Physics;
(8) Chemistry;
(9) Biology.

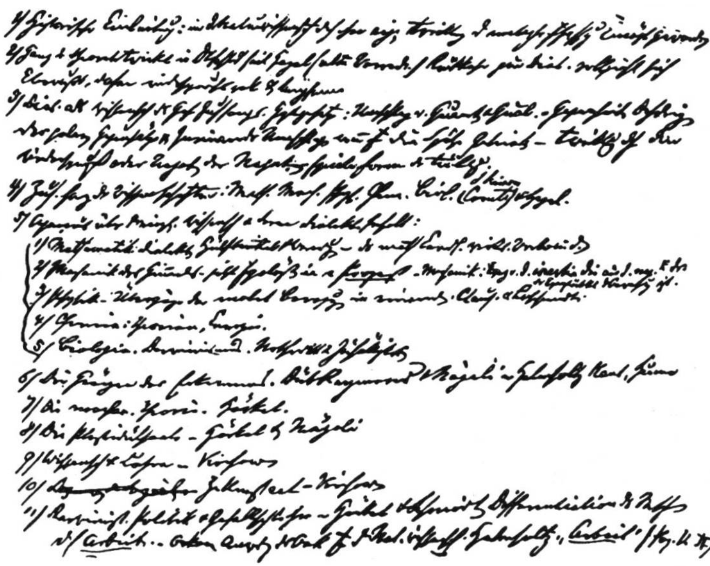
A comparison of these sections of the fragments with the headings of the ten articles and chapters of *Dialectics of Nature* shows that the arrangement of the articles and the fragments is almost the same. The first section of the fragments corresponds to the first article of *Dialectics of Nature,* the second section, to the second and third articles, the third section, to the fourth article, the fourth section, to the fifth article, the sixth section, to the sixth and seventh articles, and the seventh section, to the eighth and ninth articles. The tenth article has no counterpart among the fragments.

Within the sections, the fragments are again arranged by subjects. First come fragments dealing with more general questions, and then fragments devoted to more particular questions. In the section "From the History of Science", the fragments are arranged in historical sequence: from the rise of the sciences among the ancient peoples to Engels's contemporaries. In the section "Dialectics", the notes given first are those on the general questions and fundamental laws of dialectics, and then come notes relating to so-called subjective dialectics. As far as possible, each section ends with fragments that serve as a transition to the next section.

The material of *Dialectics of Nature* was never published in Engels's lifetime. Upon his death the manuscript was kept in the archives of the German Social-Democratic Party for thirty years. Only two of the articles included by the author in *Dialectics of Nature* saw the light of day. They were "The Part Played by Labour in the Transition from Ape to Man", published in *Die Neue Zeit* in 1896, and "Natural Science in the Spirit World", published in the yearbook *Illustrierter Neue Welt-Kalender* in 1898. The full text of *Dialectics of Nature* was first published in the Soviet Union in 1925, the German text appearing alongside a Russian translation (*Marx and Engels Archives*, Book Two). Subsequently Engels's book was reprinted more than once, corrections being introduced on each occasion into the reading of the manuscript and improvements being made in the translation and the arrangement of the material. The most important of the subsequent editions were the one in the original (Marx-Engels. *Gesamtausgabe.* F. Engels. "Herrn Eugen Dührings Umwälzung der Wissenschaft. Dialektik der Natur". Sonderausgabe. Moskau-Leningrad, 1935) and the Russian-language edition of 1941, on which numerous foreign editions were patterned.

In the present edition, the arrangement of the material is that adopted for the 1941 Russian edition. The notes and indexes, which have been considerably enlarged, are given according to Volume 20 of Karl Marx and Frederick Engels, *Collected Works*, second edition (in Russian), Moscow, 1961.

Institute of Marxism-Leninism,
the Central Committee of the C.P.S.U.



Outline of the general plan of *Dialectics of Nature*

[Plan Outlines]

[Outline of the General Plan][1]

(1) Historical introduction: the metaphysical outlook has become impossible in natural science owing to the very development of the latter.

(2) Course of the theoretical development in Germany since Hegel (old preface).[2] The return to dialectics takes place unconsciously, hence contradictorily and slowly.

(3) Dialectics as the science of universal inter-connection. Main laws: transformation of quantity and quality—mutual penetration of polar opposites and transformation into each other when carried to extremes—development through contradiction or negation of the negation—spiral form of development.

(4) The inter-connection of the sciences. Mathematics, mechanics, physics, chemistry, biology. St. Simon (Comte), and Hegel.

(5) Aperçus [reflections, remarks] on the separate sciences and their dialectical content:

1. Mathematics: dialectical aids and expressions.—Mathematical infinite really occurring.
2. Celestial mechanics—now resolved into a *process*.—Mechanics: point of departure was inertia, which is only the negative expression of the indestructibility of motion.
3. Physics—transitions of molecular motions into one another. Clausius and Loschmidt.
4. Chemistry: theories, energy.
5. Biology. Darwinism. Necessity and chance.

(6) The limits of knowledge. Du-Bois-Reymond and Nägeli.[3]—Helmholtz, Kant, Hume.

(7) The mechanical theory. Hæckel.[4]

(8) The plastidule soul—Hæckel and Nägeli.[5]

(9) Science and teaching—Virchow.[6]

(10) The cell state—Virchow.

(11) Darwinian politics and theory of society—Hæckel and Schmidt.[7]—Differentiation of man through *labour*. —Application of economics to natural science. Helmholtz's "*work*" (*Populäre Vorträge*, II).[8]

[Outline of Part of the Plan][9]

(1) Motion in general.

(2) Attraction and repulsion. Transference of motion.

(3) [Law of the] conservation of energy applied to this. Repulsion+attraction.—Addition of repulsion=energy.

(4) Gravitation—heavenly bodies—terrestrial mechanics.

(5) Physics. Heat. Electricity.

(6) Chemistry.

(7) Summary.

(*a*) Before 4: Mathematics. Infinite line. + and—are equal.

(*b*) In astronomy: performance of work by the tides.

Double calculation in Helmholtz, II, p. 120.*

"Forces" in Helmholtz, II, p. 190.**

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* See this volume, pp. 82-86.—*Ed.*

** See this volume, pp. 80-82.—*Ed.*

[Articles and Chapters]

Introduction[10]

Modern research into nature, which alone has achieved a scientific, systematic, all-round development, in contrast to the brilliant natural-philosophical intuitions of antiquity and the extremely important but sporadic discoveries of the Arabs, which for the most part vanished without results—this modern research into nature dates, like all more recent history, from that mighty epoch which we Germans term the Reformation, from the national misfortune that overtook us at that time, and which the French term the Renaissance and the Italians the *Cinquecento*, although it is not fully expressed by any of these names. It is the epoch which had its rise in the latter half of the fifteenth century. Royalty, with the support of the burghers of the towns, broke the power of the feudal nobility and established the great monarchies, based essentially on nationality, within which the modern European nations and modern bourgeois society came to development. And while the burghers and nobles were still fighting one another, the German Peasant War pointed prophetically to future class struggles, by bringing on to the stage not only the peasants in revolt—that was no longer anything new—but behind them the beginnings of the modern proletariat, with the red flag in their hands and the demand for common ownership of goods on their lips. In the manuscripts saved from the fall of Byzantium, in the antique statues dug out of the ruins of Rome, a new world was revealed to the astonished West, that of ancient Greece; the ghosts of the Middle Ages vanished before its shining forms;

Italy rose to an undreamt-of flowering of art, which was like a reflection of classical antiquity and was never attained again. In Italy, France, and Germany a new literature arose, the first modern literature; shortly afterwards came the classical epochs of English and Spanish literature. The bounds of the old *orbis terrarum* were pierced, only now for the first time was the world really discovered and the basis laid for subsequent world trade and the transition from handicraft to manufacture, which in its turn formed the starting-point for modern large-scale industry. The dictatorship of the Church over men's minds was shattered; it was directly cast off by the majority of the Germanic peoples, who adopted Protestantism, while among the Latins a cheerful spirit of free thought, taken over from the Arabs and nourished by the newly-discovered Greek philosophy, took root more and more and prepared the way for the materialism of the eighteenth century.

It was the greatest progressive revolution that mankind had so far experienced, a time which called for giants and produced giants—giants in power of thought, passion and character, in universality and learning. The men who founded the modern rule of the bourgeoisie had anything but bourgeois limitations. On the contrary, the adventurous character of the time inspired them to a greater or lesser degree. There was hardly any man of importance then living who had not travelled extensively, who did not speak four or five languages, who did not shine in a number of fields. Leonardo da Vinci was not only a great painter but also a great mathematician, mechanician, and engineer, to whom the most diverse branches of physics are indebted for important discoveries. Albrecht Dürer was painter, engraver, sculptor, and architect, and in addition invented a system of fortification embodying many of the ideas that much later were again taken up by Montalembert and the modern German science of fortification. Machiavelli was statesman, historian, poet, and at the same time the first notable military author of modern times. Luther not only cleaned the Augean stable of the Church but also that of the German language; he created modern

German prose and composed the text and melody of that triumphal hymn imbued with confidence in victory which became the Marseillaise of the sixteenth century.[11] The heroes of that time were not yet in thrall to the division of labour, the restricting effects of which, with its production of one-sidedness, we so often notice in their successors. But what is especially characteristic of them is that they almost all live and pursue their activities in the midst of the contemporary movements, in the practical struggle; they take sides and join in the fight, one by speaking and writing, another with the sword, many with both. Hence the fullness and force of character that makes them complete men. Men of the study are the exception—either persons of second or third rank or cautious philistines who do not want to burn their fingers.

At that time natural science also developed in the midst of the general revolution and was itself thoroughly revolutionary; it had indeed to win in struggle its right of existence. Side by side with the great Italians from whom modern philosophy dates, it provided its martyrs for the stake and the dungeons of the Inquisition. And it is characteristic that Protestants outdid Catholics in persecuting the free investigation of nature. Calvin had Servetus burnt at the stake when the latter was on the point of discovering the circulation of the blood, and indeed he kept him roasting alive during two hours; for the Inquisition at least it sufficed to have Giordano Bruno simply burnt alive.

The revolutionary act by which natural science declared its independence and, as it were, repeated Luther's burning of the Papal Bull was the publication of the immortal work by which Copernicus, though timidly and, so to speak, only from his death-bed, threw down the gauntlet to ecclesiastical authority in the affairs of nature.[12] The emancipation of natural science from theology dates from this, although the fighting out of particular mutual claims has dragged on down to our day and in many minds is still far from completion. Thenceforward, however, the development of the sciences proceeded with giant strides, and, it might be said, gained in force in proportion to the square of the distance (in time) from its point of departure. It was as if the world were to be shown that henceforth, for the highest product of organic matter, the human mind, the law of motion holds good that is the reverse of that for inorganic matter.

The main work in the first period of natural science that now opened lay in mastering the material immediately at hand. In most fields a start had to be made from the very beginning. Antiquity had bequeathed Euclid and the Ptolemaic solar system; the Arabs had left behind the decimal notation, the beginnings of algebra, the modern numerals, and alchemy; the Christian Middle Ages nothing at all. Of necessity, in this situation the most fundamental natural science, the mechanics of terrestrial and heavenly bodies, occupied first place, and alongside of it, as handmaiden to it, the discovery and perfecting of mathematical methods. Great things were achieved here. At the end of the period characterised by Newton and Linnaeus we find these branches of science brought to a certain perfection. The basic features of the most essential mathematical methods were established; analytical geometry by Descartes especially, logarithms by Napier, and the differential and integral calculus by Leibniz and perhaps Newton. The same holds good of the mechanics of rigid bodies, the main laws of which were made clear once for all. Finally in the astronomy of the solar system Kepler discovered the laws of planetary movement and Newton formulated them from the point of view of the general laws of motion of matter. The other branches of natural science were far removed even from this preliminary perfection. Only towards the end of the period did the mechanics of fluid and gaseous bodies receive further treatment.* Physics proper had still not gone beyond its first beginnings, with the exception of optics, the exceptional progress of which was due to the practical needs of astronomy. By the phlogistic theory,[13] chemistry for the first time emancipated itself from alchemy. Geology had not yet gone beyond the embryonic stage of mineralogy; hence palæontology could not yet

* In the margin of the manuscript Engels has noted in pencil: "Torricelli in connection with the control of alpine rivers."—*Ed.*

exist at all. Finally, in the field of biology the essential pre-occupation was still with the collection and first sifting of the immense material, not only botanical and zoological but also anatomical and properly physiological. There could as yet be hardly any talk of the comparison of the various forms of life, of the investigation of their geographical distribution and their climatic, etc., conditions of existence. Here only botany and zoology arrived at an approximate completion owing to Linnaeus.

But what especially characterises this period is the elaboration of a peculiar general outlook, the central point of which is the view *of the absolute immutability of nature*. In whatever way nature itself might have come into being, once present it remained as it was as long as it continued to exist. The planets and their satellites, once set in motion by the mysterious "first impulse", circled on and on in their predestined ellipses for all eternity, or at any rate until the end of all things. The stars remained for ever fixed and immovable in their places, keeping one another therein by "universal gravitation". The earth had remained the same without alteration from all eternity or, alternatively, from the first day of its creation. The "five continents" of the present day had always existed, and they had always had the same mountains, valleys, and rivers, the same climate, and the same flora and fauna, except in so far as change or transplantation had taken place at the hand of man. The species of plants and animals had been established once for all when they came into existence; like continually produced like, and it was already a good deal for Linnaeus to have conceded that possibly here and there new species could have arisen by crossing. In contrast to the history of mankind, which develops in time, there was ascribed to the history of nature only an unfolding in space. All change, all development in nature, was denied. Natural science, so revolutionary at the outset, suddenly found itself confronted by an out-and-out conservative nature, in which even today everything was as it had been from the beginning and in which—to the end of the world or for all eternity—everything would remain as it had been since the beginning.

High as the natural science of the first half of the eighteenth century stood above Greek antiquity in knowledge and even in the sifting of its material, it stood just as deeply below Greek antiquity in the theoretical mastery of this material, in the general outlook on nature. For the Greek philosophers the world was essentially something that had emerged from chaos, something that had developed, that had come into being. For the natural scientists of the period that we are dealing with it was something ossified, something immutable, and for most of them something that had been created at one stroke. Science was still deeply enmeshed in theology. Everywhere it sought and found the ultimate cause in an impulse from outside that was not to be explained from nature itself. Even if attraction, by Newton pompously baptised as "universal gravitation", was conceived as an essential property of matter, whence comes the unexplained tangential force which first gives rise to the orbits of the planets? How did the innumerable varieties of animals and plants arise? And how, above all, did man arise, since after all it was certain that he was not present from all eternity? To such questions natural science only too frequently answered by making the creator of all things responsible. Copernicus, at the beginning of the period, shows theology the door; Newton closes the period with the postulate of a divine first impulse. The highest general idea to which this natural science attained was that of the purposiveness of the arrangements of nature, the shallow teleology of Wolff, according to which cats were created to eat mice, mice to be eaten by cats, and the whole of nature to testify to the wisdom of the creator. It is to the highest credit of the philosophy of the time that it did not let itself be led astray by the restricted state of contemporary natural knowledge, and that—from Spinoza down to the great French materialists—it insisted on explaining the world from the world itself and left the justification in detail to the natural sciences of the future.

I include the materialists of the eighteenth century in this period because no natural-scientific material was available to them other than that above described. Kant's epoch-making work remained a secret to them, and

Laplace came long after them.[14] We should not forget that this obsolete outlook on nature, although riddled through and through by the progress of science, dominated the entire first half of the nineteenth century,* and in substance is even now still taught in all schools.**

The first breach in this petrified outlook on nature was made not by a natural scientist but by a philosopher. In 1755 appeared Kant's *Allgemeine Naturgeschichte und Theorie des Himmels*. The question of the first impulse was done away with; the earth and the whole solar system appeared as something that had *come into being* in the course of time. If the great majority of the natural scientists had had a little less of the repugnance to thinking that Newton expressed in the warning: Physics, beware of metaphysics!,[15] they would have been compelled from this single brilliant discovery of Kant's to draw conclusions that would have spared them endless deviations and immeasurable amounts of time and labour wasted in false directions. For Kant's discovery contained the point of departure for all further progress. If the earth was something that had come into being, then its present geological, geographical, and climatic state, and its plants and animals likewise, must be something that

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* In the margin of the manuscript is a note in pencil: "The rigidity of the old outlook on nature provided the basis for the general comprehension of all natural science as a single whole. The French encyclopaedists, still purely mechanically—alongside of one another; and then simultaneously St. Simon and German philosophy of nature, perfected by Hegel."—*Ed.*

** How tenaciously even in 1861 this view could be held by a man whose scientific achievements had provided highly important material for abolishing it is shown by the following classic words:

"All the arrangements of our solar system, so far as we are capable of comprehending them, aim at preservation of what exists and at unchanging continuance. Just as since the most ancient times no animal and no plant on the earth has become more perfect or in any way different, just as we find in all organisms only stages *alongside of* one another and not *following* one another, just as our own race has always remained the same in corporeal respects—so even the greatest diversity in the coexisting heavenly bodies does not justify us in assuming that these forms are merely different stages of development; it is rather that everything created is *equally* perfect in itself." (Mädler, *Populäre Astronomie*, Berlin, 1861, 5th edition, p. 316.) [*Note by Engels.*]

had come into being; it must have had a history not only of coexistence in space but also of succession in time. If at once further investigations had been resolutely pursued in this direction, natural science would now be considerably further advanced than it is. But what good could come of philosophy? Kant's work remained without immediate results, until many years later Laplace and Herschel expounded its contents and gave them a deeper foundation, thereby gradually bringing the "nebular hypothesis" into favour. Further discoveries finally brought it victory; the most important of these were: the discovery of proper motion of the fixed stars, the demonstration of a resistant medium in universal space, the proof furnished by spectral analysis of the chemical identity of the matter of the universe and of the existence of such glowing nebular masses as Kant had postulated.*

It is, however, permissible to doubt whether the majority of natural scientists would so soon have become conscious of the contradiction of a changing earth that bore immutable organisms, had not the dawning conception that nature does not just *exist*, but *comes into being* and *passes away*, derived support from another quarter. Geology arose and pointed out not only the terrestrial strata formed one after another and deposited one upon another, but also the shells and skeletons of extinct animals and the trunks, leaves, and fruits of no longer existing plants contained in these strata. The decision had to be taken to acknowledge that not only the earth as a whole but also its present surface and the plants and animals living on it possessed a history in time. At first the acknowledgement occurred reluctantly enough. Cuvier's theory of the revolutions of the earth was revolutionary in phrase and reactionary in substance. In place of a *single* divine creation, he put a whole series of repeated acts of creation, making the miracle an essential natural agent. Lyell first brought sense into geology by substituting for the sudden revolutions due to the

* In the margin of the manuscript has been added in pencil: "Retardation of rotation by the tides, also from Kant, only now understood."—*Ed.*

moods of the creator the gradual effects of a slow transformation of the earth.*

Lyell's theory was even more incompatible than any of its predecessors with the assumption of constant organic species. Gradual transformation of the earth's surface and of all conditions of life led directly to gradual transformation of the organisms and their adaptation to the changing environment, to the mutability of species. But tradition is a power not only in the Catholic Church but also in natural science. For years, Lyell himself did not see the contradiction, and his pupils still less. This can only be explained by the division of labour that had meanwhile become dominant in natural science, which more or less restricted each person to his special sphere, there being only a few whom it did not rob of a comprehensive view.

Meanwhile physics had made mighty advances, the results of which were summed up almost simultaneously by three different persons in the year 1842, an epoch-making year for this branch of natural science. Mayer in Heilbronn and Joule in Manchester demonstrated the transformation of heat into mechanical force and of mechanical force into heat. The determination of the mechanical equivalent of heat put this result beyond question. Simultaneously, by simply working up the separate results of physics already arrived at, Grove[16]—not a natural scientist by profession, but an English lawyer—proved that all so-called physical forces, mechanical force, heat, light, electricity, magnetism, indeed even so-called chemical force, become transformed into one another under definite conditions without any loss of force occurring, and so proved additionally along physical lines Descartes' principle that the quantity of motion present in the world is constant. With that the special physical forces, the as it were immutable "species" of physics, were resolved into variously differentiated forms of the motion of matter,

* The defect of Lyell's view—at least in its first form—lay in conceiving the forces at work on the earth as constant, both in quality and quantity. The cooling of the earth does not exist for him; the earth does not develop in a definite direction but merely changes in an inconsequent fortuitous manner. [*Note by Engels.*]

passing into one another according to definite laws. The fortuitousness of the existence of such and such a number of physical forces was abolished from science by the proof of their inter-connections and transitions. Physics, like astronomy before it, had arrived at a result that necessarily pointed to the eternal cycle of matter in motion as the ultimate conclusion.

The wonderfully rapid development of chemistry, since Lavoisier and especially since Dalton, attacked the old ideas about nature from another aspect. The preparation by inorganic means of compounds that hitherto had been produced only in the living organism proved that the laws of chemistry have the same validity for organic as for inorganic bodies, and to a large extent bridged the gulf between inorganic and organic nature, a gulf that even Kant regarded as for ever impassable.

Finally, in the sphere of biological research also the scientific journeys and expeditions that had been systematically organised since the middle of the previous [i.e., 18th] century, the more thorough exploration of the European colonies in all parts of the world by specialists living there, and further the progress of palæntology, anatomy, and physiology in general, particularly since the systematic use of the microscope and the discovery of the cell, had accumulated so much material that the application of the comparative method became possible and at the same time indispensable.* On the one hand the conditions of life of the various floras and faunas were established by means of comparative physical geography; on the other hand the various organisms were compared with one another according to their homologous organs, and this not only in the adult condition but at all stages of their development. The more deeply and exactly this research was carried on, the more did the rigid system of an immutably fixed organic nature crumble away at its touch. Not only did the separate species of plants and animals become more and more inextricably intermingled, but animals turned up, such as *Amphioxus* and *Lepidosiren*,[17]

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* In the margin of the manuscript is added in pencil: "Embryology."—*Ed.*

that made a mockery of all previous classification,* and finally organisms were encountered of which it was not possible to say whether they belonged to the plant or animal kingdom. More and more the gaps in the palæontological record were filled up, compelling even the most reluctant to acknowledge the striking parallelism between the history of the development of the organic world as a whole and that of the individual organism, the Ariadne's thread that was to lead the way out of the labyrinth in which botany and zoology appeared to have become more and more deeply lost. It was characteristic that, almost simultaneously with Kant's attack on the eternity of the solar system, C. F. Wolff in 1759 launched the first attack on the fixity of species and proclaimed the theory of descent.[19] But what in his case was still only a brilliant anticipation took firm shape in the hands of Oken, Lamarck, Baer, and was victoriously carried through by Darwin in 1859, exactly a hundred years later.[20] Almost simultaneously it was established that protoplasm and the cell, which had already been shown to be the ultimate morphological constituents of all organisms, occurred independently, existing as the lowest forms of organic life. This not only reduced the gulf between inorganic and organic nature to a minimum but removed one of the most essential difficulties that had previously stood in the way of the theory of descent of organisms. The new outlook on nature was complete in its main features: all rigidity was dissolved, all fixity dissipated, all particularity that had been regarded as eternal became transient, the whole of nature was shown as moving in eternal flux and cyclical course.

Thus we have once again returned to the mode of outlook of the great founders of Greek philosophy, the view that the whole of nature, from the smallest element to the greatest, from grains of sand to suns, from Protista[21] to man, has its existence in eternal coming into being and

* In the margin of the manuscript is added in pencil: "*Ceratodus*, Ditto *Archaeopteryx*, etc."[18]—Ed.

passing away, in ceaseless flux, in unresting motion and change. Only with the essential difference that what in the case of the Greeks was a brilliant intuition, is in our case the result of strictly scientific research in accordance with experience, and hence also it emerges in a much more definite and clear form. It is true that the empirical proof of this cyclical course is not wholly free from gaps, but these are insignificant in comparison with what has already been firmly established, and with each year they become more and more filled up. And how could the proof in detail be other than one containing gaps when one bears in mind that the most important branches of science—trans-planetary astronomy, chemistry, geology—have a scientific existence of barely a century, and the comparative method in physiology, one of barely fifty years, and that the basic form of almost all organic development, the cell, is a discovery not yet forty years old?*

The innumerable suns and solar systems of our island universe, bounded by the outermost stellar rings of the Milky Way, developed by contraction and cooling from swirling, glowing masses of vapour, the laws of motion of which will perhaps be disclosed after the observations of some centuries have given us an insight into the proper motion of the stars. Obviously, this development did not proceed everywhere at the same rate. Astronomy is more and more being forced to recognise the existence of dark bodies, not merely planetary in nature, hence extinct suns in our stellar system (Mädler); on the other hand (according to Secchi) a part of the vaporous nebular patches belong to our stellar system as suns not yet fully formed, which does not exclude the possibility that other nebulæ are, as Mädler maintains, distant independent island universes, the relative stage of development of which must be determined by the spectroscope.[22]

* In Engels's manuscript, this paragraph is separated from the paragraphs which precede and follow it by horizontal lines, and is crossed out slantwise, as Engels usually did with the passages which he used in other works.—*Ed.*

How a solar system develops from an individual nebular mass has been shown in detail by Laplace in a manner still unsurpassed; subsequent science has more and more confirmed him.

On the separate bodies so formed—suns as well as planets and satellites—the form of motion of matter at first prevailing is that which we call heat. There can be no question of chemical compounds of the elements even at a temperature like that still possessed by the sun; the extent to which heat is transformed into electricity or magnetism under such conditions, continued solar observations will show; it is already as good as proved that the mechanical motion taking place in the sun arises solely from the conflict of heat with gravity.

The smaller the individual bodies, the quicker they cool down, the satellites, asteroids, and meteors first of all, just as our moon has long been extinct. The planets cool more slowly, the central body slowest of all.

With progressive cooling the interplay of the physical forms of motion which become transformed into one another comes more and more to the forefront until finally a point is reached from when on chemical affinity begins to make itself felt, the previously chemically indifferent elements become differentiated chemically one after another, acquire chemical properties, and enter into combination with one another. These compounds change continually with the decreasing temperature, which affects differently not only each element but also each separate compound of the elements, changing also with the consequent passage of part of the gaseous matter first to the liquid and then the solid state, and with the new conditions thus created.

The time when the planet acquires a firm shell and accumulations of water on its surface coincides with that from when on its intrinsic heat diminishes more and more compared with the heat emitted to it from the central body. Its atmosphere becomes the arena of meteorological phenomena in the sense in which we now understand the term; its surface becomes the arena of geological changes in which the deposits resulting from atmospheric precipitation become of ever greater importance compared with the slowly decreasing external effects of the hot fluid interior.

If, finally, the temperature becomes so far equalised that over a considerable portion of the surface at least it no longer exceeds the limits within which protein is capable of life, then, if other chemical pre-conditions are favourable, living protoplasm is formed. What these pre-conditions are, we do not yet know, which is not to be wondered at since so far not even the chemical formula of protein has been established—we do not even know how many chemically different protein bodies there are—and since it is only about ten years ago that the fact became known that completely structureless protein exercises all the essential functions of life: digestion, excretion, movement, contraction, reaction to stimuli, and reproduction.

Thousands of years may have passed before the conditions arose in which the next advance could take place and this shapeless protein produce the first cell by formation of nucleus and cell membrane. But this first cell also provided the foundation for the morphological development of the whole organic world; the first to develop, as it is permissible to assume from the whole analogy of the palæontological record, were innumerable species of non-cellular and cellular Protista, of which *Eozoon canadense*[23] alone has come down to us, and of which some were gradually differentiated into the first plants and others into the first animals. And from the first animals were developed, essentially by further differentiation, the numerous classes, orders, families, genera, and species of animals; and finally vertebrates, the form in which the nervous system attains its fullest development; and among these again finally that vertebrate in which nature attains consciousness of itself—man.

Man, too, arises by differentiation. Not only individually—by development from a single egg-cell to the most complicated organism that nature produces—but also historically. When after thousands of years of struggle the differentiation of hand from foot, and erect gait, were finally established, man became distinct from the ape and the basis was laid for the development of articulate speech and the mighty development of the brain that has since

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made the gulf between man and the ape an unbridgeable one. The specialisation of the hand—this implies the *tool*, and the tool implies specific human activity, the transforming reaction of man on nature, production. Animals in the narrower sense also have tools, but only as limbs of their bodies: the ant, the bee, the beaver; animals also produce, but their productive effect on surrounding nature, in relation to nature, amounts to nothing at all. Man alone has succeeded in impressing his stamp on nature, not only by shifting plant and animal species from one place to another, but also by so altering the aspect and climate of his dwelling-place, and even the plants and animals themselves, that the consequences of his activity can disappear only with the general extinction of the terrestrial globe. And he has accomplished this primarily and essentially by means of *the hand*. Even the steam-engine, so far his most powerful tool for the transformation of nature, depends, because it is a tool, in the last resort on the hand. But step by step with the development of the hand went that of the brain; first of all came consciousness of the conditions for separate practically useful actions, and later, among the more favoured peoples and arising from that consciousness, insight into the natural laws governing them. And with the rapidly growing knowledge of the laws of nature the means for reacting on nature also grew; the hand alone would never have achieved the steam-engine if, along with and parallel to the hand, and partly owing to it, the brain of man had not correspondingly developed.

With man we enter *history*. Animals also have a history, that of their descent and gradual evolution to their present position. This history, however, is made for them, and in so far as they themselves take part in it, this occurs without their knowledge and desire. On the other hand, the more that human beings become removed from animals in the narrower sense of the word, the more they make their history themselves, consciously, the less becomes the influence of unforeseen effects and uncontrolled forces on this history, and the more accurately does the historical result correspond to the aim laid down in advance. If, however, we apply this measure to human history, to that of even the most developed peoples of the present day, we find that there still exists here a colossal disproportion between the proposed aims and the results arr ved at, that unforeseen effects predominate, and that the uncontrolled forces are far more powerful than those set into motion according to plan. And this cannot be otherwise as long as the most essential historical activity of men, the one which has raised them from the animal to the human state and which forms the material foundation of all their other activities, namely the production of their requirements of life, i.e., in our day social production, is above all subject to the interplay of unintended effects from uncontrolled forces and achieves its desired end only by way of exception, but much more frequently the exact opposite. In the most advanced industrial countries we have subdued the forces of nature and pressed them into the service of mankind; we have thereby infinitely multiplied production, so that a child now produces more than a hundred adults previously did. And what is the result? Increasing overwork and increasing misery of the masses, and every ten years a great collapse. Darwin did not know what a bitter satire he wrote on mankind, and especially on his countrymen, when he showed that free competition, the struggle for existence, which the economists celebrate as the highest historical achievement, is the normal state of the *animal kingdom*. Only conscious organisation of social production, in which production and distribution are carried on in a planned way, can lift mankind above the rest of the animal world as regards the social aspect, in the same way that production in general has done this for mankind in the specifically biological aspect. Historical evolution makes such an organisation daily more indispensable, but also with every day more possible. From it will date a new epoch of history, in which mankind itself, and with mankind all branches of its activity, and particularly natural science, will experience an advance that will put everything preceding it in the deepest shade.

Nevertheless, "all that comes into being deserves to perish".[24] Millions of years may elapse, hundreds of thousands of generations be born and die, but inexorably the time will come when the declining warmth of the sun will no longer suffice to melt the ice thrusting itself forward from the poles; when the human race, crowding more and more about the equator, will finally no longer find even there enough heat for life; when gradually even the last trace of organic life will vanish; and the earth, an extinct frozen globe like the moon, will circle in deepest darkness and in an ever narrower orbit about the equally extinct sun, and at last fall into it. Other planets will have preceded it, others will follow it; instead of the bright, warm solar system with its harmonious arrangement of members, only a cold, dead sphere will still pursue its lonely path through universal space. And what will happen to our solar system will happen sooner or later to all the other systems of our island universe; it will happen to all the other innumerable island universes, even to those the light of which will never reach the earth while there is a living human eye to receive it.

And when such a solar system has completed its life history and succumbs to the fate of all that is finite, death, what then? Will the sun's corpse roll on for all eternity through infinite space, and all the once infinitely diversely differentiated natural forces pass for ever into one single form of motion, attraction?

"Or"—as Secchi asks (p. 810)—"are there forces in nature which can reconvert the dead system into its original state of glowing nebula and re-awaken it to new life? We do not know."

Of course, we do not know it in the sense that we know that $2 \times 2 = 4$, or that the attraction of matter increases and decreases according to the square of the distance. In theoretical natural science, however, which as far as possible builds up its outlook on nature into a harmonious whole, and without which nowadays even the most unthinking empiricist cannot get anywhere, we have very often to calculate with incompletely known magnitudes, and consistency of thought must at all times help to get over defective knowledge. Modern natural science has had to take over from philosophy the principle of the indestructibility of motion; it cannot any longer exist without this principle. But the motion of matter is not merely crude mechanical motion, mere change of place, it is heat and light, electric and magnetic tension, chemical combination and dissociation, life and, finally, consciousness. To say that matter during the whole unlimited time of its existence has only once, and for what is an infinitesimally short period in comparison to its eternity, found itself able to differentiate its motion and thereby to unfold the whole wealth of this motion, and that before and after this it remains restricted for eternity to mere change of place—this is equivalent to maintaining that matter is mortal and motion transient. The indestructibility of motion cannot be conceived merely quantitatively, it must also be conceived qualitatively; matter whose purely mechanical change of place includes indeed the possibility under favourable conditions of being transformed into heat, electricity, chemical action, life, but which is not capable of producing these conditions from out of itself, such matter has *forfeited motion*; motion which has lost the capacity of being transformed into the various forms appropriate to it may indeed still have *dynamis** but no longer *energeia*,** and so has become partially destroyed. Both, however, are unthinkable.

This much is certain: there was a time when the matter of our island universe had transformed into heat such an amount of motion—of what kind we do not yet know—that there could be developed from it the solar systems appertaining to (according to Mädler) at least twenty million stars, the gradual extinction of which is likewise certain. How did this transformation take place? We know just as little as Father Secchi knows whether the future *caput mortuum* of our solar system will once again be converted into the raw material of new solar systems. But here either we must have recourse to a creator, or we are forced to the conclusion that the incandescent raw material for the solar systems of our universe was produced in a natural way by transformations of motion which are *by nature inherent* in moving matter, and the conditions for which, therefore, must also be reproduced by matter, even if only after millions and millions of years and more or

* Power.—*Ed.*
** Activity.—*Ed.*

less by chance, but with the necessity that is also inherent in chance.

The possibility of such a transformation is more and more being conceded. The view is being arrived at that the heavenly bodies are ultimately destined to fall into one another, and calculations are even made of the amount of heat which must be developed on such collisions. The sudden flaring up of new stars, and the equally sudden increase in brightness of familiar ones, of which we are informed by astronomy, are most easily explained by such collisions. Moreover, not only does our group of planets move about the sun, and our sun within our island universe, but our whole island universe also moves in space in temporary, relative equilibrium with the other island universes, for even the relative equilibrium of freely floating bodies can only exist where the motion is reciprocally determined; and it is assumed by many that the temperature in space is not everywhere the same. Finally, we know that, with the exception of an infinitesimal portion, the heat of the innumerable suns of our island universe vanishes into space and fails to raise the temperature of space even by a millionth of a degree Centigrade. What becomes of all this enormous quantity of heat? Is it for ever dissipated in the attempt to heat universal space, has it ceased to exist practically, and does it only continue to exist theoretically, in the fact that universal space has become warmer by a decimal fraction of a degree beginning with ten or more noughts? Such an assumption denies the indestructibility of motion; it concedes the possibility that by the successive falling into one another of the heavenly bodies all existing mechanical motion will be converted into heat and the latter radiated into space, so that in spite of all "indestructibility of force" all motion in general would have ceased. (Incidentally, it is seen here how inaccurate is the term "indestructibility of force" instead of "indestructibility of motion".) Hence we arrive at the conclusion that in some way, which it will later be the task of scientific research to demonstrate, it must be possible for the heat radiated into space to be transformed into another form of motion, in which it can once more be stored up and become active Thereby the chief difficulty in the way of the reconversion of extinct suns into incandescent vapour disappears.

For the rest, the eternally repeated succession of worlds in infinite time is only the logical complement to the coexistence of innumerable worlds in infinite space—a principle the necessity of which has forced itself even on the anti-theoretical Yankee brain of Draper.*

It is an eternal cycle in which matter moves, a cycle that certainly only completes its orbit in periods of time for which our terrestrial year is no adequate measure, a cycle in which the time of highest development, the time of organic life and still more that of the life of beings conscious of nature and of themselves, is just as narrowly restricted as the space in which life and self-consciousness come into operation; a cycle in which every finite mode of existence of matter, whether it be sun or nebular vapour, single animal or genus of animals, chemical combination or dissociation, is equally transient, and wherein nothing is eternal but eternally changing, eternally moving matter and the laws according to which it moves and changes. But however often, and however relentlessly, this cycle is completed in time and space; however many millions of suns and earths may arise and pass away; however long it may last before, in one solar system and only on *one* planet, the conditions for organic life develop; however innumerable the organic beings, too, that have to arise and to pass away before animals with a brain capable of thought are developed from their midst, and for a short span of time find conditions suitable for life, only to be exterminated later without mercy—we have the certainty that matter remains eternally the same in all its transformations, that none of its attributes can ever be lost, and therefore, also, that with the same iron necessity that it will exterminate on the earth its highest creation, the thinking mind, it must somewhere else and at another time again produce it.

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* "The multiplicity of worlds in infinite space leads to the conception of a succession of worlds in infinite time." (J. W. Draper, *History of the Intellectual Development of Europe*, Vol. 2 [p. 325].) [*Note by Engels.*]

Old Preface to [*Anti*]-*Dühring*. On Dialectics[25]

The following work does not by any means owe its origin to an "inner urge". On the contrary, my friend Liebknecht can testify to the great effort it cost him to persuade me to turn the light of criticism on Herr Dühring's newest socialist theory. Once I made up my mind to do so I had no choice but to investigate this theory, which claims to be the latest practical fruit of a new philosophical system, in its connection with this system, and thus to examine the system itself. I was therefore compelled to follow Herr Dühring into that vast domain in which he speaks of all possible things and of some others as well. That was the origin of a series of articles which appeared in the Leipzig *Vorwärts* from the beginning of 1877 onwards and are here presented as a connected whole.

When, because of the nature of the subject, the critique of a system, so extremely insignificant despite all self-praise, is presented in such great detail, two circumstances may be cited in excuse. On the one hand this criticism afforded me the opportunity of settting forth in positive form in various fields my outlook on controversial issues that today are of quite general scientific or practical interest. And while it does not occur to me in the least to present another system as an alternative to Herr Dühring's, it is to be hoped that, notwithstanding the variety of material examined by me, the reader will not fail to observe the inter-connection inherent also in the views which I have advanced.

On the other hand the "system-creating" Herr Dühring is by no means an isolated phenomenon in contemporary Germany. For some time now in that country philosophical, especially natural-philosophical, systems have been springing up by the dozen overnight, like mushrooms, not to mention the countless new systems of politics, economics, etc. Just as in the modern state it is presumed that every citizen is competent to pass judgement on all the issues on which he is called to vote; and just as in economics it is assumed that every buyer is a connoisseur of all the commodities which he has occasion to purchase for his maintenance—so similar assumptions are now to be made in science. Everybody can write about everything and "freedom of science" consists precisely in people deliberately writing about things they have not studied and putting this forward as the only strictly scientific method. Herr Dühring, however, is one of the most characteristic types of this bumptious pseudo-science which in Germany nowadays is forcing its way to the front everywhere and is drowning everything with its resounding sublime nonsense. Sublime nonsense in poetry, in philosophy, in economics, in historiography; sublime nonsense in the lecture room and on the platform, sublime nonsense everywhere; sublime nonsense which lays claim to a superiority and depth of thought distinguishing it from the simple, commonplace nonsense of other nations; sublime nonsense, the most characteristic mass product of Germany's intellectual industry—cheap but bad—just like other German-made goods, only that unfortunately it was not exhibited along with them at Philadelphia.[26] Even German socialism has lately, particularly since Herr-Dühring's good example, gone in for a considerable amount of sublime nonsense; the fact that the practical Social-Democratic movement so little allows itself to be led astray by this sublime nonsense is one more proof of the remarkably healthy condition of our working class in a country where otherwise, with the exception of natural science, at the present moment almost everything goes ill.

When Nägeli, in his speech at the Munich meeting of natural scientists, voiced the idea that human knowledge would never acquire the character of omniscience,[27] he must obviously have been ignorant of Herr Dühring's achievements. These achievements have compelled me to follow him into a number of spheres in which I can move at best only in the capacity of a dilettante. This applies particularly to the various branches of natural science, where hitherto it was frequently considered more than presumptuous for a "layman" to want to have any say. I am encouraged somewhat, however, by a dictum uttered, likewise in Munich, by Herr Virchow and elsewhere discussed more in detail, that outside of his own speciality every natural scientist is only a semi-initiate,[28] *vulgo*: layman. Just as such a specialist may and must take the liberty of encroaching from time to time on neighbouring fields, and is granted indulgence there by the specialists concerned in respect of minor inexactitudes and clumsiness of expression, so I have taken the liberty of citing natural processes and laws of nature as examples in proof of my general theoretical views, and I hope that I can count on the same indulgence.* The results obtained by modern natural science force themselves upon everyone who is occupied with theoretical matters with the same irresistibility with which the natural scientist today is willy-nilly driven to general theoretical conclusions. And here a certain compensation occurs. If theoreticians are semi-initiates in the sphere of natural science, then natural scientists today are actually just as much so in the sphere of theory, in the sphere of what hitherto was called philosophy.

Empirical natural science has accumulated such a tremendous mass of positive material for knowledge that the necessity of classifying it in each separate field of investigation systematically and in accordance with its inner inter-connection has become absolutely imperative. It is becoming equally imperative to bring the individual spheres of knowledge into the correct connection with one another. In doing so, however, natural science enters the field of theory and here the methods of empiricism will not work, here only theoretical thinking can be of assistance.** But theoretical thinking is an innate quality only as regards natural capacity. This natural capacity must be

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* Engels crossed out a part of his "Old Preface", from the beginning to this sentence, by a vertical stroke, since he used this part in his preface to the first edition of *Anti-Dühring*.—*Ed.*

** In the manuscript this sentence and the one preceding it are underscored in pencil.—*Ed.*

developed, improved, and for its improvement there is as yet no other means than the study of previous philosophy.

In every epoch, and therefore also in ours, theoretical thought is a historical product, which at different times assumes very different forms and, therewith, very different contents. The science of thought is therefore, like every other, a historical science, the science of the historical development of human thought. And this is of importance also for the practical application of thought in empirical fields. Because in the first place the theory of the laws of thought is by no means an "eternal truth" established once and for all, as philistine reasoning imagines to be the case with the word "logic". Formal logic itself has been the arena of violent controversy from the time of Aristotle to the present day. And dialectics has so far been fairly closely investigated by only two thinkers, Aristotle and Hegel. But it is precisely dialectics that constitutes the most important form of thinking for present-day natural science, for it alone offers the analogue for, and thereby the method of explaining, the evolutionary processes occurring in nature, inter-connections in general, and transitions from one field of investigation to another.

Secondly, an acquaintance with the historical course of evolution of human thought, with the views on the general inter-connections in the external world expressed at various times, is required by theoretical natural science for the additional reason that it furnishes a criterion of the theories propounded by this science itself. Here, however, lack of acquaintance with the history of philosophy is fairly frequently and glaringly displayed. Propositions which were advanced in philosophy centuries ago, which often enough have long been disposed of philosophically, are frequently put forward by theorising natural scientists as brand-new wisdom and even become fashionable for a while. It is certainly a great achievement of the mechanical theory of heat that it strengthened the principle of the conservation of energy by means of fresh proofs and put it once more in the forefront; but could this principle have appeared on the scene as something so absolutely new if the worthy physicists had remembered that it had already been formulated by Descartes? Since physics and chemistry once more operate almost exclusively with molecules and atoms, the atomic philosophy of ancient Greece has of necessity come to the fore again. But how superficially it is treated even by the best of natural scientists! Thus Kekulé tells us (*Ziele und Leistungen der Chemie*) that Democritus, instead of Leucippus, originated it, and he maintains that Dalton was the first to assume the existence of qualitatively different elementary atoms and was the first to ascribe to them different weights characteristic of the different elements.[29] Yet anyone can read in Diogenes Laertius (X, §§ 43-44 and 61) that already Epicurus had ascribed to atoms differences not only of magnitude and form but also of *weight*,* that is, he was already acquainted in his own way with atomic weight and atomic volume.

The year 1848, which otherwise brought nothing to a conclusion in Germany, accomplished a complete revolution there only in the sphere of philosophy. By throwing itself into the field of the practical, here setting up the beginnings of modern industry and swindling, there initiating the mighty advance which natural science has since experienced in Germany and which was inaugurated by the caricature-like itinerant preachers Vogt, Büchner, etc., the nation resolutely turned its back on classical German philosophy that had lost itself in the sands of Berlin Old-Hegelianism. Berlin Old-Hegelianism had richly deserved that. But a nation that wants to climb the pinnacles of science cannot possibly manage without theoretical thought. Not only Hegelianism but dialectics too was thrown overboard—and that just at the moment when the dialectical character of natural processes irresistibly forced itself upon the mind, when therefore only dialectics could be of assistance to natural science in negotiating the mountain of theory—and so there was a helpless relapse into the old metaphysics. What prevailed among the public since then were, on the one hand, the vapid reflections of Schopenhauer, which were fashioned to fit the philistines, and later even those of Hartmann; and, on the other hand, the vulgar itinerant-preacher materialism of a Vogt and a Büchner. At the universities the most diverse varieties of

* See this volume, p. 189.—*Ed.*

eclecticism competed with one another and had only one thing in common, namely, that they were concocted from nothing but remnants of old philosophies and were all equally metaphysical. All that was saved from the remnants of classical philosophy was a certain neo-Kantianism, whose last word was the eternally unknowable thing-in-itself, that is, the bit of Kant that least merited preservation. The final result was the incoherence and confusion of theoretical thought now prevalent.

One can scarcely pick up a theoretical book on natural science without getting the impression that natural scientists themselves feel how much they are dominated by this incoherence and confusion, and that the so-called philosophy now current offers them absolutely no way out. And here there really is no other way out, no possibility of achieving clarity, than by a return, in one form or another, from metaphysical to dialectical thinking.

This return can take place in various ways. It can come about spontaneously, by the sheer force of the natural-scientific discoveries themselves, which refuse any longer to allow themselves to be forced into the old Procrustean bed of metaphysics. But that is a protracted, laborious process during which a tremendous amount of unnecessary friction has to be overcome. To a large extent that process is already going on, particularly in biology. It could be greatly shortened if the theoreticians in the field of natural science were to acquaint themselves more closely with dialectical philosophy in its historically existing forms. Among these forms there are two which may prove especially fruitful for modern natural science.

The first of these is Greek philosophy. Here dialectical thought still appears in its pristine simplicity, still undisturbed by the charming obstacles[30] which the metaphysics of the seventeenth and eighteenth centuries—Bacon and Locke in England, Wolff in Germany—put in its own way, and with which it blocked its own progress, from an understanding of the part to an understanding of the whole, to an insight into the general inter-connection of things. Among the Greeks—just because they were not yet advanced enough to dissect, analyse nature—nature is still viewed as a whole, in general. The universal connection of natural phenomena is not proved in regard to particulars; to the Greeks it is the result of direct contemplation. Herein lies the inadequacy of Greek philosophy, on account of which it had to yield later to other modes of outlook on the world. But herein also lies its superiority over all its subsequent metaphysical opponents. If in regard to the Greeks metaphysics was right in particulars, in regard to metaphysics the Greeks were right in general. That is the first reason why we are compelled in philosophy as in so many other spheres to return again and again to the achievements of that small people whose universal talents and activity assured it a place in the history of human development that no other people can ever claim. The other reason, however, is that the manifold forms of Greek philosophy contain in embryo, in the nascent state, almost all later modes of outlook on the world. Theoretical natural science is therefore likewise forced to go back to the Greeks if it desires to trace the history of the origin and development of the general principles it holds today. And this insight is forcing its way more and more to the fore. Instances are becoming increasingly rare of natural scientists who, while themselves operating with fragments of Greek philosophy, for example atomistics, as with eternal truths, look down upon the Greeks with Baconian superciliousness because the Greeks had no empirical natural science. It would be desirable only for this insight to advance to a real familiarity with Greek philosophy.

The second form of dialectics, which is the one that comes closest to the German naturalists, is classical German philosophy, from Kant to Hegel. Here a start has already been made in that it has again become fashionable to return to Kant, even apart from the neo-Kantianism mentioned above. Since the discovery that Kant was the author of two brilliant hypotheses, without which theoretical natural science today simply cannot make progress—the theory, formerly credited to Laplace, of the origin of the solar system and the theory of the retardation of the earth's rotation by the tides—Kant is again held in honour among natural scientists, as he deserves to be. But to study dialectics in the works of Kant would be a uselessly laborious and little-remunerative task, as there is now available, in

Hegel's works, a comprehensive compendium of dialectics, developed though it be from an utterly erroneous point of departure.

After, on the one hand, the reaction against "natural philosophy" had run its course and had degenerated into mere abuse—a reaction that was largely justified by this erroneous point of departure and the helpless degeneration of Berlin Hegelianism; and after, on the other hand, natural science had been so conspicuously left in the lurch by current eclectic metaphysics in regard to its theoretical requirements, it will perhaps be possible to pronounce once more the name of Hegel in the presence of natural scientists without provoking that St. Vitus's dance which Herr Dühring so entertainingly performs.

First of all it must be established that here it is not at all a question of defending Hegel's point of departure: that spirit, mind, the idea, is primary and that the real world is only a copy of the idea. Already Feuerbach abandoned that. We all agree that in every field of science, in natural as in historical science, one must proceed from the given *facts*, in natural science therefore from the various material forms and the various forms of motion of matter*; that therefore in theoretical natural science too the interconnections are not to be built into the facts but to be discovered in them, and when discovered to be verified as far as possible by experiment.

Just as little can it be a question of maintaining the dogmatic content of the Hegelian system as it was preached by the Berlin Hegelians of the older and younger line. Hence, with the fall of the idealist point of departure, the system built upon it, in particular Hegelian natural philosophy, also falls. It must however be recalled that the natural scientists' polemic against Hegel, in so far as they at all correctly understood him, was directed solely against these two points: viz., the idealist point of departure and the arbitrary, fact-defying construction of the system.

After allowance has been made for all this, there still remains Hegelian dialectics. It is the merit of Marx that, in

* After this comes the following sentence, crossed out in the manuscript: "We socialist materialists go even considerably further in this respect than the natural scientists by also. . . ."—*Ed.*

contrast to the "peevish, arrogant, mediocre Επίγονοι who now talk large in Germany",[31] he was the first to have brought to the fore again the forgotten dialectical method, its connection with Hegelian dialectics and its distinction from the latter, and at the same time to have applied this method in *Capital* to the facts of an empirical science, political economy. And he did it so successfully that even in cultured Germany the newer economic school rises above the vulgar free-trade system only by copying from Marx (often enough incorrectly), on pretence of criticising him.

In Hegel's dialectics there prevails the same inversion of all real inter-connection as in all other ramifications of his system. But, as Marx says: "The mystification which dialectics suffers in Hegel's hands by no means prevents him from being the first to present its general form of working in a comprehensive and conscious manner. With him it is standing on its head. It must be turned right side up again, if you would discover the rational kernel within the mystical shell."[32]

In natural science itself, however, we often enough encounter theories in which the real relation is stood on its head, the reflection is taken for the original form, and which consequently need to be turned right side up again. Such theories quite often dominate for a considerable time. When for almost two centuries heat was considered a special mysterious substance instead of a form of motion of ordinary matter, that was precisely such a case and the mechanical theory of heat carried out the inverting. Nevertheless physics dominated by the caloric theory discovered a series of highly important laws of heat and cleared the way, particularly through Fourier and Sadi Carnot,[33] for the correct conception, which now for its part had to put right side up the laws discovered by its predecessor, to translate them into its own language.* Similarly, in chemistry the phlogistic theory first supplied the material, by a hundred years of experimental work, with the aid of which Lavoisier was able to discover in the oxygen obtained

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* Carnot's function C literally inverted: $\frac{1}{C}$ =absolute temperature. Without this inversion nothing can be done with it. [*Note by Engels.*]

by Priestley the real antipode of the fantastic phlogiston and thus could throw overboard the entire phlogistic theory. But this did not in the least do away with the experimental results of phlogistics. On the contrary. They persisted, only their formulation was inverted, was translated from the phlogistic into the now valid chemical language and thus they retained their validity.

The relation of Hegelian dialectics to rational dialectics is the same as that of the caloric theory to the mechanical theory of heat and that of the phlogistic theory to the theory of Lavoisier.

Natural Science in the Spirit World[34]

The dialectics that has found its way into popular consciousness is expressed in the old saying that extremes meet. In accordance with this we should hardly err in looking for the most extreme degree of fantasy, credulity, and superstition, not in that trend of natural science which, like the German philosophy of nature, tries to force the objective world into the framework of its subjective thought, but rather in the opposite trend, which, exalting mere experience, treats thought with sovereign disdain and really has gone to the furthest extreme in emptiness of thought. This school prevails in England. Its father, the much lauded Francis Bacon, already advanced the demand that his new empirical, inductive method should be pursued to attain, above all, by its means: longer life, rejuvenation—to a certain extent, alteration of stature and features, transformation of one body into another, the production of new species, power over the air and the production of storms. He complains that such investigations have been abandoned, and in his natural history he gives definite recipes for making gold and performing various miracles.[35] Similarly Isaac Newton in his old age greatly busied himself with expounding the Revelation of St. John.[36] So it is not to be wondered at if in recent years English empiricism in the person of some of its representatives—and not the worst of them—should seem to have fallen a hopeless victim to the spirit-rapping and spirit-seeing imported from America.

The first natural scientist belonging here is the very eminent zoologist and botanist, Alfred Russel Wallace, the man who simultaneously with Darwin put forward the theory of the alteration of species by natural selection. In his little work, *On Miracles and Modern Spiritualism,* London, Burns, 1875,[37] he relates that his first experiences in this branch of natural knowledge date from 1844, when he attended the lectures of Mr. Spencer Hall on mesmerism[38] and as a result carried out similar experiments on his pupils.

"I was intensely interested in the subject and pursued it with ardour." [P. 119.]

He not only produced magnetic sleep together with the phenomena of articular rigidity and local loss of sensation, he also confirmed the correctness of Gall's map of the skull,[39] because on touching any one of Gall's organs the corresponding activity was aroused in the magnetised patient and exhibited by appropriate and lively gestures. Further, he established that his patient, merely by being touched, partook of all the sensations of the operator; he made him drunk with a glass of water as soon as he told him that it was brandy. He could make one of the young men so stupid, even in the waking condition, that he no longer knew his own name, a feat, however, that other schoolmasters are capable of accomplishing without any mesmerism. And so on.

Now it happens that I also saw this Mr. Spencer Hall in the winter of 1843-44 in Manchester. He was a very mediocre charlatan, who travelled the country under the patronage of some parsons and undertook magnetico-phrenological performances with a young woman in order to prove thereby the existence of God, the immortality of the soul, and the incorrectness of the materialism that was being preached at that time by the Owenites in all big towns. The lady was sent into a magnetic sleep and then, as soon as the operator touched any part of the skull corresponding to one of Gall's organs, she gave a bountiful display of theatrical, demonstrative gestures and poses representing the activity of the organ concerned; for instance, for the organ of philoprogenitiveness she fondled and kissed an imaginary baby, etc. Moreover, the good Mr. Hall had enriched Gall's geography of the skull with a new island of Barataria[40]: right at the top of the skull he had discovered an organ of veneration, on touching which his hypnotic miss sank on to her knees, folded her hands in prayer, and depicted to the astonished, philistine audience an angel wrapt in veneration. That was the climax and conclusion of the exhibition. The existence of God had been proved.

The effect on me and one of my acquaintances was similar to that on Mr. Wallace: the phenomena interested us and we tried to find out how far we could reproduce them. A wide-awake young boy 12 years old offered himself as subject. Gently gazing into his eyes, or stroking, sent him without difficulty into the hypnotic condition. But since we were rather less credulous than Mr. Wallace and set to work with rather less fervour, we arrived at quite different results. Apart from muscular rigidity and loss of sensation, which were easy to produce, we found also a state of complete passivity of the will bound up with a peculiar hypersensitivity of sensation. The patient, when aroused from his lethargy by any external stimulus, exhibited very much greater liveliness than in the waking condition. There was no trace of any mysterious relation to the operator: anyone else could just as easily set the sleeper into activity. To put Gall's cranial organs into operation was a mere trifle for us; we went much further, we could not only exchange them for one another, or make their seat anywhere in the whole body, but we also fabricated any amount of other organs, organs of singing, whistling, piping, dancing, boxing, sewing, cobbling, tobacco-smoking, etc., and we could make their seat wherever we wanted. Wallace made his patients drunk on water, but we discovered in the great toe an organ of drunkenness which only had to be touched in order to cause the finest drunken comedy to be enacted. But it must be well understood, no organ showed a trace of action until the patient was given to understand what was expected of him; the boy soon perfected himself by practice to such an extent that the merest indication sufficed. The organs produced in this way then retained their validity for later occasions of putting to sleep, as long as they were not altered in the same way. The patient had indeed a double memory, one for the waking state and a second quite separate one for the hypnotic condition. As regards the passivity of the will and its absolute subjection to the will of a third person, this loses all its miraculous appearance when we bear in mind that the whole condition began with the subjection of the will of the patient to that of the operator, and cannot be produced without it. The most powerful magician of a magnetiser in the world will come to the end of his resources as soon as his patient laughs him in the face.

While we with our frivolous scepticism thus found that the basis of magnetico-phrenological charlatanry lay in a series of phenomena which for the most part differ only in degree from those of the waking state and require no mystical interpretation, Mr. Wallace's "ardour" led him into a series of self-deceptions, in virtue of which he confirmed Gall's map of the skull in all its details and noted a mysterious relation between operator and patient.* Everywhere in Mr. Wallace's account, the sincerity of which reaches the degree of *naïveté*, it becomes apparent that he was much less concerned in investigating the factual background of charlatanry than in reproducing all the phenomena at all costs. Only this frame of mind is needed for one who was originally a scientist to be quickly converted into an adept by means of simple and facile self-deception. Mr. Wallace ended up with faith in magnetico-phrenological miracles and so already stood with one foot in the world of spirits.

He drew the other foot after him in 1865. On returning from his twelve years of travel in the tropics, experiments in table-turning introduced him to the society of various "mediums". How rapid his progress was, and how complete his mastery of the subject, is testified to by the above-mentioned booklet. He expects us to take for good coin not only all the alleged miracles of the Homes, the brothers Davenport, and other "mediums" who all more or less exhibit themselves for money and who have for the most part been frequently exposed as impostors, but also

* As already said, the patients perfect themselves by practice. It is therefore quite possible that when the subjection of the will has become habitual the relation between the participants becomes more intimate, individual phenomena are intensified and are reflected weakly even in the waking state. [*Note by Engels.*]

a whole series of allegedly authentic spirit histories from early times. The pythonesses of the Greek oracle and the witches of the Middle Ages, were all "mediums", and Iamblichus in his *De divinatione* already described quite accurately

"the most startling phenomena of modern spiritualism". [P. 229.]

Just one example to show how lightly Mr. Wallace deals with the scientific establishment and authentication of these miracles. It is certainly a strong assumption that we should believe that the above-mentioned spirits would allow themselves to be photographed, and we have surely the right to demand that such spirit photographs should be authenticated in the most indubitable manner before we accept them as genuine. Now Mr. Wallace recounts on p. 187 that in March 1872, a leading medium, Mrs. Guppy, *née* Nichol, had herself photographed together with her husband and small boy at Mr. Hudson's in Notting Hill, and on two different photographs a tall female figure, finely draped in white gauzy robes, with somewhat Eastern features, was to be seen behind her in a pose as if giving a benediction.

"Here, then, one of two things *are** absolutely certain.** Either there was a living, intelligent, but invisible being present, or Mr. and Mrs. Guppy, the photographer, and some fourth person planned a wicked imposture, and have maintained it ever since. Knowing Mr. and Mrs. Guppy so well as I do, I feel an *absolute conviction* that they are as incapable of an imposture of this kind as any earnest inquirer after truth in the department of natural science." [P. 188.]

Consequently, either deception or spirit photography. Quite so. And, if deception, either the spirit was already on the photographic plates, or four persons must have been concerned, or three if we leave out as weak-minded or duped old Mr. Guppy who died in January 1875, at the age of 84 (it only needed that he should be sent behind

* Italics by Engels.—*Ed.*

** The spirit world is superior to grammar. A joker once caused the spirit of the grammarian Lindley Murray to testify. To the question whether he was there, he answered: "I are." The medium was from America.[41] [*Note by Engels.*]

the Spanish screen of the background). That a photographer could obtain a "model" for the spirit without difficulty does not need to be argued. But the photographer Hudson, shortly afterwards, was publicly prosecuted for habitual falsification of spirit photographs, so Mr. Wallace remarks in mitigation:

"One thing is clear; that if there has been imposture, it was at once detected by spiritualists themselves." [P. 189.]

Hence there is not much reliance to be placed on the photographer. Remains Mrs. Guppy, and for her there is only the "absolute conviction" of our friend Wallace and nothing more.—Nothing more? Not at all. The absolute trustworthiness of Mrs. Guppy is evidenced by her assertion that one evening, early in June 1871, she was carried through the air in a state of unconsciousness from her house in Highbury Hill Park to 69, Lamb's Conduit Street —three English miles as the crow flies—and deposited in the said house of No. 69 on the table in the midst of a spiritualistic *séance*. The doors of the room were closed, and although Mrs. Guppy was one of the stoutest women in London, which is certainly saying a good deal, nevertheless her sudden incursion did not leave behind the slightest hole either in the doors or in the ceiling. (Reported in the London *Echo*,[42] June 8, 1871.)[43] And if anyone still does not believe in the genuineness of spirit photography, there's no helping him.

The second eminent adept among English natural scientists is Mr. William Crookes, the discoverer of the chemical element thallium and of the radiometer[44] (in Germany also called "Lichtmühle"). Mr. Crookes began to investigate spiritualistic manifestations about 1871, and employed for this purpose a number of physical and mechanical appliances, spring balances, electric batteries, etc. Whether he brought to his task the main apparatus required, a sceptically critical mind, or whether he kept it to the end in a fit state for working, we shall see. At any rate, within a not very long period, Mr. Crookes was just as completely captivated as Mr. Wallace.

"For some years," he relates, "a young lady, Miss Florence Cook, has exhibited remarkable mediumship, which latterly culminated in the production of an entire female form purporting to be of spiritual origin, and which appeared barefooted and in white flowing robes while she lay entranced, in dark clothing and securely bound in a cabinet or adjoining room." [P. 181.]

This spirit, which called itself Katie, and which looked remarkably like Miss Cook, was one evening suddenly seized round the waist by Mr. Volckman—the present husband of Mrs. Guppy—and held fast in order to see whether it was not indeed Miss Cook in another edition. The spirit proved to be a quite sturdy damsel, it defended itself vigorously, the onlookers intervened, the gas was turned out, and when, after some scuffling, peace was re-established and the room re-lit, the spirit had vanished and Miss Cook lay bound and unconscious in her corner. Nevertheless, Mr. Volckman is said to maintain up to the present day that he had seized hold of Miss Cook and nobody else.[45] In order to establish this scientifically, Mr. Varley, a well-known electrician, on the occasion of a new experiment, arranged for the current from a battery to flow through the medium, Miss Cook, in such a way that she could not play the part of the spirit without interrupting the current. Nevertheless, the spirit made its appearance. It was, therefore, indeed a being different from Miss Cook. To establish this further was the task of Mr. Crookes. His first step was to win the *confidence* of the spiritualistic lady.

This confidence, so he says himself in the *Spiritualist*, June 5, 1874, "increased gradually to such an extent that she refused to give a *séance* unless *I made the arrangements.** She said that she always wanted *me* to be near her and in the neighbourhood of the cabinet; I found that—when this confidence had been established and she was sure that *I would not break any promise made to her**—the phenomena increased considerably in strength and there was freely forthcoming evidence that would have been unobtainable in any other way. She frequently *consulted me** in regard to the persons present at the *séances* and the places to be given them, for she had recently become very nervous as a result of certain ill-advised suggestions that, besides other more scientific methods of investigation, *force** also should be applied."[46]

The spirit lady rewarded this confidence, which was as kind as it was scientific, in the highest measure. She

* Italics by Engels.—*Ed.*

even made her appearance—which can no longer surprise us—in Mr. Crookes' house, played with his children and told them "anecdotes from her adventures in India", treated Mr. Crookes to an account of "some of the bitter experiences of her past life", allowed him to take her by the arm so that he could convince himself of her evident materiality, allowed him to take her pulse and count the number of her respirations per minute, and finally allowed herself to be photographed next to Mr. Crookes.[47]

"This figure," says Mr. Wallace, "after being seen, felt, conversed with, and photographed, *absolutely disappeared* from a small room from which there was no other exit than an adjoining room filled with spectators" [p. 183.]

—which was not such a great feat, provided that the spectators were polite enough to show as much faith in Mr. Crookes, in whose house this happened, as Mr. Crookes did in the spirit.

Unfortunately these "fully authenticated phenomena" are not immediately credible even for spiritualists. We saw above how the very spiritualistic Mr. Volckman permitted himself to make a very material grab. And now a clergyman, a member of the committee of the "British National Association of Spiritualists", has also been present at a *séance* with Miss Cook, and he established the fact without difficulty that the room through the door of which the spirit came and disappeared communicated with the outer world by a *second door*. The behaviour of Mr. Crookes, who was also present, gave "the final death-blow to my belief that there might be 'something in' the face manifestations". (*Mystic London,* by the Rev. C. Maurice Davies, London, Tinsley Brothers.)[48] And, over and above that, it came to light in America how "Katies" were "materialised". A married couple named Holmes held *séances* in Philadelphia in which likewise a "Katie" appeared and received bountiful presents from the believers. However, one sceptic refused to rest until he got on the track of the said Katie, who, anyway, had already gone on strike once because of lack of pay; he discovered her in a boarding-house as a young lady of unquestionable flesh and bone, and in possession of all the presents that had been given to the spirit.[49]

Meanwhile the Continent also had its scientific spirit-seers. A scientific association at St. Petersburg—I do not know exactly whether the University or even the Academy itself—charged the Councillor of State, Aksakov, and the chemist, Butlerov, to examine the basis of the spiritualistic phenomena, but it does not seem that very much came of this.[50] On the other hand—if the noisy announcements of the spiritualists are to be believed—Germany has now also put forward its man in the person of Professor Zöllner in Leipzig.

For years, as is well known, Herr Zöllner has been hard at work on the "fourth dimension" of space, and has discovered that many things that are impossible in a space of three dimensions are a simple matter of course in a space of four dimensions. Thus, in the latter kind of space, a closed metal sphere can be turned inside out like a glove, without making a hole in it; similarly a knot can be tied in an endless string or one which has both ends fastened, and two separate closed rings can be interlinked without opening either of them, and many more such feats. Now, according to recent triumphant reports from the spirit world, Professor Zöllner has addressed himself to one or more mediums in order with their aid to determine more details of the locality of the fourth dimension. The success is said to have been surprising. After the session the arm of the chair, on which he rested his arm while his hand never left the table, was found to have become interlocked with his arm, a string that had both ends sealed to the table was found tied into four knots, and so on. In short, all the miracles of the fourth dimension are said to have been performed by the spirits with the utmost ease. It must be borne in mind: *relata refero*, I do not vouch for the correctness of the spirit bulletin, and if it should contain any inaccuracy, Herr Zöllner ought to be thankful that I am giving him the opportunity to make a correction. If, however, it reproduces the experiences of Herr Zöllner without falsification, then it obviously signifies a new era both in the science of spiritualism and that of mathematics. The spirits prove the existence of the fourth dimension, just as the fourth dimension vouches for the existence of spirits. And this once established, an entirely new, immeasurable field is opened to science. All previous mathematics and natural science will be only a preparatory school for the mathematics of the fourth and still higher dimensions, and for the mechanics, physics, chemistry, and physiology of the spirits dwelling in these higher dimensions. Has not Mr. Crookes scientifically determined how much weight is lost by tables and other articles of furniture on their passage into the fourth dimension—as we may now well be permitted to call it—and does not Mr. Wallace declare it proven that fire there does no harm to the human body? And now we have even the physiology of the spirit bodies! They breathe, they have a pulse, therefore lungs, heart, and a circulatory apparatus, and in consequence are at least as admirably equipped as our own in regard to the other bodily organs. For breathing requires carbo-hydrates which undergo combustion in the lungs, and these carbo-hydrates can only be supplied from without; hence, stomach, intestines, and their accessories—and if we have once established so much, the rest follows without difficulty. The existence of such organs, however, implies the possibility of their falling a prey to disease, hence it may still come to pass that Herr Virchow will have to compile a cellular pathology of the spirit world. And since most of these spirits are very handsome young ladies, who are not to be distinguished in any respect whatsoever from terrestrial damsels, other than by their supramundane beauty, it could not be very long before they come into contact with "men who feel the passion of love"[51]; and since, as established by Mr. Crookes from the beat of the pulse, "the female heart is not absent", natural selection also has opened before it the prospect of a fourth dimension, one in which it has no longer any need to fear of being confused with wicked Social-Democracy.[52]

Enough. Here it becomes palpably evident which is the most certain path from natural science to mysticism. It is not the extravagant theorising of the philosophy of nature, but the shallowest empiricism that spurns all theory and distrusts all thought. It is not *a priori* necessity that proves the existence of spirits, but the empirical observations of Messrs. Wallace, Crookes, and Co. If we trust the spectrum-analysis observations of Crookes, which led to the discovery of the metal thallium, or the rich zoological discoveries of Wallace in the Malay Archipelago, we are asked to place the same trust in the spiritualistic experiences and discoveries of these two scientists. And if we express the opinion that, after all, there is a little difference between the two, namely, that we can verify the one but not the other, then the spirit-seers retort that this is not the case, and that they are ready to give us the opportunity of verifying also the spirit phenomena.

Indeed, dialectics cannot be despised with impunity. However great one's contempt for all theoretical thought, nevertheless one cannot bring two natural facts into relation with each other, or understand the connection existing between them, without theoretical thought. The only question is whether one's thinking is correct or not, and contempt of theory is evidently the most certain way to think naturalistically, and therefore incorrectly. But, according to an old and well-known dialectical law, incorrect thinking, carried to its logical conclusion, inevitably arrives at the opposite of its point of departure. Hence, the empirical contempt for dialectics is punished by some of the most sober empiricists being led into the most barren of all superstitions, into modern spiritualism.

It is the same with mathematics. The ordinary, metaphysical mathematicians boast with enormous pride of the absolute irrefutability of the results of their science. But these results include also imaginary magnitudes, which thereby acquire a certain reality. When one has once become accustomed to ascribe some kind of reality outside of our minds to $\sqrt{-1}$, or to the fourth dimension, then it is not a matter of much importance if one goes a step further and also accepts the spirit world of the mediums. It is as Ketteler said about Döllinger:

> "The man has defended so much nonsense in his life, he really could have accepted infallibility into the bargain!"[53]

In fact, mere empiricism is incapable of refuting the spiritualists. In the first place, the "higher" phenomena always show themselves only when the "investigator" concerned is already so far in the toils that he now only sees what he is meant to see or wants to see—as Crookes himself describes with such inimitable *naïveté*. In the second place, the spiritualists care nothing that hundreds of alleged facts are exposed as imposture and dozens of alleged mediums as ordinary tricksters. As long as *every* single alleged miracle has not been explained away, they have still room enough to carry on, as indeed Wallace says clearly enough in connection with the falsified spirit photographs. The existence of falsifications proves the genuineness of the genuine ones.

And so empiricism finds itself compelled to refute the importunate spirit-seers not by means of empirical experiments, but by theoretical considerations, and to say, with Huxley:

> "The only good that I can see in the demonstration of the truth of 'spiritualism' is to furnish an additional argument against suicide. Better live a crossing-sweeper than die and be made to talk twaddle by a 'medium' hired at a guinea a *séance*."[54]

Dialectics[55]

(The general nature of dialectics to be developed as the science of inter-connections, in contrast to metaphysics.)

It is, therefore, from the history of nature and human society that the laws of dialectics are abstracted. For they are nothing but the most general laws of these two aspects of historical development, as well as of thought itself. And indeed they can be reduced in the main to three:

The law of the transformation of quantity into quality and vice versa;

The law of the interpenetration of opposites;

The law of the negation of the negation.

All three are developed by Hegel in his idealist fashion as mere laws of *thought*: the first, in the first part of his *Logic*, in the Doctrine of Being; the second fills the whole of the second and by far the most important part of his *Logic*, the Doctrine of Essence; finally the third figures as the fundamental law for the construction of the whole system. The mistake lies in the fact that these laws are foisted on nature and history as laws of thought, and not deduced from them. This is the source of the whole forced and often outrageous treatment; the universe, willy-nilly, has to conform to a system of thought which itself is only the product of a definite stage of evolution of human thought. If we turn the thing round, then everything becomes simple, and the dialectical laws that look so extremely mysterious in idealist philosophy at once become simple and clear as noonday.

Moreover, anyone who is even only slightly acquainted with Hegel will be aware that in hundreds of passages Hegel is capable of giving the most striking individual illustrations of the dialectical laws from nature and history.

We are not concerned here with writing a handbook of dialectics, but only with showing that the dialectical laws are real laws of development of nature, and therefore are valid also for theoretical natural science. Hence we cannot go into the inner inter-connection of these laws with one another.

1. The law of the transformation of quantity into quality and vice versa. For our purpose, we can express this by saying that in nature, in a manner exactly fixed for each individual case, qualitative changes can only occur by the quantitative addition or quantitative subtraction of matter or motion (so-called energy).

All qualitative differences in nature rest on differences of chemical composition or on different quantities or forms of motion (energy) or, as is almost always the case, on both. Hence it is impossible to alter the quality of a body without addition or subtraction of matter or motion, i.e., without quantitative alteration of the body concerned. In this form, therefore, Hegel's mysterious principle appears not only quite rational but even rather obvious.

It is surely hardly necessary to point out that the various allotropic and aggregational states of bodies, because they depend on various groupings of the molecules, depend on greater or lesser amounts (Mengen) of motion communicated to the bodies.

But what about change of form of motion, or so-called energy? If we change heat into mechanical motion or vice versa, is not the quality altered while the quantity remains the same? Quite correct. But it is with change of form of motion as with Heine's vices; anyone can be virtuous by himself, for vices too are always necessary.[56] Change of form of motion is always a process that takes place between at least two bodies, of which one loses a definite amount of motion of one quality (e.g., heat), while the other gains a corresponding quantity of motion of another quality (mechanical motion, electricity, chemical decomposition). Here, therefore, quantity and quality mutually correspond to each other. So far it has not been found possible to convert motion from one form to another inside a single isolated body.

We are concerned here in the first place with non-living bodies; the same law holds for living bodies, but it operates under very complex conditions and at present quantitative measurement is still often impossible for us.

If we imagine any non-living body cut up into smaller and smaller portions, at first no qualitative change occurs. But this has a limit: if we succeed, as by evaporation, in obtaining the separate molecules in the free state, then it is true that we can usually divide these still further, yet only with a complete change of quality. The molecule is decomposed into its separate atoms, which have quite different properties from those of the molecule. In the case of molecules composed of different chemical elements, atoms or molecules of these elements themselves make their appearance in the place of the compound molecule; in the case of molecules of elements, the free atoms appear, which exert quite distinct qualitative effects: the free atoms of nascent oxygen are easily able to effect what the atoms of atmospheric oxygen, bound together in the molecule, can never achieve.

But the molecule is also qualitatively different from the mass of the body to which it belongs. It can carry out movements independently of this mass and while the latter remains apparently at rest, e.g., heat vibrations; by means of a change of position and of connection with neighbouring molecules it can change the body into an allotrope or a different state of aggregation.

Thus we see that the purely quantitative operation of division has a limit at which it becomes transformed into a qualitative difference: the mass consists solely of molecules, but it is something essentially different from the molecule, just as the latter is different from the atom. It is this difference that is the basis for the separation of mechanics, as the science of heavenly and terrestrial masses, from physics, as the mechanics of molecules, and from chemistry, as the physics of atoms.

In mechanics, no qualities occur; at most, states such as equilibrium, motion, potential energy, which all depend on measurable transference of motion and are themselves capable of quantitative expression. Hence, in so far as qualitative change takes place here, it is determined by a corresponding quantitative change.

In physics, bodies are treated as chemically unalterable or indifferent; we have to do with changes of their molecular states and with the change of form of motion, which in all cases, at least on one of the two sides, brings the molecule into action. Here every change is a transformation of quantity into quality, a consequence of the quantitative change of the amount of motion of one form or another that is inherent in the body or communicated to it.

"Thus the temperature of water is, in the first place, a point of no consequence in respect to its liquidity; still with the increase or diminution of the temperature of liquid water, there comes a point where this state of cohesion alters and the water is converted into steam or ice." (Hegel, *Enzyklopädie, Gesamtausgabe,* Bd. VI, S. 217.)[57]

Similarly, a definite minimum current strength is required to cause the platinum wire of an electric incandescent lamp to glow; and every metal has its temperature of incandescence and fusion, every liquid its definite freezing and boiling point at a given pressure—in so far as our means allow us to produce the temperature required; finally also every gas has its critical point at which it can be liquefied by pressure and cooling. In short, the so-called physical constants are for the most part nothing but designations of the nodal points at which quantitative addition or subtraction of motion produces qualitative change in the state of the body concerned, at which, therefore, quantity is transformed into quality.

The sphere, however, in which the law of nature discovered by Hegel celebrates its most important triumphs is that of chemistry. Chemistry can be termed the science of the qualitative changes of bodies as a result of changed quantitative composition. That was already known to Hegel himself. (*Logik, Gesamtausgabe*, III, S. 433.)[58] As in the case of oxygen: if three atoms unite into a molecule, instead of the usual two, we get ozone, a body which is

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very considerably different from ordinary oxygen in its odour and reactions. And indeed the various proportions in which oxygen combines with nitrogen or sulphur, each of which produces a substance qualitatively different from any of the others! How different is laughing gas (nitrogen monoxide N_2O) from nitric anhydride (nitrogen pentoxide, N_2O_5)! The first is a gas, the second at ordinary temperatures a solid crystalline substance. And yet the whole difference in composition is that the second contains five times as much oxygen as the first, and between the two of them are three more oxides of nitrogen (NO, N_2O_3, NO_2), each of which is qualitatively different from the first two and from one another.

This is seen still more strikingly in the homologous series of carbon compounds, especially of the simpler hydrocarbons. Of the normal paraffins, the lowest is methane, CH_4; here the four linkages of the carbon atom are saturated by four atoms of hydrogen. The second, ethane, C_2H_6, has two atoms of carbon joined together and the six free linkages are saturated by six atoms of hydrogen. And so it goes on, with C_3H_8, C_4H_{10}, etc., according to the algebraic formula C_nH_{2n+2}, so that by each addition of CH_2 a body is formed that is qualitatively distinct from the preceding one. The three lowest members of the series are gases, the highest known, hexadecane, $C_{16}H_{34}$, is a solid body with a boiling point of 278° C. Exactly the same holds good for the series of primary alcohols with the formula $C_nH_{2n+2}O$, derived (theoretically) from the paraffins, and the series of monobasic fatty acids (formula $C_nH_{2n}O_2$). What qualitative difference can be caused by the quantitative addition of C_3H_6 is taught by experience if we consume ethyl alcohol, C_2H_6O, in any drinkable form without addition of other alcohols, and on another occasion take the same ethyl alcohol but with a slight addition of amyl alcohol, $C_5H_{12}O$, which forms the main constituent of the abominable fusel oil. One's head will certainly be aware of it the next morning, much to its detriment; so that one could even say that the intoxication, and subsequent "morning after" feeling, is also quantity transformed into quality, on the one hand of ethyl alcohol and on the other hand of this added C_3H_6.

In these series we encounter the Hegelian law in yet another form. The lower members permit only of a single mutual arrangement of the atoms. If, however, the number of atoms united into a molecule attains a size definitely fixed for each series, the grouping of the atoms in the molecule can take place in more than one way; so that two or more isomeric substances can be formed, having equal numbers of C, H, and O atoms in the molecule but nevertheless qualitatively distinct from one another. We can even calculate how many such isomers are possible for each member of the series. Thus, in the paraffin series, for C_4H_{10} there are two, for C_5H_{12} there are three; among the higher members the number of possible isomers mounts very rapidly. Hence once again it is the quantitative number of atoms in the molecule that determines the possibility and, in so far as it has been proved, also the actual existence of such qualitatively distinct isomers.

Still more. From the analogy of the substances with which we are acquainted in each of these series, we can draw conclusions as to the physical properties of the still unknown members of the series and, at least for the members immediately following the known ones, predict their properties, boiling point, etc., with fair certainty.

Finally, the Hegelian law is valid not only for compound substances but also for the chemical elements themselves. We now know that

> "the chemical properties of the elements are a periodic function of their atomic weights" (Roscoe-Schorlemmer, *Ausführliches Lehrbuch der Chemie*, II, S. 823),[69]

and that, therefore, their quality is determined by the quantity of their atomic weight. And the test of this has been brilliantly carried out. Mendeleyev proved that various gaps occur in the series of related elements arranged according to atomic weights indicating that here new elements remain to be discovered. He described in advance the general chemical properties of one of these unknown elements, which he termed eka-aluminium, because it follows after aluminium in the series beginning with the latter, and he predicted its approximate specific and atomic weight as well as its atomic volume. A few years later, Lecoq de Boisbaudran actually discovered this element, and Mendeleyev's predictions fitted with only very slight discrepancies. Eka-aluminium was realised in gallium (*ibid.*, p. 828).[60] By means of the—unconscious—application of Hegel's law of the transformation of quantity into quality, Mendeleyev achieved a scientific feat which it is not too bold to put on a par with that of Leverrier in calculating the orbit of the until then unknown planet Neptune.

In biology, as in the history of human society, the same law holds good at every step, but we prefer to dwell here on examples from the exact sciences, since here the quantities are accurately measurable and traceable.

Probably the same gentlemen who up to now have decried the transformation of quantity into quality as mysticism and incomprehensible transcendentalism will now declare that it is indeed something quite self-evident, trivial, and commonplace, which they have long employed, and so they have been taught nothing new. But to have formulated for the first time in its universally valid form a general law of development of nature, society, and thought, will always remain an act of historic importance. And if these gentlemen have for years caused quantity and quality to be transformed into each other, without knowing what they did, then they will have to console themselves with Molière's Monsieur Jourdain who had spoken prose all his life without having the slightest inkling of it.[61]

Basic Forms of Motion[62]

Motion in the most general sense, conceived as the mode of existence, the inherent attribute, of matter, comprehends all changes and processes occurring in the universe, from mere change of place right up to thinking. The investigation of the nature of motion had as a matter of course to start from the lowest, simplest forms of this motion and to learn to grasp these before it could achieve anything in the way of explanation of the higher and more complicated forms. Hence, in the historical evolution of the natural sciences we see how first of all the theory of simplest change of place, the mechanics of heavenly bodies and terrestrial masses, was developed; it was followed by the theory of molecular motion, physics, and immediately afterwards, almost alongside of it and in some places in advance of it, the science of the motion of atoms, chemistry. Only after these different branches of the knowledge of the forms of motion governing non-living nature had attained a high degree of development could the explanation of the processes of motion representing the life process be successfully tackled. This advanced in proportion with the progress of mechanics, physics, and chemistry. Consequently, while mechanics has for a fairly long time already been able adequately to refer the effects in the animal body of the bony levers set into motion by muscular contraction to the laws that are valid also in non-living nature, the physico-chemical substantiation of the other phenomena of life is still pretty much at the beginning of its course. Hence, in investigating here the nature of motion, we are compelled to leave the organic forms of motion out of account. We are compelled to restrict ourselves—in accordance with the state of science—to the forms of motion of non-living nature.

All motion is bound up with some change of place, whether it be change of place of heavenly bodies, terrestrial masses, molecules, atoms, or ether particles. The higher the form of motion, the smaller this change of place. It in no way exhausts the nature of the motion concerned, but it is inseparable from the motion. It, therefore, has to be investigated before anything else.

The whole of nature accessible to us forms a system, an interconnected totality of bodies, and by bodies we understand here all material existences extending from stars to atoms, indeed right to ether particles, in so far as one grants the existence of the last named. In the fact that these bodies are interconnected is already included that they react on one another, and it is precisely this mutual reaction that constitutes motion. It already becomes evident here that matter is unthinkable without motion. And if, in addition, matter confronts us as something given, equally uncreatable as indestructible, it follows that motion also is as uncreatable as indestructible. It became impossible to reject this conclusion as soon as it was recognised that the universe is a system, an inter-connection of bodies. And since this recognition had been reached by philosophy long before it gained effective currency in natural science, one can understand why philosophy, fully two hundred years before natural science, drew the conclusion of the uncreatability and indestructibility of motion. Even the form in which it did so is still superior to the present-day formulation of natural science. Descartes' principle, that the amount (die Menge) of motion present in the universe is always the same, has only the formal defect of applying a finite expression to an infinite magnitude. On the other hand, two expressions of the same law are at present current in natural science: Helmholtz's law of the conservation of *force*, and the newer, more precise, one of the conservation of *energy*. Of these, the one, as we shall see, says the exact opposite of the other, and moreover each of them expresses only one side of the relation.

When two bodies act on each other so that a change of place of one or both of them results, this change of place can consist only in an approximation or a separation. They either attract each other or they repel each other. Or, as mechanics expresses it, the forces operating between them are central, acting along the line joining their centres. That this happens, that it is the case throughout the universe without exception, however complicated many movements may appear to be, is nowadays accepted as a matter of course. It would seem nonsensical to us to assume, when two bodies act on each other and their mutual interaction is not opposed by any obstacle or the influence of a third body, that this action should be effected otherwise than along the shortest and most direct path, i.e., along the straight line joining their centres.* It is well known, moreover, that Helmholtz (*Erhaltung der Kraft*, Berlin 1847, Sections I and II)[64] has provided the mathematical proof that central action and unalterability of the amount of motion (Bewegungsmenge)[65] are reciprocally conditioned and that the assumption of other than central actions leads to results in which motion could be either created or destroyed. Hence the basic form of all motion is approximation and separation, contraction and expansion—in short, the old polar opposites of *attraction* and *repulsion*.

It is expressly to be noted that attraction and repulsion are not regarded here as so-called "*forces*" but as *simple forms of motion*, just as Kant had already conceived matter as the unity of attraction and repulsion. What is to be understood by "forces" will be shown in due course.

All motion consists in the interplay of attraction and repulsion. Motion, however, is only possible when each individual attraction is compensated by a corresponding repulsion somewhere else. Otherwise in time one side would get the preponderance over the other and then motion would finally cease. Hence all attractions and all repulsions in the universe must mutually balance one another. Thus the law of the indestructibility and uncreatability of motion is expressed in the form that each movement of attraction in the universe must have as its complement an equivalent movement of repulsion and vice versa; or, as ancient philosophy—long before the natural-scientific

* In the margin of the manuscript is the following note written in pencil: "Kant [says], p. 22, that the three dimensions of space depend on the fact that this attraction or repulsion takes place in inverse proportion to the square of the distance."[63]—*Ed.*

formulation of the law of conservation of force or energy—expressed it: the sum of all attractions in the universe is equal to the sum of all repulsions.

However, it appears that there are here still two possibilities for all motion to cease at some time or other, either by repulsion and attraction finally cancelling each other out in actual fact, or by the total repulsion finally taking possession of one part of matter and the total attraction of the other part. For the dialectical conception, these possibilities are excluded from the outset. Dialectics has proved from the results of our experience of nature so far that all polar opposites in general are determined by the mutual action of the two opposite poles on each other, that the separation and opposition of these poles exist only within their mutual connection and union, and, conversely, that their union exists only in their separation and their mutual connection only in their opposition. This once established, there can be no question of a final cancelling out of repulsion and attraction, or of a final partition between the one form of motion in one half of matter and the other form in the other half, consequently there can be no question of mutual penetration* or of absolute separation of the two poles. It would be equivalent to demanding in the first case that the north and south poles of a magnet should mutually cancel themselves out or, in the second case, that dividing a magnet in the middle between the two poles should produce on one side a north half without a south pole, and on the other side a south half without a north pole. Although, however, the impermissibility of such assumptions follows at once from the dialectical nature of polar opposites, nevertheless, thanks to the prevailing metaphysical mode of thought of natural scientists, the second assumption at least plays a certain part in physical theory. This will be dealt with in its place.

How does motion present itself in the interaction of attraction and repulsion? We can best investigate this in the separate forms of motion itself. At the end, the general aspect of the matter will show itself.

Let us take the motion of a planet about its central

* In the sense of mutual equalisation and neutralisation.—*Ed.*

body. Ordinary school astronomy follows Newton in explaining the ellipse described as the result of the joint action of two forces, the attraction of the central body and a tangential force driving the planet along the normal to the direction of this attraction. Thus it assumes, besides the form of motion directed centrally, also another direction of motion, or so-called "force", perpendicular to the line joining the centres. Thereby it contradicts the above-mentioned basic law according to which all motion in our universe can only take place along the line joining the centres of the bodies acting on one another, or, as one says, is caused only by centrally acting "forces". Thereby also it introduces into the theory an element of motion which, as we have likewise seen, necessarily leads to the creation and destruction of motion, and therefore presupposes a creator. What had to be done, therefore, was to reduce this mysterious tangential force to a form of motion acting centrally, and this the Kant-Laplace theory of cosmogony accomplished. As is well known, according to this conception the whole solar system arose from a rotating, extremely tenuous, gaseous mass by gradual contraction. The rotational motion is obviously strongest at the equator of this gaseous sphere, and individual gaseous rings separate themselves from the mass and clump themselves together into planets, planetoids, etc., which revolve round the central body in the direction of the original rotation. This rotation itself is usually explained from the motion of the individual gaseous particles themselves. This motion takes place in all directions, but finally an excess in one particular direction makes itself evident and so causes the rotating motion, which is bound to become stronger and stronger with the progressive contraction of the gaseous sphere. But whatever hypothesis is assumed of the origin of the rotation, they all abolish the tangential force, dissolving it in a special form of the manifestation of centrally acting motion. If the one element of planetary motion, the directly central one, is represented by gravitation, the attraction between the planet and the central body, then the other, tangential, element appears as a relic, in a derivative or altered form, of the original repulsion of the individual particles of the gaseous sphere. Thus the life process of a solar system presents itself as an interplay of attraction and repulsion, in which attraction gradually more and more gets the upper hand owing to repulsion being radiated into space in the form of heat and thus more and more becoming lost to the system.

One sees at a glance that the form of motion here conceived as repulsion is the same as that which modern physics terms "*energy*". By the contraction of the system and the resulting detachment of the individual bodies of which it consists today, the system has lost "energy", and indeed this loss, according to Helmholtz's well-known calculation, already amounts to 453/454 of the total amount of motion (Bewegungsmenge) originally present in the form of repulsion.

Let us take now a mass in the shape of a body on our earth itself. It is connected with the earth by gravitation, as the earth in turn is with the sun; but unlike the earth it is incapable of a free planetary motion. It can be set in motion only by an impulse from outside, and even then, as soon as the impulse ceases, its movement speedily comes to a standstill, whether by the effect of gravity alone or by the latter in combination with the resistance of the medium in which it moves. This resistance also is in the last resort an effect of gravity, in the absence of which the earth would not have on its surface any resistant medium, any atmosphere. Hence in pure mechanical motion on the earth's surface we are concerned with a situation in which gravitation, attraction, decisively predominates, where therefore the production of the motion shows both phases: first counteracting gravity and then allowing gravity to act—in a word, rising and falling.

Thus we have again mutual action between attraction on the one hand and a form of motion taking place in the opposite direction to it, hence a repelling form of motion, on the other hand. But within the sphere of terrestrial *pure* mechanics (which deals with masses of *given* states of aggregation and cohesion taken by it as unalterable) this repelling form of motion does not occur in nature. The physical and chemical conditions under which a lump of rock becomes separated from a mountain top, or a fall of water becomes possible, lie outside its sphere of action.

Therefore, in terrestrial pure mechanics, the repelling, raising motion must be produced artificially: by human force, animal force, water or steam power, etc. And this circumstance, this necessity to combat the natural attraction artificially, causes the mechanicians to adopt the view that attraction, gravitation, or, as they say, the *force* of gravity, is the most important, indeed the basic, form of motion in nature.

When, for instance, a weight is raised and communicates motion to other bodies by falling directly or indirectly, then according to the usual view of mechanics it is not the *raising* of the weight which communicates this motion but the *force of gravity*. Thus Helmholtz, for instance, makes

"the force which is the simplest and the one with which we are best acquainted, viz., gravity, act as the driving force... for instance in clocks that are actuated by a weight. The weight ... cannot comply with the pull of gravity without setting the whole clockwork in motion". But it cannot set the clockwork in motion without itself sinking and it goes on sinking until the string from which it hangs is completely unwound: "Then the clock comes to a stop, for the operative capacity of the weight is exhausted for the time being. Its weight is not lost or diminished, it remains attracted to the same extent by the earth, but the capacity of this weight to produce movements has been lost.... We can, however, wind up the clock by the power of the human arm, whereby the weight is once more raised up. As soon as this has happened, it regains its previous operative capacity and can again keep the clock in motion." (Helmholtz, *Populäre Vorträge,* II, S. 144-45.)

According to Helmholtz, therefore, it is not the active communication of motion, the raising of the weight, that sets the clock into motion, but the passive heaviness of the weight, although this same heaviness is only withdrawn from its passivity by the raising, and once again returns to passivity after the string of the weight has unwound. If then according to the modern conception, as we saw above, *energy* is only another expression for *repulsion,* here in the older Helmholtz conception *force* appears as another expression for the opposite of repulsion, for *attraction*. For the time being we shall simply put this on record.

When, however, the process of terrestrial mechanics has reached its end, when the heavy mass has first of all been raised and then again has fallen through the same vertical distance, what becomes of the motion that constituted this process? For pure mechanics, it has disappeared. But we know now that it has by no means been destroyed. To a lesser extent it has been converted into the air vibrations of sound waves, to a much greater extent into heat—which has been communicated in part to the resisting atmosphere, in part to the falling body itself, and finally in part to the floor on which the weight comes to rest. The clock weight has also gradually given up its motion in the form of frictional heat to the separate driving wheels of the clock-work. But, although usually expressed in this way, it is not the *falling* motion, i.e., the attraction, that has passed into heat, and therefore into a form of repulsion. On the contrary, as Helmholtz correctly remarks, the attraction, the heaviness, remains what it previously was and, accurately speaking, becomes even greater. Rather it is the repulsion communicated to the raised body by raising that is *mechanically* destroyed by falling and reappears as heat. The repulsion of masses is transformed into molecular repulsion.

Heat, as already stated, is a form of repulsion. It sets the molecules of solid bodies into oscillation, thereby loosening the connections of the separate molecules until finally the transition to the liquid state takes place. In the liquid state also, on continued addition of heat, it increases the motion of the molecules until a degree is reached at which these split off altogether from the mass and, at a definite velocity determined for each molecule by its chemical constitution, they move away individually in the free state. With a still further addition of heat, this velocity is further increased, and so the molecules are more and more repelled from one another.

But heat is a form of so-called "energy"; here once again the latter proves to be identical with repulsion.

In the phenomena of static electricity and magnetism, we have a polar distribution of attraction and repulsion. Whatever hypothesis may be adopted of the *modus operandi* of these two forms of motion, in view of the facts no one has any doubt that attraction and repulsion, in so far as they are produced by static electricity or magnetism and are able to develop unhindered, completely compensate each other, as in fact necessarily follows from the very nature of the polar distribution. Two poles whose activities did not completely compensate each other would indeed not be poles, and also have so far not been met with in nature. For the time being we will leave galvanism out of account, because in its case the process is determined by chemical reactions, which makes it more complicated. Therefore, let us investigate rather the chemical processes of motion themselves.

When two parts by weight of hydrogen combine with 15.96 parts by weight of oxygen to form water vapour, an amount of heat of 68,924 heat-units is developed during the process. Conversely, if 17.96 parts by weight of water vapour are to be decomposed into two parts by weight of hydrogen and 15.96 parts by weight of oxygen, this is only possible on condition that the water vapour has communicated to it an amount of motion equivalent to 68,924 heat-units—whether in the form of heat itself or of electrical motion. The same thing holds for all other chemical processes. In the overwhelming majority of cases, motion is given off on combination and must be supplied on decomposition. Here, too, as a rule, repulsion is the active side of the process more endowed with motion or requiring the addition of motion, while attraction is the passive side producing a surplus of motion and giving off motion. On this account, the modern theory also declares that, on the whole, energy is set free on the combination of elements and is bound up on decomposition. Here, therefore, energy again stands for repulsion. And again Helmholtz declares:

"This force (chemical affinity) can be conceived as a force of *attraction*.... This force of attraction between the atoms of carbon and oxygen performs work quite as much as that exerted on a raised weight by the earth in the form of gravitation.... When carbon and oxygen atoms rush at one another and combine to form carbonic acid, the newly-formed particles of carbonic acid must be in very violent molecular motion, i.e., in heat motion.... When later they have given up their heat to the environment, we still have in the carbonic acid all the carbon, all the oxygen, and in addition the affinity of both continuing to exist just as powerfully as before. But this affinity now expresses itself solely in the fact that the atoms of carbon and oxygen stick fast to one another, and do not allow of their being separated." (Helmholtz, *ibid.*, p. 169.)

It is just as before: Helmholtz insists that in chemistry as in mechanics force consists only in *attraction*, and therefore is the exact opposite of what other physicists call energy and which is identical with *repulsion*.

Hence we have now no longer the two simple basic forms of attraction and repulsion, but a whole series of sub-forms in which the winding up and running down process of universal motion goes on within the opposition of attraction and repulsion. It is, however, by no means merely in our mind that these manifold forms of appearance are comprehended under the *single* expression of motion. On the contrary, they themselves prove in action that they are forms of one and the same motion by passing into one another under given conditions. Mechanical motion of masses passes into heat, into electricity, into magnetism; heat and electricity pass into chemical decomposition; chemical combination in turn again develops heat and electricity and, by means of the latter, magnetism; and finally, heat and electricity produce once more mechanical movement of masses. Moreover, these changes take place in such a way that a given amount of motion of one form always has corresponding to it an exactly fixed amount of another form. Further, it is a matter of indifference which form of motion provides the unit by which the amount of motion is measured, whether it serves for measuring mass motion, heat, so-called electromotive force, or the motion undergoing transformation in chemical processes.

We base ourselves here on the theory of the "conservation of energy" established by J. R Mayer* in 1842 and

* Helmholtz, in his *Pop. Vortr.*, II, p. 113, appears to ascribe a certain share in the natural-scientific proof of Descartes' principle of the quantitative immutability of motion to himself as well as to Mayer, Joule, and Colding. "I myself, without knowing anything of Mayer and Colding, and only becoming acquainted with Joule's experiments at the end of my work, *proceeded along the same path*; I occupied myself especially with searching out all the relations between the various processes of nature that could be deduced from the given mode of consideration, and I *published my investigations* in 1847 in a little work entitled *Über die Erhaltung der Kraft*."[66]—But in this work there is to be found nothing new for the position in 1847 beyond the above-mentioned, mathematically very valuable, development that

afterwards worked out internationally with such brilliant success, and we have now to investigate the fundamental concepts nowadays made use of by this theory. These are the concepts of "force" or "energy", and "work".

It has been shown above that according to the modern view, now fairly generally accepted, energy is the term used for repulsion, while Helmholtz mostly uses the word force to express attraction. One could regard this as an unimportant formal difference, inasmuch as attraction and repulsion compensate each other in the universe, and accordingly it would appear a matter of indifference which side of the relation is taken as positive and which as negative, just as it is of no importance in itself whether the positive abscissæ are counted to the right or the left of a point in a given line. Nevertheless, this is not absolutely so.

For we are concerned here, first of all, not with the universe, but with phenomena occurring on the earth and conditioned by the exactly fixed position of the earth in the solar system, and of the solar system in the universe. At every moment, however, our solar system gives out enormous quantities of motion into space, and motion of a very definite quality, viz., the sun's heat, i.e., repulsion. But our earth itself allows of the existence of life on it only owing to the sun's heat, and the earth in turn finally radiates into space the sun's heat received, after it has converted a portion of this heat into other forms of motion. Consequently, in the solar system and above all on the earth, attraction already considerably preponderates over repulsion. Without the repulsive motion radiated to us from the sun, all motion on the earth would cease. If tomorrow the sun were to become cold, the attraction on

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"conservation of force" and central action of the forces active between the various bodies of a system are only two different expressions for the same thing, and further a more accurate formulation of the law that the sum of the live and tensional forces in a given *mechanical* system is constant. In every other respect it was already superseded since Mayer's second paper of 1845. Already in 1842 Mayer maintained the "indestructibility of force", and from his new standpoint in 1845 he had much more brilliant things to say about the "relations between the various processes of nature" than Helmholtz had in 1847.[67] [*Note by Engels.*]

the earth would still, other circumstances remaining the same, be what it is today. As before, a stone of 100 kilograms, wherever situated, would weigh 100 kilograms. But the motion, both of masses and of molecules and atoms, would come to what we would regard as an absolute standstill. Therefore it is clear that for processes occurring on the *earth* today it is by no means a matter of indifference whether attraction or repulsion is conceived as the active side of motion, hence as "force" or "energy". On the contrary, on the earth today attraction has already become *altogether passive* owing to its decisive preponderance over repulsion; we owe all active motion to the supply of repulsion from the sun. Therefore, the modern school—even if it remains unclear about the nature of the relation of motion—nevertheless, in point of fact and for *terrestrial* processes, indeed for the whole solar system, is absolutely right in conceiving energy as repulsion.

The term "energy" by no means correctly expresses the entire relation of motion, for it comprehends only one aspect, the action but not the reaction. It still makes it appear as if "energy" was something external to matter, something implanted in it. But in all circumstances it is to be preferred to the expression "force".

As is generally conceded (from Hegel to Helmholtz), the notion of force is derived from the activity of the human organism within its environment. We speak of muscular force, of the lifting force of the arms, of the leaping power of the legs, of the digestive force of the stomach and intestinal tract, of the sensory force of the nerves, of the secretory force of the glands, etc. In other words, in order to save having to give the real cause of a change brought about by a function of our organism, we substitute a fictitious cause, a so-called force corresponding to the change. Then we carry this convenient method over to the external world also, and so invent as many forces as there are diverse phenomena.

In *Hegel*'s time natural science (with the exception perhaps of celestial and terrestrial mechanics) was still in this naïve state, and Hegel quite correctly attacks the prevailing way of denoting forces (passage to be quoted).[68] Similarly in another passage:

"It is better (to say) that a magnet has a *soul*" (as Thales expresses it) "than that it has an attracting force; force is a kind of property that, *separable from matter*, is put forward as a predicate—while soul, on the other hand, *is this movement itself, identical with the nature of matter*."[69] (*Geschichte der Philosophie*, I, S. 208.)

Today we no longer make it so easy for ourselves in regard to forces. Let us listen to Helmholtz:

"If we are fully acquainted with a natural law, we must also demand that it should operate without exception.... Thus the law confronts us as an objective power, and accordingly we term it a *force*. For instance, we objectivise the law of the refraction of light as a refractive power of transparent substances, the law of chemical affinities as a force of affinity of the various substances for one another. Thus we speak of the electrical force of contact of metals, of the force of adhesion, capillary force, and so on. These names objectivise laws which in the first place embrace only a limited series of natural processes, *the conditions for which are still rather complicated**.... Force is only the objectivised law of action.... The abstract idea of force introduced by us only makes the addition that we have not arbitrarily invented this law but that it is a compulsory law of phenomena. Hence our demand to *understand* the phenomena of nature, i.e., to find out their *laws*, takes on another form of expression, viz., that we have to seek out the *forces* which are the causes of the phenomena." (*Loc. cit.*, pp. 189-91. Innsbruck lecture of 1869.)

Firstly, it is certainly a peculiar manner of "objectivising" if the *purely subjective* notion of *force* is introduced into a natural law that has already been established as independent of our subjectivity and therefore completely *objective*. At most an Old-Hegelian of the strictest type might permit himself such a thing, but not a Neo-Kantian like Helmholtz. Neither the law, when once established, nor its objectivity or the objectivity of its action, acquires the slightest new objectivity by our interpolating a force into it; what is added is our *subjective assertion* that it acts in virtue of some so far entirely unknown force. The secret meaning, however, of this interpolating is seen as soon as Helmholtz gives us examples: refraction of light, chemical affinity, contact electricity, adhesion, capillarity, and raises the laws that govern these phenomena to the "objective" rank of nobility as *forces*. "These names objectivise laws which in the first place embrace only a limited

* Italics by Engels.—*Ed.*

series of natural processes, the conditions for which *are still rather complicated*." And it is just here that the "objectivising", which is rather subjectivising, gets its meaning; not because we have become fully acquainted with the law, but just because this is *not* the case. Just because we are *not* yet clear about the "rather complicated conditions" of these phenomena, we often take refuge here in the word force. We express thereby not our knowledge, but our *lack* of knowledge of the nature of the law and its mode of action. In this sense, as a short expression for a causal connection that has not yet been explained, as a makeshift expression, it may pass in current usage. Whatsoever is more than that cometh of evil. With just as much right as Helmholtz explains physical phenomena from so-called refractive force, electrical force of contact, etc., the mediæval scholastics explained temperature changes by means of a *vis calorifica* and a *vis frigifaciens* and thus saved themselves all further investigation of heat phenomena.

And even in this sense it is unfortunate, for it expresses everything in a one-sided manner. All natural processes are two-sided, they are based on the relation of at least two operative parts, action and reaction. The notion of force, however, owing to its origin from the action of the human organism on the external world, and further from terrestrial mechanics, implies that only one part is active, operative, the other part being passive, receptive; hence it lays down a not yet demonstrable extension of the difference between the sexes to non-living objects. The reaction of the second part, on which the force works, appears at most as a passive reaction, as a *resistance*. Now this mode of conception is permissible in a number of fields even outside pure mechanics, namely, where it is a matter of the simple transference of motion and its quantitative calculation. But already in the more complicated physical processes it is no longer adequate, as Helmholtz's own examples prove. The refractive force lies just as much in the light itself as in the transparent bodies. In the case of adhesion and capillarity, it is certain that the "force" is just as much situated in the surface of the solid as in the liquid. In contact electricity, at any rate, this much is certain, viz., that *both* metals contribute to it, and "chemical affinity" also is situated, if anywhere, in *both* the parts entering into combination. But a force which consists of two separated forces, an action which does not evoke its reaction, but which includes and bears this in itself, is no force in the sense of terrestrial mechanics, the only science in which one really knows what is meant by a force. For the basic conditions of terrestrial mechanics are, firstly, refusal to investigate the causes of the impulse, i.e., the nature of the particular force, and, secondly, the view of the one-sidedness of the force, it being everywhere opposed by an identical gravitational force, such that in comparison with any terrestrial distance of fall the earth's radius$=\infty$.

But let us see further how Helmholtz "objectivises" his "forces" into natural laws.

In a lecture of 1854 (*loc. cit.*, p. 119) he examines the "store of working force" originally contained in the spherical nebula from which our solar system was formed.

> "In point of fact it received an enormously large legacy in this respect, of only in the form of the general force of attraction of all its parts for one another."

This is indubitable. But it is equally indubitable that the whole of this legacy of gravity or gravitation is present undiminished in the solar system today, apart perhaps from the minute quantity that was lost together with the matter which possibly was flung out irrevocably into space. Further:

> "Chemical forces too must have been already present and ready to act; but as these forces could become effective only on intimate contact of the various kinds of masses, condensation had to take place before they came into play." [P. 120.]

If, as Helmholtz does above, we regard these chemical forces as forces of affinity, hence as *attraction*, then again we are bound to say that the sum-total of these chemical forces of attraction still exists undiminished within the solar system.

But on the same page Helmholtz gives us as the result of his calculations

> "that perhaps only the 454th part of the original mechanical force exists as such"—that is to say, in the solar system.

How is one to make sense of that? The force of attraction, general as well as chemical, is still present unimpaired in the solar system. Helmholtz does not mention any other certain source of force. In any case, according to Helmholtz, these forces have performed tremendous work. But they have neither increased nor diminished on that account. As it is with the clock weight mentioned above, so it is with every molecule in the solar system and the whole solar system itself. "Its weight is neither lost nor diminished" What happens to carbon and oxygen as previously mentioned holds good for all chemical elements: the total given quantity of each one remains, and "the total force of affinity continues to exist just as powerfully as before". What have we lost then? And what "force" has performed the tremendous work which is 453 times as great as that which, according to his calculation, the solar system is still able to perform? Up to this point Helmholtz has given no answer. But further on he says:

> "Whether [in the original spherical nebula] a further *reserve of force in the shape of heat** was present, we do not know." [P. 120.]

But, if we may be allowed to mention it, heat is a repulsive "force", it acts therefore *against* the direction of both gravitation and chemical attraction, being minus if these are put as plus. Hence if, according to Helmholtz, the original reserve of force is composed of general and chemical *attraction*, an extra reserve of heat would have to be, not added to that reserve of force, but subtracted from it. Otherwise the sun's heat would have to *strengthen* the force of attraction of the earth when it causes water to evaporate in direct *opposition* to this attraction, and the water vapour to rise; or the heat of an incandescent iron tube through which steam is passed would *strengthen* the chemical attraction of oxygen and hydrogen, whereas it puts it out of action. Or, to make the same thing clear in another form: let us assume that the spherical nebula with radius r, and therefore with volume $\frac{4}{3}\pi r^3$, has a temperature t. Let us further assume a second spherical nebula of equal

* Italics by Engels.—*Ed.*

mass having at the higher temperature T the larger radius R and volume $\frac{4}{3}\pi\ R^3$. Now it is obvious that in the second nebula the attraction, mechanical as well as physical and chemical, can act with the same force as in the first only when it has shrunk from radius R to radius r, i.e., when it has radiated into space heat corresponding to the temperature difference $T—t$. A hotter nebula will therefore condense later than a colder one; consequently the heat, considered from Helmholtz's standpoint as an obstacle to condensation, is no plus but a minus of the "reserve of force". Helmholtz, by presupposing the possibility of an amount of *repulsive* motion in the form of heat becoming added to the *attractive* forms of motion and increasing the total of these latter, commits a definite error of calculation.

Let us now bring the whole of this "reserve of force", possible as well as demonstrable, under the same mathematical sign so that an addition is possible. Since for the time being we cannot reverse the heat and replace its repulsion by the equivalent attraction, we shall have to perform this reversal with the two forms of attraction. Then, instead of the general force of attraction, instead of the chemical affinity, and instead of the heat, which moreover possibly already existed as such at the outset, we have simply to put the sum of the repulsive motion or so-called energy present in the gaseous sphere at the moment when it becomes independent. And by so doing Helmholtz's calculation will also hold, in which he wants to calculate "the heating that must arise from the assumed initial condensation of the heavenly bodies of our system from nebulously scattered matter". By thus reducing the whole "reserve of force" to heat, repulsion, he also makes it possible to add on the assumed "reserve of force of heat". The calculation then asserts that 453/454 of all the energy, i.e., repulsion, originally present in the gaseous sphere, has been radiated into space in the form of heat, or, to put it accurately, that the sum of all attraction in the present solar system is to the sum of all repulsion, still present in the same, as 454:1. But then it directly contradicts the text of the lecture to which it is added as proof.

If then the notion of force, even in the case of a physicist like Helmholtz, gives rise to such confusion of ideas, this is the best proof that it is altogether insusceptible of scientific use in all branches of investigation which go beyond mathematical mechanics. In mechanics the causes of motion are taken as given and their origin is disregarded, only their effects being taken into account. Hence if a cause of motion is termed a force, this does no damage to mechanics as such; but it becomes the custom to transfer this term also to physics, chemistry, and biology, and then confusion is inevitable. We have already seen this and shall frequently see it again.

For the concept of work, see the next chapter.

The Measure of Motion.—Work[70]

"On the other hand, I have always found hitherto that the basic concepts in this field" (i.e., "the basic physical concepts of work and its unalterability") "seem very difficult to grasp for persons who have not gone through the school of mathematical mechanics, in spite of all zeal, all intelligence, and even a fairly high degree of natural-scientific knowledge. Moreover, it cannot be denied that they are abstractions of a quite peculiar kind. It was not without difficulty that even such an intellect as that of I. Kant succeeded in understanding them, as is proved by his polemic against Leibniz on this subject."

So says Helmholtz. (*Pop. wiss. Vortr.*, II, Preface.)

According to this, we are venturing now into a very dangerous field, the more so since we cannot very well take the liberty of guiding the reader "through the school of mathematical mechanics". Perhaps, however, it will turn out that, where it is a question of concepts, dialectical thinking will carry us at least as far as mathematical calculation.

Galileo discovered, on the one hand, the law of falling, according to which the distances traversed by falling bodies are proportional to the squares of the times taken in falling. On the other hand, as we shall see, he put forward the not quite compatible proposition that the quantity of motion of a body (its *impeto* or *momento*) is determined by the mass and the velocity in such a way that for constant mass it is proportional to the velocity. Descartes adopted this latter proposition and made the product of the mass and the velocity of a moving body quite generally into the measure of its motion.

Huyghens had already found that, on elastic impact, the sum of the products of the masses and the squares of their velocities remains the same before and after impact, and that an analogous law holds good in various other cases of motion of bodies united into a system.

Leibniz was the first to realise that the Cartesian measure of motion was in contradiction to the law of falling. On the other hand, it could not be denied that in many cases the Cartesian measure was correct. Accordingly, Leibniz divided moving forces into dead forces and live ones. The dead were the "pushes" or "pulls" of bodies at rest, and their measure the product of the mass and the velocity with which the body would move if it were to pass from a state of rest to one of motion. On the other hand, he put forward as the measure of *vis viva*, of the real motion of a body, the product of the mass and the square of the velocity. This new measure of motion he derived directly from the law of falling.

"The same force is required," so Leibniz concluded, "to raise a body of four pounds in weight one foot as to raise a body of one pound in weight four feet; but the distances are proportional to the square of the velocity, for when a body has fallen four feet, it attains twice the velocity reached on falling only one foot. However, bodies on falling acquire the force for rising to the same height as that from which they fell; hence the forces are proportional to the square of the velocity." (Suter, *Geschichte der mathematischen Wissenschaften*, II, S. 367.)[71]

But he showed further that the measure of motion *mv* is in contradiction to the Cartesian law of the constancy of the quantity of motion, for if it was really valid the force (i.e., the amount of motion) in nature would continually increase or diminish. He even suggested an apparatus (1690, *Acta Eruditorum*) which, if the measure *mv* were correct, would be bound to act as a *perpetuum mobile* with continual gain of force, which, however, would be absurd.[72] Recently, Helmholtz has again frequently employed this kind of argument.

The Cartesians protested with might and main and there developed a famous controversy lasting many years, in which Kant also participated in his very first work (*Gedanken von der wahren Schätzung der lebendigen Kräfte*, 1746),[73] without, however, seeing clearly into the matter. Mathematicians today look down with a certain amount of scorn on this "barren" controversy which "dragged out for more than forty years and divided the mathematicians of Europe into two hostile camps, until at last d'Alembert by his *Traité de dynamique* (1743), as it were by a royal edict, put an end to the *useless verbal dispute*,* for it was nothing else". (Suter, *loc. cit.*, p. 366.)

It would, however, seem that a controversy could not rest entirely on a useless verbal dispute when it had been initiated by a Leibniz against a Descartes, and had occupied a man like Kant to such an extent that he devoted to it his first work, a fairly large volume. And in point of fact, how is it to be understood that motion has two contradictory measures, that on one occasion it is proportional to the velocity, and on another to the square of the velocity? Suter makes it very easy for himself; he says

both sides were right and both were wrong; "nevertheless, the expression *'vis viva'* has endured up to the present day; *only it no longer serves as the measure of force*,* but is merely a term that was once adopted for the product of the mass and half the square of the velocity, a product so full of significance in mechanics." [P. 368.]

Hence, *mv* remains the measure of motion, and *vis viva* is only another expression for $\frac{mv^2}{2}$, concerning which formula we learn indeed that it is of great significance for mechanics, but now most certainly do not know what significance it has.

Let us, however, take up the salvation-bringing *Traité de dynamique*[74] and look more closely at d'Alembert's "royal edict"; it is to be found in the Preface.

In the text, it says, the whole question does not occur, on account of *l'inutilité parfaite dont elle est pour la mécanique*. [P. XVII.]

This is quite correct for *purely mathematical* mechanics, in which, as in the case of Suter above, words used as designations are only other expressions or names for algebraic formulæ, names in connection with which it is best not to think at all.

Nevertheless, since such important people have concerned themselves with the matter, he desires to examine it briefly in the Preface. Clearness of thought demands that by the force of moving bodies one should understand only their property of overcoming obstacles

* Italics by Engels.—*Ed.*

or resisting them. Hence, force is to be measured neither by mv nor by mv^2, but solely by the obstacles and the resistance they offer.

Now, there are, he says, three kinds of obstacles: (1) insuperable obstacles which totally destroy the motion, and for that very reason cannot be taken into account here; (2) obstacles whose resistance suffices to arrest the motion and to do so instantaneously: the case of equilibrium; (3) obstacles which only gradually arrest the motion: the case of retarded motion. [Pp. XVII-XVIII.] "Everyone will agree that two bodies are in equilibrium when the products of their masses and virtual velocities, that is to say the velocities with which they tend to move, are equal on each side. Hence, in equilibrium the product of the mass and the velocity, or, what is the same thing, the quantity of motion, can represent the force. Everyone will agree also that in retarded motion the number of obstacles overcome is as the square of the velocity, so that, for instance, a body which has compressed a spring with a certain velocity, could, with twice the velocity, compress simultaneously or successively not two, but four springs similar to the first, or nine with triple the velocity, and so on. Whence the partisans of *vis viva*" (the Leibnizians) "conclude that the force of bodies actually in motion is in general proportional to the product of the mass and the square of the velocity. Basically, what inconvenience could there be in forces being measured differently in equilibrium and in retarded motion since, if one wants to use only clear views in reasoning, one should understand by the word *force* only the effect produced in surmounting the obstacle or resisting it?" (Preface, pp. XIX-XX of the original edition.)

D'Alembert, however, is far too much of a philosopher not to realise that the contradiction of a twofold measure of one and the same force is not to be got over so easily. Therefore, after repeating what is basically only the same thing as Leibniz had already said—for his *équilibre* is precisely the same thing as the "dead pushes" of Leibniz—he suddenly goes over to the side of the Cartesians and finds the following way out:

The product mv can serve as a measure of force, even in the case of retarded motion, "if in this last case the force is measured, not by the absolute magnitude of the obstacles, but by the sum of the resistances of these same obstacles. For it could not be doubted that this sum of the resistances would be proportional to the quantity of motion (mv),* since, by general agreement, the quantity of motion lost by the body at each instant is proportional to the product of the resistance and the infinitely small duration of the instant, and the sum of these products evidently makes up the total resistance." This latter mode of calculation seems to him the more natural one, "for an obstacle is only such in as much as it offers resistance, and,

* Added by Engels.—*Ed.*

properly speaking, it is the sum of the resistances that constitutes the obstacle overcome; moreover, in estimating the force in this way, one has the advantage of having a common measure for the equilibrium and for the retarded motion". Still, everyone can take that as he likes. [Pp. XX-XXI.]

And so, believing he has solved the question, by what, as Suter himself acknowledges, is a mathematical blunder, he concludes with unkind remarks on the confusion reigning among his predecessors, and asserts that after the above remarks there is possible only a very futile metaphysical discussion or a still more discreditable purely verbal dispute.

D'Alembert's proposal for reaching a reconciliation amounts to the following calculation:

A mass 1, with velocity 1, compresses 1 spring in unit time.

A mass 1, with velocity 2, compresses 4 springs, but requires two units of time; i.e., only 2 springs per unit of time.

A mass 1 , with velocity 3, compresses 9 springs in three units of time, i.e., only 3 springs per unit of time.

Hence if we divide the effect by the time required for it, we again come from mv^2 to mv.

This is the same argument that Catelan[75] in particular had already employed against Leibniz; it is true that a body with velocity 2 rises against gravity four times as high as one with velocity 1, but it requires double the time for it; consequently the amount of motion (die Bewegungsmenge) must be divided by the time, and =2, not 4. Curiously enough, this is also Suter's view, who indeed deprived the expression "*vis viva*" of all logical meaning and left it only a mathematical one. But this is natural. For Suter it is a question of saving the formula mv in its significance as sole measure of the amount of motion (Bewegungsmenge); hence logically mv^2 is sacrificed in order to arise again transfigured in the heaven of mathematics.

However, this much is correct: Catelan's argument provides one of the bridges connecting mv with mv^2, and so is of importance.

The mechanicians subsequent to d'Alembert by no means accepted his "royal edict", for his final verdict was indeed in favour of mv as the measure of motion. They adhered to his expression of the distinction which Leibniz had already made between dead and live forces: mv is valid for equilibrium, i.e., for statics; mv^2 is valid for motion against resistance, i.e., for dynamics. Although on the whole correct, the distinction in this form has, however, logically no more meaning than the famous decision of the N.C.O.: on duty always "to me", off duty always "me".[76] It is accepted tacitly, it just exists. We cannot alter it, and if a contradiction lurks in this double measure, what can we do about it?

Thus, for instance, Thomson and Tait say (*A Treatise on Natural Philosophy*, Oxford, 1867,[77] p. 162):

> "The *quantity of motion*, or the *momentum*, of a rigid body moving without rotation is proportional to its mass and velocity conjointly. Thus a double mass, or a double velocity, would correspond to double quantity of motion."

And immediately below that they say:

> "The *vis viva* or *kinetic energy* of a moving body is proportional to the mass and the square of the velocity conjointly."

The two contradictory measures of motion are put side by side in this very glaring form. Not so much as the slightest attempt is made to explain the contradiction, or even to disguise it. In the book by these two Scotsmen, thinking is forbidden, only calculation is permitted. No wonder that at least one of them, Tait, is accounted one of the most pious Christians of pious Scotland.

In Kirchhoff's *Vorlesungen über mathematische Mechanik*,[78] the formulæ mv and mv^2 do not occur at all *in this form*.

Perhaps Helmholtz will aid us. In his *Erhaltung der Kraft*[79] he proposes to express *vis viva* by $\frac{mv^2}{2}$ —a point to which we shall return later. Then, on page 20 *et seq.*, he enumerates briefly the cases in which so far the principle of the conservation of *vis viva* (hence of $\frac{mv^2}{2}$) has been used already and is recognised. Included therein under No. 2 is

> "the transference of motions by incompressible solid and fluid bodies, in so far as friction or impact of inelastic materials does not

occur. For these cases our general principle is usually expressed in the rule that motion propagated and already by mechanical powers always decreases in intensity of force in the same proportion as it increases in velocity. If, therefore, we imagine a weight m being raised with velocity c by a machine in which a force for performing work is produced uniformly by some process or other, then with a different mechanical arrangement the weight nm could be raised, but only with velocity $\frac{c}{n}$, so that in both cases the quantity of tensile force produced by the machine in unit time is represented by mgc, where g is the intensity of the gravitational force." [P. 21.]

Thus, here too we have the contradiction that an "intensity of force", which decreases and increases in simple proportion to the velocity, has to serve as proof for the conservation of an intensity of force which decreases and increases in proportion to the square of the velocity.

In any case, it becomes evident here that mv and $\frac{mv^2}{2}$ serve to determine two quite distinct processes, but we certainly knew that long ago, for mv^2 cannot equal mv, unless $v=1$. What has to be done is to make it comprehensible why motion should have a twofold measure, a thing which is surely just as impermissible in science as in commerce. Let us, therefore, attempt this in another way.

By mv, then, one measures "a motion propagated and altered by mechanical powers"; hence this measure holds good for the lever and all its derivative forms, for wheels, screws, etc., in short, for all machinery for the transference of motion. But from a very simple and by no means new consideration it becomes evident that in so far as mv applies here, so also does mv^2. Let us take any mechanical contrivance in which the sums of the lever arms on the two sides are related to each other as 4:1, in which, therefore, a weight of 1 kg. holds a weight of 4 kg. in equilibrium. Hence, by a quite insignificant additional force on one arm of the lever we can raise 1 kg. by 20 metres; the same additional force, when applied to the other arm of the lever, raises 4 kg. a distance of 5 metres, and the preponderating weight sinks in the same time that the other weight requires for rising. Mass and velocity are inversely proportional to each other: mv, $1\times 20=m'v'$, 4×5. On the other hand, if we let each of the weights, after it has been raised, fall freely to the original level, then the one, 1 kg., after falling a distance of 20 metres (the acceleration due to gravity is put in round figures=10 metres instead of 9.81 metres), attains a velocity of 20 metres; the other, 4 kg., after falling a distance of 5 metres, attains a velocity of 10 metres.[80]

$$mv^2=1\times20\times20=400=m'v'^2=4\times10\times10=400.$$

On the other hand the times of fall are different: the 4 kg. traverse their 5 m. in 1 second, the 1 kg. traverses its 20 m. in 2 seconds. Friction and air resistance are, of course, neglected here.

But after each of the two bodies has fallen from its height, its motion ceases. Therefore, *mv* appears here as the measure of simply transferred, hence lasting, mechanical motion, and mv^2 as the measure of the vanished mechanical motion.

Further, the same thing applies to the impact of perfectly elastic bodies: the sum both of *mv* and of mv^2 is unaltered before and after impact. Both measures have the same validity.

This is not the case on impact of inelastic bodies. Here, too, the current elementary text-books (higher mechanics is hardly concerned at all any more with such trifles) teach that before and after impact the sum of *mv* remains the same. On the other hand a loss of *vis viva* occurs, for if the sum of mv^2 after impact is subtracted from the sum of mv^2 *before* impact, there is under all circumstances a positive remainder. By this amount (or the half of it, according to the point of view) the *vis viva* is diminished owing both to the mutual penetration and to the change of form of the colliding bodies.—The latter is now clear and obvious, but not so the first assertion that the sum of *mv* remains the same before and after impact. In spite of Suter, *vis viva* is motion, and if a part of it is lost, motion is lost. Consequently, either *mv* here incorrectly expresses the amount of motion (die Bewegungsmenge), or the above assertion is untrue. In general the whole theorem has been handed down from a period when there was as yet no inkling of the transformation of motion; when, therefore, a disappearance of mechanical motion was only conceded where there was no other way out. Thus, the equality here of the sum of mv before and after impact was taken as proved by the fact that no loss or gain of this sum had been introduced. If, however, the bodies lose *vis viva* in internal friction corresponding to their inelasticity, they also lose velocity, and the sum of mv after impact must be smaller than before. For it surely does not do to neglect internal friction in calculating mv, when it makes itself felt so clearly in calculating mv^2.

But this does not matter. Even if we admit the theorem, and calculate the velocity after impact, on the assumption that the sum of mv has remained the same, this decrease of the sum of mv^2 is still found. Here, therefore, mv and mv^2 conflict, and they do so by the difference of the mechanical motion that has actually disappeared. Moreover, the calculation itself shows that the sum of mv^2 expresses the amount of motion correctly, while the sum of mv expresses it incorrectly.

Such are pretty nearly all the cases in which mv is employed in mechanics. Let us now look at some cases in which mv^2 is employed.

When a cannon-ball is fired, it uses up in its flight an amount of motion that is proportional to mv^2, irrespective of whether it encounters a solid target or comes to a standstill owing to air resistance and gravitation. If a railway train runs into a stationary one, the violence of the collision, and the corresponding destruction, is proportional to its mv^2. Similarly, mv^2 serves wherever it is necessary to calculate the mechanical force required for overcoming a resistance.

But what is the meaning of this convenient phrase, so current in mechanics: overcoming a resistance?

If we overcome the resistance of gravity by raising a weight, there disappears an amount of motion (Bewegungsmenge), an amount of mechanical force, equal to that which can be produced anew by the direct or indirect fall of the raised weight from the height reached back to its original level. The amount is measured by half the product of the mass and square of the final velocity after falling, $\frac{mv^2}{2}$.

What then occurred on raising the weight? Mechanical motion, or force, has disappeared as such. But it has not been annihilated; it has been converted into mechanical force of tension, to use Helmholtz's expression; into potential energy, as the moderns say; into ergal as Clausius calls it; and this can at any moment, by any mechanically appropriate means, be reconverted into the same amount of mechanical motion as was necessary to produce it. The potential energy is only the negative expression of the *vis viva*, and vice versa.

A 24-lb. cannon-ball moving with a velocity of 400 m. per second strikes the one-metre-thick armour-plating of a warship and under these conditions has apparently no effect on the armour. Consequently an amount of mechanical motion has vanished equal to $\frac{mv^2}{2}$, i.e. (since 24 lbs.*= =12 kg.)$=12\times400\times400\times{}^1/_2=960{,}000$ kilogram-metres. What has become of it? A small portion has been expended in the concussion and molecular alteration of the armour-plate. A second portion goes in smashing the cannon-ball into innumerable fragments. But the greater part has been converted into heat and raises the temperature of the cannon-ball to red heat. When the Prussians, in making the crossing to Alsen in 1864, brought their heavy batteries into play against the armoured sides of the *Rolf Krake*,[81] after each hit they saw in the darkness the flare produced by the suddenly glowing shot. Even earlier, Whitworth had proved by experiment that explosive shells need no detonator when used against armoured warships; the glowing metal itself ignites the charge. Taking the mechanical equivalent of the unit of heat as 424 kilogram-metres,[82] the amount of heat corresponding to the above-mentioned amount of mechanical motion is 2,264 units. The specific heat of iron=0.1140; that is to say, the amount of heat that raises the temperature of 1 kg. of water by 1° C. (which serves as the unit of heat) suffices to raise the temperature of $\frac{1}{0.1140}=8{,}772$ kg. of iron by 1° C. Therefore the 2,264 heat-units mentioned above raise the

* This refers to the German pound (500 grams).—*Ed.*

temperature of 1 kg. of iron by $8{,}772\times2{,}264=19{,}860°$ or 19,860 kg. of iron by 1° C. Since this amount of heat is distributed uniformly in the armour and the shot, the latter has its temperature raised by $\frac{19{,}860°}{2\times12}=828°$, amounting to quite a good glowing heat. But since the foremost, striking end of the shot receives at any rate by far the greater part of the heat, certainly double that of the rear half, the former would be raised to a temperature of 1,104° C. and the latter to 552° C., which would fully suffice to explain the glowing effect even if we make a big deduction for the actual mechanical work performed on impact.

Mechanical motion also disappears in friction, to reappear as heat; it is well known that, by the most accurate possible measurement of the two mutually corresponding processes, Joule in Manchester and Colding in Copenhagen were the first to make an approximate experimental measurement of the mechanical equivalent of heat.

The same thing applies to the production of an electric current in a magneto-electrical machine by means of mechanical force, e.g., from a steam-engine. The amount of so-called electromotive force produced in a given time is proportional to the amount of mechanical motion used up in the same period, being equal to it if expressed in the same units. We can imagine this mechanical motion being produced, not by a steam-engine, but by a weight sinking under the pressure of gravity. The mechanical force that this is capable of supplying is measured by the *vis viva* that it would obtain on falling freely through the same distance, or by the force required to raise it again to the original height; in both cases $\frac{mv^2}{2}$.

Hence we find that mechanical motion has indeed a twofold measure, but also that each of these measures holds good for a very definitely demarcated series of phenomena. If already existing mechanical motion is transferred in such a way that it remains as mechanical motion, the transference takes place in proportion to the product of the mass and the velocity. If, however, it is transferred in such a way that it disappears as mechanical motion in

4 Зак. № 819

order to reappear in the form of potential energy, heat, electricity, etc., in short, if it is converted into another form of motion, then the amount of this new form of motion is proportional to the product of the originally moving mass and the square of the velocity. In short, mv is mechanical motion measured by mechanical motion; $\frac{mv^2}{2}$ is mechanical motion measured by its capacity to become converted into a definite amount of another form of motion. And, as we have seen, these two measures, because different, do not contradict each other.

It becomes clear from this that Leibniz's quarrel with the Cartesians was by no means a mere verbal dispute, and that d'Alembert's "royal edict" in point of fact settled nothing at all. D'Alembert might have spared himself his tirades on the unclearness of his predecessors, for he was just as unclear as they were. In fact, as long as it was not known what becomes of the apparently annihilated mechanical motion, the absence of clarity was inevitable. And as long as mathematical mechanicians like Suter remain obstinately shut in by the four walls of their special science, they are bound to remain just as unclear as d'Alembert and to fob us off with empty and contradictory phrases.

But how does modern mechanics express this conversion of mechanical motion into another form of motion, proportional in quantity to the former?—It has *performed work*, and indeed a definite amount of work.

But this does not exhaust the concept of work in the physical sense of the word. If, as in a steam or heat engine, heat is converted into mechanical motion, i.e., molecular motion is converted into mass motion, if heat breaks up a chemical compound, if it becomes converted into electricity in a thermopile, if an electric current liberates the elements of water from dilute sulphuric acid, or, conversely, if the motion (alias energy) set free in the chemical process of a generating cell takes the form of electricity and this in the closed circuit once more becomes converted into heat—in all these processes the form of motion that initiates the process, and which is converted by it into another form, performs work, and indeed an amount of work corresponding to its own amount.

Work, therefore, is change of form of motion regarded in its quantitative aspect.

But how so? If a raised weight remains suspended and at rest, is its potential energy during the period of rest also a form of motion? Certainly. Even Tait arrives at the conviction that potential energy is subsequently resolved into a form of actual motion (*Nature*).[83] And, apart from that, Kirchhoff goes much further in saying (*Math. Mech.*, p. 32):

> "Rest is a special case of motion",

and thus proves that he can not only calculate but can also think dialectically.

Hence, by a consideration of the two measures of mechanical motion, we arrive, incidentally, easily, and almost as a matter of course, at the concept of work, which was described to us as being so difficult to comprehend without mathematical mechanics. At any rate, we now know more about it than from Helmholtz's lecture *Über die Erhaltung der Kraft* (1862), which was intended precisely

> "to make as clear as possible the basic physical concepts of work and its unalterability".

All that we learn there about work is that it is something which is expressed in foot-pounds or in units of heat, and that the number of these foot-pounds or units of heat is invariable for a definite quantity of work; and, further, that besides mechanical forces and heat, chemical and electric forces can perform work, but that all these forces exhaust their capacity for work to the extent that they actually result in work. We learn also that it follows from this that the sum of all effective quantities of force in nature as a whole remains eternally and invariably the same throughout all the changes taking place in nature. The concept of work is neither developed, nor even defined.*

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* We get no further by consulting Clerk Maxwell. He says (*Theory of Heat*, 4th edition, London, 1875, p. 87): "Work is done when resistance is overcome", and on p. 185, "The energy of a body is its capacity for doing work." That is all that we learn about it. [*Note by Engels.*]

And it is precisely the quantitative invariability of the magnitude of work which prevents him from realising that the qualitative alteration, the change of form, is the basic condition for all physical work. And so Helmholtz can go so far as to assert that

> "friction and inelastic impact are processes in which *mechanical work is destroyed** and heat is produced instead". (*Pop. Vortr.*, II, S. 166.)

Just the contrary. Here mechanical work is not *destroyed*, here mechanical work is *performed*. It is mechanical *motion* that is *apparently* destroyed. But mechanical motion *can* never perform even a millionth part of a kilogram-metre of work, without apparently being destroyed as such, without becoming converted into another form of motion.

But, as we have seen, the capacity for work contained in a given amount of mechanical motion is what is known as its *vis viva*, and until recently was measured by mv^2. Here, however, a new contradiction arose. Let us listen to Helmholtz. (*Erhaltung der Kraft*, S. 9.) We read there that the magnitude of work can be expressed by a weight m being raised to a height h, when, if the force of gravity is put as g, the magnitude of work $=mgh$. For the body m to rise freely to the vertical height h, it requires a velocity $v=\sqrt{2gh}$, and it attains the same velocity on falling. Consequently, $mgh=\frac{mv^2}{2}$, and Helmholtz proposes

> "to take the magnitude $\frac{mv^2}{2}$ as the quantity of *vis viva*, whereby it becomes identical with the measure of the magnitude of work. From the viewpoint of how the concept of *vis viva* has been applied hitherto... this change has no significance, but it will offer us essential advantages in the future."

It is scarcely to be believed. In 1847, Helmholtz was so little clear about the mutual relations of *vis viva* and work, that he even fails to notice at all how he transforms the former proportional measure of *vis viva* into its absolute measure, and remains quite unconscious of the important discovery he has made by his audacious handling, recommend-

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* Italics by Engels.—*Ed.*

ing his $\frac{mv^2}{2}$ only because of its convenience as compared with mv^2! And it is as a matter of convenience that mechanicians have given general currency to $\frac{mv^2}{2}$. Only gradually was $\frac{mv^2}{2}$ also proved mathematically. Naumann (*Allg. Chemie,* S. 7)[84] gives an algebraical proof, Clausius (*Mech. Wärmetheorie*, 2. Aufl., I, S. 18),[85] an analytical one, which is then to be met with in another form and with a different method of deduction in Kirchhoff (*loc. cit.*, p. 27). Clerk Maxwell (*loc. cit.*, p. 88) gives an elegant algebraical deduction of $\frac{mv^2}{2}$ from mv. This does not prevent our two Scotsmen, Thomson and Tait, from asserting (*loc. cit.*, p. 163):

"The *vis viva*, or kinetic energy, of a moving body is proportional to the mass and the square of the velocity conjointly. If we adopt the same units of mass and velocity as before (namely, unit of mass moving with unit velocity), there is *particular advantage** in defining kinetic energy as *half* the product of the mass and the square of its velocity."

Here, therefore, we find that not only the ability to think, but also to calculate, has come to a standstill in the two foremost mechanicians of Scotland. The particular advantage, the convenience of the formula, accomplishes everything in the most beautiful fashion.

For us, who have seen that *vis viva* is nothing but the capacity of a given amount of mechanical motion to perform work, it is obvious on the face of it that the expression in mechanical terms of this capacity for work and the work actually performed by the latter must be equal to each other; and that, consequently, if $\frac{mv^2}{2}$ measures the work, the *vis viva* must likewise be measured by $\frac{mv^2}{2}$. But that is what happens in science. Theoretical mechanics arrives at the concept of *vis viva*, the practical mechanics of the engineer arrives at the concept of work and forces it on the theoreticians. And, immersed in their calculations,

* Italics by Engels.—*Ed.*

the theoreticians have become so unaccustomed to thinking that for years they fail to recognise the connection between the two concepts, measuring one of them by mv^2, the other by $\frac{mv^2}{2}$, and finally accepting $\frac{mv^2}{2}$ for both, not from comprehension, but for the sake of simplicity of calculation!*

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* The word "work" and the corresponding idea is derived from English engineers. But in English, practical work is called "work", while work in the economic sense is called "labour". Hence, physical work also is termed "work", thereby excluding all confusion with work in the economic sense. This is not the case in German; therefore it has been possible in recent pseudoscientific literature to make various peculiar applications of work in the physical sense to economic conditions of labour and vice versa. But we have also the word "*Werk*" which, like the English word "work", is excellently adapted for signifying physical work. Economics, however, being a sphere far too remote from our natural scientists, they will scarcely decide to introduce it to replace the word *Arbeit*, which has already obtained general currency—unless, perhaps, when it is too late. Only Clausius has made the attempt to retain the expression "*Werk*", at least alongside the expression "*Arbeit*". [*Note by Engels.*]

Tidal Friction. Kant and Thomson—Tait

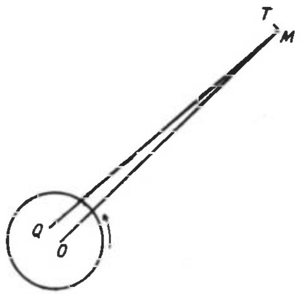
Rotation of the Earth and Lunar Attraction[86]

Thomson and Tait, *Nat. Philos.*, I, p. 191 (paragraph 276):

"There are also indirect resistances,[87] owing to friction impeding the tidal motions, on all bodies which, like the earth, have portions of their free surfaces covered by liquid, which, as long as these bodies move relatively to neighbouring bodies, must keep drawing off energy from their relative motions. Thus, if we consider, in the first place, the action of the moon alone on the earth with its oceans, lakes, and rivers, we perceive that it must tend to equalise the periods of the earth's rotation about its axis, and of the revolution of the two bodies about their centre of inertia; because as long as these periods differ, the tidal action of the earth's surface must keep subtracting energy from their motions. To view the subject more in detail, and, at the same time, to avoid unnecessary complications, let us suppose the moon to be a uniform spherical body. The mutual action and reaction of gravitation between her mass and the earth's will be equivalent to a single force in some line through her centre; *and must be such as to impede the earth's rotation as long as this is performed in a shorter period than the moon's motion round the earth.** It must, therefore, lie in some such direction as the line *MQ* in the diagram, which represents, necessarily with enormous exaggeration, its deviation, *OQ*, from the earth's centre. Now the actual force on the moon in the line *MQ* may be regarded as consisting of a force in the line *MO* towards the earth's centre, sensibly equal in amount to the whole force, and a comparatively very small force in the line *MT* perpendicular to *MO*. This latter is very nearly tangential to the moon's path, and is in the direction *with* her motion. Such a force, if suddenly commencing to act, would, in the first place, increase the moon's velocity; but after a certain time she would have moved so much farther from the earth, in virtue of this acceleration, as to have lost, by moving against the earth's attraction, as much velocity as she had gained by the tangential accelerating force. The effect of a continued tangential force, acting with the motion, but so small in amount as to make only a small deviation at any moment from the circular

* Italics by Engels.—*Ed.*

form of the orbit, is to gradually increase the distance from the central body, and to cause as much again as its own amount of work to be done against the attraction of the central mass, by the kinetic energy of motion lost. The circumstances will be readily understood by considering this motion round the central body in a very gradual spiral path tending outwards. Provided the law of force is the inverse square of the distance, the tangential component of gravity against the motion will be twice as great as the disturbing tangential force in the direction with the motion; and therefore one-half of the amount of work done against the former is done by the latter, and the other half by kinetic energy taken from the motion. The integral effect on the moon's motion, of the particular disturbing cause now under consideration, is most easily found by using the principle of moments of momenta. Thus we see that as much moment of momentum is gained in any time by the motions of the centres of inertia, of the moon and earth relatively to their common centre of inertia, as is lost by the earth's rotation about its axis. The sum of the moments of momentum of the centres of inertia of the moon and earth as moving at present, is about 4.45 times the present moment of momentum of the earth's rotation. The average plane of the former is the ecliptic; and therefore the axes of the two moments are inclined to one another at the average angle of 23°27.5′, which, as we are neglecting the sun's influence on the plane of the moon's motion, may be taken as the actual inclination of the two axes at present. The resultant, or whole moment of momentum, is therefore 5.38 times that of the earth's present rotation, and its axis is inclined 19°13′ to the axis of the earth. Hence the ultimate tendency of the *tides** is to reduce the earth and the moon to a simple uniform rotation with this resultant moment round this resultant axis, as if they were two parts of one rigid body: in which condition the moon's distance would be increased (approximately) in the ratio 1:1.46, being the ratio of the square of the present moment of momentum of the centres of inertia to the square of the whole moment of momentum; and the period of revolution in the ratio 1:1.77, being that of the cubes of the same quantities. The distance would therefore be increased to 347,100 miles, and the period lengthened to 48.36 days. Were there no other body in the universe but the earth and the moon, these two bodies might go on moving thus for ever, in circular orbits round their common centre of inertia, and the earth rotating about



* Italics by Engels.—*Ed.*

its axis in the same period, so as always to turn the same face to the moon, and, therefore, to have all the liquids at its surface at rest relatively to the solid. But the existence of the sun would prevent any such state of things from being permanent. There would be solar tides—twice high water and twice low water—in the period of the earth's revolution relatively to the sun (that is to say, twice in the solar day, or, which would be the same thing, the month). This could not go on without *loss of energy by fluid friction.** It is not easy to trace the whole course of the disturbance in the earth's and moon's motions which this cause would produce, but its ultimate effect must be to bring the earth, moon, and sun to rotate round their common centre of inertia, like parts of one rigid body."

Kant, in 1754, was the first to put forward the view that the rotation of the earth is retarded by tidal friction and that this effect will only reach its conclusion

"when its (the earth's) surface will be at relative rest in relation to the moon, i.e., when it will rotate on its axis in the same period that the moon takes to revolve round the earth, and consequently will always turn the same side to the latter".[88]

He held the view that this retardation had its origin in tidal friction alone, arising, therefore, from the presence of fluid masses on the earth:

"If the earth were a quite solid mass without any fluid, neither the attraction of the sun nor of the moon would do anything to alter its free axial rotation; for it draws with equal force both the eastern and western parts of the terrestrial sphere and so does not cause any inclination either to the one or to the other side; consequently it allows the earth full freedom to continue this rotation unhindered as if there were no external influence on it."[89]

Kant could rest content with this result. All scientific prerequisites were lacking at that time for penetrating deeper into the effect of the moon on the rotation of the earth. Indeed, it required almost a hundred years before Kant's theory obtained general recognition, and still longer before it was discovered that the ebb and flow of the tides are only the *visible* aspect of the effect exercised by the attraction of the sun and moon on the rotation of the earth.

This more general conception of the matter is just that which has been developed by Thomson and Tait. The at-

* Italics by Engels.—*Ed.*

traction of the moon and sun affects not only the fluids of the terrestrial body or its surface, but the whole mass of the earth in general in a manner that hinders the rotation of the earth. As long as the period of the earth's rotation does not coincide with the period of the moon's revolution round the earth, so long the attraction of the moon—to deal with this alone first of all—has the effect of bringing the two periods closer and closer together. If the rotational period of the (relative) central body were longer than the period of revolution of the satellite, the former would be gradually shortened; if it were shorter, as is the case for the earth, it would be lengthened. But neither in the one case will kinetic energy be created out of nothing, nor in the other will it be annihilated. In the first case, the satellite would approach closer to the central body and shorten its period of revolution, in the second it would increase its distance from it and acquire a longer period of revolution. In the first case, the satellite by approaching the central body loses exactly as much potential energy as the central body gains in kinetic energy from the accelerated rotation; in the second case the satellite, by increasing its distance, gains exactly the same amount of potential energy as the central body loses in kinetic energy of rotation. The total amount of dynamic energy, potential and kinetic, present in the earth-moon system remains the same; the system is fully conservative.

It is seen that this theory is entirely independent of the physico-chemical constitution of the bodies concerned. It is derived from the general laws of motion of free heavenly bodies, the connection between them being produced by attraction in proportion to their masses and in inverse proportion to the square of the distances between them. The theory has obviously arisen as a generalisation of Kant's theory of tidal friction, and is even presented here by Thomson and Tait as its substantiation on mathematical lines. But in reality—and remarkably enough the authors have simply no inkling of this—in reality it excludes the special case of tidal friction.

Friction is hindrance to the motion of masses, and for centuries it was regarded as the destruction of such motion, and therefore of kinetic energy. We now know that friction and impact are the two forms in which kinetic energy is converted into molecular energy, into heat. In all friction, therefore, kinetic energy as such is lost in order to reappear, not as potential energy in the sense of dynamics, but as molecular motion in the definite form of heat. The kinetic energy lost by friction is, therefore, in the first place *really lost* for the dynamic aspects of the system concerned. It can only become dynamically effective again if it is *reconverted* from the form of heat into kinetic energy.

How then does the matter stand in the case of tidal friction? It is obvious that here also the whole of the kinetic energy communicated to the masses of water on the earth's surface by lunar attraction is converted into heat, whether by friction of the water particles among themselves in virtue of the viscosity of the water, or by friction at the rigid surface of the earth and the comminution of rocks which stand up against the tidal motion. Of this heat there is reconverted into kinetic energy only the infinitesimally small part that contributes to evaporation at the surface of the water. But even this infinitesimally small amount of kinetic energy, ceded by the total earth-moon system to a part of the earth's surface, remains first of all at the earth's surface and is subject to the conditions prevailing there, and these conditions lead to all energy active there reaching one and the same final destiny: final conversion into heat and radiation into space.

Consequently, to the extent that tidal friction indisputably has an impeding effect on the rotation of the earth, the kinetic energy used for this purpose is absolutely lost to the dynamic earth-moon system. It can therefore not reappear within this system as dynamic potential energy. In other words, of the kinetic energy expended in impeding the earth's rotation by means of the attraction of the moon, only that part that acts on the *solid mass* of the earth's body can entirely reappear as dynamic potential energy, and hence be compensated for by a corresponding increase of the distance of the moon. On the other hand, the part that acts on the fluid masses of the earth can do so only in so far as it does not set these masses themselves into a motion opposite in direction to that of the earth's rotation, for such a motion is *wholly* converted into heat and is finally lost to the system by radiation.

What holds good for tidal friction at the surface of the earth is equally valid for the often hypothetically assumed tidal friction of a supposed fluid core of the earth.

The peculiar part of the matter is that Thomson and Tait do not notice that in order to establish the theory of tidal friction they are putting forward a theory that proceeds from the tacit assumption that the earth is *an entirely rigid* body, and so excludes any possibility of tides and hence also of tidal friction.

Heat[90]

As we have seen, there are two forms in which mechanical motion, *vis viva,* disappears. The first is its conversion into mechanical potential energy, for instance on lifting a weight. This form has the peculiarity that not only can it be re-transformed into mechanical motion—this mechanical motion, moreover, having the same *vis viva* as the original one—but also that it is capable only of this change of form. Mechanical potential energy can never produce heat or electricity, unless it has been converted first into real mechanical motion. To use Clausius' term, it is a "reversible process".

The second form in which mechanical motion disappears is in friction and impact—which differ only in degree. Friction can be conceived as a series of small impacts occurring successively and side by side, impact as friction concentrated at one spot and in a single moment of time. Friction is chronic impact, impact is acute friction. The mechanical motion that disappears here, disappears *as such.* It cannot be restored immediately out of itself. The process is not directly reversible. The motion has been transformed into qualitatively different forms of motion, into heat, electricity—into forms of molecular motion.

Hence, friction and impact lead from the motion of masses, the subject-matter of mechanics, to molecular motion, the subject-matter of physics.

In calling* physics the mechanics of molecular motion, it has not been overlooked that this expression by no means covers the entire field of contemporary physics. On

* See *Anti-Dühring*, Moscow, 1962, p. 95, and this volume, pp. 65-66, 70.—*Ed.*

the contrary. Ether vibrations, which are responsible for the phenomena of light and radiant heat, are certainly not molecular motions in the modern sense of the word. But their terrestrial actions concern molecules first and foremost: refraction of light, polarisation of light, etc., are determined by the molecular constitution of the bodies concerned. Similarly the most important scientists now almost unanimously regard electricity as a motion of ether particles, and Clausius even says of heat that

> in "the movement of ponderable atoms" (it would be better to say molecules) "... the ether within the body can also participate". (*Mechan. Wärmetheorie*, I, S. 22.)

But in the phenomena of electricity and heat, once again it is primarily molecular motions that have to be considered; it could not be otherwise, so long as our knowledge of the ether is so small. But when we have got so far as to be able to present the mechanics of the ether, this subject will include, of course, a great deal that is now of necessity allocated to physics.

The physical processes in which the structure of the molecules is altered, or even destroyed, will be dealt with later on. They form the transition from physics to chemistry.

Only with molecular motion does the change of form of motion acquire complete freedom. Whereas, at the boundary of mechanics the motion of masses can assume only a few other forms—heat or electricity—here, a quite different, lively capacity for change of form is to be seen. Heat passes into electricity in the thermopile, it becomes identical with light at a certain stage of radiation, and in its turn reproduces mechanical motion. Electricity and magnetism, a twin pair like heat and light, not only become transformed into each other, but also into heat and light as well as mechanical motion. And this takes place in such definite measure relations that a given amount of any one of these forms can be expressed in any other—in kilogram-metres, in heat-units, in volts,[91] and similarly any unit of measurement can be translated into any other.

The practical discovery of the conversion of mechanical motion into heat is so very ancient that it can be taken as marking the beginning of human history. Whatever discoveries, in the way of tools and domestication of animals, may have preceded it, the making of fire by friction was the first instance of men pressing a non-living force of nature into their service. Popular superstitions today still show how greatly the almost immeasurable import of this gigantic advance impressed itself on the mind of mankind. Long after the introduction of the use of bronze and iron the invention of the stone knife, the first tool, continued to be celebrated, all religious sacrifices being performed with stone knives. According to the Jewish legend, Joshua decreed that men born in the wilderness should be circumcised with stone knives[92]; the Celts and Germans used only stone knives in their human sacrifices. But all this long ago passed into oblivion. It was different with the making of fire by friction. Long after other methods of producing fire had become known, every sacred fire among the majority of peoples had to be obtained by friction. But even today, in the majority of the European countries the popular superstition persists that fire with miraculous powers (e.g., our German bonfire against epidemics) may be lighted only by means of friction. Thus, down to our own day, the grateful memory of the first great victory of mankind over nature lives on—half unconsciously—in popular superstition, in the relics of heathen-mythological recollections among the most educated peoples in the world.

However, the process of making fire by friction is still one-sided. By it mechanical motion is converted into heat. To complete the process, it must be reversed; heat must be converted into mechanical motion. Only then is justice done to the dialectics of the process, the cycle of the process being completed—for the first stage, at least. But history has its own pace, and however dialectical its course may be in the last analysis, dialectics has often to wait for history a fairly long time. Many thousands of years must have elapsed between the discovery of fire by friction and the time when Hero of Alexandria (*ca.* 120 B.C.) invented a machine which was set in rotary motion by the steam issuing from it. And almost another two thousand years elapsed before the first steam-engine was built, the first apparatus for the conversion of heat into really usable mechanical motion.

The steam-engine was the first really international invention, and this fact, in turn, testifies to a mightly historical advance. The Frenchman, Papin, invented the first steam-engine, and he invented it in Germany. It was the German, Leibniz, scattering around him, as always, brilliant ideas, without caring whether the merit for them would be awarded to him or someone else, who, as we know now from Papin's correspondence (published by Gerland),[93] gave him the main idea of the machine: the employment of a cylinder and piston. Soon after that, the Englishmen, Savery and Newcomen, invented similar machines; finally, their fellow-countryman, Watt, by introducing a separate condenser, brought the steam-engine in principle up to the level of today. The cycle of inventions in this sphere was completed; the conversion of heat into mechanical motion was achieved. What came afterwards were improvements in details.

Practice, therefore, solved after its own fashion the problem of the relations between mechanical motion and heat. It had, to begin with, converted the first into the second, and then it converted the second into the first. But how did matters stand in regard to theory?

The situation was pitiable enough. Although it was just in the seventeenth and eighteenth centuries that innumerable accounts of travel appeared, teeming with descriptions of savage peoples who knew no way of producing fire other than by friction, yet physicists were almost uninterested in it; they were equally indifferent to the steam-engine during the whole of the eighteenth century and the first decades of the nineteenth. For the most part they were satisfied simply to record the facts.

Finally, in the twenties [of the nineteenth century], Sadi Carnot took the matter in hand, and indeed so very skilfully that his best calculations, afterwards presented by Clapeyron in geometrical form, have retained their validity to the present day in the works of Clausius and Clerk Maxwell. Sadi Carnot almost got to the bottom of the question. It was not the lack of factual data that prevented him from completely solving it, but solely a preconceived *false theory*. Moreover, this false theory was not one which had been forced upon physicists by some variety of malicious philosophy, but was one concocted by the physicists themselves, by means of their own naturalistic mode of thought, allegedly so very superior to the metaphysical-philosophical method.

In the seventeenth century heat was regarded, at any rate in England, as a property of bodies,

> as "a *motion** of a particular kind, the nature of which has never been explained in a satisfactory manner".

That is what Th. Thomson called it, two years before the discovery of the mechanical theory of heat. (*Outline of the Sciences of Heat and Electricity*, 2nd edition, London, 1840.)[94] But in the eighteenth century the view came more and more to the forefront that heat, as also light, electricity, and magnetism, is a special substance, and that all these peculiar substances differ from ordinary matter in having no weight, in being imponderable.

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* Italics by Engels.—*Ed.*

Electricity*

Electricity, like heat, only in a different way, has also a certain omnipresent character. Hardly any change can occur on the earth without being accompanied by electrical phenomena. If water evaporates, if a flame burns, if two different metals, or two metals of different temperature, touch, or if iron comes into contact with a solution of copper sulphate, and so on, electrical processes take place simultaneously with the more apparent physical and chemical phenomena. The more exactly we investigate natural processes of the most diverse nature, the more do we find evidence of electricity. In spite of its omnipresence, in spite of the fact that for half a century electricity has become more and more pressed into the industrial service of mankind, it remains precisely that form of motion the nature of which is still enveloped in the greatest obscurity. The discovery of the galvanic current is approximately 25 years younger than that of oxygen and is at least as significant for the theory of electricity as the latter discovery was for chemistry. Yet what a difference obtains even today between the two fields! In chemistry, thanks especially to Dalton's discovery of atomic weights, there is order, relative certainty about what has been achieved, and systematic, almost planned, attack on the territory still unconquered, comparable to the regular siege of a fortress. In the theory of electricity there is a barren lum-

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* For the factual material in this chapter we rely mainly on Wiedemann's *Lehre vom Galvanismus und Elektromagnetismus*, 2 B-de in 3 Abt., 2. Auflage, Braunschweig, 1872-74.[95]

In *Nature*, June 15, 1882, there is a reference to this "admirable treatise, which in its forthcoming shape, with electro-statics added, will be the greatest experimental treatise on electricity in existence."[96] [*Note by Engels.*]

ber of ancient, doubtful experiments, neither definitely confirmed nor definitely refuted; an uncertain fumbling in the dark; unco-ordinated research and experiment on the part of numerous isolated individuals, who attack the unknown territory with their scattered forces like the attack of a swarm of nomadic horsemen. It must be admitted, indeed, that in the sphere of electricity a discovery like that of Dalton, giving the whole science a central point and a firm basis for research, is still to seek. It is essentially this confused state of the theory of electricity, which for the time being makes it impossible to establish a comprehensive theory, that is responsible for the fact that a one-sided empiricism prevails in this sphere, an empiricism which as far as possible forbids itself thought, and which precisely for that reason not only thinks incorrectly but also is incapable of faithfully pursuing the facts or even of reporting them faithfully, and which, therefore, becomes transformed into the opposite of true empiricism.

If in general those natural scientists who cannot say anything bad enough of the crazy *a priori* speculations of the German philosophy of nature are to be recommended to read the theoretico-physical works of the empirical school, not only of the contemporary but even of a much later period, this holds good quite especially for the theory of electricity. Let us take a work of the year 1840: *An Outline of the Sciences of Heat and Electricity*, by Thomas Thomson. Old Thomson was indeed an authority in his day; moreover he had already at his disposal a very considerable part of the work of the greatest electrician so far—Faraday. Yet his book contains at least just as crazy things as the corresponding section of the much older Hegelian philosophy of nature. The description of the electric spark, for instance, might have been translated directly from the corresponding passage in Hegel. Both enumerate all the wonders that people sought to discover in the electric spark, prior to knowledge of its real nature and manifold diversity, and which have now been shown to be mainly special cases or errors. More than that, Thomson recounts quite seriously on p. 416 Dessaigne's cock-and-bull stories, such as that, with a rising barometer and falling thermometer, glass, resin, silk, etc., become negatively electrified on immersion in mercury, but positively if instead the barometer is falling and the temperature rising; that in summer gold and several other metals become positive on warming and negative on cooling, but in winter the reverse; that with a high barometer and northerly wind they are strongly electric, positive if the temperature is rising and negative if it is falling, etc. So much for the treatment of the facts. As regards *a priori* speculation, Thomson favours us with the following theory of the electric spark, derived from no lesser person than Faraday himself:

"The spark is a discharge or lowering of the polarised inductive state of many dielectric particles, by a particular action of a few of the particles occupying a very small and limited space. Faraday conceives that the few particles where the discharge occurs are not merely pushed apart, but assume a peculiar state, a highly exalted condition for the time; that is to say, have thrown upon them all the surrounding forces in succession, and rising up to proportionate intensity of condition perhaps equal to that of chemically combining atoms; discharge the powers, possibly in the same manner as they do theirs, by some operation at present unknown to us; and so the end of the whole. The ultimate effect is exactly as if a metallic particle had been put into the place of the discharging particles, and it does not seem impossible that the principles of action, in both cases, may hereafter prove to be the same."[97] "I have," adds Thomson, "given this explanation of Faraday's in his own words, because I do not clearly understand it."

This will certainly have been the experience of other persons also, quite as much as when they read in Hegel that in the electric spark "the special materiality of the charged body does not as yet enter into the process but is determined within it only in an elementary and spiritual way", and that electricity is "the anger, the effervescence, proper to the body", its "angry self" that "is exhibited by every body when excited". (*Naturphilosophie*, paragraph 324, addendum.)[98] Yet the basic thought of both Hegel and Faraday is the same. Both oppose the idea that electricity is not a state of matter but a special, distinct variety of matter. And since in the spark electricity is apparently exhibited as independent, free, separated from any foreign material substratum, and yet perceptible to the senses, they arrive at the necessity, in the state of science at the time, of having to conceive of the spark as the transient phenomenal form of a "force" momentarily freed from all matter. For us, of course, the riddle is solved, since we know that on the spark discharge between metal electrodes real "metallic particles" leap across, and hence "the special materiality of the charged body" in actual fact "enters into the process".

As is well known, electricity and magnetism, like heat and light, were at first regarded as special imponderable substances. As far as electricity is concerned, it is well known that the view soon developed that there are two opposing substances, two "fluids", one positive and one negative, which in the normal state neutralise each other, until they are forced apart by a so-called "electric force of separation". It is then possible to charge two bodies, one with positive, the other with negative electricity; on uniting them by a third conducting body equalisation occurs, either suddenly or by means of a continuous current, according to circumstances. The sudden equalisation appeared very simple and comprehensible, but the current offered difficulties. The simplest hypothesis, that the current in every case is a movement of either purely positive or purely negative electricity, was opposed by Fechner, and in more detail by Weber, with the view that in every closed circuit two equal currents of positive and negative electricity flow in opposite directions in channels lying side by side between the ponderable molecules of the bodies. Weber's detailed mathematical working out of this theory finally arrives at the result that a function, of no interest to us here, is multiplied by a magnitude $\frac{1}{r}$, where $\frac{1}{r}$ denotes "*the ratio . . . of the unit of electricity to the milligram*".* (Wiedemann, *Lehre vom Galvanismus, etc.*, 2. Aufl., III, S. 569.) The ratio to a measure of weight can naturally only be a weight ratio. Hence one-sided empiricism had already to such an extent forgotten the practice of thought in calculating that here it even makes the imponderable electricity ponderable and introduces its weight into the mathematical calculation.

The formulæ derived by Weber sufficed only within

* Italics by Engels.—*Ed.*

certain limits, and Helmholtz, in particular, only a few years ago calculated from them results that come into conflict with the principle of the conservation of energy. In opposition to Weber's hypothesis of the double current flowing in opposite directions, C. Neumann in 1871 put forward the other hypothesis that in the current only one of the two electricities, for instance the positive, moves, while the other, negative one, remains firmly bound up with the mass of the body. On this Wiedemann includes the remark:

> "This hypothesis could be linked up with that of Weber if to Weber's supposed double current of electric masses $\pm \frac{1}{2} e$ flowing in opposite directions there was added a further *current of neutral electricity*,* externally inactive, which carried with it amounts of electricity $\pm \frac{1}{2} e$ in the direction of the positive current." (III, p. 577).

This proposition is once again characteristic of one-sided empiricism. In order to bring about the flow of electricity at all, it is decomposed into positive and negative. All attempts, however, to explain the current with these two substances meet with difficulties: both the assumption that only one of them is present in every case in the current and that the two of them flow in opposite directions simultaneously, and, finally, the third assumption also that one flows and the other is at rest. If we adopt this last assumption how are we to explain the inexplicable idea that negative electricity, which is mobile enough in the electrostatic machine and the Leyden jar, in the current is firmly united with the mass of the body? Quite simply. Besides the positive current $+e$, flowing through the wire to the right, and the negative current, $-e$, flowing to the left, we make yet another current, this time of neutral electricity, $\pm \frac{1}{2} e$, flow to the right. First we assume that the two electricities, to be able to flow at all, must be separated from each other; and then, in order to explain the phenomena that occur on the flow of the separated electricities, we assume that they can also flow unseparated. First we make a supposition to explain a particular phenomenon, and at the first

* Italics by Engels.—*Ed.*

difficulty encountered we make a second supposition which directly negates the first one. What must be the sort of philosophy that these gentlemen have the right to complain of?

However, alongside this view of the material nature of electricity, there soon appeared a second view, according to which it is to be regarded as a mere state of the body, a "force" or, as we would say today, a special form of motion. We saw above that Hegel, and later Faraday, adhered to this view. After the discovery of the mechanical equivalent of heat had finally disposed of the idea of a special "heat stuff", and heat was shown to be a molecular motion, the next step was to treat electricity also according to the new method and to attempt to determine its mechanical equivalent. This attempt was fully successful. Particularly owing to the experiments of Joule, Favre, and Raoult, not only was the mechanical and thermal equivalent of the so-called "electromotive force" of the galvanic current established, but also its complete equivalence with the energy liberated by chemical processes in the generating cell or used up in the electrolytic cell. This made the assumption that electricity is a special material fluid more and more untenable.

The analogy, however, between heat and electricity was not perfect. The galvanic current still differed in very essential respects from the conduction of heat. It was still not possible to say *what* it was that moved in the electrically affected bodies. The assumption of a mere molecular vibration as in the case of heat seemed insufficient. In view of the enormous velocity of motion of electricity, even exceeding that of light,[99] it remained difficult to overcome the view that here some material substance is in motion between the molecules of the body. Here the most recent theories put forward by Clerk Maxwell (1864), Hankel (1865), Reynard (1870), and Edlund (1872) are in complete agreement with the assumption, already advanced for the first time in 1846 as a suggestion by Faraday, that electricity is a motion of an elastic medium permeating the whole of space and hence all bodies as well, the discrete particles of which medium repel one another according to the law of the inverse square of the distance. In other words, it is a motion of ether particles, and the molecules of the body take part in this motion. As to the manner of this motion, the various theories are divergent; those of Maxwell, Hankel, and Reynard, taking as their basis modern investigations of vortex motion, explain it, too, in various ways from vortices, so that the vortex of old Descartes also once more comes into favour in an increasing number of new fields. We refrain from going more closely into the details of these theories. They differ strongly from one another and they will certainly still experience many transformations. But a decisive advance appears to lie in their common basic conception: that electricity is a motion of the particles of the luminiferous ether that penetrates all ponderable matter, this motion reacting on the molecules of the body. This conception reconciles the two earlier ones. According to it, in electrical phenomena it is indeed something substantial that moves, something different from ponderable matter. But this substance is not electricity itself, which in fact proves rather to be a form of motion, although not a form of the immediate, direct motion of ponderable matter. While, on the one hand, the ether theory shows a way of getting over the primitive clumsy idea of two opposed electrical fluids, on the other hand it gives a prospect of explaining *what* the real, material substratum of electrical motion is, *what* sort of a thing it is whose motion produces electrical phenomena.

The ether theory has already had *one* decisive success. As is well known, there is at least one point where electricity directly alters the motion of light: it rotates the latter's plane of polarisation. On the basis of his theory mentioned above, Clerk Maxwell calculates that the electric specific inductive capacity of a body is equal to the square of its index of refraction. Boltzmann has investigated dielectric constants of various nonconductors and he found that in sulphur, rosin, and paraffin, the square roots of these constants were respectively equal to their indices of refraction. The highest deviation—in sulphur—amounted to only 4 per cent. Consequently, the Maxwellian ether theory in this particular has hereby been experimentally confirmed.

It will, however, require a lengthy period and cost much labour before new series of experiments extract a firm kernel from these mutually contradictory hypotheses. Until then, or until the ether theory, too, is perhaps supplanted by an entirely new one, the theory of electricity finds itself in the uncomfortable position of having to employ a mode of expression which it itself admits to be false. Its whole terminology is still based on the idea of two electric fluids. It still speaks quite unashamedly of "electric masses flowing in the bodies", of "a division of electricities in every molecule", etc. This is a misfortune which for the most part, as already said, follows inevitably from the present transitional state of science, but which also, with the one-sided empiricism that prevails especially in this branch of investigation, contributes not a little to preserving the existing confusion of thought.

The opposition between so-called static or frictional electricity and dynamic electricity or galvanism can now be regarded as bridged over, since we have learned to produce continuous currents by means of the electric machine and, conversely, by means of the galvanic current to produce so-called static electricity, to charge Leyden jars, etc. We shall not here touch on the sub-form of static electricity, or on magnetism, which is now recognised to be also a sub-form of electricity. In any case, the theoretical explanation of the phenomena belonging here will have to be sought in the theory of the galvanic current, and consequently we shall keep mainly to this.

A continuous current can be produced in many different ways. Mechanical mass motion produces *directly*, by friction, in the first place only static electricity, and a continuous current only with great dissipation of energy; for the major part, at least, to become transformed into electric motion, the intervention of magnetism is required, as in the well-known magneto-electric machines of Gramme, Siemens, and others. Heat can be converted directly into an electric current, as occurs, for instance, at the junction of two different metals. The energy set free by chemical action, which under ordinary circumstances appears in the form of heat, is converted under appropriate conditions into electric motion. Conversely, the latter form of motion, as soon as the requisite conditions are present, passes into any other form of motion: into mass motion (to a very small extent directly into electro-dynamic attractions and repulsions; to a large extent, however, by the intervention again of magnetism in the electro-magnetic machine); into heat—throughout a closed circuit, unless other changes are brought about; into chemical energy—in electrolytic cells and voltameters introduced into the circuit, where the current dissociates compounds that are attacked in vain by other means.

All these transformations are governed by the basic law of the quantitative equivalence of motion through all its changes of form. Or, as Wiedemann expresses it: "by the law of conservation of force the mechanical work exerted in any way for the production of the current must be equivalent to the work exerted in producing all the effects of the current." [III, p. 472.] The conversion of mass motion or heat into electricity* offers us no difficulties here; it has been shown that the so-called "electromotive force" in the first case is equal to the work expended on that motion, and in the second case it is "at every junction of the thermopile directly proportional to its absolute temperature" (Wiedemann, III, S. 482), i.e., to the quantity of heat present at every junction measured in absolute units. The same law has in fact been proved valid also for electricity produced from chemical energy. But here the matter seems to be not so simple, at least for the theory now current. Let us, therefore, go into this somewhat more deeply.

One of the most beautiful series of experiments on the transformations of form of motion as a result of the action of a galvanic pile is that of Favre (1857-58).[100] He put a Smee pile of five elements in a calorimeter; in a second calorimeter he put a small electro-magnetic motor, with the main axle and pulley wheel projecting so as to be available for any kind of coupling. Each production in the pile of one gram of hydrogen, or solution of 32.6 grams of zinc

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* I use the term "electricity" in the sense of electric motion with the same justification that the general term "heat" is used to express the form of motion that our senses perceive as heat. This is the less open to objection in as much as any possible confusion with the state of *tension* of electricity is here expressly excluded in advance. [*Note by Engels.*]

(the old chemical equivalent of zinc, equal to half the now accepted atomic weight 65.2, and expressed in grams), gave the following results:

A. The pile enclosed in the calorimeter, excluding the motor: heat production 18,682 or 18,674 units of heat.

B. Pile and motor linked in the closed circuit, but the motor prevented from moving: heat in the pile 16,448, in the motor 2,219, together 18,667 units of heat.

C. As B, but the motor in motion without, however, lifting a weight: heat in the pile 13,888, in the motor 4,769, together 18,657 units of heat.

D. as C, but the motor raises a weight and so performs mechanical work=131.24 kilogram-metres: heat in the pile 15,427, in the motor 2,947, total 18,374 units of heat; loss in contrast to the above 18,682 equals 308 units of heat. But the mechanical work performed amounting to 131.24 kilogram-metres, multiplied by 1,000 (in order to bring the kilograms into line with the grams of the chemical results) and divided by the mechanical equivalent of heat=423.5 kilogram-metres,[101] gives 309 units of heat, hence exactly the loss mentioned above as the heat equivalent of the mechanical work performed.

The equivalence of motion in all its transformations is, therefore, strikingly proved for electric motion also, within the limits of unavoidable error. And it is likewise proved that the "electromotive force" of the galvanic battery is nothing but chemical energy converted into electricity, and the battery itself nothing but a device, an apparatus, that converts chemical energy on its liberation into electricity, just as a steam-engine transforms the heat supplied to it into mechanical motion, without in either case the converting apparatus supplying further energy on its own account.

A difficulty arises here, however, in relation to the traditional mode of conception. The latter ascribes an "*electric force of separation*" to the battery in virtue of the conditions of contact present in it between the fluids and metals, which force is proportional to the electromotive force and therefore for a given battery represents a definite quantity of energy. What then is the relation of this electric force of separation, of this source of energy which, according to the traditional mode of conception, is inherent in the battery as such even without chemical action, to the energy set free by chemical action? And if it is a source of energy independent of the latter, whence comes the energy furnished by it?

This question in a more or less unclear form constitutes the point of dispute between the contact theory founded by Volta and the chemical theory of the galvanic current that arose immediately afterwards.

The contact theory explained the current from the electric tensions arising in the battery on contact of the metals with one or more of the liquids, or even merely on contact of the liquids themselves, and from their neutralisation or that of the opposing electricities thus generated in the circuit. The pure contact theory regarded any chemical changes that might thereby occur as quite secondary. On the other hand, as early as 1805, Ritter maintained that a current could only be formed if the excitants reacted chemically even *before* closing the circuit. In general this older chemical theory is summarised by Wiedemann (I, p. 784) to the effect that according to it so-called contact electricity

> "makes its appearance only if at the same time there comes into play a real chemical action of the bodies in contact, or at any rate a disturbance of the chemical equilibrium, even if not directly bound up with chemical processes, a 'tendency towards chemical action' between the bodies in contact".

It is seen that both sides put the question of the source of energy of the current only indirectly, as indeed could hardly be otherwise at the time. Volta and his successors found it quite in order that the mere contact of heterogeneous bodies should produce a continuous current, and consequently be able to perform definite work without equivalent return. Ritter and his supporters are just as little clear how the chemical action makes the battery capable of producing the current and its performance of work. But if this point has long ago been cleared up for chemical theory by Joule, Favre, Raoult, and others, the opposite is the case for the contact theory. In so far as it has persisted, it remains essentially at the point where it started. Notions belonging to a period long outlived, a period when one had to be satisfied to ascribe a particular effect to the first available apparent cause that showed itself on the surface, regardless of whether motion was thereby made to arise out of nothing—notions that directly contradict the law of the conservation of energy—thus continue to exist in the theory of electricity of today. And if the most objectionable aspects of these ideas are shorn off, weakened, watered down, castrated, glossed over, this does not improve matters at all: the confusion is bound to become only so much the worse.

As we have seen, even the older chemical theory of the current declares the contact relations of the battery to be absolutely indispensable for the formation of the current: it maintains only that these contacts can never achieve a continuous current without simultaneous chemical action. And even today it is still taken as a matter of course that the contact arrangements of the battery provide precisely the apparatus by means of which liberated chemical energy is transformed into electricity, and that it depends essentially on these contact arrangements whether and how much chemical energy actually passes into electric motion.

Wiedemann, as a one-sided empiricist, seeks to save what can be saved of the old contact theory. Let us follow what he has to say.

> "In contrast to what was formerly believed," says Wiedemann (I, p. 799), "the effect of contact of chemically indifferent bodies, e.g., of metals, is *neither indispensable for the theory of the pile,** nor proved by the facts that *Ohm* derived his law from it, a law that can be derived without this assumption, and that *Fechner*, who confirmed this law experimentally, likewise defended the contact theory. Nevertheless, the excitation of electricity by *metallic** contact, at least according to the experiments now available, is not to be denied, even though the quantitative results obtainable in this respect may always be tainted with an inevitable uncertainty owing to the impossibility of keeping absolutely clean the surfaces of the bodies in contact."

It is seen that the contact theory has become very modest. It concedes that it is not at all indispensable for explaining the current, and neither proved theoretically by Ohm nor experimentally by Fechner. It even concedes that the so-called fundamental experiments, on which alone

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* Italics by Engels.—*Ed.*

it can still rest, can never furnish other than uncertain results in a quantitative respect, and finally it asks us merely to recognise that in general it is by contact—although only of *metals*!—that electric motion occurs.

If the contact theory remained content with this, there would not be a word to say against it. It will certainly be granted that on the contact of two metals electrical phenomena occur, by means of which a preparation of a frog's leg can be made to twitch, an electroscope charged, and other movements brought about. The only question that arises in the first place is: whence comes the energy required for this?

To answer this question, we shall, according to Wiedemann (I, p. 14):

> "adduce *more or less the following** considerations: if the heterogeneous metal plates *A* and *B* are brought within a close distance of each other, they attract each other in consequence of the forces of adhesion. On mutual contact they lose the *vis viva* of motion imparted to them by this attraction. (If we assume that the molecules of the metals are in a state of permanent vibration, it *could** also happen that, if on contact of the heterogeneous metals the molecules not vibrating simultaneously come into contact, an alteration of their vibration is thereby brought about with loss of *vis viva*.) The lost *vis viva* is *to a large extent** converted into heat. A *small portion** of it, however, is expended in bringing about a different distribution of the electricities previously unseparated. As we have already mentioned above, the bodies brought together become charged with equal quantities of positive and negative electricity, *possibly** as the result of an unequal attraction for the two electricities."

The modesty of the contact theory becomes greater and greater. At first it is admitted that the powerful electric force of separation, which has later such a gigantic work to perform, in itself possesses no energy of its own, and that it cannot function if energy is not supplied to it from outside. And then it has allotted to it a more than diminutive source of energy, the *vis viva* of adhesion, which only comes into play at scarcely measurable distances and which allows the bodies to travel a scarcely measurable length. But it does not matter: it undeniably exists and equally undeniably vanishes on contact. But even this minute source still furnishes too much energy

* Italics by Engels.—*Ed.*

for our purpose: a *large* part is converted into heat and only a *small* portion serves to evoke the electric force of separation. Now, although it is well known that cases enough occur in nature where extremely minute impulses bring about extremely powerful effects, Wiedemann himself seems to feel that his hardly trickling source of energy can with difficulty suffice here, and he seeks a possible second source in the assumption of an interference of the molecular vibrations of the two metals at the surfaces of contact. Apart from other difficulties encountered here, Grove and Gassiot have shown that for exciting electricity actual contact is not at all indispensable, as Wiedemann himself tells us on the previous page. In short, the more we examine it the more does the source of energy for the electric force of separation dwindle to nothing.

Yet up to now we hardly know of any other source for the excitation of electricity on metallic contact. According to Naumann (*Allgemeine und physikalische Chemie*, Heidelberg, 1877, S. 675), "the contact-electromotive forces convert heat into electricity"; he finds "the assumption natural that the ability of these forces to produce electric motion depends on the quantity of heat present, or, in other words, that it is a function of the temperature", as has also been proved experimentally by Le Roux. Here, too, we find ourselves groping in the dark. The law of the voltaic series of metals forbids us to have recourse to the chemical processes that to a small extent are continually taking place at the contact surfaces, which are always covered by a thin layer of air and impure water, a layer as good as inseparable as far as we are concerned; hence it forbids us to explain the excitation of electricity by the presence of an invisible active electrolyte between the contact surfaces. An electrolyte should produce a continuous current in the closed circuit, but the electricity of mere metallic contact, on the contrary, disappears on closing the circuit. And here we come to the real point: whether, and in what manner, the production of a continuous current on the contact of chemically indifferent bodies is made possible by this "electric force of separation", which Wiedemann himself first of all restricted to metals, declaring it incapable of functioning without energy being supplied from outside, and then referred exclusively to a truly microscopic source of energy.

The voltaic series arranges the metals in such a sequence that each one behaves as electro-negative in relation to the preceding one and as electro-positive in relation to the one that follows it. Hence if we arrange a series of pieces of metal in this order, e.g., zinc, tin, iron, copper, platinum, we shall be able to obtain an electric tension at each end. If, however, we arrange the series of metals to form a closed circuit so that the zinc and platinum are in contact, the electric tension is at once neutralised and disappears. "Therefore the production of a continuous current of electricity is not possible in a closed circuit of bodies belonging to the voltaic series." [I, p. 45.]

Wiedemann further supports this statement by the following theoretical consideration:

> "In fact, if a continuous electric current were to make its appearance in the circuit, it would produce heat in the metallic conductors themselves, and this heating could at the most be counterbalanced by cooling at the metallic junctions. In any case it would give rise to an uneven distribution of heat; moreover an electro-magnetic motor could be driven continuously by the current without any sort of supply from outside, and thus work would be performed, which is impossible, since on firmly joining the metals, for instance by soldering, no further changes to compensate for this work could take place even at the contact surfaces." [I, pp. 44-45.]

And not content with the theoretical and experimental proof that the contact electricity of metals by itself cannot produce any current, we shall see too that Wiedemann finds himself compelled to put forward a special hypothesis to abolish its activity even where it might perhaps make itself evident in the current.

Let us, therefore, try another way of passing from contact electricity to the current. Let us imagine, with Wiedemann,

> "two metals, such as a zinc rod and a copper rod, soldered together at one end, but with their free ends connected by a third body which does *not* act electromotively in relation to the two metals, but only conducts the opposing electricities collected on their surfaces, so that they are neutralised in it. Then the electric force of separation would always restore the previous difference of potential, thus a continuous electric current would make its appearance in the circuit, a current

that would be able to perform work without any compensation, which again is impossible. Accordingly, there cannot be a body which only conducts electricity without electromotive activity in relation to the other bodies." [I, p. 45.]

We are no better off than before: the impossibility of creating motion again bars the way. By the contact of chemically indifferent bodies, hence by contact electricity as such, we shall never produce a current. Let us therefore go back again and try a third way pointed out by Wiedemann:

"Finally, if we immerse a zinc plate and a copper plate in a liquid that contains a so-called *binary* compound, which therefore can be decomposed into two chemically distinct constituents that completely saturate one another, e.g., dilute hydrochloric acid (H+Cl), etc., then according to paragraph 27 the zinc becomes negatively charged and the copper positively. On joining the metals, these electricities neutralise each other through the place of contact, through which, *therefore, a current of positive electricity* flows from the copper to the zinc. Moreover, since the electric force of separation making its appearance on the contact of these two metals *conveys* the positive electricity *in the same direction*, the effects of the electric forces of separation are *not* abolished as in a closed metallic circuit. *Hence there arises a continuous current of positive electricity,* flowing in the closed circuit from the copper through its place of contact with the zinc, in the direction of the latter, and through the liquid from the zinc to the copper. We shall return in a moment (paragraph 34, et seq.) to the question how far the individual electric forces of separation present in the circuit *really* participate in the formation of the current.—A combination of conductors providing such a 'galvanic current' we term a galvanic element, or also a galvanic battery." [I, p. 45.]*

Thus the miracle has been accomplished. By the mere electric force of separation of the contact which, according to Wiedemann himself, cannot be effective without energy being supplied from outside, a continuous current has been produced. And if we were offered nothing more for its explanation than the above passage from Wiedemann, it would indeed remain an absolute miracle. What have we learned here about the process?

1. If zinc and copper are immersed in a liquid containing a so-called *binary* compound, then, according to paragraph 27, the zinc becomes negatively charged and the cop-

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* All italics by Engels.—*Ed.*

per positively charged.—But in the whole of paragraph 27 there is no word of any binary compound. It describes only a simple voltaic element of a zinc plate and a copper plate, with a piece of cloth moistened by an *acid* liquid interposed between them, and then investigates, without mentioning any chemical processes, the resulting static-electric charges of the two metals. Hence, the so-called *binary* compound has been smuggled in here by the back-door.

2. What this binary compound is doing here remains a complete mystery. The circumstance that it "*can* be decomposed into two chemical constituents that fully saturate each other" (fully saturate each other after they have been decomposed?!) could at most teach us something new if it were *actually to decompose*. But we are not told a word about that, hence for the time being we have to assume that it does *not* decompose, e.g., in the case of paraffin.

3. When the zinc in the liquid has been negatively charged, and the copper positively charged, we bring them into contact (outside the liquid). At once "these electricities neutralise each other through the place of contact, through which, *therefore*, a current of *positive* elecrticity flows from the copper to the zinc". Again, we do not learn why only a current of "positive" electricity flows in the one direction, and not also a current of "negative" electricity in the opposite direction. We do not learn at all what becomes of the negative electricity, which, hitherto, was just as necessary as the positive; the effect of the electric force of separation consisted precisely in setting them free to oppose each other. Now it has been suddenly suppressed, as it were eliminated, and it is made to appear as if there exists only positive electricity.

But then again, on p. 51, the precise opposite is said, for here "*the electricities unite* in one current"; consequently both negative and positive flow in it! Who will rescue us from this confusion?

4. "Moreover, *since* the electric force of separation making its appearance on the contact of these two metals *conveys* the positive electricity *in the same direction*, the effects of the electric forces of separation are not abolished as in a closed metallic circuit. *Hence*, there arises a continuous current," etc.

This is a bit thick. For, as we shall see, Wiedemann proves to us a few pages later (p. 52) that

on the "formation of a continuous current... the electric force of separation at the place of contact of the metals... *must be inactive*",*

that not only does a current occur even when this force, instead of conveying the positive electricity in the same direction, acts in opposition to the direction of the current, but that in this case too it is not compensated by a definite share of the force of separation of the battery and, hence, once again is inactive. Consequently, how can Wiedemann on p. 45 make an electric force of separation participate as a necessary factor in the formation of the current, when on p. 52 he puts it out of action for the duration of the current, and that, moreover, by a hypothesis erected specially for this purpose?

5. "Hence there arises a *continuous current* of positive electricity, flowing in the closed circuit from the copper through its place of contact with the zinc, in the direction of the latter, and through the liquid from the zinc to the copper."

But in the case of such a continuous electric current, "heat would be produced by it in the conductors themselves", and also it would be possible for "an electromagnetic motor to be driven by it and thus work performed", which, however, is impossible without supply of energy. Since Wiedemann up to now has not breathed a syllable as to whether such a supply of energy occurs, or whence it comes, the continuous current so far remains just as much an impossibility as in both the previously investigated cases.

No one feels this more than Wiedemann himself. So he finds it desirable to hurry as quickly as possible over the many ticklish points of this remarkable explanation of current formation, and instead to entertain the reader throughout several pages with all kinds of elementary anecdotes about the thermal, chemical, magnetic, and physiological effects of this still mysterious current, in the

* All italics in these quotations by Engels.—*Ed.*

course of which by way of exception he even adopts a quite popular tone. Then he suddenly continues (p. 49):

"We have now to investigate in what way the electric forces of separation are active in a closed circuit of two metals and a liquid, e.g., zinc, copper, and hydrochloric acid.

"We *know* that when the current flows through the liquid the constituents of the binary compound (HCl) contained in it become separated in such a manner that one constituent (H) *is set free* on the copper, and an equivalent amount of the other (Cl) on the zinc, *whereby* the latter constituent combines with an equivalent amount of zinc to form ZnCl."*

We know! If we know this, we certainly do not know it from Wiedemann who, as we have seen, so far has not breathed a syllable about this process. Further, *if* we do know anything of this process, it is that it cannot proceed in the way described by Wiedemann.

On the formation of a molecule of HCl from gaseous hydrogen and gaseous chlorine, an amount of energy= 22,000 units of heat is liberated (Julius Thomsen).[102] Therefore, to break away the chlorine from its combination with hydrogen, the same quantity of energy must be supplied from outside for each molecule of HCl. Where does the battery derive this energy? Wiedemann's description does not tell us, so let us look for ourselves.

When chlorine combines with zinc to form zinc chloride a considerably greater quantity of energy is liberated than is necessary to separate chlorine from hydrogen; (Zn, Cl_2) develops 97,210 and 2(H, Cl) 44,000 units of heat (Julius Thomsen). With that the process in the battery becomes comprehensible. Hence it is not, as Wiedemann relates, that hydrogen without more ado is liberated on the copper, and chlorine on the zinc, "whereby" then subsequently and accidentally the zinc and chlorine enter into combination. On the contrary, the union of the zinc with the chlorine is the essential, basic condition for the whole process, and as long as this does not take place, one would wait in vain for hydrogen on the copper.

* Italics by Engels.—*Ed.*

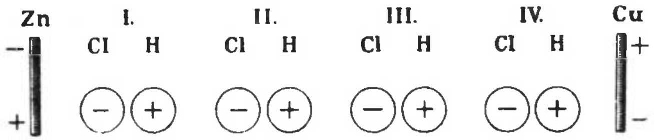
The excess of energy liberated on formation of a molecule of $ZnCl_2$ over that expended on liberating two atoms of H from two molecules of HCl, is converted in the battery into electric motion and provides the entire "electromotive force" that makes its appearance in the current circuit. Hence it is not a mysterious "electric force of separation" that tears asunder hydrogen and chlorine without any demonstrable source of energy, it is the total chemical process taking place in the battery that endows all the "electric forces of separation" and "electromotive forces" of the closed circuit with the energy necessary for their existence.

For the time being, therefore, we put on record that Wiedemann's *second* explanation of the current gives us just as little assistance as his first one, and let us proceed further with the text:

"This process proves that the behaviour of the binary substance between the metals does not consist merely in a simple predominant attraction of its entire mass for one electricity or the other, as in the case of metals, but that in addition a special action of its constituents is exhibited. Since the constituent Cl is given off where the current of positive electricity enters the fluid, and the constituent H where the negative electricity enters, *we assume** that each equivalent of chlorine in the compound HCl is charged with a definite amount of negative electricity determining its attraction by the entering positive electricity. It is the *electro-negative constituent* of the compound. Similarly the equivalent H must be charged with positive electricity and so represent the electro-positive constituent of the compound. These charges *could** be produced on the combination of H and Cl in just the same way as on the contact of zinc and copper. Since the compound HCl as such is non-electric, *we must assume** accordingly that in it the atoms of the positive and negative constituents contain equal quantities of positive and negative electricity.

"If now a zinc plate and a copper plate are dipped in dilute hydrochloric acid, *we can suppose** that the zinc has a stronger attraction towards the electro-negative constituent (Cl) than towards the electro-positive one (H). Consequently, the molecules of hydrochloric acid in contact with the zinc *would* dispose themselves so that their electro-negative constituents are turned towards the zinc, and their electro-positive constituents towards the copper. Owing to the constituents when so arranged exerting their electrical attraction on the constituents of the next molecules of HCl, the whole series of molecules between the zinc and copper plates becomes arranged as follows:

* Italics by Engels.—*Ed.*



If the second metal acted on the positive hydrogen as the zinc does on the negative chlorine, it would help to promote the arrangement. If it acted in the opposite manner, only more weakly, at least the direction would remain unaltered.

"By the influence exerted by the negative electricity of the electro-negative constituent Cl adjacent to the zinc, the electricity *would* be so distributed in the zinc that places on it which are close to the Cl of the immediately adjacent atom[103] of acid would become charged positively, those farther away negatively. Similarly, negative electricity would accumulate in the copper next to the electro-positive constituent (H) of the adjacent atom of hydrochloric acid, and the positive electricity would be driven to the more remote parts.

"*Next*, the positive electricity in the zinc *would* combine with the negative electricity of the immediately adjacent atom of Cl, and the latter itself with the zinc [to form non-electric ZnCl].* The electro-positive atom H, which was previously combined with this atom of Cl, *would* unite with the atom of Cl turned towards it belonging to the second atom of HCl, with simultaneous combination of the electricities contained in these atoms; similarly, the H of the second atom of HCl *would combine* with the Cl of the third atom, and so on, until finally on the copper an atom of H *would*** be set free, the positive electricity of which would unite with the distributed negative electricity of the copper, so that it would escape in a non-electrified state." This process would "repeat itself until the repulsive action of the electricities accumulated in the metal plates on the electricities of the hydrochloric acid constituents turned towards them balances the chemical attraction of the latter by the metals. If, however, the metal plates are joined by a conductor, the free electricities of the metal plates unite with one another and the above-mentioned processes can recommence. *In this way*** a constant flow of electricity would come into being.

"It is evident that thereby a continual loss of *vis viva* occurs, owing to the constituents of the binary compound on their migration to the metals moving to the latter with a definite velocity and then coming to rest, either with formation of a compound (ZnCl) or by escaping in the free state (H). (*Note* [*by Wiedemann*]: Since the gain in *vis viva* on separation of the constituents Cl and H... is compensated by the *vis viva* lost on the union of these constituents with the constituents of the adjacent atoms, the influence of this process can be neglected.) This loss of *vis viva* is equivalent to the quantity of

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* The words in brackets were omitted by Engels.—*Ed.*

** All italics by Engels.—*Ed.*

heat which is set free in the visibly occurring chemical process, essentially, therefore, that produced on the solution of an equivalent of zinc in the dilute acid. This value must be the same as that of the work expended on separating the electricities. If, therefore, the electricities unite to form a current, then, during the solution of an equivalent of zinc and the giving off of an equivalent of hydrogen from the liquid, there must make its appearance in the whole circuit, whether in the form of heat or in the form of external performance of work, an amount of work that is likewise equivalent to the development of heat corresponding to this chemical process." [I, pp. 49-51.]

"Let us assume—could—we must assume—we can suppose—would be distributed—would become charged", etc., etc. Sheer conjecture and subjunctives from which only three actual indicatives can be definitely extracted: firstly, that the combination of the zinc with the chlorine is *now* pronounced to be the condition for the liberation of hydrogen; secondly, as we now learn right at the end and as it were incidentally, that the energy herewith liberated is the source, and indeed the exclusive source, of all energy required for the formation of the current; and thirdly, that this explanation of the current formation is as directly in contradiction to both those previously given as the latter are themselves mutually contradictory.

Further it is said:

"For the formation of a continuous current, therefore, there is active *purely and solely** the electric force of separation which is derived from the unequal attraction and polarisation of the atoms of the binary compound in the exciting liquid of the battery by the metal electrodes; at the place of contact of the metals, at which no further mechanical changes can occur, the electric force of separation *must on the other hand be inactive.** That this force, if perchance it *counteracts** the electromotive excitation of the metals by the liquid (as on immersion of tin and lead in potassium cyanide solution), is not compensated by a definite share of the force of separation at the place of contact, is proved by the above-mentioned complete proportionality of the total electric force of separation (and electromotive force) in the closed circuit, with the above-mentioned heat equivalent of the chemical processes. Hence it must be neutralised in another way. This would most simply occur on the assumption that on contact of the exciting liquid with the metals the electromotive force is produced in a double manner; on the one hand by an unequally strong attraction of the *mass** of the liquid as a whole towards one or the other electricity, on the other hand by the unequal attraction

* Italics by Engels.—*Ed.*

of the metals towards the ***constituents*** of the liquid charged with opposite electricities.... Owing to the former unequal (mass) attraction towards the electricities, the liquids would fully conform to the law of the voltaic series of metals, and in a closed circuit ... complete neutralisation to zero of the electric forces of separation (and electromotive forces) take place; the second (*chemical**) action ... on the other hand would *by itself** supply the electric force of separation necessary for the formation of the current and the corresponding electromotive force." (I, pp. 52-53.)

Herewith the last relics of the contact theory are now happily eliminated from formation of the current, and simultaneously also the last relics of Wiedemann's first explanation of current formation given on p. 45. It is finally conceded without reservation that the galvanic battery is a simple apparatus for converting chemical energy in process of liberation into electric motion, into so-called electric force of separation and electromotive force, just as the steam-engine is an apparatus for converting heat energy into mechanical motion. In the one case, as in the other, the apparatus provides only the conditions for liberation and further transformation of the energy, but supplies no energy on its own account. This once established, it remains for us now to make a closer examination of this third version of Wiedemann's explanation of the current. How are the energy transformations in the closed circuit of the battery represented here?

It is evident, he says, that in the battery "a continual loss of *vis viva* occurs, owing to the constituents of the binary compound on their migration to the metals moving to the latter with a definite velocity and then coming to rest, either with formation of a compound (ZnCl) or by escaping in the free state (H). This loss is equivalent to the quantity of heat which is set free in the visibly occurring chemical process, essentially, therefore, that produced on the solution of an equivalent of zinc in the dilute acid."

Firstly, if the process goes on in *pure* form, no heat at all is set free in the battery on solution of the zinc; the liberated energy is indeed converted directly into electricity and only from this converted further into heat by the resistance of the whole circuit.

Secondly, *vis viva* is half the product of the mass and the square of the velocity. Hence the above statement

* Italics by Engels.—*Ed.*

would read: the energy set free on solution of an equivalent of zinc in dilute hydrochloric acid, equalling so many calories, is likewise equivalent to half the product of the mass of the ions and the square of the velocity with which they migrate to the metals. Expressed in this way, the statement is obviously false; the *vis viva* appearing on the migration of the ions is far from being equivalent to the energy set free by the chemical process.* But if it were to be so, no current would be possible, since there would be no energy remaining over for the current in the remainder of the closed circuit. Hence the further remark is introduced that the ions come to rest "either with formation of a compound or by escaping in the free state". But if the loss of *vis viva* is to include also the energy transformations taking place on these two processes, then we have indeed arrived at a dead-lock. For it is precisely to these two processes taken together that we owe the whole liberated energy, so that there can be absolutely no question here of a *loss* of *vis viva*, but at most of a *gain*.

It is therefore obvious that Wiedemann himself did not mean anything definite by this proposition; rather the "loss of *vis viva*" represents only the *deus ex machina* which is to enable him to make the fatal leap from the old contact theory to the chemical explanation of the current. In point of fact, the loss of *vis viva* has now performed its

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* F. Kohlrausch has recently calculated (*Wiedemanns Annalen*,[104] VI [Leipzig 1879], p. 206) that "immense forces" are required to drive the ions through the water solvent. To cause one milligram to move through a distance of one millimetre requires an attractive force which for H=32,500 kg., for Cl=5,200 kg., hence for HCl=37,700 kg.—Even if these figures are absolutely correct, they do not affect what has been said above. But the calculation contains the hypothetical factors hitherto inevitable in the sphere of electricity and therefore requires control by experiment. Such control appears possible. In the first place, these "immense forces" must reappear as a definite quantity of heat in the place where they are consumed, i.e., in the above case in the battery. Secondly, the energy consumed by them must be smaller than that supplied by the chemical processes of the battery, and there should be a definite difference. Thirdly, this difference must be used up in the rest of the closed circuit and likewise be quantitatively demonstrable there. Only after confirmation by this control can the above figures be regarded as final. The demonstration in the electrolytic cell appears still more susceptible of realisation. [*Note by Engels.*]

function and is dismissed; henceforth the chemical process in the battery is recognised indisputably as the sole source of energy for current formation, and the only remaining anxiety of our author is as to how he can politely rid the current of the last relic of excitation of electricity on the contact of chemically indifferent bodies, namely, the force of separation active at the place of contact of the two metals.

Reading the above explanation of current formation given by Wiedemann, one could believe oneself in the presence of a specimen of the kind of *apologia* that wholly- and semi-orthodox theologians of almost forty years ago employed to meet the philologico-historical bible criticism of Strauss, Wilke, Bruno Bauer, etc. The method is exactly the same, and it is bound to be so. For in both cases it is a question of saving the *inherited tradition* from scientific thought. Exclusive empiricism, which at most allows itself thinking in the form of mathematical calculation, imagines that it operates only with undeniable facts. In reality, however, it operates predominantly with traditional notions, with the largely obsolete products of thought of its predecessors, and such are positive and negative electricity, the electric force of separation, the contact theory. These serve it as the foundation of endless mathematical calculations in which, owing to the strictness of the mathematical formulation, the hypothetical nature of the premises gets comfortably forgotten. This kind of empiricism is as credulous towards the results of the thought of its predecessors as it is sceptical in its attitude to the results of contemporary thought. For it even the experimentally established facts have gradually become inseparable from their traditional interpretations; the simplest electric phenomenon is presented falsely, e.g., by smuggling in the two electricities; this empiricism *cannot* any longer describe the facts correctly, because the traditional interpretation is woven into the description. In short, we have here in the field of the theory of electricity a tradition just as highly developed as that in the field of theology. And since in both fields the results of recent research, the establishment of hitherto unknown or disputed facts and of the necessarily following theoretical conclusions, run pitilessly counter to the old traditions, the defenders of these traditions find themselves in the direst dilemma. They have to resort to all kinds of subterfuges and untenable expedients, to the glossing over of irreconcilable contradictions, and thus finally land themselves into a medley of contradictions from which they have no escape. It is this faith in all the old theory of electricity that entangles Wiedemann here into most inextricably contradicting himself, simply owing to the hopeless attempt to reconcile rationally the old explanation of the current by "contact force" with the modern one by liberation of chemical energy.

It will perhaps be objected that the above criticism of Wiedemann's explanation of the current rests on juggling with words; that although at the beginning Wiedemann expresses himself somewhat carelessly and inaccurately, still he does finally give the correct account in accord with the principle of the conservation of energy and so sets everything right. As against this view, we give below another example, his description of the process in the battery: zinc—dilute sulphuric acid—copper:

"If, however, the two plates are joined by a wire, a galvanic current arises.... *By the electrolytic process,** one equivalent of hydrogen is given off on the copper from the *water** of the dilute sulphuric acid, this hydrogen escaping in bubbles. On the zinc there is formed one equivalent of oxygen which oxidises the zinc to form zinc oxide, the latter becoming dissolved in the surrounding acid to form sulphuric zinc oxide." (I, p. 593.)

To break up water into gaseous hydrogen and gaseous oxygen requires an amount of energy of 68,924 heat-units for each molecule of water. Whence then comes the energy in the above battery? "By the electrolytic process." And where does the electrolytic process get it from? No answer is given.

But Wiedemann further tells us, not once, but at least twice (I, p. 472 and p. 614), that "according to recent experiments [in electrolysis] the water itself is not decomposed", but that in our case it is the sulphuric acid H_2SO_4 that splits up into H_2 on the one hand and into SO_3+O on the other hand, whereby under suitable conditions H_2 and

* Italics by Engels.—*Ed.*

O can escape in gaseous form. But this alters the whole nature of the process. The H_2 of the H_2SO_4 is directly replaced by the bivalent zinc, forming zinc sulphate, $ZnSO_4$. There remains over, on the one side H_2, on the other SO_3+O. The two gases escape in the proportions in which they unite to form water, the SO_3 unites with the water H_2O of the solution to reform H_2SO_4, i.e., sulphuric acid. The formation of $ZnSO_4$, however, develops sufficient energy not only to displace and liberate the hydrogen of the sulphuric acid, but also to leave over a considerable excess, which in our case is expended in forming the current. Hence the zinc does not wait until the electrolytic process puts free oxygen at its disposal, in order first to become oxidised and then to become dissolved in the acid. On the contrary, it enters directly into the process, which only comes into being at all *by this participation of the zinc*.

We see here how obsolete chemical notions come to the aid of the obsolete contact notions. According to modern views, a salt is an acid in which hydrogen has been replaced by a metal. The process under investigation confirms this view; the direct replacement of the hydrogen of the acid by the zinc fully explains the transformation of energy. The old view, adhered to by Wiedemann, regards a salt as a compound of a metallic oxide with an acid and therefore speaks of sulphuric zinc oxide instead of zinc sulphate. But to arrive at sulphuric zinc oxide in our battery of zinc and sulphuric acid, the zinc must first be oxidised. In order to oxidise the zinc fast enough, we must have free oxygen. In order to get free oxygen, we must assume—since hydrogen appears on the copper—that the water is decomposed. In order to decompose water, we need tremendous energy. How are we to get this? Simply "by the electrolytic process" which itself cannot come into operation as long as its chemical end product, the "sulphuric zinc oxide", has not begun to be formed. The child gives birth to the mother.

Consequently, here again Wiedemann puts the whole process absolutely the wrong way round and upside down. And the reason is that he lumps together active and passive electrolysis, two directly opposite processes, simply as electrolysis.

So far we have only examined the events in the battery, i.e., that process in which an excess of energy is set free by chemical action and is converted into electricity by the arrangements of the battery. But it is well known that this process can also be reversed: the electricity of a continuous current produced in the battery from chemical energy can, in its turn, be reconverted into chemical energy in an electrolytic cell inserted in the closed circuit. The two processes are obviously the opposites of each other; if the first is regarded as chemico-electric, then the second is electro-chemical. Both can take place in the same circuit with the same substances. Thus, the voltaic pile from gas elements, the current of which is produced by the union of hydrogen and oxygen to form water, can, in an electrolytic cell inserted in the circuit, furnish gaseous hydrogen and gaseous oxygen in the proportion in which they form water. The usual view lumps these two opposite processes together under the *single* expression: electrolysis, and does not even distinguish between active and passive electrolysis, between an exciting liquid and a passive electrolyte. Thus Wiedemann treats of electrolysis in general for 133 pages and then adds at the end some remarks on "electrolysis in the battery", in which, moreover, the processes in actual batteries only occupy the lesser part of the seventeen pages of this section. Also in the "theory of electrolysis" that follows, this contrast of battery and electrolytic cell is not even mentioned, and anyone who looked for some treatment of the transformations of energy in the closed circuit in the next chapter, "The Influence of Electrolysis on the Conduction Resistance and the Electromotive Force in the Circuit", would be bitterly disappointed.

Let us now consider the irresistible "electrolytic process" which is able to separate H_2 from O without visible supply of energy, and which plays the same role in these sections of the book as did previously the mysterious "electric force of separation".

"Alongside the *primary, purely electrolytic** process of separation of the ions, a number of *secondary, purely chemical* processes, quite independent of the first, take place by the action of the ions split

* Italics by Engels.—*Ed.*

off by the current. This action can take place on the material of the electrodes and on the bodies that are decomposed, and in the case of solutions also on the solvent." (I, p. 481.)

Let us return to the above-mentioned battery: zinc and copper in dilute sulphuric acid. Here, according to Wiedemann's own statement, the separated ions are the H_2 and O of the water. Consequently, for him the oxidation of the zinc and the formation of $ZnSO_4$ is a secondary, purely chemical process, independent of the electrolytic process, in spite of the fact that it is only through it that the primary process becomes possible. Let us now examine somewhat in detail the confusion that must necessarily arise from this inversion of the true course of events.

Let us consider in the first place the so-called secondary processes in the electrolytic cell, of which Wiedemann puts forward some examples* (pp. 481-82):

I. The electrolysis of sodium sulphate (Na_2SO_4) dissolved in water.

This "breaks up ... into 1 equivalent of SO_3+O ... and 1 equivalent of Na.... The latter, however, reacts on the water solvent and splits off from it 1 equivalent of H, while 1 equivalent of caustic soda [NaOH] is formed and becomes dissolved in the surrounding water."

The equation is:

$$Na_2SO_4 + 2H_2O = O + SO_3 + 2NaOH + 2H.$$

In fact, in this example the decomposition

$$Na_2SO_4 = Na_2 + SO_3 + O$$

could be regarded as the primary, electro-chemical process, and the further transformation

$$Na_2 + 2H_2O = 2NaOH + 2H$$

as the secondary, purely chemical one. But this secondary process is effected immediately at the electrode where

* It may be noted here once for all that Wiedemann employs throughout the old chemical equivalent values, writing HO, ZnCl, etc. In my equations, the modern atomic weights are everywhere employed, putting, therefore, H_2O, $ZnCl_2$, etc. [*Note by Engels.*]

the hydrogen appears, the very considerable quantity of energy (111,810 heat-units for Na, O, H, aq. according to Julius Thomsen) thereby liberated is therefore, at least for the most part, converted into electricity, and only a portion in the cell is transformed directly into heat. But the latter can also happen to the chemical energy directly or primarily liberated in the *battery*. The quantity of energy which has thus become available and converted into electricity, however, is to be subtracted from that which the current has to supply for continued decomposition of the Na_2SO_4. If the conversion of sodium into hydrated oxide appeared in the *first* moment of the total process as a secondary process, from the second moment onwards it becomes an essential factor of the total process and so ceases to be secondary.

But yet a third process takes place in this electrolytic cell: SO_3 combines with H_2O to form H_2SO_4, sulphuric acid, provided the SO_3 does not enter into combination with the metal of the positive electrode, in which case again energy would be liberated. But this change does not necessarily proceed immediately at the electrode, and consequently the quantity of energy (21,320 heat-units, J. Thomsen) thereby liberated becomes converted wholly or mainly into heat in the cell itself, and provides at most a very small portion of the electricity in the current. The only really secondary process occurring in this cell is therefore not mentioned at all by Wiedemann.

II. "If a solution of copper sulphate [$CuSO_4 + 5H_2O$] is electrolysed between a positive copper electrode and a negative one of platinum, 1 equivalent of copper separates out for 1 equivalent of water decomposed at the negative platinum electrode, with simultaneous decomposition of sulphuric acid in the same current circuit; at the positive electrode, 1 equivalent of SO_4 should make its appearance; but this combines with the copper of the electrode to form 1 equivalent of $CuSO_4$, which becomes dissolved in the water of the electrolysed solution." [I, p. 481.]

In the modern chemical mode of expression we have, therefore, to represent the process as follows: copper is deposited on the platinum; the liberated SO_4, which cannot exist as such, splits up into SO_3+O, the latter escaping in the free state; the SO_3 takes up H_2O from the aqueous solvent and forms H_2SO_4, which again combines with the copper of the electrode to form $CuSO_4$, H_2 being set free. Strictly speaking, we have here three processes: (1) the separation of Cu and SO_4; (2) $SO_3+O+H_2O=H_2SO_4+O$; (3) $H_2SO_4+Cu=H_2+CuSO_4$. It is natural to regard the first as primary, the two others as secondary. But if we inquire into the energy transformations, we find that the first process is completely compensated by a part of the third: the separation of copper from SO_4 by the reuniting of both at the other electrode. If we leave out of account the energy required for shifting the copper from one electrode to the other, and likewise the inevitable, not accurately determinable, loss of energy in the battery by conversion into heat, we have here a case where the so-called primary process withdraws no energy from the current. The current provides energy exclusively to make possible the separation of H_2 and O, which moreover is indirect, and this proves to be the real chemical result of the whole process—hence, for carrying out a *secondary*, or even tertiary, process.

Nevertheless, in both the above examples, as in other cases also, it is undeniable that the distinction of primary and secondary processes has a relative justification. Thus in both cases, among other things, water also is apparently decomposed and the elements of water given off at the opposite electrodes. Since, according to the most recent experiments, absolutely pure water comes as near as possible to being an ideal non-conductor, hence also a non-electrolyte, it is important to show that in these and similar cases it is not the water that is directly electrochemically decomposed, but that the elements of water are separated from the acid, in the formation of which here it is true the water of the solution must participate.

III. "If one electrolyses simultaneously in two U-tubes ... hydrochloric acid [$HCl + 8H_2O$] ... using in one tube a zinc positive electrode and in the other tube one of copper, then in the first tube a quantity of zinc 32.53 is dissolved, in the other a quantity of copper 2×31.7." [I, p. 482.]

For the time being let us leave the copper out of account and consider the zinc. The decomposition of HCl is regarded here as the primary process, the solution of Zn as secondary.

According to this conception, therefore, the current brings to the electrolytic cell from outside the energy necessary for the separation of H and Cl, and after this separation is completed, the Cl combines with the Zn, whereby a quantity of energy is set free that is subtracted from that required for separating H and Cl; the current needs only therefore to supply the difference. So far everything agrees beautifully; but if we consider the two amounts of energy more closely we find that the one liberated on the formation of $ZnCl_2$ is *larger* than that used up in separating 2HCl; consequently, that the current not only does not need to supply energy, but on the contrary *receives energy*. We are no longer confronted by a passive electrolyte, but by an exciting fluid, not an electrolytic cell but a *battery*, which strengthens the current-forming voltaic pile by a new element; the process which we are supposed to conceive as secondary becomes absolutely primary, becoming the source of energy of the whole process and making the latter independent of the current supplied by the voltaic pile.

We see clearly here the source of the whole confusion prevailing in Wiedemann's theoretical description. Wiedemann's point of departure is electrolysis; whether this is active or passive, battery or electrolytic cell, is all one to him: saw-bones is saw-bones, as the old Major said to the Doctor of Philosophy[105] doing his year's military service. And since it is easier to study electrolysis in the electrolytic cell than in the battery, he does, in fact, take the electrolytic cell as his point of departure, and he makes the processes taking place in it, and the partly justifiable division of them into primary and secondary, the measure of the altogether reverse processes in the battery, not even noticing when his electrolytic cell becomes surreptitiously transformed into a battery. Hence he is able to put forward the proposition:

> "the chemical affinity that the separated substances have for the electrodes has no influence on the electrolytic process as such" (I, p. 471),

a proposition which in this absolute form, as we have seen, is totally false. Hence, further, his threefold theory of current formation: firstly, the old traditional one, by means of pure contact; secondly, that derived by means of the abstractly conceived electric force of separation, which in an inexplicable manner obtains for itself or for the "electrolytic process" the requisite energy for splitting apart the H and Cl in the battery and for forming a current as well; and finally, the modern, chemico-electric theory which demonstrates the source of this energy in the algebraic sum of all the chemical reactions in the battery. Just as he does not notice that the second explanation overthrows the first, so also he has no idea that the third in its turn overthrows the second. On the contrary, the principle of the conservation of energy is merely added in a quite superficial way to the old theory handed down from routine, just as a new geometrical theorem is appended to the earlier ones. He has no inkling that this principle makes necessary a revision of the whole traditional point of view in this as in all other fields of natural science. Hence Wiedemann confines himself to noting the principle in his explanation of the current, and then calmly puts it on one side, taking it up again only right at the end of the book, in the chapter on the work performed by the current. Even in the theory of the excitation of electricity by contact (I, p. 781 et seq.) the conservation of energy plays no role at all in relation to the chief subject dealt with, and is only incidentally brought in for throwing light on subsidiary matters: it is and remains a "secondary process".

Let us return to the above example III. There the same current was used to electrolyse hydrochloric acid in two U-tubes, but in one there was a positive electrode of zinc, in the other the positive electrode used was of copper. According to Faraday's basic law of electrolysis, the same galvanic current decomposes in each cell equivalent quantities of electrolyte, and the quantities of the substances liberated at the two electrodes are also in proportion to the equivalents. (I, p. 470.) In the above case it was found that in the first tube a quantity of zinc 32.53 was dissolved, and in the other a quantity of copper 2×31.7.

"Nevertheless," continues Wiedemann, "this is no proof for the equivalence of these values. They are observed only in the case of very weak currents with the formation of zinc chloride ... on the one hand, and of copper chloride ... on the other. In the case of stronger currents, with the same amount of zinc dissolved, the quantity of dissolved copper would sink ... down to 31.7 with formation of increasing quantities of chloride."

It is well known that zinc forms only a single compound with chlorine, zinc chloride, $ZnCl_2$; copper on the other hand forms two compounds, cupric chloride, $CuCl_2$, and cuprous chloride, Cu_2Cl_2. Hence the process is that the weak current splits off two copper atoms from the electrode for each two chlorine atoms, the two copper atoms remaining united by *one* of their two valencies, while their two free valencies unite with the two chlorine atoms:

Cu—Cl
|
Cu—Cl

On the other hand, if the current becomes stronger, it splits the copper atoms apart altogether, and each one unites with two chlorine atoms:

$$Cu\begin{matrix}/Cl\\ \backslash Cl\end{matrix}$$

In the case of currents of medium strength, both compounds are formed side by side. Thus it is solely the strength of the current that determines the formation of one or the other compound, and therefore the process is essentially *electro*-chemical, if this word has any meaning at all. Nevertheless Wiedemann declares explicitly that it is secondary, hence not electro-chemical, but purely chemical.

The above experiment is one performed by Renault (1867) and is one of a whole series of similar experiments in which the same current is led in one U-tube through salt solution (positive electrode—zinc), and in another cell through a varying electrolyte with various metals as the positive electrode. The amounts of the other metals dissolved here for each equivalent of zinc diverged very considerably, and Wiedemann gives the results of the whole series of experiments which, however, in point of fact, are mostly self-evident chemically and could not be otherwise. Thus, for 1 equivalent of zinc, only two-thirds of an equivalent of gold is dissolved in hydrochloric acid. This can only appear remarkable if, like Wiedemann, one adheres to the old equivalent weights and writes ZnCl for zinc chloride, according to which both the chlorine and the zinc appear in the chloride with only a *single* valency. In reality two chlorine atoms stick to one zinc atom ($ZnCl_2$), and as soon as we know this formula we see at once that in the above determination of equivalents, the chlorine atom is to be taken as the unit and not the zinc atom. The formula for gold chloride, however, is $AuCl_3$, from which it is at once seen that $3ZnCl_2$ contains exactly as much chlorine as $2AuCl_3$, and so all primary, secondary, and tertiary processes in the battery or cell are compelled to transform, for each part by weight[106] of zinc converted into zinc chloride, neither more nor less than two-thirds of a part by weight of gold into gold chloride. This holds absolutely unless the compound AuCl also could be prepared by galvanic means, in which case even two equivalents of gold would have to be dissolved for one equivalent of zinc, when also similar variations according to the current strength could occur as in the case of copper and chlorine mentioned above. The value of Renault's experiments consists in the fact that they show how Faraday's law is confirmed by facts that appear to contradict it. But what they are supposed to contribute in throwing light on secondary processes in electrolysis is not evident.

Wiedemann's third example led us again from the electrolytic cell to the battery. And in fact the battery offers by far the greatest interest when one investigates the electrolytic processes in relation to the transformations of energy taking place here. Thus we not infrequently encounter batteries in which the chemico-electric processes seem to take place in direct contradiction to the law of the conservation of energy and in opposition to chemical affinity.

According to Poggendorff's[107] measurements, the battery: zinc—concentrated salt solution—platinum, provides a current of strength 134.6.* Hence we have here quite a respectable quantity of electricity, one-third more than in the Daniell cell. What is the source of the energy appearing here as electricity? The "primary" process is the replacement of sodium in the chlorine compound by zinc. But in ordinary chemistry it is not zinc that replaces sodium, but vice versa, sodium replacing zinc from chlorine and other compounds. The "primary" process, far from being able to give the current the above quantity of energy, on the contrary requires itself a supply of energy from outside in order to come into being. Hence, with the mere "primary" process we are again at a standstill. Let us look, therefore, at the real process. Then we find that the change is not

$$Zn + 2NaCl = ZnCl_2 + 2Na,$$

but

$$Zn + 2NaCl + 2H_2O = ZnCl_2 + 2NaOH + H_2.$$

In other words, the sodium is not split off in the free state at the negative electrode, but forms a hydroxide as in the above example I (pp. 143-44).

To calculate the energy transformations taking place here, Julius Thomsen's determinations provide us at least with certain important data. According to them, the energy liberated on combination is as follows:

$(ZnCl_2) = 97{,}210$,	$(ZnCl_2, \text{aqua}) = 15{,}630$,	
making a total for dissolved zinc chloride	$= 112{,}840$	heat-units.
2 (Na, O, H, aqua)	$= 223{,}620$	" "
	336,460	" "

Deducting consumption of energy on the separations:

2 (Na, Cl, aq.)	$= 193{,}020$	heat-units
2 (H_2,O)	$= 136{,}720$	" "
	329,740	" "

The excess of liberated energy equals 6,720 heat-units. This amount is obviously small for the current strength obtained, but it suffices to explain, on the one hand, the

* "Putting the current strength of the Daniell cell=100." [*Note by Engels.*]

separation of the sodium from chlorine, and on the other hand, the current formation in general.

We have here a striking example of the fact that the distinction of primary and secondary processes is purely relative and leads us *ad absurdum* as soon as we take it absolutely. The primary electrolytic process, taken alone, not only cannot produce any current, but cannot even take place itself. It is only the secondary, ostensibly purely chemical process that makes the primary one possible and, moreover, supplies the whole surplus energy for current formation. In reality, therefore, it proves to be the primary process and the other the secondary one. When the rigid differences and opposites, as imagined by the metaphysicians and metaphysical natural scientists, were dialectically turned into their opposites by Hegel, it was said that he had twisted the words in their mouths. But if nature itself proceeds exactly like old Hegel, it is surely time to examine the matter more closely.

With greater justification one can regard as secondary those processes which, while taking place *in consequence* of the chemico-electric process of the battery or the electrochemical process of the electrolytic cell, do so independently and separately, occurring therefore at some distance from the electrodes. Hence the energy transformations taking place in such secondary processes likewise do not enter into the electric process; directly they neither withdraw energy from it nor supply energy to it. Such processes occur very frequently in the electrolytic cell; we saw an instance in the example I above on the formation of sulphuric acid during electrolysis of sodium sulphate. They are, however, of lesser interest here. Their occurrence in the battery, on the other hand, is of greater practical importance. For although they do not directly supply energy to, or withdraw it from, the chemico-electric process, nevertheless they alter the total available energy present in the battery and thus affect it indirectly.

There belong here, besides subsequent chemical changes of the ordinary kind, the phenomena that occur when the ions are liberated at the electrodes in a different condition from that in which they usually occur in the free state, and when they pass over to the latter only after moving away from the electrodes. In such cases the ions can assume a different density or a different state of aggregation. They can also undergo considerable changes in regard to their molecular constitution, and this case is the most interesting. In all these cases, an analogous heat change corresponds to the secondary chemical or physical change of the ions taking place at a certain distance from the electrodes; usually heat is set free, in some cases it is consumed. This heat change is, of course, restricted primarily to the place where it occurs: the liquid in the battery or electrolytic cell becomes warmer or cooler while the rest of the circuit remains unaffected by this change. Hence this heat is called *local* heat. The liberated chemical energy available for conversion into electricity is, therefore, diminished or increased by the equivalent of this positive or negative local heat produced in the battery. According to Favre, in a battery with hydrogen peroxide and hydrochloric acid two-thirds of the total energy set free is consumed as local heat; the Grove cell, on the other hand, on closing the circuit became considerably cooler and therefore supplied energy from outside to the circuit by absorption of heat. Hence we see that these secondary processes also react on the primary one. We can make whatever approach we like, the distinction between primary and secondary processes remains merely a relative one and is regularly suspended in the interaction of the one with the other. If this is forgotten and such relative opposites are treated as absolute, one finally gets hopelessly involved in contradictions, as we have seen above.

As is well known, on the electrolytic liberation of gases the metal electrodes become covered with a thin layer of gas; in consequence the current strength decreases until the electrodes are saturated with gas, whereupon the weakened current again becomes constant. Favre and Silbermann have shown that local heat arises also in such an electrolytic cell; this local heat, therefore, can only be due to the fact that the gases are not liberated at the electrodes in the state in which they usually occur, but that they are only brought into this usual state after their separation from the electrodes, by a further process bound up with the development of heat. But what is the state in which the gases are given off at the electrodes? One cannot express oneself more cautiously on this than Wiedemann does. He terms it a "certain", an "allotropic", an "active", and finally, in the case of oxygen, several times an "ozonised" state. In the case of hydrogen his statements are still more mysterious. Incidentally, the view comes out that ozone and hydrogen peroxide are the forms in which this "active" state is realised. Our author is so keen in his pursuit of ozone that he even explains the extreme electro-negative properties of certain peroxides from the fact that they "possibly contain a part of the oxygen *in the ozonised state*!"* (I, p. 57.) Certainly both ozone and hydrogen peroxide are formed on the so-called decomposition of water, but only in small quantities. There is no basis at all for assuming that in the case mentioned local heat is produced first of all by the origin and then by the decomposition of any large quantities of the above two compounds. We do not know the heat of formation of ozone (O_3) from *free* oxygen atoms. According to Berthelot[108] the heat of formation of hydrogen peroxide from H_2O (liquid)$+O=$ $=21{,}480$; the origin of this compound in any large amount would therefore give rise to a large excess of energy (about 30 per cent of the energy required for the separation of H_2 and O), which could not but be evident and demonstrable. Finally, ozone and hydrogen peroxide would take only oxygen into account (apart from current reversals, where both gases would come together at the same electrode), but not hydrogen. Yet the latter also escapes in an "active" state, in such a way that in the combination: potassium nitrate solution between platinum electrodes, it combines directly with the nitrogen split off from the acid to form ammonia.

In point of fact, all these difficulties and doubts have no existence. The electrolytic process has no monopoly of splitting off bodies "in an active state". Every chemical decomposition does the same thing. It splits off the liberated chemical element in the first place in the form of free atoms of O, H, N, etc., which only after their liberation can unite to form molecules O_2, H_2, N_2, etc., and on thus uniting give off a definite, though up-to-now still undeter-

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* Italics by Engels.—*Ed.*

mined, quantity of energy which appears as heat. But during the infinitesimal moment of time when the atoms are free, they are the bearers of the total quantity of energy that they can take up at all; while possessed of their maximum energy they are free to enter into any combination offered them. Hence they are "in an active state" in contrast to the molecules O_2, H_2, N_2, which have already surrendered a part of this energy and cannot enter into combination with other elements without this quantity of energy surrendered being re-supplied from outside. We have no need, therefore, to resort only to ozone and hydrogen peroxide, which themselves are merely products of this active state. For instance, we can undertake the above-mentioned formation of ammonia on electrolysis of potassium nitrate even without a battery, simply by chemical means, by adding nitric acid or a nitrate solution to a liquid in which hydrogen is set free by a chemical process. In both cases the active state of the hydrogen is the same. But the interesting point about the electrolytic process is that here the transitory existence of the free atoms becomes as it were tangible. The process here is divided into two phases: the electrolysis provides free atoms at the electrodes, but their combination to form molecules occurs at some distance from the electrodes. However infinitesimally minute this distance may be compared to measurements relating to masses, it suffices to prevent the energy liberated on formation of the molecules being used for the electric process, at least for the most part, and so determines its conversion into heat—the local heat in the battery. But it is owing to this that the fact is established that the elements have been split off as free atoms and for a moment have existed in the battery as free atoms. This fact, which in pure chemistry can only be established by theoretical conclusions, is here proved experimentally, in so far as this is possible without sensuous perception of the atoms and molecules themselves. Herein lies the high scientific importance of the so-called local heat of the battery.

The conversion of chemical energy into electricity by means of the battery is a process about whose course we know next to nothing, and we shall become more closely acquainted with it only when the *modus operandi* of electric motion itself becomes better known.

The battery has ascribed to it an "electric force of separation" which is given for each particular battery. As we saw at the outset, Wiedemann conceded that this electric force of separation is not a definite form of energy. On the contrary, it is primarily nothing more than the capacity, the property, of a battery to convert a definite quantity of liberated chemical energy into electricity in unit time. Throughout the whole process, this chemical energy itself never assumes the form of an "electric force of separation", but, on the contrary, at once and immediately takes on the form of so-called "electromotive force", i.e., of electric motion. If in ordinary life we speak of the force of a steam-engine in the sense that it is capable in unit time of converting a definite quantity of heat into the motion of masses, this is not a reason for introducing the same confusion of ideas into scientific thought also. We might just as well speak of the varying force of a pistol, a carbine, a smooth-bored gun, and a rifle, because, with equal gunpowder charges and projectiles of equal weight, they shoot varying distances. But here the wrongness of the expression is quite obvious. Everyone knows that it is the ignition of the gunpowder charge that drives the bullet, and that the varying range of the weapon is only determined by the greater or lesser dissipation of energy according to the length of the barrel, the clearance of the projectile,[109] and the form of the latter. But it is the same for the force of steam and for the electric force of separation. Two steam-engines—other conditions being equal, i.e., assuming the quantity of energy liberated in equal periods of time to be equal in both—or two galvanic batteries, of which the same thing holds good, differ as regards performance of work only owing to their greater or lesser dissipation of energy. And if until now all armies have been able to develop the technique of fire-arms without the assumption of a special shooting force of weapons, the science of electricity has absolutely no excuse for assuming an "electric force of separation" analogous to this shooting force, a force which embodies absolutely no energy and which therefore of itself cannot perform a millionth of a milligram-millimetre of work.

The same thing holds good for the second form of this "force of separation", the "electric force of contact of metals" mentioned by Helmholtz. It is nothing but the property of metals to convert on their contact the existing energy of another form into electricity. Hence it is likewise a force that does not contain a particle of energy. If we assume with Wiedemann that the source of energy of contact electricity lies in the *vis viva* of the motion of adhesion, then this energy exists in the first place in the form of this mass motion and on its vanishing becomes converted immediately into electric motion, without even for a moment assuming the form of an "electric force of contact".

And now we are assured in addition that the electromotive force, i.e., the chemical energy, reappearing as electric motion is proportional to this "electric force of separation", which not only contains no energy, but owing to the very conception of it *cannot* contain any! This proportionality between non-energy and energy obviously belongs to the same mathematics as that in which there figures the "ratio of the unit of electricity to the milligram".* But the absurd form, which owes its existence only to the conception of a simple *property* as a mystical *force,* conceals a quite simple tautology: the capacity of a given battery to convert liberated chemical energy into electricity is measured—by what? By the quantity of the energy reappearing in the closed circuit as electricity in relation to the chemical energy consumed in the battery. That is all.

In order to arrive at an electric force of separation, one must take seriously the emergency device of the two electric fluids. To convert these from their neutrality to their polarity, hence to split them apart, requires a certain expenditure of energy—the electric force of separation. Once separated, the two electricities can, on being reunited, again give off the same quantity of energy—electromotive force. But since nowadays no one, not even Wiedemann, regards the two electricities as having a real existence, it means that one is writing for a defunct public if one deals at length with such a point of view.

* See this volume, p. 117.—*Ed.*

The basic error of the contact theory consists in the fact that it cannot divorce itself from the idea that contact force or electric force of separation is a *source of energy*, which of course was difficult when the mere property of an apparatus to bring about transformation of energy had been converted into a *force*; for indeed, a *force* ought precisely to be a definite form of energy. Because Wiedemann cannot rid himself of this unclear notion of force, although side by side with it the modern ideas of indestructible and uncreatable energy have been forced upon him, he falls into his nonsensical explanation No. 1, of the current, and into all the later demonstrated contradictions.

If the expression "electric force of separation" is directly contrary to reason, the other "electromotive force" is at least superfluous. We had heat engines long before we had electromotors, and yet the theory of heat has been developed quite well without any special thermo-motor force. Just as the simple expression "heat" includes all phenomena of motion that belong to this form of energy, so also can the expression "electricity" in its own sphere. Moreover, very many forms of action of electricity are not at all directly "motor": the magnetisation of iron, chemical decomposition, conversion into heat. And finally, in every natural science, even in mechanics, it is always an advance if the word *force* can somewhere be got rid of.

We saw that Wiedemann did not accept the chemical explanation of the processes in the battery without a certain reluctance. This reluctance continually attacks him; where he can blame anything on the so-called chemical theory, this is certain to occur. Thus,

> "it is by no means established that electromotive force is proportional to the intensity of chemical action". (I, p. 791.)

Certainly not in every case; but where this proportionality does not occur, it is only a proof that the battery has been badly constructed, that dissipation of energy takes place in it. For that reason Wiedemann is quite right in paying absolutely no attention in his theoretical deductions to such subsidiary circumstances which falsify the purity of the process, but in simply assuring us that the electromotive force of a cell is equal to the mechanical equivalent of the chemical action taking place in it in unit time with unit intensity of current.

In another passage we read:

> "That further, in the acid-alkali battery, the combination of acid and alkali is not the cause of current formation follows from the experiments, paragraph 61 (Becquerel and Fechner), paragraph 260 (Du-Bois-Reymond), and paragraph 261 (Worm-Müller), according to which in certain cases when these are present in equivalent quantities no current makes its appearance, and likewise from the experiment (Henrici) mentioned in paragraph 62, that on interposing a solution of potassium nitrate between the potassium hydroxide and nitric acid, the electromotive force makes its appearance in the same way as without this interposition."* (I, p. 791.)

The question whether the combination of acid and alkali is the cause of current formation is a matter of very serious concern for our author. Put in this form it is very easy to answer. The combination of acid and alkali is first of all the cause of a *salt* being formed with liberation of energy. Whether this energy wholly or partly takes the form of electricity depends on the circumstances under which it is liberated. For instance, in the battery: nitric acid and potassium hydroxide between platinum electrodes, this will be at least partially the case, and it is a matter of indifference for the *formation* of the current whether a potassium nitrate solution is interposed between the acid and alkali or not, since this can at most slow down the salt formation but not prevent it. If, however, a battery is formed like one of Worm-Müller's, to which Wiedemann constantly refers, where the acid and the alkali solutions are in the middle, but a solution of their salt at both ends, and in the same concentration as the solution that is formed in the battery, then it is obvious that no current can arise, because on account of the end members—since everywhere identical bodies are formed—*no ions can be produced*. Hence the conversion of the liberated energy into electricity has been prevented in as direct a manner as if the circuit had not been closed at all; it is therefore not to be wondered at that no current is obtained. But that acid and alkali can in general produce a current is proved

* Names included in brackets are added by Engels.—*Ed.*

by the battery: carbon, sulphuric acid (one part in ten of water), potassium hydroxide (one part in ten of water), carbon, which according to Raoult has a current strength of 73.* And that, with suitable arrangement of the battery, acid and alkali can provide a current strength corresponding to the large quantity of energy set free on their combination, is seen from the fact that the most powerful batteries known depend almost exclusively on the formation of alkali salts, e.g., that of Wheatstone: platinum, platinic chloride, potassium amalgam—current strength 230; lead peroxide, dilute sulphuric acid, potassium amalgam=326; manganese peroxide instead of lead peroxide==280; in each case, if zinc amalgam was employed instead of potassium amalgam, the current strength fell almost exactly by 100. Similarly in the battery: manganese dioxide, potassium permanganate solution, potassium hydroxide, potassium, Beetz obtained the current strength 302, and further: platinum, dilute sulphuric acid, potassium=293.8; Joule: platinum, nitric acid, potassium hydroxide, potassium amalgam=302. The "cause" of these exceptionally high current strengths is certainly the combination of acid and alkali, or alkali metal, and the large quantity of energy thereby liberated.[110]

A few pages further on it is again stated:

"It must, however, be carefully borne in mind that the equivalent in work of the whole chemical action occurring at the place of contact of the heterogeneous bodies is not to be directly regarded as the measure of the electromotive force in the closed circuit. When, for instance, in the acid-alkali battery (*iterum Crispinus!*)[111] of Becquerel, these two substances combine; when carbon is consumed in the battery: platinum, molten potassium nitrate, carbon; when zinc is rapidly dissolved in an ordinary cell of copper, impure zinc, dilute sulphuric acid, with formation of local currents, then a large part of the work produced" (it should read: energy liberated) "in these chemical processes... is converted into heat and is thus lost for the total current circuit." (I, p. 798.)

All these processes are to be referred to loss of energy in the battery; they do not affect the fact that the electric motion arises from transformed chemical energy, but only affect the quantity of energy transformed.

* In all the following data relating to current strength, the Daniell cell is put=100. [*Note by Engels.*]

Electricians have devoted an endless amount of time and trouble to composing the most diverse batteries and measuring their "electromotive force". The experimental material thus accumulated contains very much of value, but certainly still more that is valueless. For instance, what is the scientific value of experiments in which "water" is employed as the electrolyte, when, as has now been proved by F. Kohlrausch, water is the worst conductor and therefore also the worst electrolyte,* and where, therefore, it is not the water but its unknown impurities that caused the process? And yet, for instance, almost half of all Fechner's experiments depend on such employment of water, even his "*experimentum crucis*",[112] by which he sought to establish the contact theory impregnably on the ruins of the chemical theory. As is already evident from this, in almost all such experiments, a few only excepted, the chemical processes in the battery, which however form the source of the so-called electromotive force, remain practically disregarded. There are, however, a number of batteries whose chemical composition does not allow of any certain conclusion being drawn as to the chemical changes proceeding in them when the current circuit is closed. On the contrary, as Wiedemann (I, p. 797) says, it is "not to be denied that we are by no means in all cases able to obtain an insight into the chemical attractions in the battery". Hence, from the ever more important chemical aspect, all such experiments are valueless unless they are repeated with these processes under control.

In these experiments it is indeed only quite by way of exception that any account is taken of the energy transformations taking place in the battery. Many of them were made before the law of the equivalence of motion was recognised in natural science, but as a matter of custom they continue to be dragged from one textbook into another without having been checked or brought to a finish. It has been said that electricity has no inertia (which has about

* A column of the purest water prepared by Kohlrausch 1 mm. in length offered the same resistance as a copper conductor of the same diameter and a length approximately that of the moon's orbit. (Naumann, *Allgemeine Chemie*, S. 729.) [*Note by Engels.*]

as much sense as saying velocity has no specific gravity), but this certainly cannot be said of the *theory* of electricity.

So far, we have regarded the galvanic cell as an apparatus in which, in consequence of the contact relations established, chemical energy is liberated in some way for the time being unknown, and converted into electricity. We have likewise described the electrolytic cell as an apparatus in which the reverse process is set up, electric motion being converted into chemical energy and used up as such. In so doing we had to put in the foreground the chemical aspect of the process, the aspect that has been so much neglected by electricians, because this was the only way of getting rid of the lumber of notions handed down from the old contact theory and the theory of the two electric fluids. This once accomplished, the question was whether the chemical process in the battery takes place under the same conditions as outside it, or whether special phenomena make their appearance that are dependent on the electric excitation.

In every science, incorrect notions are, in the last resort, apart from errors of observation, incorrect notions of correct facts. The latter remain even when the former are shown to be false. Although we have discarded the old contact theory, the established facts remain, of which this theory was supposed to be the explanation. Let us consider these and with them the electric aspect proper of the process in the battery.

It is not disputed that on the contact of heterogeneous bodies, with or without chemical changes, an excitation of electricity occurs which can be demonstrated by means of an electroscope or a galvanometer. As we have already seen at the outset, it is difficult to establish in a particular case the source of energy of these in themselves extremely minute phenomena of motion; it suffices that the existence of such an external source is generally conceded.

In 1850-53, Kohlrausch published a series of experiments in which he assembled the separate components of a battery in pairs and tested the static electric tensions produced in each case; the electromotive force of the cell should, then be composed of the algebraic sum of these tensions. Thus, taking the tension of Zn/Cu=100, he calculates the relative strengths of the Daniell and Grove cells as follows:

Daniell:

$$Zn/Cu+amalg.\ Zn/H_2SO_4+CU/SO_4CU=100+149-21=228;$$

Grove:

$$Zn/Pt+amalg.\ Zn/H_2SO_4+Pt/HNO_3=107+149+149=405,$$

which closely agrees with the direct measurement of the current strengths of these cells. These results, however, are by no means certain. In the first place, Wiedemann himself calls attention to the fact that Kohlrausch only gives the final result but "unfortunately no figures for the results of the separate experiments". [I, p. 104.] In the second place, Wiedemann himself repeatedly recognises that all attempts to determine quantitatively the electric excitations on contact of metals, and still more on contact of metal and liquid, are at least very uncertain on account of the numerous unavoidable sources of error. If, nevertheless, he repeatedly uses Kohlrausch's figures in his calculations, we shall do better not to follow him here, the more so as another means of determination is available which is not open to these objections.

If the two exciting plates of a battery are immersed in the liquid and afterwards joined into a closed circuit by the terminals of a galvanometer, then, according to Wiedemann, "the initial deflection of its magnetic needle, before chemical changes have altered the strength of the electric excitation, is a measure of the sum of the electromotive forces in the closed circuit". [I, p. 62.] Batteries of various strengths, therefore, give initial deflections of various strengths, and the magnitude of these initial deflections is proportional to the current strength of the corresponding batteries.

It looks as if we had here tangibly before our eyes the "electric force of separation", the "contact force", which causes motion independently of any chemical action. And this in fact is the opinion of the whole contact theory. In reality we are confronted here by a relation between electric excitation and chemical action that we have not yet investigated. In order to pass to this subject, we shall first

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of all examine rather more closely the so-called electromotive law; in so doing, we shall find that here also the traditional contact notions not only provide no explanation, but once again directly bar the way to an explanation.

If in any cell consisting of two metals and a liquid, e.g., zinc, dilute hydrochloric acid, and copper, one inserts a third metal such as a platinum plate, without connecting it to the external circuit by a wire, then the initial deflection of the galvanometer will be exactly the same as *without* the platinum plate. Consequently it has no effect on the excitation of electricity. But it is not permissible to express this so simply in electromotive language. Hence one reads:

"The sum of the electromotive forces of zinc and platinum and platinum and copper now takes the place of the electromotive force of zinc and copper in the liquid. Since the path of the electricities is not perceptibly altered by the insertion of the platinum plate, we can conclude from the identity of the galvanometer readings in the two cases, that the electromotive force of zinc and copper in the liquid is equal to that of zinc and platinum plus that of platinum and copper in the same liquid. This would correspond to Volta's theory of the excitation of electricity between the metals as such. The result, which holds good for all liquids and metals, is expressed by saying: On their electromotive excitation by liquids, metals follow the law of the voltaic series. This law is also given the name of the *electromotive law*." (Wiedemann, I, p. 62.).

In saying that in this combination the platinum does not act at all as an exciter of electricity, one expresses what is simply a fact. If one says that it does act as an exciter of electricity, but in two opposite directions with equal strength so that the effect is neutralised, the fact is converted into a hypothesis merely for the sake of doing honour to the "electromotive force". In both cases the platinum plays the role of a supernumerary.

During the first deflection there is still no closed circuit. The acid, being undecomposed, does not conduct; it can only conduct by means of the ions. If the third metal has no influence on the first deflection, this is simply because it is still *isolated*.

How does the third metal behave *after* the establishment of the continuous current and during the latter?

In the voltaic series of metals in most liquids, zinc lies after the alkali metals fairly close to the positive end and platinum at the negative end, copper being between the two. Hence, if platinum is put as above between copper and zinc it is negative to them both. If the platinum had any effect at all, the current in the liquid would have to flow to the platinum both from the zinc and from the copper, that is away from both electrodes to the unconnected platinum, which would be a *contradictio in adjecto*. The basic condition for the efficacy of several different metals in the battery consists precisely in their being connected among themselves externally into a closed circuit. An unconnected, superfluous metal in the battery acts as a non-conductor; it can neither form ions nor allow them to pass through, and without ions we know of no conduction in electrolytes. Hence it is no mere supernumerary, it even stands in the way by forcing the ions to go round it.

The same thing holds good if we connect the zinc and platinum, leaving the copper unconnected in the middle; here the latter, if it had any effect at all, would produce a current from the zinc to the copper and another from the copper to the platinum; hence it would have to act as a sort of intermediary electrode and give off gaseous hydrogen on the side turned towards the zinc, which again is impossible.

If we discard the traditional electromotive mode of expression the case becomes extremely simple. As we have seen, the galvanic battery is an apparatus in which chemical energy is liberated and transformed into electricity. It consists as a rule of one or more liquids and two metals as electrodes, which must be connected together by a conductor outside the liquids. That constitutes the apparatus. Anything else that is dipped unconnected into the exciting liquid, whether metal, glass, resin, or anything else, cannot participate in the chemico-electric process taking place in the battery, in the formation of the current, so long as the liquid is not chemically altered by it; it can at most *hinder* the process. Whatever the capacity for exciting electricity of a third metal dipped into the liquid may be in relation to the liquid or to one or both electrodes of the battery, it cannot have any effect so long as this metal is not connected to the closed circuit outside the liquid.

Consequently, not only is Wiedemann's *derivation*, as given above, of the so-called electromotive law false, but the interpretation which he gives to this law is also false. One cannot speak of a compensating electromotive activity of the unconnected metal, since the sole condition for such activity is cut off from the outset; nor can the so-called electromotive law be deduced from a fact which lies outside the sphere of this law.

In 1845, old Poggendorff published a series of experiments in which he measured the electromotive force of the most various batteries, that is to say the quantity of electricity supplied by each of them in unit time. Of these experiments, the first twenty-seven are of special value, in each of which three given metals were one after another connected in the same exciting liquid to three different batteries, and the latter investigated and compared as regards the quantity of electricity produced. As a good adherent of the contact theory, Poggendorff also put the third metal unconnected in the battery in each experiment and so had the satisfaction of convincing himself that in all eighty-one batteries this "third in the alliance"[113] remained a pure supernumerary. But the significance of these experiments by no means consists in this fact but rather in the confirmation and establishment of the correct meaning of the so-called electromotive law.

Let us consider the above series of batteries in which zinc, copper, and platinum were connected together in pairs in dilute hydrochloric acid. Here Poggendorff found the quantities of electricity produced to be as follows, taking that of a Daniell cell as 100:

Zinc-copper	78.8
Copper-platinum	74.3
Total	153.1
Zinc-platinum	153.7

Thus, zinc in direct connection with platinum produced almost exactly the same quantity of electricity as zinc-copper+copper-platinum. The same thing occurred in all other batteries, whatever liquids and metals were employed.

When, from a series of metals in the same exciting liquid, batteries are formed in such a way that, according to the voltaic series valid for this liquid, the second, third, fourth, etc., one after the other are made to serve as negative electrodes for the preceding one and as positive electrodes for the one which follows, then the sum of the quantities of electricity produced by all these batteries is equal to the quantity of electricity produced by a battery formed directly between the two end members of the whole metallic series. For instance, in dilute hydrochloric acid the sum-total of the quantities of electricity produced by the batteries zinc-tin, tin-iron, iron-copper, copper-silver, and silver-platinum, would be equal to that produced by the battery: zinc-platinum. A pile formed from all the cells of the above series would, other things being equal, be exactly neutralised by the introduction of a zinc-platinum cell with a current of the opposite direction.

In this form, the so-called electromotive law has a real and considerable significance. It reveals a new aspect of the inter-connection between chemical and electrical action. Hitherto, on investigating mainly the *source* of energy of the galvanic current, this source, the chemical change, appeared as the active side of the process; the electricity was produced from it and therefore appeared primarily as passive. Now this is reversed. The electric excitation determined by the constitution of the heterogeneous bodies put into contact in the battery can neither add energy to nor subtract energy from the chemical action (other than by conversion of liberated energy into electricity). It can, however, according as the battery is made up, accelerate or slow down this action. If the battery, zinc-dilute hydrochloric acid-copper, produced in unit time only half as much electricity for the current as the battery, zinc-dilute hydrochloric acid platinum, this means in chemical terms that the first battery produces in unit time only half as much zinc chloride and hydrogen as the second. *Hence the chemical action has been doubled, although the purely chemical conditions have remained the same*. The electric excitation has become the regulator of the chemical action; it appears now as the active side, and the chemical action as the passive side.

Thus, it becomes comprehensible that a number of processes previously regarded as purely chemical now appear as electro-chemical. Chemically pure zinc is not attacked at all by dilute acid, or only very weakly; ordinary commercial zinc, on the other hand, is rapidly dissolved with formation of a salt and production of hydrogen; it contains an admixture of other metals and carbon, which make their appearance in unequal amounts at various places of the surface. Local currents are formed in the acid between them and the zinc itself, the zinc areas forming the positive electrodes and the other metals the negative electrodes, the hydrogen bubbles being given off on the latter. Likewise the phenomenon that when iron is dipped into a solution of copper sulphate it becomes covered with a layer of copper is now seen to be an electro-chemical phenomenon, one determined by the currents which arise between the heterogeneous areas of the surface of the iron.

In accordance with this we find also that the voltaic series of metals in liquids corresponds on the whole to the series in which metals replace one another from their compounds with halogens and acid radicals. At the extreme negative end of the voltaic series we regularly find the metals of the gold group: gold, platinum, palladium, rhodium, which oxidise with difficulty, are little or not at all attacked by acids, and which are easily precipitated from their salts by other metals. At the extreme positive end are the alkali metals, which exhibit exactly the opposite behaviour: they are scarcely to be split off from their oxides even with the greatest expenditure of energy; they occur in nature almost exclusively in the form of salts, and of all the metals they have by far the greatest affinity for halogens and acid radicals. Between these two come the other metals in somewhat varying sequence, but in such a way that on the whole electrical and chemical behaviour correspond to one another. The sequence of the separate members varies according to the liquids and has hardly been finally established for any single liquid. It is even permissible to doubt whether there exists such an *absolute* voltaic series of metals for any single liquid. Given suitable batteries and electrolytic cells, two pieces of the same metal can act as positive and negative electrodes respectively, hence the same metal can be both positive and negative towards itself. In thermo-cells which convert heat into electricity, with large temperature differences at the two junctions, the direction of the current is reversed; the previously positive metal becomes negative and vice versa. Similarly, there is no absolute series according to which the metals replace one another from their chemical compounds with a particular halogen or acid radical; in many cases by supplying energy in the form of heat we are able almost at will to alter and reverse the series valid for ordinary temperatures.

Hence we find here a peculiar interaction between chemism and electricity. The chemical action in the battery, which provides the electricity with the total energy for current formation, is in many cases first brought into operation, and in all cases quantitatively regulated by the electric tensions developed in the battery. If previously the processes in the battery seemed to be chemico-electric in nature, we see here that they are just as much electrochemical. From the point of view of formation of the *continuous* current, chemical action appears to be primary; from the point of view of *excitation* of current it appears as secondary and accessory. The reciprocal action excludes any absolute primary or absolute secondary; but it is just as much a double-sided process which from its very nature can be regarded from two different standpoints; to be understood in its totality it must even be investigated from both standpoints one after the other, before the total result can be arrived at. If, however, we adhere one-sidedly to a single standpoint as the absolute one in contrast to the other, or if we arbitrarily jump from one to the other according to the momentary needs of our argument, we shall remain entangled in the one-sidedness of metaphysical thinking; the inter-connection escapes us and we become involved in one contradiction after another.

We saw above that, according to Wiedemann, the initial deflection of the galvanometer, immediately after dipping the exciting plates into the liquid of the battery and before chemical changes have altered the strength of the electric excitation, "is a measure of the sum of the electromotive forces in the closed circuit".

So far we have become acquainted with the so-called electromotive force as a form of energy, which in our case was produced in an equivalent amount from chemical energy, and which in the further course of the process became converted again into equivalent quantities of heat, mass motion, etc. Here all at once we learn that the "sum of the electromotive forces in the closed circuit" is already in existence *before* this energy has been liberated by chemical changes; in other words, that the electromotive force is nothing but the capacity of a particular battery to liberate a particular quantity of chemical energy in unit time and to convert it into electric motion. As previously in the case of the electric force of separation, so here also the electromotive force appears as a force which does not contain a single spark of energy. Consequently, Wiedemann understands by "electromotive force" two totally different things: on the one hand, the capacity of a battery to liberate a definite quantity of given chemical energy and to convert it into electric motion, and, on the other hand, the quantity of electric motion itself that is developed. The fact that the two are proportional, that the one is a measure for the other, does not do away with the difference between them. The chemical action in the battery, the quantity of electricity developed, and the heat in the circuit derived from it, when otherwise no work is performed, are even more than proportional, they are even equivalent; but that does not do away with the difference between them. The capacity of a steam-engine with a given cylinder bore and piston stroke to produce a given quantity of mechanical motion from the heat supplied is very different from this mechanical motion itself, however proportional to the latter it may be. And while such a mode of speech was tolerable at a time when in natural science nothing had yet been said of the conservation of energy, nevertheless it is obvious that since the recognition of this basic law it is no longer permissible to confuse real active energy in any form with the capacity of any apparatus to impart this form to energy which is being liberated. This confusion is a corollary of the confusion of force and energy in the case of the electric force of separation; these two confusions provide a harmonious background for Wiedemann's three mutually contradictory explanations of the current, and in the last resort are the basis in general for all his errors and confusions in regard to so-called "electromotive force".

Besides the above-considered peculiar interaction between chemism and electricity there is also a second point that they have in common, which likewise indicates a closer kinship between these two forms of motion. Both can exist only while they *disappear*. The chemical process takes place suddenly for each group of atoms undergoing it. It can be prolonged only by the presence of new material that continually enters into it. The same thing holds for electric motion. Hardly has it been produced from some other form of motion than it is once more converted into a third form; only the continual readiness of available energy can produce the continuous current, in which at each moment new amounts of motion (Bewegungsmengen) assume the form of electricity and lose it again.

An insight into this close connection of chemical with electric action and vice versa will lead to important results in both spheres of investigation. Such an insight is already becoming more and more widespread. Among chemists, Lothar Meyer, and after him Kekulé, have plainly stated that a revival of the electro-chemical theory in a rejuvenated form is impending. Among electricians also, as indicated especially by the latest works of F. Kohlrausch, the conviction seems finally to have taken hold that only exact attention to the chemical processes in the battery and elecrolytic cell can help their science to emerge from the blind alley of old traditions.

And in fact one cannot see how else a firm foundation is to be given to the theory of galvanism and so secondarily to that of magnetism and static electricity, other than by a chemically exact general revision of all traditional, uncontrolled experiments made from an obsolete scientific standpoint, with exact attention to establishing the energy transformations and preliminary rejection of all traditional theoretical notions about electricity.

The Part Played by Labour in the Transition from Ape to Man[114]

Labour is the source of all wealth, the political economists assert. And it really is the source—next to nature, which supplies it with the material that it converts into wealth. But it is even infinitely more than this. It is the prime basic condition for all human existence, and this to such an extent that, in a sense, we have to say that labour created man himself.

Many hundreds of thousands of years ago, during an epoch, not yet definitely determinable, of that period of the earth's history known to geologists as the Tertiary period, most likely towards the end of it, a particularly highly-developed race of anthropoid apes lived somewhere in the tropical zone—probably on a great continent that has now sunk to the bottom of the Indian Ocean. Darwin has given us an approximate description of these ancestors of ours. They were completely covered with hair, they had beards and pointed ears, and they lived in bands in the trees.[115]

Climbing assigns different functions to the hands and the feet, and when their mode of life involved locomotion on level ground, these apes gradually got out of the habit of using their hands [in walking—*Tr.*] and adopted a more and more erect posture. This was *the decisive step in the transition from ape to man.*

All extant anthropoid apes can stand erect and move about on their feet alone, but only in case of urgent need and in a very clumsy way. Their natural gait is in a half-erect posture and includes the use of the hands. The majority rest the knuckles of the fist on the ground and, with legs drawn up, swing the body through their long arms, much as a cripple moves on crutches. In general, all the transition stages from walking on all fours to walking on two legs are still to be observed among the apes today. The latter gait, however, has never become more than a makeshift for any of them.

It stands to reason that if erect gait among our hairy ancestors became first the rule and then, in time, a necessity, other diverse functions must, in the meantime, have devolved upon the hands. Already among the apes there is some difference in the way the hands and the feet are employed. In climbing, as mentioned above, the hands and feet have different uses. The hands are used mainly for gathering and holding food in the same way as the fore paws of the lower mammals are used. Many apes use their hands to build themselves nests in the trees or even to construct roofs between the branches to protect themselves against the weather, as the chimpanzee, for example, does. With their hands they grasp sticks to defend themselves against enemies, and with their hands they bombard their enemies with fruits and stones. In captivity they use their hands for a number of simple operations copied from human beings. It is in this that one sees the great gulf between the undeveloped hand of even the most man-like apes and the human hand that has been highly perfected by hundreds of thousands of years of labour. The number and general arrangement of the bones and muscles are the same in both hands, but the hand of the lowest savage can perform hundreds of operations that no simian hand can imitate—no simian hand has ever fashioned even the crudest stone knife.

The first operations for which our ancestors gradually learned to adapt their hands during the many thousands of years of transition from ape to man could have been only very simple ones. The lowest savages, even those in whom regression to a more animal-like condition with a simultaneous physical degeneration can be assumed, are nevertheless far superior to these transitional beings. Before the first flint could be fashioned into a knife by human hands, a period of time probably elapsed in comparison with which the historical period known to us appears insignificant. But the decisive step had been taken, *the hand had become free* and could henceforth attain ever greater dexterity;

the greater flexibility thus acquired was inherited and increased from generation to generation.

Thus the hand is not only the organ of labour, *it is also the product of labour*. Labour, adaptation to ever new operations, the inheritance of muscles, ligaments, and, over longer periods of time, bones that had undergone special development and the ever-renewed employment of this inherited finesse in new, more and more complicated operations, have given the human hand the high degree of perfection required to conjure into being the pictures of a Raphael, the statues of a Thorwaldsen, the music of a Paganini.

But the hand did not exist alone, it was only one member of an integral, highly complex organism. And what benefited the hand, benefited also the whole body it served; and this in two ways.

In the first place, the body benefited from the law of correlation of growth, as Darwin called it. This law states that the specialised forms of separate parts of an organic being are always bound up with certain forms of other parts that apparently have no connection with them. Thus all animals that have red blood cells without cell nuclei, and in which the head is attached to the first vertebra by means of a double articulation (condyles), also without exception possess lacteal glands for suckling their young. Similarly, cloven hoofs in mammals are regularly associated with the possession of a multiple stomach for rumination. Changes in certain forms involve changes in the form of other parts of the body, although we cannot explain the connection. Perfectly white cats with blue eyes are always, or almost always, deaf. The gradually increasing perfection of the human hand, and the commensurate adaptation of the feet for erect gait, have undoubtedly, by virtue of such correlation, reacted on other parts of the organism. However, this action has not as yet been sufficiently investigated for us to be able to do more here than to state the fact in general terms.

Much more important is the direct, demonstrable influence of the development of the hand on the rest of the organism. It has already been noted that our simian ancestors were gregarious; it is obviously impossible to seek the derivation of man, the most social of all animals, from non-gregarious immediate ancestors. Mastery over nature began with the development of the hand, with labour, and widened man's horizon at every new advance. He was continually discovering new, hitherto unknown properties in natural objects. On the other hand, the development of labour necessarily helped to bring the members of society closer together by increasing cases of mutual support and joint activity, and by making clear the advantage of this joint activity to each individual. In short, men in the making arrived at the point where *they had something to say* to each other. Necessity created the organ; the undeveloped larynx of the ape was slowly but surely transformed by modulation to produce constantly more developed modulation, and the organs of the mouth gradually learned to pronounce one articulate sound after another.

Comparison with animals proves that this explanation of the origin of language from and in the process of labour is the only correct one. The little that even the most highly-developed animals need to communicate to each other does not require articulate speech. In a state of nature, no animal feels handicapped by its inability to speak or to understand human speech. It is quite different when it has been tamed by man. The dog and the horse, by association with man, have developed such a good ear for articulate speech that they easily learn to understand any language within their range of concept. Moreover they have acquired the capacity for feelings such as affection for man, gratitude, etc., which were previously foreign to them. Anyone who has had much to do with such animals will hardly be able to escape the conviction that in many cases they *now* feel their inability to speak as a defect, although, unfortunately, it is one that can no longer be remedied because their vocal organs are too specialised in a definite direction. However, where vocal organs exist, within certain limits even this inability disappears. The buccal organs of birds are as different from those of man as they can be, yet birds are the only animals that can learn to speak; and it is the bird with the most hideous voice, the parrot, that speaks best of all. Let no one object that the parrot does not understand what it says. It is true that for the sheer pleasure of talking and associating with human beings, the parrot will chatter for hours at a stretch, continually repeating its whole vocabulary. But within the limits of its range of concepts it can also learn to understand what it is saying. Teach a parrot swear words in such a way that it gets an idea of their meaning (one of the great amusements of sailors returning from the tropics); tease it and you will soon discover that it knows how to use its swear words just as correctly as a Berlin costermonger. The same is true of begging for titbits.

First labour, after it and then with it speech—these were the two most essential stimuli under the influence of which the brain of the ape gradually changed into that of man, which for all its similarity is far larger and more perfect. Hand in hand with the development of the brain went the development of its most immediate instruments—the senses. Just as the gradual development of speech is inevitably accompanied by a corresponding refinement of the organ of hearing, so the development of the brain as a whole is accompanied by a refinement of all the senses. The eagle sees much farther than man, but the human eye discerns considerably more in things than does the eye of the eagle. The dog has a far keener sense of smell than man, but it does not distinguish a hundredth part of the odours that for man are definite signs denoting different things. And the sense of touch, which the ape hardly possesses in its crudest initial form, has been developed only side by side with the development of the human hand itself, through the medium of labour.

The reaction on labour and speech of the development of the brain and its attendant senses, of the increasing clarity of consciousness, power of abstraction and of conclusion, gave both labour and speech an ever-renewed impulse to further development. This development did not reach its conclusion when man finally became distinct from the ape, but on the whole made further powerful progress, its degree and direction varying among different peoples and at different times, and here and there even being interrupted by local or temporary regression. This further development has been strongly urged forward, on the one hand, and guided along more definite directions, on the other, by a new element which came into play with the appearance of fully-fledged man, namely, *society*.

Hundreds of thousands of years—of no greater significance in the history of the earth than one second in the life of man*—certainly elapsed before human society arose out of a troupe of tree-climbing monkeys. Yet it did finally appear. And what do we find once more as the characteristic difference between the troupe of monkeys and human society? *Labour*. The ape herd was satisfied to browse over the feeding area determined for it by geographical conditions or the resistance of neighbouring herds; it undertook migrations and struggles to win new feeding grounds, but it was incapable of extracting from them more than they offered in their natural state, except that it unconsciously fertilised the soil with its own excrement. As soon as all possible feeding grounds were occupied, there could be no further increase in the ape population; the number of animals could at best remain stationary. But all animals waste a great deal of food, and, in addition, destroy in the germ the next generation of the food supply. Unlike the hunter, the wolf does not spare the doe which would provide it with the young the next year; the goats in Greece, that eat away the young bushes before they grow to maturity, have eaten bare all the mountains of the country. This "predatory economy" of animals plays an important part in the gradual transformation of species by forcing them to adapt themselves to other than the usual food, thanks to which their blood acquires a different chemical composition and the whole physical constitution gradually alters, while species that have remained unadapted die out. There is no doubt that this predatory economy contributed powerfully to the transition of our ancestors from ape to man. In a race of apes that far surpassed all others in intelligence and adaptability, this predatory economy must have led to a continual increase in the number of plants used for food and to the consumption of more and more edible parts of food plants. In short, food became more and more varied, as

* A leading authority in this respect, Sir William Thomson, has calculated that *little more than a hundred million years* could have elapsed since the time when the earth had cooled sufficiently for plants and animals to be able to live on it. [*Note by Engels*.]

did also the substances entering the body with it, substances that were the chemical premises for the transition to man. But all that was not yet labour in the proper sense of the word. Labour begins with the making of tools. And what are the most ancient tools that we find—the most ancient judging by the heirlooms of prehistoric man that have been discovered, and by the mode of life of the earliest historical peoples and of the rawest of contemporary savages? They are hunting and fishing implements, the former at the same time serving as weapons. But hunting and fishing presuppose the transition from an exclusively vegetable diet to the concomitant use of meat, and this is another important step in the process of transition from ape to man. A *meat diet* contained in an almost ready state the most essential ingredients required by the organism for its metabolism. By shortening the time required for digestion, it also shortened the other vegetative bodily processes that correspond to those of plant life, and thus gained further time, material and desire for the active manifestation of animal life proper. And the farther man in the making moved from the vegetable kingdom the higher he rose above the animal. Just as becoming accustomed to a vegetable diet side by side with meat converted wild cats and dogs into the servants of man, so also adaptation to a meat diet, side by side with a vegetable diet, greatly contributed towards giving bodily strength and independence to man in the making. The meat diet, however, had its greatest effect on the brain, which now received a far richer flow of the materials necessary for its nourishment and development, and which, therefore, could develop more rapidly and perfectly from generation to generation. With all due respect to the vegetarians man did not come into existence without a meat diet, and if the latter, among all peoples known to us, has led to cannibalism at some time or other (the forefathers of the Berliners, the Weletabians or Wilzians, used to eat their parents as late as the tenth century),[116] that is of no consequence to us today.

The meat diet led to two new advances of decisive importance—the harnessing of fire and the domestication of animals. The first still further shortened the digestive process, as it provided the mouth with food already, as it were, half-digested; the second made meat more copious by opening up a new, more regular source of supply in addition to hunting, and moreover provided, in milk and its products, a new article of food at least as valuable as meat in its composition. Thus both these advances were, in themselves, new means for the emancipation of man. It would lead us too far afield to dwell here in detail on their indirect effects notwithstanding the great importance they have had for the development of man and society.

Just as man learned to consume everything edible, he also learned to live in any climate. He spread over the whole of the habitable world, being the only animal fully able to do so of its own accord. The other animals that have become accustomed to all climates—domestic animals and vermin—did not become so independently, but only in the wake of man. And the transition from the uniformly hot climate of the original home of man to colder regions, where the year was divided into summer and winter, created new requirements—shelter and clothing as protection against cold and damp, and hence new spheres of labour, new forms of activity, which further and further separated man from the animal.

By the combined functioning of hands, speech organs and brain, not only in each individual but also in society, men became capable of executing more and more complicated operations, and were able to set themselves, and achieve, higher and higher aims. The work of each generation itself became different, more perfect and more diversified. Agriculture was added to hunting and cattle raising; then came spinning, weaving, metalworking, pottery and navigation. Along with trade and industry, art and science finally appeared. Tribes developed into nations and states. Law and politics arose, and with them that fantastic reflection of human things in the human mind—religion. In the face of all these images, which appeared in the first place to be products of the mind and seemed to dominate human societies, the more modest productions of the working hand retreated into the background, the more so since the mind that planned the labour was able, at a very early stage in the development of society (for example, already in the primitive family), to have the labour that had been planned carried out by other hands than its own. All merit for the swift advance of civilisation was ascribed to the mind, to the development and activity of the brain. Men became accustomed to explain their actions as arising out of thoughts instead of their needs (which in any case are reflected and perceived in the mind); and so in the course of time there emerged that idealistic world outlook which, especially since the fall of the world of antiquity, has dominated men's minds. It still rules them to such a degree that even the most materialistic natural scientists of the Darwinian school are still unable to form any clear idea of the origin of man, because under this ideological influence they do not recognise the part that has been played therein by labour.

Animals, as has already been pointed out, change the environment by their activities in the same way, even if not to the same extent, as man does, and these changes, as we have seen, in turn react upon and change those who made them. In nature nothing takes place in isolation. Everything affects and is affected by every other thing, and it is mostly because this manifold motion and interaction is forgotten that our natural scientists are prevented from gaining a clear insight into the simplest things. We have seen how goats have prevented the regeneration of forests in Greece; on the island of St. Helena, goats and pigs brought by the first arrivals have succeeded in exterminating its old vegetation almost completely, and so have prepared the ground for the spreading of plants brought by later sailors and colonists. But animals exert a lasting effect on their environment unintentionally and, as far as the animals themselves are concerned, accidentally. The further removed men are from animals, however, the more their effect on nature assumes the character of premeditated, planned action directed towards definite preconceived ends. The animal destroys the vegetation of a locality without realising what it is doing. Man destroys it in order to sow field crops on the soil thus released, or to plant trees or vines which he knows will yield many times the amount planted. He transfers useful plants and domestic animals from one country to another and thus changes the flora and fauna of whole continents. More than this. Through artificial breeding both plants and animals are so changed by the hand of man that they become unrecognisable. The wild plants from which our grain varieties originated are still being sought in vain. There is still some dispute about the wild animals from which our very different breeds of dogs or our equally numerous breeds of horses are descended.

It goes without saying that it would not occur to us to dispute the ability of animals to act in a planned, premeditated fashion. On the contrary, a planned mode of action exists in embryo wherever protoplasm, living albumen, exists and reacts, that is, carries out definite, even if extremely simple, movements as a result of definite external stimuli. Such reaction takes place even where there is yet no cell at all, far less a nerve cell. There is something of the planned action in the way insect-eating plants capture their prey, although they do it quite unconsciously. In animals the capacity for conscious, planned action is proportional to the development of the nervous system, and among mammals it attains a fairly high level. While fox-hunting in England one can daily observe how unerringly the fox makes use of its excellent knowledge of the locality in order to elude its pursuers, and how well it knows and turns to account all favourable features of the ground that cause the scent to be lost. Among our domestic animals, more highly developed thanks to association with man, one can constantly observe acts of cunning on exactly the same level as those of children. For, just as the development history of the human embryo in the mother's womb is only an abbreviated repetition of the history, extending over millions of years, of the bodily evolution of our animal ancestors, starting from the worm, so the mental development of the human child is only a still more abbreviated repetition of the intellectual development of these same ancestors, at least of the later ones. But all the planned action of all animals has never succeeded in impressing the stamp of their will upon the earth. That was left for man.

In short, the animal merely *uses* its environment, and brings about changes in it simply by its presence; man by his changes makes it serve his ends, *masters* it. This is the final, essential distinction between man and other animals, and once again it is labour that brings about this distinction.*

Let us not, however, flatter ourselves overmuch on account of our human victories over nature. For each such victory nature takes its revenge on us. Each victory, it is true, in the first place brings about the results we expected, but in the second and third places it has quite different, unforeseen effects which only too often cancel the first. The people who, in Mesopotamia, Greece, Asia Minor and elsewhere, destroyed the forests to obtain cultivable land, never dreamed that by removing along with the forests the collecting centres and reservoirs of moisture they were laying the basis for the present forlorn state of those countries.[117] When the Italians of the Alps used up the pine forests on the southern slopes, so carefully cherished on the northern slopes, they had no inkling that by doing so they were cutting at the roots of the dairy industry in their region; they had still less inkling that they were thereby depriving their mountain springs of water for the greater part of the year, and making it possible for them to pour still more furious torrents on the plains during the rainy seasons. Those who spread the potato in Europe were not aware that with these farinaceous tubers they were at the same time spreading scrofula. Thus at every step we are reminded that we by no means rule over nature like a conqueror over a foreign people, like someone standing outside nature—but that we, with flesh, blood and brain, belong to nature, and exist in its midst, and that all our mastery of it consists in the fact that we have the advantage over all other creatures of being able to learn its laws and apply them correctly.

And, in fact, with every day that passes we are acquiring a better understanding of these laws and getting to perceive both the more immediate and the more remote consequences of our interference with the traditional course of nature. In particular, after the mighty advances made by the natural sciences in the present century, we are more than ever in a position to realise, and hence to control, even the more remote natural consequences of at least our day-

* In the margin of the manuscript is written in pencil: "Ennoblement."—*Ed.*

to-day production activities. But the more this progresses the more will men not only feel but also know their oneness with nature, and the more impossible will become the senseless and unnatural idea of a contrast between mind and matter, man and nature, soul and body, such as arose after the decline of classical antiquity in Europe and obtained its highest elaboration in Christianity.

It required the labour of thousands of years for us to learn a little of how to calculate the more remote *natural* effects of our actions in the field of production, but it has been still more difficult in regard to the more remote *social* effects of these actions. We mentioned the potato and the resulting spread of scrofula. But what is scrofula compared to the effect which the reduction of the workers to a potato diet had on the living conditions of the masses of the people in whole countries, or compared to the famine the potato blight brought to Ireland in 1847, which consigned to the grave a million Irishmen, nourished solely or almost exclusively on potatoes, and forced the emigration overseas of two million more? When the Arabs learned to distil spirits, it never entered their heads that by so doing they were creating one of the chief weapons for the annihilation of the aborigines of the then still undiscovered American continent. And when afterwards Columbus discovered this America, he did not know that by doing so he was laying the basis for the Negro slave trade and giving a new lease of life to slavery, which in Europe had long ago been done away with. The men who in the seventeenth and eighteenth centuries laboured to create the steam-engine had no idea that they were preparing the instrument which more than any other was to revolutionise social relations throughout the world. Especially in Europe, by concentrating wealth in the hands of a minority and dispossessing the huge majority, this instrument was destined at first to give social and political domination to the bourgeoisie, but later, to give rise to a class struggle between bourgeoisie and proletariat which can end only in the overthrow of the bourgeoisie and the abolition of all class antagonisms. But in this sphere, too, by long and often cruel experience and by collecting and analysing historical material, we are gradually learning to get a clear view of the indirect, more remote social effects of our production activity, and so are afforded an opportunity to control and regulate these effects as well.

This regulation, however, requires something more than mere knowledge. It requires a complete revolution in our hitherto existing mode of production, and simultaneously a revolution in our whole contemporary social order.

All hitherto existing modes of production have aimed merely at achieving the most immediately and directly useful effect of labour. The further consequences, which appear only later and become effective through gradual repetition and accumulation, were totally neglected. The original common ownership of land corresponded, on the one hand, to a level of development of human beings in which their horizon was restricted in general to what lay immediately available, and presupposed, on the other hand, a certain superfluity of land that would allow some latitude for correcting the possible bad results of this primeval type of economy. When this surplus land was exhausted, common ownership also declined. All higher forms of production, however, led to the division of the population into different classes and thereby to the antagonism of ruling and oppressed classes. Thus the interests of the ruling class became the driving factor of production, since production was no longer restricted to providing the barest means of subsistence for the oppressed people. This has been put into effect most completely in the capitalist mode of production prevailing today in Western Europe. The individual capitalists, who dominate production and exchange, are able to concern themselves only with the most immediate useful effect of their actions. Indeed, even this useful effect—inasmuch as it is a question of the usefulness of the article that is produced or exchanged—retreats far into the background, and the sole incentive becomes the profit to be made on selling.*

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Classical political economy, the social science of the bourgeoisie, in the main examines only social effects of human

* The MS ends here. What follows was written on a separate sheet of paper with a note in a different hand to the effect that it was the last page of the first draft.—*Ed.*

actions in the fields of production and exchange that are actually intended. This fully corresponds to the social organisation of which it is the theoretical expression. As individual capitalists are engaged in production and exchange for the sake of the immediate profit, only the nearest, most immediate results must first be taken into account. As long as the individual manufacturer or merchant sells a manufactured or purchased commodity with the usual coveted profit, he is satisfied and does not concern himself with what afterwards becomes of the commodity and its purchasers. The same thing applies to the natural effects of the same actions. What cared the Spanish planters in Cuba, who burned down forests on the slopes of the mountains and obtained from the ashes sufficient fertiliser for *one* generation of very highly profitable coffee trees—what cared they that the heavy tropical rainfall afterwards washed away the unprotected upper stratum of the soil, leaving behind only bare rock! In relation to nature, as to society, the present mode of production is predominantly concerned only about the immediate, the most tangible result; and then surprise is expressed that the more remote effects of actions directed to this end turn out to be quite different, are mostly quite the opposite in character; that the harmony of supply and demand is transformed into the very reverse opposite, as shown by the course of each ten years' industrial cycle—even Germany has had a little preliminary experience of it in the "crash";[118] that private ownership based on one's own labour must of necessity develop into the expropriation of the workers, while all wealth becomes more and more concentrated in the hands of non-workers; that [. . .]*

* Here the manuscript breaks off.—*Ed.*

[Notes and Fragments]

[From the History of Science]

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The successive development of the separate branches of natural science should be studied.—First of all, *astronomy,* which, if only on account of the seasons, was absolutely indispensable for pastoral and agricultural peoples. Astronomy can only develop with the aid of *mathematics*. Hence this also had to be tackled.—Further, at a certain stage of agriculture and in certain regions (raising of water for irrigation in Egypt), and especially with the origin of towns. big building structures and the development of handicrafts, *mechanics* also arose. This was soon needed also for *navigation* and *war*.—Moreover, it requires the aid of mathematics and so promotes the latter's development. Thus, from the very beginning the origin and development of the sciences has been determined by production.

Throughout antiquity, scientific investigation proper remained restricted to these three branches, and indeed in the form of exact, systematic research it occurs for the first time in the post-classical period (the Alexandrines, Archimedes, etc.). In physics and chemistry, which were as yet hardly separated in men's minds (theory of the elements, absence of the concept of a chemical element), in botany, zoology, human and animal anatomy, it had only been possible until then to collect facts and arrange them as systematically as possible. Physiology was sheer guess-work, as soon as one went beyond the most tangible things—e.g., digestion and excretion—and it could not be otherwise when even the circulation of the blood was not known.—At the end of the period, chemistry makes its appearance in the primitive form of alchemy.

If, after the dark night of the Middle Ages was over the sciences suddenly arose anew with undreamt-of force, developing at a miraculous rate, once again we owe this miracle to production. In the first place, following the crusades, industry developed enormously and brought to light a quantity of new mechanical (weaving, clockmaking, milling), chemical (dyeing, metallurgy, alcohol), and physical (spectacles) facts, and this not only gave enormous material for observation, but also itself provided quite other means for experimenting than previously existed, and allowed the construction of *new* instruments; it can be said that really systematic experimental science now became possible for the first time. Secondly, the whole of West and Middle Europe, including Poland, now developed in a connected fashion, even though Italy was still at the head owing to its old-inherited civilisation. Thirdly, geographical discoveries—made purely for the sake of gain and, therefore, in the last resort, of production—opened up an infinite and hitherto inaccessible amount of material of a meteorological, zoological, botanical, and physiological (human) bearing. Fourthly, there was the *printing press*.*

Now—apart from mathematics, astronomy, and mechanics, which were already in existence—physics becomes definitely separate from chemistry (Torricelli, Galileo—the former in connection with industrial waterworks studied first of all the movement of liquids, see Clerk Maxwell). Boyle put chemistry on a stable basis as a science. Harvey did the same for physiology (human and animal) by the discovery of the blood circulation. Zoology and botany remain at first collecting sciences, until palæontology appeared on the scene —Cuvier—and shortly afterwards came the discovery of the cell and the development of organic chemistry. Therewith comparative morphology and physiology became possible and from then on both are true sciences. Geology was founded at the end of the last [18th] century, and recently anthropology, badly so-called, enabling the transition from the morphology and physiology of man and human races to history. This to be studied further in detail and to be developed.

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* In the margin of the manuscript opposite this paragraph is written: "Hitherto, what has been boasted of is what production owes to science, but science owes infinitely more to production."—*Ed.*

The Ancients' Outlook on Nature

[Hegel, ***Geschichte der Philosophie,*** **Vol. I,—*Greek Philosophy*]**[119]

Of the first philosophers, Aristotle says (*Metaphysics,* I, 3) that they assert:

"That of which all things consist, from which they first come and into which they are ultimately resolved ... of which the essence (οὐσία) persists although modified by its affections (πάθεσι) — this is the element (στοιχετον) and principle (ἀρχή) of all being.... Hence they believe that nothing is either generated (οὔτε γίγνεσθαι οὐδέν) or destroyed, since this kind of primary entity always persists." (P. 198.)

Here, therefore, is already the whole original spontaneous materialism which at its beginning quite naturally regards the unity of the infinite diversity of natural phenomena as a matter of course, and seeks it in something definitely corporeal, a particular thing, as Thales does in water.

Cicero says:

"*Thales** of Miletos ... declared that water is the basis of things, and God that mind that forms everything out of water." (*De Natura Deorum*, I, p. 10.)

Hegel quite rightly declares that this is an addition of Cicero's, and says:

"However, we are not concerned here with this question whether, in addition, Thales believed in God; it is not a matter here of supposition, belief, popular religion ... and even if he spoke of God as having created all things from that water, we would not thereby know anything more of this being ... it is an empty word without its idea," p. 209 (*ca.* 600 [B.C.]).

The oldest Greek philosophers were at the same time investigators of nature: *Thales,* a geometrician, fixed the year at 365 days, and is said to have predicted a solar eclipse.—*Anaximander* constructed a sun clock, a kind of map (περίμετρον) of land and sea, and various astronomical instruments.—*Pythagoras* was a mathematician.

Anaximander of Miletos, according to Plutarch (*Quæstiones convivales*,** VIII, p. 8), makes "*man come from a*

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* Italics by Engels.—*Ed.*

** *Table Talk.*—*Ed.*

*fish, emerging from the water on to the land,"** p. 213. For him the ἀρχή καὶ στοιχεῖον τὸ ἄπειρον **, without determining (διορίζων) it as air or water or anything else (Diogenes Laertius II, paragraph 1). This infinite correctly reproduced by Hegel, p. 215, as "undetermined matter" (*ca.* 580).

Anaximenes of Miletos takes *air* as principle and basic element, declaring it to be infinite (Cicero, *De Natura Deorum,* I, p. 10) and that

> "everything arises from it, in it everything is again dissolved" (Plutarch, *De placitis philosophorum,**** I, p. 3).

Here air ἀὴρ = πνεῦμα :*****

> "Just as our soul, which is air, holds us together, so also a spirit (πνεῦμα) and air hold the whole world together. Spirit and air have the same meaning" (Plutarch).[120] [Pp. 215-16.]

Soul and air conceived as a general medium (*ca.* 555).

Aristotle already says that these ancient philosophers put the primordial essence in a form of matter: air and water (and perhaps Anaximander in something midway between both), later Heraclitus in fire, but none in earth on account of its multiple composition (διὰ τὴν μεγαλομέρειαν) *Metaphysics,* I, 8. (P. 217.)

Aristotle correctly remarks of all of them that they leave the origin of motion unexplained (p. 218 et seq.).

Pythagoras of Samos (*ca.* 540): *number* is the basic principle:

> "That *number* is the essence of all things, and the organisation of the universe as a whole in its determinations is a *harmonious system of numbers and their relations.*"*) (Aristotle, *Metaphysics*, I, 5 *passim.*)

Hegel justly points out

> "the audacity of such language, which at one blow strikes down all that is regarded by the imagination as being or as essential (true), and annihilates the sensuous essence", and puts the essence in a

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* Italics by Engels.—*Ed.*

** beginning and element is the *infinite* (italics by Engels).—*Ed.*

*** *On the Opinions of Philosophers.—Ed.*

**** breath, spirit.—*Ed.*

*) Italics by Engels.—*Ed.*

thought determination, even if it is a very restricted and one-sided one. [Pp. 237-38.]

Just as number is subject to definite laws, so also the universe; hereby its obedience to law was expressed for the first time. To Pythagoras is ascribed the reduction of musical harmonies to mathematical relations. Likewise:

"The Pythagoreans put fire in the centre, but the earth as a star which revolves in a circle around this central body." (Aristotle, *De coelo*,* II, 13.) [P. 265.]

This fire, however, is not the sun; nevertheless this is the first inkling that *the earth moves.*

Hegel on the planetary system:

"...the harmonious element, which determines the distances [between the planets]—all mathematics has still not been able to give any basis for it. The empirical numbers are accurately known; but it has all the appearance of chance, not of necessity. An approximate regularity in the distances is known, and thus with luck planets between Mars and Jupiter have been guessed at, where later Ceres, Vesta, Pallas, etc., were discovered; but astronomy still did not find a consistent series in which there was any sense, any reason. Rather it looks with contempt on the regular presentation of this series; for itself, however, it is an extremely important point which must not be surrendered." (Pp. 267-68.)

For all the naïve materialism of the total outlook, the kernel of the later split is already to be found among the ancient Greeks. For Thales, the soul is already something special, something different from the body (just as he ascribes a soul also to the magnet), for Anaximenes it is air (as in *Genesis*),[121] for the Pythagoreans it is already immortal and migratory, the body being purely accidental to it. For the Pythagoreans, also, the soul is "a chip of the ether (ἀπόσπασμα αἴθερος)" (Diogenes Laertius, VIII, p. 26-28), where the cold ether is the air, the dense ether the sea and moisture. [Pp. 279-80.]

Aristotle correctly reproaches the Pythagoreans also:

With their numbers "they do not say how motion comes into being, and how, without motion and change, there is coming into being and passing away, or states and activities of heavenly things". (*Metaphysics*, I, 8.) [P. 277.]

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* *Concerning the Sky.—Ed.*

Pythagoras is supposed to have discovered the identity of the morning and evening star, that the moon gets its light from the sun, and finally the Pythagorean theorem.

"Pythagoras is said to have slaughtered a hecatomb on discovering this theorem ... and however remarkable it may be that his joy went so far on that account as to order a great feast, to which the rich and the whole people were invited, it was worth the trouble. It is joyousness, joy of the spirit (knowledge)—at the expense of the oxen." (P. 279.)

The Eleatics.

* * *

Leucippus and Democritus.[122]

"Leucippus, however, and his disciple Democritus hold that the elements are the *Full* and the Void—calling the one 'what is' and the other 'what is not'. Of these they identify the *full* or *solid* with 'what is' (i.e., the atoms) and the void or *rare* with 'what is not'. Hence they hold that what is not is no less real than what is ... and they say that these are the material causes of things. And just as those who make the underlying substance a unity generate all other things by means of its modifications ... so these thinkers hold that the '*differences*' (namely, of the atoms) are the causes of everything else. These differences, *they say, are three*: *shape, arrangement*, and position.... Thus, e.g., *A* differs from *N* in shape, *AN* from *NA* in *arrangement*, and *Z* from *N* in position." (Aristotle, *Metaphysics*, Book I, Chapter IV.)

Leucippus "was the first to set up atoms as general principles ... and these he calls elements. Out of them arise the worlds unlimited in number and into them they are dissolved. This is how the worlds are formed. *In a given section* many atoms of all manner of shapes are carried from the unlimited into the vast empty space. These collect together and *form a single vortex*, in which they jostle against each other and, circling round in every possible way, separate off, by like atoms joining like. And, the atoms being so numerous that they can no longer revolve *in equilibrium, the light ones pass into the empty space outside*, as if they were being winnowed; the remainder keep together and, becoming entangled, go on their circuit together, and form a primary spherical system." (Diogenes Laertius, Book IX, Chap. 6.)

The following about Epicurus.

"The atoms are in continual *motion* through all eternity. Further, he says below that the atoms move *with equal speed*, since the *void* makes way *for the lightest and heaviest alike*.... Atoms have no quality at all except *shape, size*, and *weight*.... *They are not of any and* *every size; at any rate no atom has ever been seen by our sense.*" (Diogenes Laertius, Book X, par. 43-45.) "When they are travelling through the void and meet with no resistance, the atoms must move with equal speed. Neither will heavy atoms travel more quickly than small and light ones, so long as nothing meets them, nor will small atoms travel more quickly than large ones, *provided they always find a suitable passage*, and provided also that they meet with no obstruction." (*Ibid*., par. 61.)

"Thus it is clear that in every kind [of things] the *one* is of a definite nature and that in none of them does this, the one, have its nature." (Aristotle, *Metaphysics*, Book IX, Chap. 2.)[123]

* * *

Aristarchus of Samos, 270 B. C., already held the *Copernican theory of the Earth and Sun*. (Mädler, p. 44, Wolf, pp. 35-37.)[124]

Democritus had already surmised that the *Milky Way* sheds on us the combined light of innumerable small stars. (Wolf, p. 313.)

* * *

Difference Between the Situation at the End of the Ancient World, *CA*. 300—and at the End of the Middle Ages—1453:

1. Instead of a thin strip of civilisation along the coast of the Mediterranean, stretching its arms sporadically into the interior and as far as the Atlantic coast of Spain, France, and England, which could thus easily be broken through and rolled back by the Germans and Slavs from the North, and by the Arabs from the South-East, there was now a closed area of civilisation—the whole of West Europe with Scandinavia, Poland, and Hungary as outposts.

2. Instead of the contrast between the Greeks, or Romans, and the barbarians, there were now six civilised peoples with civilised languages, not counting the Scandinavian, etc., all of whom had developed to such an extent that they could participate in the mighty rise of literature in the fourteenth century, and guaranteed a far more diversified culture than that of the Greek and Latin languages, which were already in decay and dying out at the end of ancient times.

3. An infinitely higher development of industrial production and trade, created by the burghers of the Middle Ages; on the one hand production more perfected, more varied and on a larger scale, and, on the other hand, commerce much stronger, navigation being infinitely more enterprising since the time of the Saxons, Frisians, and Normans, and on the other hand also an amount of inventions and importation of oriental inventions, which not only for the first time made possible the importation and diffusion of Greek literature, the maritime discoveries, and the bourgeois religious revolution, but also gave them a quite different and quicker range of action. In addition they produced a mass of scientific facts, although as yet unsystematised, such as antiquity never had: the magnetic needle, printing, type, flax paper (used by the Arabs and Spanish Jews since the twelfth century, cotton paper gradually making its appearance since the tenth century, and already more widespread in the thirteenth and fourteenth centuries, papyrus quite obsolete in Egypt since the Arabs), gunpowder, *spectacles, mechanical clocks,* great progress both of *chronology* and of *mechanics.*

(See No. 11 concerning inventions.)*

In addition material provided by travels (Marco Polo, *ca.* 1272, etc.).

General education, even though still bad, much more widespread owing to the universities.

With the rise of Constantinople and the fall of Rome, antiquity comes to an end. The end of the Middle Ages is indissolubly linked with the fall of Constantinople. The new age begins with the return to the Greeks—Negation of the negation!

* * *

Historical Material.—Inventions

B. C.:

Fire-hose, water-clock, *ca.* 200 B.C. Street paving (Rome). Parchment, *ca.* 160.

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* Engels is referring to the eleventh sheet of his notes. The list of inventions given in that sheet is printed below.—*Ed.*

A. D.:

Watermills *on the Moselle, ca.* 340, in Germany in the time of Charles the Great.

First signs of glass windows, street lighting in Antioch, *ca.* 370.

Silk-worms from China, *ca.* 550 in Greece.

Quill pens in the sixth century.

Cotton paper from China to the Arabs in the seventh century, in the ninth in Italy.

Water-powered organs in France in the eighth century.

Silver mines in the Harz worked since the tenth century.

Windmills, about 1000.

Notes, Guido of Arezzo's musical scale, about 1000.

Sericulture introduced in Italy, about 1100.

Clocks with wheels—ditto.

Magnetic needle from the Arabs to the Europeans, *ca.* 1180.

Street paving in Paris, 1184.

Spectacles in Florence. Glass mirrors.
Herring-salting. Sluices.
Striking clocks. Cotton paper in France.
Second half of thirteenth century.

Rag-paper—beginning of fourteenth century.

Bills of exchange—middle of ditto.

First paper mill in Germany (Nuremberg), 1390.

Street lighting in London. Beginning of fifteenth century.

Post in Venice—ditto.

Wood-cuts and printing—ditto.

Copper-engraving—middle ditto.

Horse post in France, 1464.

Silver mines in the Saxon Erzgebirge, 1471.

Pedal clavichord invented, 1472.

Pocket watches. Air-guns. Flintlock—end of fifteenth century.

Spinning-wheel, 1530.

Diving bell, 1538.

* * *

Historical[125]

Modern natural science—the only one which can come into consideration *qua* science as against the brilliant intuitions of the Greeks and the sporadic unconnected investigations of the Arabs—begins with that mighty epoch when feudalism was smashed by the burghers. In the background of the struggle between the burghers of the towns and the feudal nobility this epoch showed the peasant in revolt, and behind the peasant the revolutionary beginnings of the modern proletariat, already red flag in hand and with communism on its lips. It was the epoch which brought into being the great monarchies in Europe, broke the spiritual dictatorship of the Pope, evoked the revival of Greek antiquity and with it the highest artistic development of the new age, broke through the boundaries of the old world, and for the first time really discovered the world.

It was the greatest revolution that the world had so far experienced. Natural science also flourished in this revolution, was revolutionary through and through, advanced hand in hand with the awakening modern philosophy of the great Italians, and provided its martyrs for the stake and the prisons. It is characteristic that Protestants and Catholics vied with one another in persecuting it. The former burned Servetus, the latter Giordano Bruno. It was a time that called for giants and produced giants, giants in learning, intellect, and character, a time that the French correctly called the Renaissance and Protestant Europe with one-sided prejudice called that of the Reformation.

At that time natural science also had its declaration of independence,[126] though it is true it did not come right at the beginning, any more than that Luther was the first Protestant. What Luther's burning of the papal bull was in the religious field, in the field of natural science was the great work of Copernicus, in which he, although timidly, after thirty-six years' hesitation and so to say on his deathbed, threw down a challenge to ecclesiastical superstition. From then on natural science was in essence emancipated from religion, although the complete settlement of accounts in all details has gone on to the present day and in many minds is still far from being complete. But from then on the development of science went forward with giant strides, increasing, so to speak, proportionately to the square of the distance in time from its point of departure, as if it wanted to show the world that for the motion of the highest product of organic matter, the human mind, the law that holds

7 Зак. № 819

good is the reverse of that for the motion of inorganic matter.

The first period of modern natural science ends—in the inorganic sphere—with Newton. It is the period in which the available subject-matter was mastered; it performed a great work in the fields of mathematics, mechanics and astronomy, statics and dynamics, especially owing to Kepler and Galileo, from whose work Newton drew the conclusions. In the organic sphere, however, there was no progress beyond the first beginnings. The investigation of the forms of life historically succeeding one another and replacing one another, as well as the changing conditions of life corresponding to them—palæontology and geology did not yet exist. Nature was not at all regarded as something that developed historically, that had a history in time; only extension in space was taken into account; the various forms were grouped not one after the other, but only one beside the other; natural history was valid for all periods, like the elliptical orbits of the planets. For any closer analysis of organic structure both the immediate bases were lacking, viz., chemistry and knowledge of the essential organic structure, the cell. Natural science, at the outset revolutionary, was confronted by an out-and-out conservative nature, in which everything remained today as it was at the beginning of the world, and in which right to the end of the world everything would remain as it had been in the beginning.

It is characteristic that this conservative outlook on nature both in the inorganic and in the organic sphere [. . .]*

Astronomy	Physics	Geology
Mechanics	Chemistry	Palæontology
Mathematics		Mineralogy

Plant physiology	Therapeutics
Animal physiology	Diagnostics
Anatomy	

The first breach: Kant and Laplace. The second: geology and palæontology (Lyell, slow development). The third: organic chemistry, which prepares organic bodies and shows the validity of chemical laws for living bodies. The

* The sentence was not finished.—*Ed.*

fourth: 1842, mechanical [theory of] heat, Grove. The fifth: Darwin, Lamarck, the cell, etc. (struggle, Cuvier and Agassiz). The sixth: the *comparative element* in anatomy, climatology (isotherms), animal and plant geography (scientific travel expeditions since the middle of the eighteenth century), physical geography in general (Humboldt), the assembling of the material in its inter-connection. Morphology (embryology, Baer).*

The old teleology has gone to the devil, but it is now firmly established that matter in its eternal cycle moves according to laws which at a definite stage—now here, now there—necessarily give rise to the thinking mind in organic beings.

The normal existence of animals is given by the contemporary conditions in which they live and to which they adapt themselves—those of man, as soon as he differentiates himself from the animal in the narrower sense, have as yet never been present, and are only to be elaborated by the ensuing historical development. Man is the sole animal capable of working his way out of the merely animal state —his normal state is one appropriate to his consciousness, *one that has to be created by himself*.

* * *

Omitted from "Feuerbach"[127]

[The vulgarising peddlers who dealt in materialism in the Germany of the fifties in no wise went beyond these limits of their teachers.** All the advances made by natural science since then served them merely] as fresh arguments against the belief in a creator of the universe; and in fact the further development of theory was quite outside their line of business. Idealism was hard hit owing to 1848 but materialism in this renovated form of it sank still lower.

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* Up to this point the text of the note has been crossed out in the manuscript by a vertical stroke as having been used by Engels in the first part of the "Introduction" (see this volume, pp. 20-31). The two further paragraphs, partially used in the second part of the "Introduction" (pp. 31-39), were not crossed out.—*Ed.*

** i.e., the French materialists of the eighteenth century.—*Ed.*

Feuerbach was absolutely right in repudiating responsibility for *this* materialism; only he had no right to confuse the doctrine of the itinerant preachers with materialism in general.

At about the same time, however, empirical natural science made such an advance and arrived at such brilliant results that not only did it become possible to overcome completely the mechanical one-sidedness of the eighteenth century, but also natural science itself, owing to the proof of the inter-connections existing in nature itself between the various fields of investigation (mechanics, physics, chemistry, biology, etc.), was transformed from an empirical into a theoretical science and, by generalising the results achieved, into a system of the materialist knowledge of nature. The mechanics of gases; newly-created organic chemistry, which stripped the last remnants of incomprehensibility from one so-called organic compound after another by preparing them from inorganic substances; scientific embryology dating from 1818; geology and palæontology; comparative anatomy of plants and animals—all these furnished new material in an unprecedented measure. Three great discoveries, however, were of decisive importance.

The first was the proof of the transformation of energy arising out of the discovery of the mechanical equivalent of heat (by Robert Mayer, Joule and Colding). All the innumerable acting causes in nature, which had hitherto led a mysterious, inexplicable existence as so-called forces—mechanical force, heat, radiation (light and radiant heat), electricity, magnetism, chemical force of association and dissociation—have now been proved to be special forms, modes of existence of one and the same energy, i.e., motion. We can not only demonstrate its conversion from one form into another, which continually takes place in nature, but we can carry out this conversion in the laboratory and in industry, and indeed in such a way that a given quantity of energy in one form always corresponds to a given quantity of energy in some other form. Thus we can express the unit of heat in kilogram-metres and the units or any quantity of electrical or chemical energy once more in heat-units and vice versa; we can likewise measure the energy consumption and energy intake of a living organism and express it in any desired unit, e.g., in heat-units. The unity of all motion in nature is no longer a philosophical assertion, but a natural-scientific fact.

The second discovery—earlier in point of time—was that of the organic cell by Schwann and Schleiden, as being the unit out of which, by its multiplication and differentiation, all organisms with the exception of the lowest are formed and develop. This discovery for the first time gave a firm basis to the investigation of the organic, living products of nature—both comparative anatomy and physiology, and embryology. The origin, growth and structure of organisms were deprived of their mysterious character; the hitherto incomprehensible miracle was merged in a process which takes place according to a law that is essentially identical for all multicellular organisms.

But an essential gap still remained. If all multicellular organisms—both plants and animals, including man—in each case grow out of a single cell according to the law of cell division, what then is the source of the infinite diversity of these organisms? This question was answered by the third great discovery, the theory of evolution, which for the first time was comprehensively worked out and substantiated by Darwin. However many transformations this theory will still undergo as regards details, in the main it has already solved the problem in a more than adequate manner. The evolutionary series of organisms from a few simple forms to increasingly multifarious and complicated ones, as it confronts us today, and extending right up to man, has been established as far as its main features are concerned. Thanks to this, not only has it become possible to explain the existing stock of organic products of nature but the basis has also been provided for the pre-history of the human mind, for tracing the various stages of its development, from the simple protoplasm—structureless but sensitive to stimuli—of the lowest organisms right up to the thinking human brain. Without this pre-history, however, the existence of the thinking human brain remains a miracle.

By means of these three great discoveries, the main processes of nature were explained and referred to natural causes. One thing still remains to be done here: to explain the origin of life from inorganic nature. At the present stage of science that implies nothing less than the preparation of protein bodies from inorganic substances. Chemistry is approaching closer and closer to the solution of this task, but it is still a long way from it. If, however, we bear in mind that it was only in 1828 that Wöhler prepared the first organic body, urea, from inorganic materials, and what an innumerable number of so-called organic compounds are now artificially prepared without any organic materials, we shall not be inclined to bid chemistry halt when confronted by protein. So far chemistry has been able to prepare every organic substance, the composition of which is accurately known. As soon as the composition of the protein bodies becomes known, chemistry will be able to set about the preparation of living protein. But to demand that it should achieve overnight what nature itself succeeds in doing only under very favourable circumstances on a few cosmic bodies after millions of years, would be to demand a miracle.

Thus the materialist outlook on nature rests today on a much firmer foundation than it did in the previous century. At that time only the motion of the heavenly bodies and that of terrestrial solid bodies under the influence of gravity was at all exhaustively understood; almost the entire field of chemistry and the whole of organic nature remained mysterious and not understood. Today the whole of nature lies spread out before us as a system of inter-connections and processes that, at least in its main features, has been explained and understood. At all events, the materialist outlook on nature means nothing more than the simple conception of nature just as it is, without alien addition, and hence among the Greek philosophers it was originally understood in this way as a matter of course. But between those ancient Greeks and us lie more than two thousand years of an essentially idealist outlook on the world, and so the return to self-evident understanding is more difficult than it appears to be at first sight. For it is by no means a matter of simply throwing overboard the entire thought content of those two thousand years, but of a criticism of it, of extracting the results—that had been won within a form that was false and idealistic but which was inevitable for its time and for the course of evolution itself—from this transitory form. And how difficult that is, is proved for us by those numerous natural scientists who are inexorable materialists within their science but outside it are not merely idealists, but even pious and indeed orthodox Christians.

All these epoch-making advances of natural science passed Feuerbach by without affecting him in any essential respect. This was not so much his fault as that of the miserable German conditions, owing to which the university chairs were occupied by empty-headed, eclectic hair-splitters, while Feuerbach, who towered high above them, was compelled almost to rusticate in lonely village isolation. That is why, on the subject of nature, he wastes so much labour—except for a few brilliant generalisations—on empty belletristic writing. Thus he says:

> "Life is, of course, not the product of a chemical process, nor in general is it the product of an isolated natural force or phenomenon, to which the metaphysical materialist reduces it; it is a result of the whole of nature."[128]

That life is a result of the whole of nature in no way contradicts the fact that protein, which is the exclusive independent bearer of life, arises under definite conditions determined by the whole inter-connection of nature, but arises precisely as the product of a chemical process. <Had Feuerbach lived in conditions which permitted him to follow even superficially the development of natural science, it would never have happened that he would speak of a chemical process as the effect of an isolated force of nature.>* To the same solitariness must be ascribed the fact that Feuerbach loses himself in a circle of barren speculations on the relation of thought to the thinking organ, the brain—a sphere in which Starcke follows him willingly.

Enough, Feuerbach revolts against the name materialism.[129] And not entirely without reason; for he never completely ceases to be an idealist. In the field of nature he is a materialist; but in the human field [. . .].**

* This sentence was crossed out by Engels.—*Ed.*

** Page 19 of the original manuscript of *L. Feuerbach* ends here. The end of this sentence occurs on the following page, which has not come down to us. On the basis of the printed text of *L. Feuer-*

* * *

God is nowhere treated worse than by the natural scientists who believe in him. Materialists simply explain the *facts*, without making use of such phrases, they do this first when importunate pious believers try to force God upon them, and then they answer curtly, either like Laplace: *Sire, je n'avais pas, etc.,*[130] or more rudely in the manner of the Dutch merchants who, when German commercial travellers press their shoddy goods on them, are accustomed to turn them away with the words: *Ik kan die zaken niet gebruiken*,* and that is the end of the matter. But what God has had to suffer at the hands of his defenders! In the history of modern natural science, God is treated by his defenders as Frederick William III was treated by his generals and officials in the Jena campaign. One division of the army after another lays down its arms, one fortress after another capitulates before the march of science, until at last the whole infinite realm of nature is conquered by science, and there is no place left in it for the Creator. Newton still allowed Him the "first impulse" but forbade Him any further interference in his solar system. Father Secchi bows Him out of the solar system altogether, with all canonical honours it is true, but none the less categorically for all that, and he only allows Him a creative act as regards the primordial nebula. And so in all spheres. In biology, his last great Don Quixote, Agassiz, even ascribes positive nonsense to Him; He is supposed to have created not only the actual animals but also abstract animals, the fish as such!** And finally Tyndall totally forbids Him any entry into nature and relegates Him to the world of emotional processes, only admitting Him because, after all, there must be somebody who knows more about all these things (nature) than John Tyndall![131] What a distance from the old God—the Creator of heaven and earth, the maintainer of all things—without whom not a hair can fall from the head!

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bach it may be supposed that this sentence read approximately as follows: "In the sphere of human history he is an idealist."—*Ed.*

* I have no use for the things.—*Ed.*

** See this volume, pp. 206-10.—*Ed.*

Tyndall's emotional need proves nothing. The Chevalier des Grieux also had an emotional need to love and possess Manon Lescaut, who sold herself and him over and over again; for her sake he became a cardsharper and pimp, and if Tyndall wants to reproach him, he would reply with his "emotional need"!

God=*nescio*; but *ignorantia non est argumentum* (Spinoza).[132]

[Natural Science and Philosophy]

* * *

Büchner[133]

Rise of the tendency. The passing of German philosophy into materialism—control over science abolished—outbreak of shallow materialist popularisation, in which the materialism had to make up for the lack of science. Its flourishing at the time of the deepest degradation of bourgeois Germany and official German science—1850-60. Vogt, Moleschott, Büchner. Mutual assurance. New impetus by the coming into fashion of Darwinism, which was immediately monopolised by these gentlemen.

One could let them alone and leave them to their not unpraiseworthy if narrow occupation of teaching atheism, etc., to the German philistine but for: 1, abuse directed against philosophy (passages to be quoted),* which in spite of everything is the glory of Germany, and 2, the presumption of applying the theories about nature to society and of reforming socialism. Thus they compel us to take note of them.

First of all, what do they achieve in their own sphere? Quotations.

2. Turning point, pages 170-171. Whence this sudden Hegelianism?[135] Transition to dialectics.

Two philosophical tendencies, the metaphysical with

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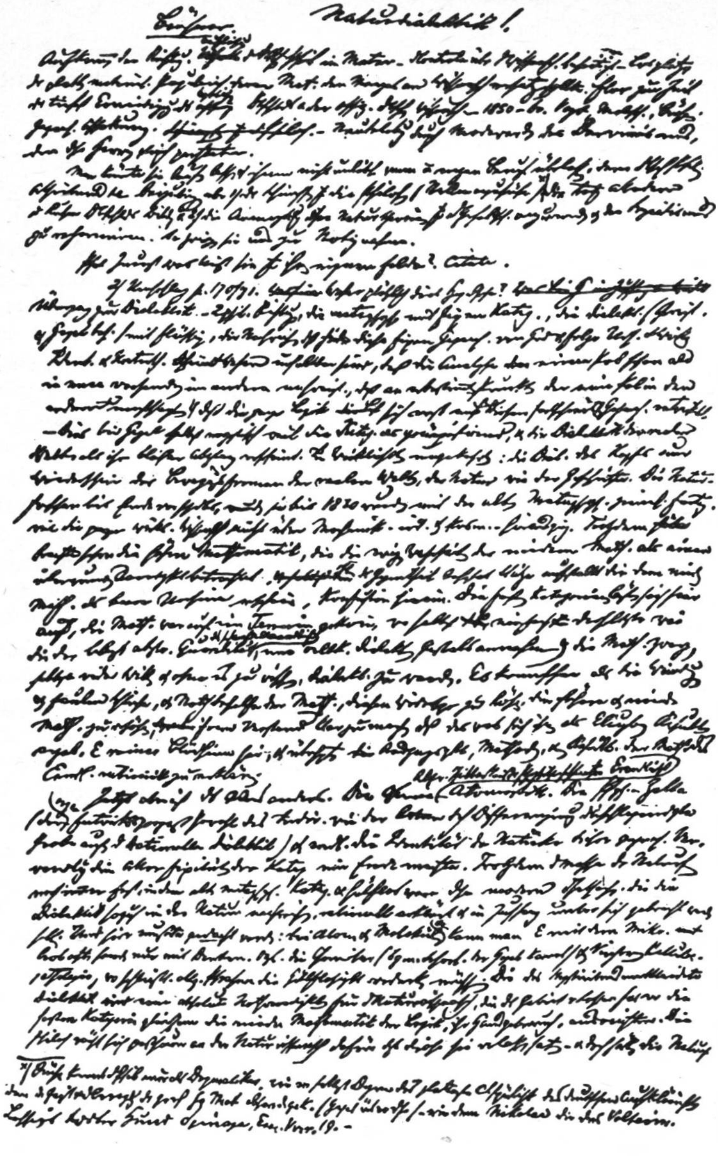
* Büchner is acquainted with philosophy only as a dogmatist, just as he himself is a dogmatist of the shallowest reflection of the German would-be Enlightenment, which missed the spirit and movement of the great French materialists (Hegel on this)—just as Nicolai had that of Voltaire. Lessing's "dead dog Spinoza".[134] ([Hegel] *Enzyklopädie*, Preface, p. 19.) [*Note by Engels.*]

fixed categories, the dialectical (Aristotle and especially Hegel) with fluid categories; the proofs that these fixed opposites of basis and consequence, cause and effect, identity and difference, appearance and essence are untenable, that analysis shows one pole already present in the other *in nuce*, that at a definite point the one pole becomes transformed into the other, and that all logic develops only from these progressing contradictions.—This mystical in Hegel himself, because the categories appear as pre-existing and the dialectics of the real world as their mere reflection. In reality it is the reverse: the dialectics of the mind is only the reflection of the forms of motion of the real world, both of nature and of history. Until the end of the last century, indeed until 1830, natural scientists could manage pretty well with the old metaphysics, because real science did not go beyond mechanics—terrestrial and cosmic. Nevertheless confusion had already been introduced by higher mathematics, which regards the eternal truth of lower mathematics as a superseded point of view, often asserting the contrary, and putting forward propositions which appear sheer nonsense to the lower mathematician. The rigid categories disappeared here; mathematics arrived at a field where even such simple relations as those of mere abstract quantity, bad infinity, assumed a completely dialectical form and compelled the mathematicians to become dialectical, unconsciously and against their will. There is nothing more comical than the twistings, subterfuges, and expedients employed by the mathematicians to solve this contradiction, to reconcile higher and lower mathematics, to make clear to their understanding that what they had arrived at as an undeniable result is not sheer nonsense, and in general rationally to explain the starting-point, method, and result of the mathematics of the infinite.

Now, however, everything is quite different. Chemistry, the abstract divisibility of physical things, bad infinity—atomistics. Physiology—the cell (the organic process of development, both of the individual and of species, by differentiation, the most striking test of rational dialectics), and finally the identity of the forces of nature and their mutual convertibility, which put an end to all fixity of categories. Nevertheless, the bulk of natural scientists are


Naturdialektik!

First page of the folder of *Dialectics of Nature* still held fast in the old metaphysical categories and helpless when these modern facts, which so to say prove the dialectics in nature, have to be rationally explained and brought into relation with one another. And here *thinking* is necessary: atoms and molecules, etc., cannot be observed under the microscope, but only by the process of thought. Compare the chemists (except for Schorlemmer, who is acquainted with Hegel) and Virchow's *Cellular Pathology,* where in the end the helplessness has to be concealed by general phrases. Dialectics divested of mysticism becomes an absolute necessity for natural science, which has forsaken the field where rigid categories sufficed, which represent as it were the lower mathematics of logic, its everyday weapons. Philosophy takes its revenge posthumously on natural science for the latter having deserted it; and yet the scientists could have seen even from the successes in natural science achieved by philosophy that the latter possessed something that was superior to them even in their own special sphere (Leibniz—the founder of the mathematics of the infinite, in contrast to whom the inductive ass Newton[136] appears as a plagiarist[137] and corrupter; Kant—the theory of the origin of the universe *before* Laplace; Oken—the first in Germany to accept the theory of evolution; Hegel—whose [. . .]* comprehensive treatment and rational grouping of the natural sciences is a greater achievement than all the materialistic nonsense put together).

On Büchner's claim to pronounce judgement on socialism and political economy on the basis of the struggle for existence: Hegel (*Enzyklopädie,* I, p. 9), on cobbling.[138]

On politics and socialism. The understanding for which the world has waited, p. 11.[139]

Separation, coexistence, and succession. Hegel, *Enzyklopädie*, p. 35! as determination of the sensuous, of the idea.[140]

Hegel, *Enzyklopädie,* p. 40. Natural phenomena[141]—but in Büchner not *thought about*, merely copied out, hence it is superfluous.

* One word has not been deciphered, being covered by an ink blot in the manuscript.—*Ed.*

Page 42. Solon's laws were "produced out of his head"—Büchner is able to do the same for modern society.

Page 45. Metaphysics—the science of *things*—not of movements.

Page 53. "In experience everything depends upon the mind we bring to bear upon actuality. A great mind is great in its experience; and in the motley play of phenomena at once perceives the point of real significance."

Page 56. The parallelism between the human individual and history[142]—the parallelism between embryology and palæontology.

* * *

Just as Fourier is a mathematical poem[143] and yet still used, so Hegel a dialectical poem.

* * *

The incorrect *theory of porosity* (according to which the various false matters, caloric, etc., are situated in the pores of one another and yet do not penetrate one another) is presented by Hegel as a pure *figment of the mind* (*Enzyklopädie*, I, p. 259. See also his *Logik*[144]).

* * *

Hegel, *Enzyklopädie*, I, pp. 205-206,[145] a prophetic passage on atomic weights in contrast to the physical views of the time, and on atoms and molecules as *thought* determinations, on which *thinking* has to decide.

* * *

If Hegel regards nature as a manifestation of the eternal "idea" in its alienation, and if this is such a serious crime, what are we to say of the morphologist Richard Owen:

> "The archetypal idea was manifested in the flesh under diverse modifications upon this planet, long prior to the existence of those animal species that actually exemplify it." (*Nature of Limbs*, 1849.)[146]

If that is said by a mystical natural scientist, who means nothing by it, it is calmly allowed to pass, but if a philosopher says the same thing, and one who means something by it, and indeed *au fond* something correct, although in inverted form, then it is mysticism and a terrible crime.

* * *

Natural-scientific thought. Agassiz's plan of creation, according to which God proceeded in creation from the general to the particular and individual, first creating the vertebrate as such, then the mammal as such, the animal of prey as such, the cat as such, and only finally the lion, etc.! That is to say, first of all abstract ideas in the shape of concrete things and then concrete things! (See Hæckel, p. 59.)[147]

* * *

In *Oken* (Hæckel, p. 85 et seq.) the nonsense that has arisen from the dualism between natural science and philosophy is evident. By the path of thought, Oken discovers protoplasm and the cell, but it does not occur to anyone to follow up the matter along the lines of natural-scientific investigation—it is to be accomplished by *thinking*! And when protoplasm and the cell were discovered, Oken was in general disrepute!

* * *

Hofmann (*Ein Jahrhundert Chemie unter den Hohenzollern*) cites the philosophy of nature. A quotation from Rosenkranz, the belletrist, whom no real Hegelian recognises. To make the philosophy of nature responsible for Rosenkranz is as foolish as Hofmann making the Hohenzollerns responsible for Marggraf's discovery of beet sugar.[148]

* * *

Theory and empiricism.—The oblateness of the earth was theoretically established by Newton. The Cassinis[149] and other Frenchmen maintained a long time afterwards, on the basis of their empirical measurements, that the earth is ellipsoidal and the polar axis the longest one.

* * *

The contempt of the empiricists for the Greeks receives a peculiar illustration if one reads, for instance, Th. Thomson (*On Electricity*[150]), where people like Davy and even Faraday grope in the dark (the electric spark, etc.), and make experiments that quite remind one of the stories of Aristotle and Pliny about physico-chemical phenomena. It is precisely in this new science that the empiricists entirely reproduce the blind groping of the ancients. And when Faraday with his genius gets on the right track, the philistine Thomson has to protest against it. (P. 397).

* * *

Hæckel, *Anthropogenie*, p. 707.

"According to the materialist outlook on the world, *matter or substance* was present *earlier than motion* or *vis viva*, matter created force."* This is just as false as that force created matter, since force and matter are inseparable.[151]

Where does he get his materialism from?

* * *

Causae finales and *efficientes* transformed by Hæckel (pp. 89, 90) into *purposively* acting and *mechanically* acting causes, because for him *causa finalis*=God! Likewise for him "mechanical", adopted out of hand from Kant, =monistic, not =mechanical in the sense of mechanics. With such confusion of language, nonsense is inevitable. What Hæckel says here of Kant's *Kritik der Urteilskraft* does not agree with Hegel. (*Geschichte der Philosophie* [Vol. III], S. 603.)[152]

Another example** of polarity in Hæckel: mechanism=monism, and vitalism or teleology=dualism. Already in Kant and Hegel *inner* purpose is a protest against dualism. Mechanism applied to life is a helpless category, at the most we could speak of chemism, if we do not want to

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* Italics by Engels.—*Ed.*

** This word refers to the note "Polarity", which was written immediately before the present note on the same sheet (see this volume, p. 220).—*Ed.*

renounce all understanding of names. Purpose: Hegel, V, p. 205:[153]

"Thus mechanism manifests itself as a tendency of totality in that it seeks to seize nature for itself as a whole which requires no other for its notion—a totality which is *not found in end and the extra-mundane understanding which is associated therewith*."*

The point is, however, that mechanism (and also the materialism of the eighteenth century) does not get away from abstract necessity, and hence not from chance either. That matter evolves out of itself the thinking human brain is for mechanism a pure accident, although necessarily determined, step by step, where it happens. But the truth is that it is the nature of matter to advance to the evolution of thinking beings, hence this always necessarily occurs wherever the conditions for it (not necessarily identical at all places and times) are present.

Further, Hegel, V, p. 206:

"Consequently, in its connection of external necessity, this principle (of mechanism)** affords the consciousness of infinite freedom as against teleology, which sets up as something absolute whatever it contains that is trivial or even contemptible; and here a more universal thought can only feel infinitely cramped or even nauseated."

Here, again, the colossal waste of matter and motion in nature. In the solar system there are perhaps three planets at most on which life and thinking beings could exist—under present conditions. And the whole enormous apparatus for their sake!

The *inner purpose* in the organism, according to Hegel (V, p. 244),[154] operates through *impulse*. *Pas trop fort*. Impulse is supposed to bring the single living being more or less into harmony with the idea of it. From this it is seen how much the whole *inner purpose* is itself an ideological determination. And yet Lamarck is contained in this.

* * *

Natural scientists believe that they free themselves from philosophy by ignoring it or abusing it. They cannot,

* Italics by Engels.—*Ed.*

** Added by Engels.—*Ed.*

however, make any headway without thought, and for thought they need thought determinations. But they take these categories unreflectingly from the common consciousness of so-called educated persons, which is dominated by the relics of long obsolete philosophies, or from the little bit of philosophy compulsorily listened to at the University (which is not only fragmentary, but also a medley of views of people belonging to the most varied and usually the worst schools), or from uncritical and unsystematic reading of philosophical writings of all kinds. Hence they are no less in bondage to philosophy, but unfortunately in most cases to the worst philosophy, and those who abuse philosophy most are slaves to precisely the worst vulgarised relics of the worst philosophies.

* * *

Natural scientists may adopt whatever attitude they please, they are still under the domination of philosophy. It is only a question whether they want to be dominated by a bad, fashionable philosophy or by a form of theoretical thought which rests on acquaintance with the history of thought and its achievements.

"Physics, beware of metaphysics", is quite right, but in a different sense.[155]

Natural scientists allow philosophy to prolong an illusory existence by making shift with the dregs of the old metaphysics. Only when natural and historical science has become imbued with dialectics will all the philosophical rubbish—other than the pure theory of thought—be superfluous, disappearing in positive science.

[Dialectics]

[A] General Questions of Dialectics. The Fundamental Laws of Dialectics]

* * *

Dialectics, so-called *objective* dialectics, prevails throughout nature, and so-called subjective dialectics, dialectical thought, is only the reflection of the motion through opposites which asserts itself everywhere in nature, and which by the continual conflict of the opposites and their final passage into one another, or into higher forms, determines the life of nature. Attraction and repulsion. Polarity begins with magnetism, it is exhibited in one and the same body; in the case of electricity it distributes itself over two or more bodies which become oppositely charged. All chemical processes reduce themselves to processes of chemical attraction and repulsion. Finally, in organic life the formation of the cell nucleus is likewise to be regarded as a polarisation of the living protein material, and from the simple cell onwards the theory of evolution demonstrates how each advance up to the most complicated plant on the one side, and up to man on the other, is effected by the continual conflict between heredity and adaptation. In this connection it becomes evident how little applicable to such forms of evolution are categories like "positive" and "negative". One can conceive of heredity as the positive, conservative side, adaptation as the negative side that continually destroys what has been inherited, but one can just as well take adaptation as the creative, active, positive activity, and heredity as the resisting, passive, negative activity. But just as in history progress makes its appearance as the negation of the existing state of things, so here also—on purely *practical* grounds—adaptation is better conceived as negative activity. In history, motion through opposites is most markedly exhibited in all critical epochs of the foremost peoples. At such moments a people has only the choice between the two horns of a dilemma: "either—or!" and indeed the question is always put in a way quite different from that in which the philistines, who dabble in politics in every age, would have liked it put. Even the liberal German philistine of 1848 found himself in 1849 suddenly, unexpectedly, and against his will confronted by the question: a return to the old reaction in an intensified form, or continuance of the revolution up to the republic, perhaps even the one and indivisible republic with a socialist background. He did not spend long in reflection and helped to create the Manteuffel reaction as the flower of German liberalism. Similarly, in 1851, the French bourgeois when faced with the dilemma which he certainly did not expect: a caricature of the empire, pretorian rule, and the exploitation of France by a gang of scoundrels, or a social-democratic republic—and he bowed down before the gang of scoundrels so as to be able, under their protection, to go on exploiting the workers.

* * *

Hard and fast lines are incompatible with the theory of evolution. Even the border-line between vertebrates and invertebrates is now no longer rigid, just as little is that between fishes and amphibians, while that between birds and reptiles dwindles more and more every day. Between *Compsognathus*[156] and *Archæopteryx* only a few intermediate links are wanting, and birds' beaks with teeth crop up in both hemispheres. "Either—or" becomes more and more inadequate. Among lower animals the concept of the individual cannot be established at all sharply. Not only as to whether a particular animal is an individual or a colony, but also where in development *one* individual ceases and the other begins (nurses).[157]

For a stage in the outlook on nature where all differences become merged in intermediate steps, and all opposites pass into one another through intermediate links, the old metaphysical method of thought no longer suffices. Dialectics, which likewise knows no hard and fast lines, no unconditional, universally valid "either—or" and which bridges the fixed metaphysical differences, and besides "either—or" recognises also in the right place "both this—and that" and reconciles the opposites, is the sole method of thought appropriate in the highest degree to this stage. Of course, for everyday use, for the small change of science, the metaphysical categories retain their validity.

* * *

The transformation of quantity into quality="mechanical" world outlook, quantitative change alters quality. The gentlemen never suspected that!

* * *

The character of mutual opposites belonging to the thought determinations of reason: *polarisation*. Just as electricity, magnetism, etc., become polarised and move in opposites, so do thoughts. Just as in the former it is not possible to maintain any one-sidedness, and no natural scientist would think of doing so, so also in the latter.

* * *

The true nature of the determinations of "essence" is expressed by Hegel himself (*Enzyklopädie*, I, paragraph 111, addendum): "In essence everything is *relative*"* (e.g., positive and negative, which have meaning only in their relation, not each for itself).

* * *

Part and whole, for instance, are already categories which become inadequate in organic nature. The ejection of seeds—the embryo—and the new-born animal are not to be conceived as a "part" that is separated from the "whole"; that would give a distorted treatment. It becomes a part only in a dead body. (*Enzyklopädie*, I, p. 268.)[158]

* * *

* Italics by Engels.—*Ed.*

Simple and compound. Categories which even in organic nature likewise lose their meaning and become inapplicable. An animal is expressed neither by its mechanical composition from bones, blood, gristle, muscles, tissues, etc., nor by its chemical composition from the elements. Hegel (*Enzyklopädie,* I, p. 256).[159] The organism is *neither* simple *nor* compound, however complex it may be.

* * *

Abstract identity ($a=a$; and negatively, a cannot be simultaneously equal and unequal to a) is likewise inapplicable in organic nature. The plant, the animal, every cell is at every moment of its life identical with itself and yet becoming distinct from itself, by absorption and excretion of substances, by respiration, by cell formation and death of cells, by the process of circulation taking place, in short, by a sum of incessant molecular changes which make up life and the sum-total of whose results is evident to our eyes in the phases of life—embryonic life, youth, sexual maturity, process of reproduction, old age, death. The further physiology develops, the more important for it become these incessant, infinitely small changes, and hence the more important for it also the consideration of difference *within* identity, and the old abstract standpoint of formal identity, that an organic being is to be treated as something simply identical with itself, as something constant, becomes out of date.* Nevertheless, the mode of thought based thereon, together with its categories, persists. But even in inorganic nature identity as such is in reality non-existent. Every body is continually exposed to mechanical, physical, and chemical influences, which are always changing it and modifying its identity. Abstract identity, with its opposition to difference, is in place only in mathematics—an abstract science which is concerned with creations of thought, even though they are reflections of reality—and even there it is continually being sublated. Hegel, *Enzyklopädie*, I, p. 235.[160] The fact that identity

* In the margin of the manuscript occurs the remark: "*Apart, moreover, from the evolution of species.*"—*Ed.*

contains difference within itself is expressed in *every sentence*, where the predicate is necessarily different from the subject; the *lily* is a *plant*, the *rose is red*, where, either in the subject or in the predicate, there is something that is not covered by the predicate or the subject. Hegel, p. 231.[161] That from the outset *identity with itself* requires *difference from everything else* as its complement, is self-evident.

Continual change, i.e., sublation of abstract identity with itself, is also found in so-called inorganic nature. Geology is its history. On the surface, mechanical changes (denudation, frost), chemical changes (weathering); internally, mechanical changes (pressure), heat (volcanic), chemical (water, acids, binding substances); on a large scale—upheavals, earthquakes, etc. The slate of today is fundamentally different from the ooze from which it is formed, the chalk from the loose microscopic shells that compose it, even more so limestone, which indeed according to some is of purely organic origin, and sandstone from the loose sea sand, which again is derived from disintegrated granite, etc., not to speak of coal.

* * *

The law of identity in the old metaphysical sense is the fundamental law of the old outlook: $a=a$. Each thing is equal to itself. Everything was permanent, the solar system, stars, organisms. This law has been refuted by natural science bit by bit in each separate case, but theoretically it still prevails and is still put forward by the supporters of the old in opposition to the new: a thing cannot simultaneously be itself and something else. And yet the fact that true, concrete identity includes difference, change, has recently been shown in detail by natural science (see above).

Abstract identity, like all metaphysical categories, suffices for *everyday* use, where small dimensions or brief periods of time are in question; the limits within which it is usable differ in almost every case and are determined by the nature of the object; for a planetary system, where in ordinary astronomical calculation the ellipse can be taken as the basic form for practical purposes without error, they are much wider than for an insect that completes its metamorphosis in a few weeks. (Give other examples, e.g., alteration of species, which is reckoned in periods of thousands of years.) For natural science in its comprehensive role, however, even in each single branch, abstract identity is totally inadequate, and although on the whole it has now been abolished in practice, theoretically it still dominates people's minds, and most natural scientists imagine that identity and difference are irreconcilable opposites, instead of one-sided poles which represent the truth only in their reciprocal action, in the inclusion of difference *within* identity.

* * *

Identity and difference—necessity and chance—cause and effect—the two main opposites* which, treated separately, become transformed into one another.

And then "first principles" must help.

* * *

Positive and negative. Can also be given the reverse names: in electricity, etc.; North and South ditto. If one reverses this and alters the rest of the terminology accordingly, everything remains correct. We can call West East and East West. The sun rises in the West, and planets revolve from East to West, etc., the names alone are changed. Indeed, in physics we call the real South pole of the magnet, which is attracted by the North pole of the earth's magnetism, the *North pole*, and it does not matter.

* * *

That positive and negative are equivalent, irrespective of which side is positive and which negative, [holds good] not only in analytical geometry, but still more in physics (see Clausius, p. 87 et seq.).[162]

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* In the manuscript: "die beiden Hauptgegensätze" (the two main opposites). Engels has in mind: (1) The antithesis of identity and difference, and (2) the antithesis of cause and effect. The words "necessity and chance" were written between the lines afterwards. —*Ed.*

* * *

Polarity. A magnet, on being cut through, polarises the neutral middle portion, but in such a way that the old poles remain. On the other hand a worm, on being cut into two, retains the receptive mouth at the positive pole and forms a new negative pole at the other end with excretory anus; but the old negative pole (the anus) now becomes positive, becoming a mouth, and a new anus or negative pole is formed at the cut end. *Voilà* transformation of positive into negative.

* * *

Polarisation. For J. Grimm it was still a firmly established law that a German dialect must be either High German or Low German. In this he totally lost sight of the Frankish dialect.[163] Because the written Frankish of the later Carlovingian period was High German (since the High German shifting of consonants had taken possession of the Frankish South-East), he imagined that Frankish passed in one place into old High German, in another place into French. It then remained absolutely impossible to explain the source of the Netherland dialect in the ancient Salic regions. Frankish was only rediscovered after Grimm's death: Salic in its rejuvenation as the Netherland dialect, Ripuaric in the Middle and Lower Rhine dialects, which in part have been shifted to various stages of High German, and in part have remained Low German, so that Frankish is a dialect that is *both* High German *and* Low German.

* * *

Chance and Necessity

Another opposition in which metaphysics is entangled is that of chance and necessity. What can be more sharply contradictory than these two thought determinations? How is it possible that both are identical, that the accidental is necessary, and the necessary is also accidental? Common sense, and with it the majority of natural scientists, treats necessity and chance as determinations that exclude each other once for all. A thing, a circumstance, a process is either accidental or necessary, but not both. Hence both exist side by side in nature; nature contains all sorts of objects and processes, of which some are accidental, the others necessary, and it is only a matter of not confusing the two sorts with each other. Thus, for instance, one assumes the decisive specific characters to be necessary, other differences between individuals of the same species being termed accidental, and this holds good of crystals as it does for plants and animals. Then again the lower group becomes accidental in relation to the higher, so that it is declared to be a matter of chance how many different species are included in the genus *felis* or *equus*, or how many genera and orders there are in a class, and how many individuals of each of these species exist, or how many different species of animals occur in a given region, or what in general the fauna and flora are like. And then it is declared that the necessary is the sole thing of scientific interest and that the accidental is a matter of indifference to science. That is to say: what can be brought under laws, hence what one *knows*, is interesting; what cannot be brought under laws, and therefore what one does not know, is a matter of indifference and can be ignored. Thereby all science comes to an end, for it has to investigate precisely that which we do *not* know. That is to say: what can be brought under general laws is regarded as necessary, and what cannot be so brought as accidental. Anyone can see that this is the same sort of science as that which proclaims natural what it can explain, and ascribes what it cannot explain to supernatural causes; whether I term the cause of the inexplicable chance, or whether I term it God, is a matter of complete indifference as far as the thing itself is concerned. Both are only equivalents for: I do not know, and therefore do not belong to science. The latter ceases where the requisite connection is wanting.

In opposition to this view there is determinism, which passed from French materialism into natural science, and which tries to dispose of chance by denying it altogether. According to this conception only simple, direct necessity prevails in nature. That a particular pea-pod contains five peas and not four or six, that a particular dog's tail is five inches long and not a whit longer or shorter, that this year a particular clover flower was fertilised by a bee and another not, and indeed by precisely one particular bee and at a particular time, that a particular windblown dandelion seed has sprouted and another not, that last night I was bitten by a flea at four o'clock in the morning, and not at three or five o'clock, and on the right shoulder and not on the left calf—these are all facts which have been produced by an irrevocable concatenation of cause and effect, by an unshatterable necessity of such a nature indeed that the gaseous sphere, from which the solar system was derived, was already so constituted that these events had to happen thus and not otherwise. With this kind of necessity we likewise do not get away from the theological conception of nature. Whether with Augustine and Calvin we call it the eternal decree of God, or Kismet[164] as the Turks do, or whether we call it necessity, is all pretty much the same for science. There is no question of tracing the chain of causation in any of these cases; so we are just as wise in one as in another, the so-called necessity remains an empty phrase, and with it—chance also remains what it was before. As long as we are not able to show on what the number of peas in the pod depends, it remains just a matter of chance, and the assertion that the case was foreseen already in the primordial constitution of the solar system does not get us a step further. Still more. A science which was to set about the task of following back the *casus* of this individual pea-pod in its causal concatenation would be no longer science but pure trifling; for this same pea-pod alone has in addition innumerable other individual, accidentally appearing qualities: shade of colour, thickness and hardness of the pod, size of the peas, not to speak of the individual peculiarities revealed by the microscope. The *one* pea-pod, therefore, would already provide more causal connections for following up than all the botanists in the world could solve.

Hence chance is not here explained by necessity, but rather necessity is degraded to the production of what is merely accidental. If the fact that a particular pea-pod contains six peas, and not five or seven, is of the same order as the law of motion of the solar system, or the law of the transformation of energy, then as a matter of fact chance is not elevated into necessity, but rather necessity degraded into chance. Furthermore, however much the diversity of the organic and inorganic species and individuals existing side by side in a given area may be asserted to be based on irrefragable necessity, for the separate species and individuals it remains what it was before, a matter of chance. For the individual animal it is a matter of chance, where it happens to be born, what environment it finds for living, what enemies and how many of them threaten it. For the mother plant it is a matter of chance whither the wind scatters its seeds, and, for the daughter plant, where the seed finds soil for germination; and to assure us that here also everything rests on irrefragable necessity is a poor consolation. The jumbling together of natural objects in a given region, still more in the whole world, for all the primordial determination from eternity, remains what it was before—a matter of chance.

In contrast to both conceptions, Hegel came forward with the hitherto quite unheard-of propositions that the accidental has a cause because it is accidental, and just as much also has no cause because it is accidental; that the accidental is necessary, that necessity determines itself as chance, and, on the other hand, this chance is rather absolute necessity. (*Logik*, II, Book III, 2: *Reality*.) Natural science has simply ignored these propositions as paradoxical trifling, as self-contradictory nonsense, and, as regards theory, has persisted on the one hand in the barrenness of thought of Wolffian metaphysics, according to which a thing is *either* accidental *or* necessary, but not both at once; or, on the other hand, in the hardly less thoughtless mechanical determinism which in words denies chance in general only to recognise it in practice in each particular case.

While natural science continued to think in this way, what *did it do* in the person of Darwin?

Darwin in his epoch-making work,[165] set out from the widest existing basis of chance. Precisely the infinite, accidental differences between individuals within a single species, differences which become accentuated until they break through the character of the species, and whose immediate causes even can be demonstrated only in extremely few cases, compelled him to question the previous basis of all regularity in biology, viz., the concept of species in its previous metaphysical rigidity and unchangeability. Without the concept of species, however, all science was nothing. All its branches needed the concept of species as basis: human anatomy and comparative anatomy—embryology, zoology, palæontology, botany, etc., what were they without the concept of species? All their results were not only put in question but directly set aside. Chance overthrows necessity, as conceived hitherto.* The previous idea of necessity breaks down. To retain it means dictatorially to impose on nature as a law a human arbitrary determination that is in contradiction to itself and to reality, it means to deny thereby all inner necessity in living nature, it means generally to proclaim the chaotic kingdom of chance to be the sole law of living nature.

"*Gilt nichts mehr der Tausves Jontof*,"[166] cried out quite logically the biologists of all schools.

Darwin.**

* * *

Hegel, ***Logic,*** **Vol. I.**[167]

"Nothing that is opposed to something, the *nothing of any something, is a determinate nothing*." (P. 74.)***

"In view of the mutually determinant connection of the (world) whole, metaphysics could make the assertion (*which is really a tautology*) that if the least grain of dust were destroyed the whole universe must collapse." (P. 78.)

Negation, main passage. "Introduction", p. 38:

"that the self-contradictory resolves itself not into nullity, into abstract Nothingness, but essentially only *into the negation of its particular content*", etc.

Negation of the negation. Phänomenologie, Preface, p. 4. Bud, flower, fruit, etc.[168]

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* Note in the margin of the manuscript: "The material on chance occurrences accumulated in the meantime has suppressed and shattered the old idea of necessity."—*Ed.*

** Cf. this volume, p. 306.—*Ed.*

*** Engels used this quotation in the note on zero (see this volume, pp. 261-62).—*Ed.*

[B] Dialectical Logic and the Theory of Knowledge. On the "Limits of Knowledge"]

* * *

Unity of nature and mind. To the Greeks it was self-evident that nature could not be unreasonable, but even today the stupidest empiricists prove by their reasoning (however wrong it may be) that they are convinced from the outset that nature cannot be unreasonable or reason contrary to nature.

* * *

The evolution of a concept, or of a conceptual relation (positive and negative, cause and effect, substance and accidency) in the history of thought, is related to its development in the mind of the individual dialectician, just as the evolution of an organism in palæontology is related to its development in embryology (or rather in history and in the single embryo). That this is so was first discovered for concepts by Hegel. In historical development, chance plays its part, which in dialectical thinking, as in the development of the embryo, *is summed up in necessity.*

* * *

Abstract and concrete. The general law of the change of form of motion is much more concrete than any single "concrete" example of it.

* * *

Understanding and reason. This Hegelian distinction, according to which only dialectical thinking is reasonable, has a definite meaning. We have in common with animals all activity of the understanding: *induction*, *deduction*, and hence also *abstraction* (Dido's[169] generic concepts: quadrupeds and bipeds), *analysis* of unknown objects (even the cracking of a nut is a beginning of analysis), *synthesis* (in animal tricks), and, as the union of both, *experiment* (in the case of new obstacles and unfamiliar situations). In their nature all these modes of procedure—hence all means of scientific investigation that ordinary logic recognises—are absolutely the same in men and the higher animals. They differ only in degree (of development of the method in each case). The basic features of the method are the same and lead to the same results in man and animals, so long as both operate or make shift merely with these elementary methods.

On the other hand, dialectical thought—precisely because it presupposes investigation of the nature of concepts themselves—is only possible for man, and for him only at a comparatively high stage of development (Buddhists and Greeks), and it attains its full development much later still through modern philosophy—and yet we have the colossal results already among the Greeks which by far anticipate investigation!

* * *

[On the Classification of Judgements]

Dialectical logic, in contrast to the old, merely formal logic, is not, like the latter, content with enumerating the forms of motion of thought, i.e., the various forms of judgement and conclusion, and placing them side by side without any connection. On the contrary, it derives these forms out of one another, it makes one subordinate to another instead of putting them on an equal level, it develops the higher forms out of the lower. Faithful to his division of the whole of logic, Hegel groups judgements as:[170]

1. Judgement of inherence, the simplest form of judgement, in which a general property is affirmatively or negatively predicated of a single thing (positive judgement: the rose is red; negative judgement: the rose is not blue; infinite judgement: the rose is not a camel);

2. Judgement of subsumption, in which a relation determination is predicated of the subject (singular judgement: this man is mortal; particular judgement: some, many men are mortal; universal judgement: all men are mortal, or man is mortal);[171]

3. Judgement of necessity, in which its substantial determination is predicated of the subject (categorical judge-

ment: the rose is a plant; hypothetical judgement: when the sun rises it is day-time; disjunctive judgement: *Lepidosiren* is either a fish or an amphibian);

4. Judgement of the notion, in which is predicated of the subject how far it corresponds to its general nature or, as Hegel says, to the notion of it (assertoric judgement: this house is bad; problematic judgement: if a house is constituted in such and such a way, it is good; apodeictic judgement: the house that is constituted in such and such a way is good.

1. *Individual Judgement*. 2 and 3. *Special*. 4. *General*.

However dry this sounds here, and however arbitrary at first sight this classification of judgements may here and there appear, yet the inner truth and necessity of this grouping will become clear to anyone who studies the brilliant exposition in Hegel's *Larger Logic*. (*Works,* V, pp. 63-115.)[172] To show how much this grouping is based not only on the laws of thought but also on the laws of nature, we should like to put forward here a very well-known example outside this connection.

That friction produces heat was already known practically to prehistoric man, who discovered the making of fire by friction perhaps more than 100,000 years ago, and who still earlier warmed cold parts of the body by rubbing. But from that to the discovery that friction is in general a source of heat, who knows how many thousands of years elapsed? Enough that the time came when the human brain was sufficiently developed to be able to formulate the judgement: *friction is a source of heat,* a judgement of inherence, and indeed a positive one.

Still further thousands of years passed until, in 1842, Mayer, Joule, and Colding investigated this special process in its relation to other processes of a similar kind that had been discovered in the meantime, i.e., as regards its immediate general conditions, and formulated the judgement: *all mechanical motion is capable of being converted into heat by means of friction*. So much time and an enormous amount of empirical knowledge were required before we could make the advance in knowledge of the object from the above positive judgement of inherence to this universal judgement of subsumption.

But from now on things went quickly. Only three years later, Mayer was able, at least in substance, to raise the judgement of subsumption to the level at which it now stands: *any form of motion, under conditions fixed for each case, is both able and compelled to undergo transformation, directly or indirectly, into any other form of motion*—a judgement of the notion, and moreover an apodeictic one, the highest form of judgement altogether.

What, therefore, in Hegel appears as a development of the thought form of judgement as such, confronts us here as the development of our *empirically* based theoretical knowledge of the nature of motion in general. This shows, however, that laws of thought and laws of nature are necessarily in agreement with one another, if only they are correctly known.

We can regard the first judgement as that of individuality; the isolated fact that friction produces heat is registered. The second judgement is that of particularity: a special form of motion, mechanical motion, exhibits the property, under special conditions (through friction), of passing into another special form of motion, viz., heat. The third judgement is that of universality: any form of motion proves able and compelled to undergo transformation into any other form of motion. In this form the law attains its final expression. By new discoveries we can give new illustrations of it, we can give it a new and richer content. But we cannot add anything to the law itself as here formulated. In its universality, equally universal in form and content, it is not susceptible of further extension: it is an absolute law of nature.

Unfortunately we are in a difficulty about the form of motion of protein, alias life, so long as we are not able to make protein.

* * *

Above, however, it has also been proved that to make judgements involves not merely Kant's "power of judgement", but a [. . .]*

* This unfinished note closes the fourth page of the double sheet of which the second and third pages and the beginning of the fourth

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Individuality, particularity, universality—these are the three determinations in which the whole "Doctrine of the Notion"[173] moves. Under these heads, progression from the individual to the particular and from the particular to the universal takes place not in one but in many modalities, and this is often enough exemplified by Hegel as the progression: individual, species, genus. And now the Hæckels come forward with their induction and trumpet it as a great fact—against Hegel—that progression must be from the individual to the particular and then to the universal (!), from the individual to the species and then to the genus —and then permit *deductive* conclusions which are supposed to lead further. These people have got into such a dead-lock over the opposition between induction and deduction that they reduce all logical forms of conclusion to these two, and in so doing do not notice that they (1) unconsciously employ quite different forms of conclusion under those names, (2) deprive themselves of the whole wealth of forms of conclusion in so far as it cannot be forced under these two, and (3) thereby convert both forms, induction and deduction, into sheer nonsense.

* * *

Induction and deduction. Hæckel, p. 75 et seq., where Goethe draws the inductive conclusion that man, who *does not normally have* a premaxillary bone, *must* have one, hence by *incorrect* induction arrives at something correct![174]

* * *

Hæckel's nonsense: induction against deduction. As if it were not the case that deduction=conclusion, and therefore induction is also a deduction. This comes from

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page constitute the preceding large fragment on the classification of judgements. Engels apparently meant to finish the note by counterposing his thesis on the *empirical* basis of all knowledge to the Kantian apriorism (cf. this volume, p. 224).—*Ed.*

polarisation. Hæckel's *Schöpfungsgeschichte*, pp. 76-77. The conclusion polarised into induction and deduction!

* * *

By induction it was discovered 100 years ago that crayfish and spiders were insects and all lower animals were worms. By induction it has now been found that this is nonsense and there exist *x* classes. Wherein then lies the advantage of the so-called inductive conclusion, which can be just as false as the so-called deductive conclusion, the basis of which is nevertheless classification?

Induction can never prove that there will never be a mammal without lacteal glands. Formerly nipples were the mark of a mammal. But the platypus has none.

The whole swindle of induction [is derived] from the Englishmen; Whewell, inductive sciences, comprising the purely mathematical [sciences],[175] and so the antithesis to deduction invented. Logic, old or new, knows nothing of this. All forms of conclusion that start from the individual are experimental and based on experience, indeed the inductive conclusion even starts from U—I—P[176] (universal).

It is also characteristic of the thinking capacity of our natural scientists that Hæckel fanatically champions induction at the very moment when the *results* of induction—the classifications—are everywhere put in question (*Limulus* a spider, *Ascidia* a vertebrate or *chordate,* the *Dipnoi*, however, being fishes,[177] in opposition to all original definitions of amphibia) and daily new facts are being discovered which overthrow the *entire* previous classification by induction. What a beautiful confirmation of Hegel's thesis that the inductive conclusion is essentially a problematic one! Indeed, owing to the theory of evolution, even the whole classification of organisms has been taken away from induction and brought back to "deduction", to descent—one species being literally *deduced* from another by descent—and it is impossible to prove the theory of evolution by induction alone, since it is quite anti-inductive. The concepts with which induction operates: species, genus, class, have been rendered fluid by the theory of evolution and so have become *relative*: but one cannot use relative concepts for induction.

* * *

*To the Pan-Inductionists.** With all the induction in the world we would never have got to the point of becoming clear about the *process* of induction. Only the *analysis* of this process could accomplish this.—Induction and deduction belong together as necessarily as synthesis and analysis.** Instead of one-sidedly lauding one to the skies at the expense of the other, we should seek to apply each of them in its place, and that can only be done by bearing in mind that they belong together, that they supplement each other.

According to the inductionists, induction is an infallible method. It is so little so that its apparently surest results are every day overthrown by new discoveries. Light corpuscles and caloric were results of induction. Where are they now? Induction taught us that all vertebrates have a central nervous system differentiated into brain and spinal cord, and that the spinal cord is enclosed in cartilaginous or bony vertebræ—whence indeed the name is derived. Then *Amphioxus* was revealed as a vertebrate with an undifferentiated central nervous strand and *without* vertebræ. Induction established that fishes are those vertebrates which throughout life breathe exclusively by means of gills. Then animals come to light whose fish character is almost universally recognised, but which, besides gills, have also well-developed lungs, and it turns out that every fish carries a potential lung in the swim bladder. Only by audacious application of the theory of evolution did Hæckel rescue the inductionists, who were feeling quite comfortable in these contradictions.

If induction were really so infallible, whence come the rapid successive revolutions in classification of the organic

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* In the manuscript: "Den Allinduktionisten", i.e., to those who regard induction as the only correct method.—*Ed.*

** Note in the margin: "Chemistry, in which *analysis* is the predominant form of investigation, is nothing without its opposite—synthesis."—*Ed.*

world? They are the most characteristic product of induction, and yet they annihilate one another.

* * *

Induction and analysis. A striking example of how little induction can claim to be the sole or even the predominant form of scientific discovery occurs in thermodynamics: the steam-engine provided the most striking proof that one can impart heat and obtain mechanical motion. 100,000 steam-engines did not prove this more than *one*, but only more and more forced the physicists into the necessity of explaining it. Sadi Carnot was the first seriously to set about the task. But not by induction. He studied the steam-engine, analysed it, and found that in it the process which mattered does not appear *in pure form* but is concealed by all sorts of subsidiary processes. He did away with these subsidiary circumstances that have no bearing on the essential process, and constructed an ideal steam-engine (or gas engine), which it is true is as little capable of being realised as, for instance, a geometrical line or surface, but in its way performs the same service as these mathematical abstractions: it presents the process in a pure, independent, and unadulterated form. And he came right up against the mechanical equivalent of heat (see the significance of his function *C*),* which he only failed to discover and see because he believed in *caloric*. Here also proof of the damage done by false theories.

* * *

The empiricism of observation alone can never adequately prove necessity. *Post hoc* but not *propter hoc*. (*Enzyklopädie*, I, S. 84.)[178] This is so very correct that it does not follow from the continual rising of the sun in the morning that it will rise again tomorrow, and in fact we know now that a time will come when one morning the sun will *not rise*. But the proof of necessity lies in human activity, in

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* Cf. This volume, p. 48.—*Ed.*

experiment, in work: if I am able to *make* the *post hoc*, it becomes identical with the *propter hoc*.

* * *

Causality. The first thing that strikes us in considering matter in motion is the inter-connection of the individual motions of separate bodies, their *being determined* by one another. But not only do we find that a particular motion is followed by another, we find also that we can evoke a particular motion by setting up the conditions in which it takes place in nature, that we can even produce motions which do not occur at all in nature (industry), at least not in this way, and that we can give these motions a predetermined direction and extent. *In this way*, by the *activity of human beings*, the idea of *causality* becomes established, the idea that one motion is the *cause* of another. True, the regular sequence of certain natural phenomena can by itself give rise to the idea of causality: the heat and light that come with the sun; but this affords no proof, and to that extent Hume's scepticism was correct in saying that a regular *post hoc* can never establish a *propter hoc*. But the activity of human beings *forms the test* of causality. If we bring the sun's rays to a focus by means of a concave mirror and make them act like the rays of an ordinary fire, we thereby prove that heat comes from the sun. If we bring together in a rifle the priming, the explosive charge, and the bullet and then fire it, we count upon the effect known in advance from previous experience, because we can follow in all its details the whole process of ignition, combustion, explosion by the sudden conversion into gas and pressure of the gas on the bullet. And here the sceptic cannot even say that because of previous experience it does not follow that it will be the same next time. For, as a matter of fact, it does sometimes happen that it is *not* the same, that the priming or the gunpowder fails to work, that the barrel bursts, etc. But it is precisely this which *proves* causality instead of refuting it, because we can find out the cause of each such deviation from the rule by appropriate investigation: chemical decomposition of the priming, dampness, etc., of the gunpowder, defect in the barrel, etc., etc., so that here the test of causality is so to say a *double* one.

Natural science, like philosophy, has hitherto entirely neglected the influence of men's activity on their thought; both know only nature on the one hand and thought on the other. But it is precisely *the alteration of nature by men*, not solely nature as such, which is the most essential and immediate basis of human thought, and it is in the measure that man has learned to change nature that his intelligence has increased. The naturalistic conception of history, as found, for instance, to a greater or lesser extent in Draper and other scientists, as if nature exclusively reacts on man, and natural conditions everywhere exclusively determined his historical development, is therefore one-sided and forgets that man also reacts on nature, changing it and creating new conditions of existence for himself. There is devilishly little left of "nature" as it was in Germany at the time when the Germanic peoples immigrated into it. The earth's surface, climate, vegetation, fauna, and the human beings themselves have infinitely changed, and all this owing to human activity, while the changes of nature in Germany which have occurred in this period of time without human interference are incalculably small.

* * *

Reciprocal action is the first thing that we encounter when we consider matter in motion as a whole from the standpoint of modern natural science. We see a series of forms of motion, mechanical motion, heat, light, electricity, magnetism, chemical union and decomposition, transitions of states of aggregation, organic life, all of which, if *at present* we *still* make an exception of organic life, pass into one another, mutually determine one another, are in one place cause and in another effect, the sum-total of the motion in all its changing forms remaining the same (Spinoza: *substance is causa sui* strikingly expresses the reciprocal action).[179] Mechanical motion becomes transformed into heat, electricity, magnetism, light, etc., and vice versa. Thus natural science confirms what Hegel has said (where?), that reciprocal action is the true *causa finalis* of things. We cannot go back further than to knowledge of this reciprocal action, for the very reason that there is nothing behind to know. If we know the forms of motion of matter (for which it is true there is still very much lacking, in view of the short time that natural science has existed), then we know matter itself, and therewith our knowledge is complete. (Grove's whole misunderstanding about causality rests on the fact that he does not succeed in arriving at the category of reciprocal action; he has the thing, but not the abstract thought, and hence the confusion—pp. 10-14.[180]) Only from this universal reciprocal action do we arrive at the real causal relation. In order to understand the separate phenomena, we have to tear them out of the general inter-connection and consider them in isolation, and *then* the changing motions appear, one as cause and the other as effect.

* * *

For one who denies causality every natural law is a hypothesis, among others also the chemical analysis of heavenly bodies by means of the prismatic spectrum. What shallowness of thought to remain at such a viewpoint!

* * *

On Nägeli's Incapacity to Know the Infinite[181]

***Nägeli*, pp. 12, 13**

Nägeli first of all says that we cannot know real qualitative differences, and immediately afterwards says that such "absolute differences" do not occur in nature! (P. 12.)

Firstly, every quality has infinitely many quantitative gradations, e.g., shades of colour, hardness and softness, length of life, etc., and these, although qualitatively distinct, are measurable and knowable.

Secondly, qualities do not exist but only things *with* qualities and indeed with infinitely many qualities. Two different things always have certain qualities (properties of corporeality at least) in common, others differing in degree, while still others may be entirely abseut in one of them. If we consider two such extremely different things—e.g., a meteorite and a man—in separation, we get very little out of it, at most that heaviness and other general properties of bodies are common to both. But an infinite series of other natural objects and natural processes can be put between the two things, permitting us to complete the series from meteorite to man and to allocate to each its place in the inter-connection of nature and thus to *know* them. Năgeli himself admits this.

Thirdly, our various senses might give us impressions differing absolutely as regards quality. In that case, properties which we experience by means of sight, hearing, smell, taste, and touch would be absolutely different. But even here the differences disappear with the progress of investigation. Smell and taste have long ago been recognised as allied senses belonging together, which perceive conjoint if not identical properties. Sight and hearing both perceive wave oscillations. Touch and sight supplement each other to such an extent that from the appearance of an object we can often enough predict its tactile properties. And, finally, it is always the same "*I*" that receives and elaborates all these different sense impressions, that therefore comprehends them into a unity, and likewise these various impressions are provided by the same thing, appearing as its *common* properties, and therefore helping us to know it. To explain these different properties accessible only to different senses, to bring them into connection with one another, is precisely the task of science, which so far has not complained because we have not a general sense in place of the five special senses, or because we are not able to see or hear tastes and smells.

Wherever we look, nowhere in nature are there to be found such "qualitatively or absolutely distinct fields", [p. 12] which are alleged to be incomprehensible. The whole confusion springs from the confusion about quality and quantity. In accordance with the prevailing mechanical view, Năgeli regards all qualitative differences as explained only in so far as they can be reduced to quantitative differences (on which what is necessary is said elsewhere), or because quality and quantity are for him absolutely distinct categories. Metaphysics.

"We can know *only the finite*",* etc. [P. 13.]

This is quite correct in so far as only finite objects enter the sphere of our knowledge. But the proposition needs to be supplemented by this: "fundamentally we can know *only the infinite*." In fact all real, exhaustive knowledge consists solely in raising the individual thing in thought from individuality into particularity and from this into universality, in seeking and establishing the infinite in the finite, the eternal in the transitory. The form of universality, however, is the form of self-completeness, hence of infinity; it is the comprehension of the many finites in the infinite. We know that chlorine and hydrogen, within certain limits of temperature and pressure and under the influence of light, combine with an explosion to form hydrochloric acid gas, and as soon as we know this, we know also that this takes place *everywhere* and *at all times* where the above conditions are present, and it can be a matter of indifference, whether this occurs once or is repeated a million times, or on how many heavenly bodies. The form of universality in nature is *law*, and no one talks more of *the eternal character of the laws of nature* than the natural scientists. Hence when Nägeli says that the finite is made impossible to understand by not desiring to investigate merely this finite, but instead adding something eternal to it, then he denies either the possibility of knowing the laws of nature or their eternal character. All true knowledge of nature is knowledge of the eternal, the infinite, and hence essentially absolute.

But this absolute knowledge has an important drawback. Just as the infinity of knowable matter is composed of the purely finite things, so the infinity of the thought which knows the absolute is composed of an infinite number of finite human minds, working side by side and successively at this infinite knowledge, committing practical and theoretical blunders, setting out from erroneous, one-sided, and false premises, pursuing false, tortuous, and uncertain paths, and often not even finding what is right when they run their noses against it (Priestley[182]). The cognition of

* Italics by Engels.—*Ed.*

the infinite is therefore beset with double difficulty and from its very nature can only take place in an infinite asymptotic progress. And that fully suffices us in order to be able to say: the infinite is just as much knowable as unknowable, and that is all that we need.

Curiously enough, Năgeli says the same thing:

"We can know only the finite, but we can know *all the finite** that comes into the sphere of our sensuous perception."

The finite that comes into the sphere, etc., constitutes in sum precisely the infinite, for *it is just from this that Năgeli has derived his idea of the infinite*! Without this finite, etc., he would have indeed no idea of the infinite!

(Bad infinity, as such, to be dealt with elsewhere.)

Before this investigation of infinity comes the following:

(1) The "insignificant sphere" in regard to space and time.

(2) The "probably defective development of the sense organs".

(3) That we "only know the finite, changing, transitory, only what is different in degree and relative, because we can only transfer mathematical concepts to natural objects and judge the latter only by measures obtained from them themselves. We have no notions for all that is infinite or eternal, for all that is permanent, for all absolute differences. We know exactly the meaning of an hour, a metre, a kilogram, but we do not know what time, space, force and matter, motion and rest, cause and effect are."

It is the old story. First of all one makes sensuous things into abstractions and then one wants to know them through the senses, to see time and smell space. The empiricist becomes so steeped in the habit of empirical experience, that he believes that he is still in the field of sensuous experience when he is operating with abstractions. We know what an hour is, or a metre, but not what time and space are! As if time was anything other than just hours, and space anything but just cubic metres! The two forms of existence of matter are naturally nothing without matter, empty concepts, abstractions which exist only in our minds. But, of course, we are supposed not to know what matter and motion are! Of course not, for matter as such and motion as

* Italics by Engels.—*Ed.*

such have not yet been seen or otherwise experienced by anyone, but only the various, actually existing material things and forms of motion. Matter is nothing but the totality of material things from which this concept is abstracted, and motion as such nothing but the totality of all sensuously perceptible forms of motion; words like matter and motion are nothing but *abbreviations* in which we comprehend many different sensuously perceptible things according to their common properties. Hence matter and motion *can* be known in no other way than by investigation of the separate material things and forms of motion, and by knowing these, we also *pro tanto* know matter and motion *as such*. Consequently, in saying that we do not know what time, space, matter, motion, cause and effect are, Nägeli merely says that first of all we make abstractions of the real world through our minds, and then cannot know these self-made abstractions because they are creations of thought and not sensuous objects, while all knowing is *sensuous measurement*! This is just like the difficulty mentioned by Hegel; we can eat cherries and plums, but not *fruit*, because no one has so far eaten fruit as such.[183]

When Nägeli asserts that there are probably a whole number of forms of motion in nature which we cannot perceive by our senses, that is a poor apology, equivalent to the suspension—*at least for our knowledge*—of the law of the uncreatability of motion. For they could certainly be *transformed into motion perceptible to us*! That would be an easy explanation of, for instance, contact electricity.

* * *

Ad vocem Nägeli. Impossibility of conceiving the infinite. When we say that matter and motion are not created and are indestructible, we are saying that the world exists as infinite progress, i.e., in the form of bad infinity, and thereby we have understood all of this process that is to be understood. At the most the question still arises whether this process is an eternal repetition—in great cycles—or whether the cycles have descending and ascending branches.

* * *

Bad infinity. True infinity was already correctly put by Hegel in *filled* space and time, in the process of nature and in history. The whole of nature also is now merged in history, and history is only differentiated from natural history as the evolutionary process of *self-conscious* organisms. This infinite complexity of nature and history has within it the infinity of space and time—bad infinity—only as a sublated factor, essential but not predominant. The extreme limit of our natural science until now has been *our* universe, and we do not need the infinitely numerous universes outside it to have knowledge of nature. Indeed, only a *single* sun among millions, with its solar system, forms the essential basis of our astronomical researches. For terrestrial mechanics, physics, and chemistry we are more or less restricted to our little earth, and for organic science entirely so. Yet this does not do any essential injury to the practically infinite diversity of phenomena and natural knowledge, any more than history is harmed by the similar, even greater limitation to a comparatively short period and small portion of the earth.

* * *

1. According to Hegel, infinite progress is a barren waste because it appears only as *eternal repetition of the same thing*: 1+1+1, etc.

2. In reality, however, it is no repetition, but a development, an advance or regression, and thereby it becomes a necessary form of motion. This apart from the fact that it is not infinite: the end of the earth's lifetime can already be foreseen. But then, the earth is not the whole universe. In Hegel's system, any development was excluded from the temporal history of nature, otherwise nature would not be the being-beyond-self of spirit. But in human history infinite progress is recognised by Hegel as the sole true form of existence of "spirit", except that fantastically this development is assumed to have an end—in the production of the Hegelian philosophy.

3. There is also infinite knowing*: *questa infinità che le cose non hanno in progresso, la hanno in giro.*** Thus the law of the change of form of motion is an infinite one, including itself in itself. Such infinities, however, are in their turn smitten with finiteness, and only occur piecemeal. So also $\frac{1}{r^2}$.[186]

* * *

The eternal laws of nature also become transformed more and more into historical ones. That water is fluid from 0°-100°C. is an eternal law of nature, but for it to be valid, there must be (1) water, (2) the given temperature, (3) normal pressure. On the moon there is no water, in the sun only its elements, and the law does not exist for these two heavenly bodies.

The laws of meteorology are also eternal, but only for the earth or for a body of the size, density, axial inclination, and temperature of the earth, and on condition that it has an atmosphere of the same mixture of oxygen and nitrogen and with the same amounts of water vapour being evaporated and precipitated. The moon has no atmosphere, the sun one of glowing metallic vapours; the former has no meteorology, that of the latter is quite different from ours.

Our whole official physics, chemistry, and biology are exclusively *geocentric*, calculated only for the earth. We are still quite ignorant of the conditions of electric and magnetic tensions on the sun, fixed stars, and nebulæ, even on the planets of a different density from ours. On the sun, owing to high temperature, the laws of chemical combination of the elements are suspended or only momentarily operative at the limits of the solar atmosphere, the compounds becoming dissociated again on approaching the sun. The chemistry of the sun is just in process of arising, and is necessarily quite different from that of the earth, not overthrowing the latter but standing outside it. In the

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* In the manuscript is the following subsequent addition by Engels: "(Quantity, p. 259. Astronomy)."[184]—*Ed.*

** This infinite, which things do not have in progress, they have in circling.[185]—*Ed.*

nebulæ perhaps there do not exist even those of the 65 elements which are possibly themselves of compound nature. Hence, if we wish to speak of general laws of nature that are uniformly applicable to *all* bodies—from the nebula to man—we are left only with gravity and perhaps the most general form of the theory of the transformation of energy, *vulgo* the mechanical theory of heat. But, on its general, consistent application to all phenomena of nature, this theory itself becomes converted into a historical presentation of the successive changes occurring in a system of the universe from its origin to its passing away, hence into a history in which at each stage different laws, i.e., different phenomenal forms of the same universal motion, predominate, and so nothing remains as absolutely universally valid except—*motion.*

* * *

The *geocentric* standpoint in astronomy is prejudiced and has rightly been abolished. But as we go deeper in our investigations, it comes more and more into its own. The sun, etc., *serve* the earth (Hegel, *Naturphilosophie*, p. 155).[187] (The whole huge sun exists merely for the sake of the little planets.) Anything other than geocentric physics, chemistry, biology, meteorology, etc., is impossible for us, and these sciences lose nothing by saying that they only hold good for the earth and are therefore only relative. If one takes that seriously and demands a centreless science, one puts a stop to *all* science. It suffices us to know that under the same conditions everywhere the same *must take place*, at a distance to the right or the left of us that is a million million times as great as the distance from the earth to the sun.

* * *

Cognition. Ants have eyes different from ours, they can see chemical (?) light-rays (*Nature*, June 8, 1882, Lubbock),[188] but as regards knowledge of these rays that are invisible to us, we are considerably more advanced than the ants, and the very fact that we are able to demonstrate that ants can see things invisible to us, and that this proof is based solely on perceptions made with *our* eyes, shows that the special construction of the human eye sets no absolute barrier to human cognition.

In addition to the eye, we have not only the other senses but also our thought activity. With regard to the latter, matters stand exactly as with the eye. To know what can be discovered by our thinking, it is no use, a hundred years after Kant, to try and find out the range of thought from the critique of reason or the investigation of the instrument of knowing. It is as little use as when Helmholtz uses the imperfection of our sight (indeed a necessary imperfection, for an eye that could see *all* rays would for that very reason see *nothing at all*), and the construction of our eye—which restricts sight to definite limits and even so does not give quite correct reproduction—as proof that the eye acquaints us incorrectly or unreliably with the nature of what is seen. What can be discovered by our thought is more evident from what it has already discovered and is every day still discovering. And that is already enough both as regards quantity and quality. On the other hand, the investigation of the *forms* of thought, the thought determinations, is very profitable and necessary, and since Aristotle this has been systematically undertaken only by Hegel.

In any case we shall never find out *how* chemical rays appear to ants. Anyone who is distressed by this is simply beyond help.

* * *

The form of development of natural science, in so far as it thinks, is the *hypothesis*. A new fact is observed which makes impossible the previous method of explaining the facts belonging to the same group. From this moment onwards new methods of explanation are required—at first based on only a limited number of facts and observations. Further observational material weeds out these hypotheses, doing away with some and correcting others, until finally the law is established in a pure form. If one should wait until the material for a law was *in a pure form*, it would mean suspending the process of thought in investigation until then and, if only for this reason, the law would never come into being.

The number and succession of hypotheses supplanting one another—given the lack of logical and dialectical education among natural scientists—easily gives rise to the idea that we cannot know the *essence* of things (Haller and Goethe).[189] This is not peculiar to natural science since all human knowledge develops in a much twisted curve; and in the historical sciences also, including philosophy, theories displace one another, from which, however, nobody concludes that formal logic, for instance, is nonsense.

The last form of this outlook is the "thing-in-itself" In the first place, this assertion that we cannot know the thing-in-itself (Hegel, *Enzyklopädie*, paragraph 44) passes out of the realm of science into that of fantasy. Secondly, it does not add a word to our scientific knowledge, for if we cannot occupy ourselves with things, they do not exist for us. And, thirdly, it is a mere phrase and is never applied. Taken in the abstract it sounds quite sensible. But suppose one applies it. What would one think of a zoologist who said: "A dog *seems* to have four legs, but we do not know whether in reality it has four million legs or none at all"? Or of a mathematician who first of all defines a triangle as having three sides, and then declares that he does not know whether it might not have 25? That 2×2 *seems* to be 4? But scientists take care not to apply the phrase about the thing-in-itself in natural science, they permit themselves this only in passing into philosophy. This is the best proof how little seriously they take it and what little value it has itself. If they did take it seriously, what would be the good of investigating anything?

Taken historically the thing would have a certain meaning: we can only know under the conditions of our epoch and *as far as these allow*.

* * *

The thing-in-itself: Hegel, *Logik*, II, p. 10, also later a whole section on it[190]:

"Scepticism did not dare to affirm '*it is*'; modern idealism (i.e., Kant and Fichte) did not dare to regard cognition as a knowledge of the thing-in-itself*.... But at the same time, scepticism admitted

* In the margin of the manuscript is the remark: "Cf. *Enzyklopädie*, I, p. 252."[191]—*Ed.*

manifold determinations of its show, or rather its show had for content all the manifold riches of the world. In the same manner the '*appearance*'* of idealism (i.e., what idealism calls appearance) comprehends the whole range of these manifold determinatenesses.... The content may then have no basis in any being nor in any thing nor thing-in-itself: *for itself it remains as it is*; *it has only been translated from being into show*."*

Hegel, therefore, is here a much more resolute materialist than the modern natural scientists.

* * *

Valuable self-criticism of the Kantian *thing-in-itself*, which shows that Kant suffers shipwreck also on the thinking ego and likewise discovers in it an unknowable thing-in-itself. (Hegel, V. p. 256 et seq.)[192]

* Italics by Engels.—*Ed.*

[Forms of Motion of Matter, Classification of the Sciences]

Causa finalis—matter and its inherent motion. This matter is *no abstraction*. Even in the sun the different substances are dissociated and without distinction in their action. But in the *gaseous sphere of the nebula* all substances, although separately present, *become merged in pure matter as such*, acting only as matter, not according to their specific properties.

(Moreover already in Hegel the antithesis of *causa efficiens* and *causa finalis* is sublated in reciprocal action.)

* * *

Primordial matter.

"The conception of matter as original and pre-existent, and as naturally formless, is a very ancient one; it meets us even among the Greeks, at first in the mythical shape of chaos, which is supposed to represent the unformed substratum of the existing world." (Hegel, *Enzyklopädie*, I, p. 258.)[193]

We find this chaos again in Laplace, and approximately in the nebula which also has only the *beginning* of form. Differentiation comes afterwards.

* * *

Gravity as *the most general determination of materiality* is commonly accepted. That is to say, attraction is a necessary property of matter, but not repulsion. But attraction and repulsion are as inseparable as positive and negative, and hence from dialectics itself it can already be predicted that the true theory of matter must assign as important a place to repulsion as to attraction, and that a theory of matter based on mere attraction is false, inadequate, and one-sided. In fact sufficient phenomena occur that demonstrate this in advance. If only on account of light, the ether is not to be dispensed with. Is the ether of material nature? If it *exists* at all, it must be of material nature, it must come under the concept of matter. But it is not affected by gravity. The tail of a comet is granted to be of material nature. It shows a powerful repulsion. Heat in a gas produces repulsion, etc.

* * *

Attraction and gravitation. The whole theory of gravitation rests on saying that attraction is the essence of matter. This is necessarily false. Where there is attraction, it must be complemented by repulsion. Hence already Hegel was quite right in saying that the essence of matter is attraction *and* repulsion.[194] And in fact we are more and more becoming forced to recognise that the dissipation of matter has a limit where attraction is transformed into repulsion, and conversely the condensation of the repelled matter has a limit where it becomes attraction.*

* * *

The transformation of attraction into repulsion and vice versa is mystical in Hegel, but in substance he anticipated by it the scientific discovery that came later. Even in a gas there is repulsion of the molecules, still more so in more finely-divided matter, for instance in the tail of a comet, where it even operates with enormous force. Hegel shows his genius even in the fact that he derives attraction as something secondary from repulsion as something preceding it: a solar system is only formed by the gradual preponderance of attraction over the originally prevailing repulsion.—Expansion by heat=repulsion. The kinetic theory of gases.

* * *

* Cf. also the note on "cohesion" (this volume, pp. 285-86.).—*Ed.*

The divisibility of matter. For science the question is in practice a matter of indifference. We know that in chemistry there is a definite limit to divisibility, beyond which bodies can no longer act chemically—the atom; and that several atoms are always in combination—the molecule. Ditto in physics we are driven to the acceptance of certain—for physical analysis—smallest particles, the arrangement of which determines the form and cohesion of bodies, their vibrations becoming evident as heat, etc. But whether the physical and chemical molecules are identical or different, we do not yet know.

Hegel very easily gets over this question of divisibility by saying that matter is both divisible and continuous, and at the same time neither of the two,[195] which is no answer but is now almost proved (see sheet 5,3 below: Clausius*).

* * *

Divisibility. The mammal is indivisible, the reptile can regrow a foot.—Ether waves, divisible and measurable to the infinitesimally small.—Every body divisible, in practice, within certain limits, e.g., in chemistry.

* * *

"Its essence (of motion) is to be the immediate unity of space and time... to motion belong space and time; velocity, the quantum of motion, is space in relation to a definite time that has elapsed." ([Hegel,] *Naturphilosophie*, S. 65.) "...Space and time are filled with matter.... Just as there is no motion without matter, so there is no matter without motion." (P. 67.)[196]

* * *

The indestructibility of motion in *Descartes*' principle that *the universe always contains the same quantity of motion*.[197] Natural scientists express this imperfectly as the "indestructibility of force". The merely quantitative expression of Descartes is likewise inadequate: motion as such, as essential activity, the mode of existence of matter,

* Engels is referring to the Note "Kinetic Theory of Gases", which is at the end of page 3 of the 5th double sheet of *Dialectics of Nature* (see this volume, p. 286).—*Ed.*

is indestructible as the latter itself, this formulation includes the quantitative element. So here again the philosopher has been confirmed by the natural scientist after 200 years.

* * *

The indestructibility of motion. A pretty passage in Grove —p. 20 et seq.[198]

* * *

Motion and equilibrium. Equilibrium is inseparable from motion.* In the motion of the heavenly bodies there is *motion in equilibrium* and *equilibrium in motion* (relative). But all specifically relative motion, i.e., here all separate motion of individual bodies on one of the heavenly bodies in motion, is an effort to establish relative rest, equilibrium. The possibility of bodies being at relative rest, the possibility of temporary states of equilibrium, is the essential condition for the differentiation of matter and hence for life. On the sun there is no equilibrium of the various substances, only of the mass as a whole, or at any rate only a very restricted one, determined by considerable differences of density; on the surface there is eternal motion and unrest, dissociation. On the moon, equilibrium appears to prevail exclusively, without any relative motion—death (moon=negativity). On the earth motion has become differentiated into interchange of motion and equilibrium: the individual motion strives towards equilibrium, the motion as a whole once more destroys the individual equilibrium. The rock comes to rest, but weathering, the action of the ocean surf, of rivers and glacier ice continually destroy the equilibrium. Evaporation and rain, wind, heat, electric and magnetic phenomena offer the same spectacle. Finally, in the living organism we see continual motion of all the smallest particles as well as of the larger organs, resulting in the continual equilibrium of the total organism during the normal period of life, which yet always remains in motion, the living unity of motion and equilibrium.

All equilibrium is only *relative* and *temporary.*

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* Note in the margin of the manuscript: "Equilibrium=predominance of attraction over repulsion."—*Ed.*

* * *

(1) Motion of the heavenly bodies. Approximate equilibrium of attraction and repulsion in motion.

(2) Motion on one heavenly body. Mass. In so far as this motion comes from pure mechanical causes, here also there is equilibrium. The masses are at rest on their foundation. On the moon this is apparently complete. Mechanical attraction has overcome mechanical repulsion. From the standpoint of pure mechanics, we do not know what has become of the repulsion, and pure mechanics just as little explains whence come the "forces", by which nevertheless masses on the earth, for example, are set in motion *against* gravity. It takes the fact for granted. Here therefore there is simple communication of repelling, displacing motion from mass to mass, with equality of attraction and repulsion.

(3) The overwhelming majority of all terrestrial motions, however, are made up of the conversion of one form of motion into another—mechanical motion into heat, electricity, chemical motion—and of each form into any other; hence either* the transformation of attraction into repulsion—mechanical motion into heat, electricity, chemical decomposition (the transformation is the conversion of the original *lifting* mechanical motion into heat, not of the *falling* motion, which is only the semblance) [—or transformation of repulsion into attraction].

(4) All energy now active on the earth is transformed heat from the sun.[199]

* * *

Mechanical motion. Among natural scientists motion is always as a matter of course taken to mean mechanical motion, change of place. This has been handed down from the pre-chemical eighteenth century and makes a clear conception of the processes much more difficult. Motion, as applied to matter, is *change in general*. From the same

* This "either" is not followed by "or". Engels probably intended to mention, at the end of the sentence, the reverse transformation of repulsion into attraction, but did not do so. The presumable ending of the sentence is given in brackets.—*Ed.*

misunderstanding is derived also the craze to reduce everything to mechanical motion—even Grove is

> "strongly inclined to believe that the other affections of matter ... are, and will ultimately be resolved into, modes of motion", p. 16[200]—

which obliterates the specific character of the other forms of motion. This is not to say that each of the higher forms of motion is not always necessarily connected with some real mechanical (external or molecular) motion, just as the higher forms of motion simultaneously also produce other forms, and just as chemical action is not possible without change of temperature and electric changes, organic life without mechanical, molecular, chemical, thermal, electric, etc., changes. But the presence of these subsidiary forms does not exhaust the essence of the main form in each case. One day we shall certainly "reduce" thought experimentally to molecular and chemical motions in the brain; but does that exhaust the essence of thought?

* * *

Dialectics of natural science[201]: Subject-matter—matter in motion. The different forms and varieties of matter itself can likewise only be known through motion, only in this are the properties of bodies exhibited; of a body that does not move there is nothing to be said. Hence the nature of bodies in motion results from the forms of motion.

1. The first, simplest form of motion is the mechanical form, pure change of place:

(a) Motion of a single body does not exist—[it can be spoken of]* only in a relative sense—falling.

(b) The motion of separated bodies: trajectory, astronomy—apparent equilibrium—the end always *contact*.

(c) The motion of bodies in contact in relation to one another—pressure. Statics. Hydrostatics and gases. The lever and other forms of mechanics proper—which all in their simplest form of contact amount to friction or impact,

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* The words in brackets have been taken from Engels's letter to Marx, May 30, 1873.—*Ed.*

which are different only in degree. But friction and impact, in fact contact, have also other consequences never pointed out here by natural scientists: they produce, according to circumstances, sound, heat, light, electricity, magnetism.

2. These different forces (with the exception of sound)—physics of heavenly bodies—

(a) pass into one another and mutually replace one another, and

(b) on a certain quantitative development of each force, different for each body, applied to the bodies, whether they are chemically compound or several chemically simple bodies, *chemical* changes take place, and we enter the realm of chemistry. Chemistry of heavenly bodies. Crystallography—part of chemistry.

3. Physics had to leave out of consideration the living organic body, or could do so; chemistry finds only in the investigation of organic compounds the real key to the true nature of the most important bodies, and, on the other hand, it synthesises bodies which only occur in organic nature. Here chemistry leads to organic life, and it has gone far enough to assure us that *it alone* will explain to us the dialectical transition to the organism.

4. The *real* transition, however, is in *history*—of the solar system, the earth; the *real* pre-condition for organic nature.

5. Organic nature.

* * *

Classification of the sciences, each of which analyses a single form of motion, or a series of forms of motion that belong together and pass into one another, is therefore the classification, the arrangement, of these forms of motion themselves according to their inherent sequence, and herein lies its importance.

At the end of the last [18th] century, after the French materialists, who were predominantly mechanical, the need became evident for an *encyclopædic summing up* of the entire natural science of the *old* Newton-Linnaeus school, and two men of the greatest genius undertook this, *Saint-Simon* (uncompleted) and *Hegel*. Today, when the new outlook on nature is complete in its basic features, the same need makes itself felt, and attempts are being made in this direction. But since the general evolutionary connection in nature has now been demonstrated, an external side by side arrangement is as inadequate as Hegel's artificially constructed dialectical transitions. The transitions must make themselves, they must be natural. Just as one form of motion develops out of another, so their reflections, the various sciences, must arise necessarily out of one another.

* * *

How little Comte can have been the author of his encyclopædic arrangement of the natural sciences,[202] which he copied from Saint-Simon, is already evident from the fact that it only serves him for the purpose of *arranging the means of instruction* and *course of instruction*, and so leads to the crazy *enseignement intégral*, where one science is always exhausted before another is even broached, where a basically correct idea is pushed to a mathematical absurdity.

* * *

Hegel's division (the original one) into mechanics, chemics, and organics,[203] fully adequate for the time. Mechanics: the movement of masses. Chemics: molecular (for physics is also included in this and, indeed, both—physics as well as chemistry—belong to the same order) motion and atomic motion. Organics: the motion of bodies in which the two are inseparable. For the organism is certainly *the higher unity which within itself unites mechanics, physics, and chemistry into a whole* where the trinity can no longer be separated. In the organism, mechanical motion is effected directly by physical and chemical change, in the form of nutrition, respiration, secretion, etc., just as much as pure muscular movement.

Each group in turn is twofold. Mechanics: (1) celestial, (2) terrestrial.

Molecular motion: (1) physics, (2) chemistry.

Organics: (1) plant, (2) animal.

* * *

Physiography. After the transition from chemistry to life has been made, then in the first place it is necessary to analyse the conditions in which life has been produced and continues to exist, i.e., first of all geology, meteorology, and the rest. Then the various forms of life themselves, which indeed without this are incomprehensible.

* * *

On the "Mechanical" Conception of Nature[204]

Re page 46:* The Various Forms of Motion and the Sciences Dealing with Them

Since the above article appeared (*Vorwärts*, Feb. 9, 1877),** Kekulé (*Die wissenschaftlichen Ziele und Leistungen der Chemie*) has defined mechanics, physics, and chemistry in a quite similar way:

> "If this idea of the nature of matter is made the basis, one could define chemistry as *the science of atoms* and physics as *the science of molecules*, and then it would be natural to separate that part of modern physics which deals with *masses* as a special science, reserving for it the name of *mechanics*. Thus mechanics appears as the basic science of physics and chemistry, in so far as in certain aspects and especially in certain calculations both of these have to treat their molecules or atoms as masses."[205]

It will be seen that this formulation differs from that in the text and in the previous note*** only by being rather less definite. But when an English journal (*Nature*) put the above statement of Kekulé in the form that mechanics is the statics and dynamics of masses, physics the statics and dynamics of molecules, and chemistry the statics and dynamics of atoms,[206] then it seems to me that this

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* F. Engels, *Anti-Dühring*, Moscow, 1962, p. 95.

** Engels is referring to Chapter VII of *Anti-Dühring*.—*Ed.*

*** i.e., in the text of *Anti-Dühring* and in the Note "On the Prototypes of the Mathematical Infinite in the Real World" (see *Anti-Dühring*, Moscow, 1962, p. 95, and pp. 266-72 of this volume).—*Ed.*

unconditional reduction of even chemical processes to merely mechanical ones unduly restricts the field, at least of chemistry. And yet it is so much the fashion that, for instance, Hæckel continually uses "mechanical" and "monistic" as having the same meaning, and in his opinion

> "modern physiology ... in its field allows only of the operation of physico-chemical—or *in the wider sense*,* mechanical—forces". (*Perigenesis*.)[207]

If I term physics the mechanics of molecules, chemistry the physics of atoms, and furthermore biology the chemistry of proteins, I wish thereby to express the passing of each of these sciences into another, hence both the connection, the continuity, and the distinction, the discrete separation, between the two of them. To go further and to define chemistry as likewise a kind of mechanics seems to me inadmissible. Mechanics—in the wider or narrower sense—knows only quantities, it calculates with velocities and masses, and at most with volumes. Where the quality of bodies comes across its path, as in hydrostatics and aerostatics, it cannot achieve anything without going into molecular states and molecular motions, it is itself only an auxiliary science, the prerequisite for physics. In physics, however, and still more in chemistry, not only does continual qualitative change take place in consequence of quantitative change, the transformation of quantity into quality, but there are also many qualitative changes to be taken into account whose dependence on quantitative change is by no means proven. That the present tendency of science goes in this direction can be readily granted, but does not prove that this direction is the exclusively correct one, that the pursuit of this tendency will *exhaust* the whole of physics and chemistry. All motion includes mechanical motion, change of place of the largest or smallest portions of matter, and the *first* task of science, but only the *first*, is to obtain knowledge of this motion. But this mechanical motion does not exhaust motion as a whole. Motion is not merely change of place, in fields higher than mechanics it is also change of quality. The discovery that heat is a

* Italics by Engels.—*Ed.*

molecular motion was epoch-making. But if I have nothing more to say of heat than that it is a certain displacement of molecules, I should best be silent. Chemistry seems to be well on the way to explaining a number of chemical and physical properties of elements from the ratio of the atomic volumes to the atomic weights. But no chemist would assert that all the properties of an element are exhaustively expressed by its position in the Lothar Meyer curve,[208] that it will ever be possible by this alone to explain, for instance, the peculiar constitution of carbon that makes it the essential bearer of organic life, or the necessity for phosphorus in the brain. Yet the "mechanical" conception amounts to nothing else. It explains all change from change of place, all qualitative differences from quantitative ones, and overlooks that the relation of quality and quantity is reciprocal, that quality can become transformed into quantity just as much as quantity into quality, that, in fact, reciprocal action takes place. If all differences and changes of quality are to be reduced to quantitative differences and changes, to mechanical displacement, then we inevitably arrive at the proposition that all matter consists of *identical* smallest particles, and that all qualitative differences of the chemical elements of matter are caused by quantitative differences in number and by the spatial grouping of those smallest particles to form atoms. But we have not got so far yet.

It is our modern natural scientists' lack of acquaintance with any other philosophy than the most mediocre vulgar philosophy, like that now rampant in the German universities, which allows them to use expressions like "mechanical" in this way, without taking into account, or even suspecting, the consequences with which they thereby necessarily burden themselves. The theory of the absolute qualitative identity of matter has its supporters—empirically it is equally impossible to refute it or to prove it. But if one asks these people who want to explain everything "mechanically" whether they are conscious of this consequence and accept the identity of matter, what a variety of answers will be heard!

The most comical part about it is that to make "materialist" equivalent to "mechanical" derives from *Hegel*, who wanted to throw contempt on materialism by the addition "mechanical". Now the materialism criticised by Hegel—the French materialism of the eighteenth century—was in fact exclusively *mechanical*, and indeed for the very natural reason that at that time physics, chemistry, and biology were still in their infancy, and were very far from being able to offer the basis for a general outlook on nature. Similarly Hæckel takes from Hegel the translation: *causae efficientes*="mechanically acting causes", and *causae finales*="purposively acting causes"; where Hegel, therefore, puts "mechanical" as equivalent to blindly acting, unconsciously acting, and not as equivalent to mechanical in Hæckel's sense of the word. But this whole antithesis is for Hegel himself so much a superseded standpoint that he *does not even mention* it in either of his two expositions of causality in his *Logic*—but only in his *History of Philosophy*, in the place where it comes historically (hence a sheer misunderstanding on Hæckel's part due to superficiality!) and quite incidentally in dealing with teleology (*Logik*, III, II, 3) where he mentions it as the form in which the *old metaphysics* conceived the antithesis of mechanism and teleology, but otherwise treating it as a long superseded standpoint. Hence Hæckel copied incorrectly in his joy at finding a confirmation of his "mechanical" conception and so arrived at the beautiful result that if a particular change is produced in an animal or plant by natural selection it has been effected by a *causa efficiens*, but if the same change arises by *artificial* selection then it has been effected by a *causa finalis*! The breeder a *causa finalis*! Of course a dialectician of Hegel's calibre could not be caught in the vicious circle of the narrow antithesis of *causa efficiens* and *causa finalis*. And for the modern standpoint the whole hopeless rubbish about this antithesis is put an end to because we *know* from experience and from theory that both matter and its mode of existence, motion, are uncreatable and are, therefore, their own final cause; while to give the name *effective* causes to the individual causes which momentarily and locally become isolated in the mutual interaction of the motion of the universe, or which are isolated by our reflecting mind, adds absolutely no new determination but only a confusing element. A cause that is not effective is no cause.

N. B. Matter as such is a pure creation of thought and an abstraction. We leave out of account the qualitative differences of things in lumping them together as corporeally existing things under the concept matter. Hence matter as such, as distinct from definite existing pieces of matter, is not anything sensuously existing. When natural science directs its efforts to seeking out uniform matter as such, to reducing qualitative differences to merely quantitative differences in combining identical smallest particles, it is doing the same thing as demanding to see fruit as such instead of cherries, pears, apples, or the mammal as such[209] instead of cats, dogs, sheep, etc., gas as such, metal, stone, chemical compound as such, motion as such. The Darwinian theory demands such a primordial mammal, Hæckel's pro-mammal,[210] but, at the same time, it has to admit that if this pro-mammal contained within itself in *germ* all future and existing mammals, it was in reality lower in rank than all existing mammals and primitively crude, hence more transitory than any of them. As Hegel has already shown (*Enzyklopädie,* I, S. 199), this view, this "one-sided mathematical view", according to which matter must be looked upon as having only quantitative determination, but, qualitatively, as identical originally, is "no other standpoint than that" of the French materialism of the eighteenth century.[211] It is even a retreat to Pythagoras, who regarded number, quantitative determination as the essence of things.

* * *

In the first place, Kekulé.[212] Then: the systematising of natural science, which is now becoming more and more necessary, cannot be found in any other way than in the inter-connections of phenomena themselves. Thus the mechanical motion of small masses on any heavenly body ends in the contact of two bodies, which has two forms, differing only in degree, viz., friction and impact. So we investigate first of all the mechanical effect of friction and impact. But we find that the effect is not thereby exhausted: friction produces heat, light, and electricity, impact produces heat and light if not electricity also—hence conversion of motion of masses into molecular motion. We enter the realm of molecular motion, physics, and investigate further. But here too we find that molecular motion does not represent the conclusion of the investigation. Electricity passes into and arises from chemical transformation. Heat and light, ditto. Molecular motion becomes transformed into motion of atoms—chemistry. The investigation of chemical processes is confronted by the organic world as a field for research, that is to say, a world in which chemical processes take place, although under different conditions, according to the same laws as in the inorganic world, for the explanation of which chemistry suffices. In the organic world, on the other hand, all chemical investigations lead back in the last resort to a body—protein—which, while being the result of ordinary chemical processes, is distinguished from all others by being a self-acting, permanent chemical process. If chemistry succeeds in preparing this protein, in the specific form in which it obviously arose, that of a so-called protoplasm, a specificity, or rather absence of specificity, such that it contains potentially within itself all other forms of protein (though it is not necessary to assume that there is only one kind of protoplasm), then the dialectical transition will have been proved in reality, hence completely proved. Until then, it remains a matter of thought, alias of hypothesis. When chemistry produces protein, the chemical process will reach out beyond itself, as in the case of the mechanical process above, that is, it will come into a more comprehensive realm, that of the organism. Physiology is, of course, the physics and especially the chemistry of the living body, but with that it ceases to be specially chemistry: on the one hand its domain becomes restricted but, on the other hand, inside this domain it becomes raised to a higher power.

[Mathematics]

* * *

The so-called axioms of mathematics are the few thought determinations which mathematics needs for its point of departure. Mathematics is the science of magnitudes; its point of departure is the concept of magnitude. It defines this lamely and then adds the other elementary determinations of magnitude, not contained in the definition, from outside as axioms, so that they appear as unproved, and naturally also as *mathematically* unprovable. The analysis of magnitude would yield all these axiom determinations as necessary determinations of magnitude. Spencer is right in as much as what thus appears to us to be the *self-evidence* of these axioms is *inherited*. They are provable dialectically, in so far as they are not pure tautologies.

* * *

Mathematics. Nothing appears more solidly based than the difference between the four species of arithmetical operations, the elements of all mathematics. Yet right at the outset multiplication is seen to be an abbreviated addition, and division an abbreviated subtraction, of a definite number of equal numerical magnitudes; and in one case—when the divisor is a fraction—division is even carried out by multiplying by the inverted fraction. In algebraic calculation the thing is carried much further. Every subtraction $(a-b)$ can be represented as an addition $(-b+a)$, every division $\frac{a}{b}$ as a multiplication $a\times\frac{1}{b}$. In calculations with powers of magnitudes one goes much further still. All rigid differences between the kinds of calculation

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disappear, everything can be presented in the opposite form. A power can be put as a root $\left(x^2=\sqrt{x^4}\right)$, a root as a power $\left(\sqrt{x}=x^{\frac{1}{2}}\right)$. Unity divided by a power or root can be put as a power of the denominator $\left(\frac{1}{\sqrt{x}}=x^{-\frac{1}{2}};\ \frac{1}{x^3}=x^{-3}\right)$. Multiplication or division of the powers of a magnitude becomes converted into addition or subtraction of their exponents. Any number can be conceived and expressed as the power of any other number (logarithms, $y=a^x$). And this transformation of one form into the opposite one is no idle trifling, it is one of the most powerful levers of mathematical science, without which today hardly any of the more difficult calculations are carried out. If negative and fractional powers alone were abolished from mathematics, how far could one get?

($-\cdot-=+$, $\frac{-}{-}=+$, $\sqrt{-1}$, etc., to be expounded earlier.)

The turning point in mathematics was Descartes' *variable magnitude*. With that came *motion* and hence *dialectics* in mathematics, and *at once, too, of necessity the differential and integral calculus*, which moreover immediately begins, and which on the whole was completed by Newton and Leibniz, not discovered by them.

* * *

Quantity and quality. Number is the purest quantitative determination that we know. But it is chock-full of qualitative differences. 1. Hegel, number and unity, multiplication, division, raising to a higher power, extraction of roots. Thereby, and this is not shown in Hegel, qualitative differences already make their appearance: prime numbers and products, simple roots and powers. 16 is not merely the sum of 16 ones, it is also the square of 4, the fourth power of 2. Still more. Prime numbers communicate new, definitely determined qualities to numbers derived from them by multiplication with other numbers; only even numbers are divisible by 2, and there is a similar determination in the case of 4 and 8. For 3 there is the rule of the sum of the figures, and the same thing for 9 and also for

6, in the last case in combination with the even number. For 7 there is a special rule. These form the basis for tricks with numbers which seem incomprehensible to the uninitiated. Hence what Hegel says (*Quantity*, p. 237) on the absence of thought in arithmetic is incorrect. Compare, however, *Measure*.[213]

When mathematics speaks of the infinitely large and infinitely small, it introduces a qualitative difference which even takes the form of an unbridgeable qualitative opposition: quantities so enormously different from one another that every rational relation, every comparison, between them ceases, that they become quantitatively incommensurable. Ordinary incommensurability, for instance of the circle and the straight line, is also a dialectical qualitative difference; but here* it is the difference in *quantity* of *similar* magnitudes that increases the difference of *quality* to the point of incommensurability.

* * *

Number. The individual number becomes endowed with quality already in the numerical system itself, and the quality depends on the system used. 9 is not only 1 added together 9 times, but also the basis for 90, 99, 900,000, etc. All numerical laws depend upon and are determined by the system adopted. In dyadic and triadic systems 2 multiplied by 2 does not equal 4, but=100 or=11. In all systems with an odd basic number, the difference between odd and even numbers falls to the ground, e.g., in the system based on 5, 5=10, 10=20, 15=30. Likewise in the same system the sums of digits $3n$ of products of 3 or 9 (6=11, 9=14). Hence the basic number determines not only its own quality but also that of all the other numbers.

With powers of numbers, the matter goes still further: any number can be conceived as the power of any other number—there are as many logarithmic systems as there are whole and fractional numbers.

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* i.e., in the mathematics of the infinite.—*Ed.*

One. Nothing looks simpler than quantitative unity, and nothing is more manifold than it, as soon as we investigate it in connection with the corresponding plurality and according to its various modes of origin from plurality. First of all, one is the basic number of the whole positive and negative system of numbers, all other numbers arising by the successive addition of one to itself.

One is the expression of all positive, negative, and fractional powers of one: 1^2, $\sqrt{1}$, 1^{-2} are all equal to one.

It is the content of all fractions in which the numerator and denominator prove to be equal. It is the expression of every number that is raised to the power of zero, and therewith the sole number the logarithm of which is the same in all systems, viz.,$=0$. Thus one is the boundary that divides all possible systems of logarithms into two parts: if the base is greater than one, then the logarithms of all numbers more than one are positive, and of all numbers less than one negative; if it is smaller than one, the reverse is the case.

Hence, if every number contains unity in itself in as much as it is compounded entirely of ones added together, unity likewise contains all other numbers in itself. This is not only a possibility, in as much as we can construct any number solely of ones, but also a reality, in as much as one is a definite power of every other number. But the very same mathematicians who, without turning a hair, interpolate into their calculations, wherever it suits them, $x^0=1$, or a fraction whose numerator and denominator are equal and which therefore likewise represents one, who therefore apply mathematically the plurality contained in unity, turn up their noses and grimace if they are told in general terms that unity and plurality are inseparable, mutually penetrating concepts and that plurality is not less contained in unity than unity is in plurality. How much this is the case we see as soon as we forsake the field of pure numbers. Already in the measurement of lines, surfaces, and the volumes of bodies it becomes apparent that we can take any desired magnitude of the appropriate order as unity, and the same thing holds for measurement of time, weight, motion, etc. For the measurement of cells even millimetres and milligrams are too large, for the measurement of stellar distances or the velocity of light even the kilometre is uncomfortably small, just as the kilogram for planetary or, even more so, solar masses. Here is seen very clearly what diversity and multiplicity is contained in the concept of unity, at first sight so simple.

* * *

Zero, because it is the negation of any definite quantity, is not therefore devoid of content. On the contrary, zero has a very definite content. As the border-line between all positive and negative magnitudes, as the sole really neutral number, which can be neither positive nor negative, it is not only a very definite number, but also in itself more important than all other numbers bounded by it. In fact, zero is richer in content than any other number. Put on the right of any other number, it gives to the latter, in our system of numbers, the tenfold value. Instead of zero one could use here any other sign, but only on the condition that this sign taken by itself signifies zero, $=0$. Hence it is part of the nature of zero itself that it finds this application and that it alone *can* be applied in this way. Zero annihilates every other number with which it is multiplied; united with any other number as divisor or dividend, in the former case it makes this infinitely large, in the latter infinitely small; it is the only number that stands in a relation of infinity to every other number. $\frac{0}{0}$ can express every number between $-\infty$ and $+\infty$, and in each case represents a real magnitude.

The real content of an equation first clearly emerges when all its members have been brought to *one* side, and the equation is thus reduced to zero value, as already happens for quadratic equations, and is almost the general rule in higher algebra. The function $F(x, y)=0$ can then also be put equal to z, and this z, although it is $=0$, differentiated like an ordinary dependent variable and its partial derivative determined.

The nothing of every quantity, however, is itself quantitatively determined, and only on that account is it possible to calculate with zero. The very same mathematicians who are quite unembarrassed in reckoning with zero in the above manner, i.e., in operating with it as a definite quantitative concept, bringing it into quantitative relation to other quantitative concepts, clutch their heads in desperation when they read this in Hegel generalised as: the nothing of a something is a *determinate* nothing.*

But now for (analytical) geometry. Here zero is a definite point from which measurements are taken along a line, in one direction positively, in the other negatively. Here, therefore, the zero point has not only just as much significance as any point denoted by a positive or negative magnitude, but a much greater significance than all of them: it is the point on which they are all dependent, to which they are all related, and by which they are all determined. In many cases it can even be taken quite arbitrarily. But once adopted, it remains the central point of the whole operation, often determining even the direction of the line along which the other points—the end points of the abscissæ—are to be inserted. If, for example, in order to arrive at the equation of the circle, we choose any point of the periphery as the zero point, then the line of the abscissæ must go through the centre of the circle. All this finds just as much application in mechanics, where likewise in the calculation of the motions the point taken as zero in each case forms the main point and pivot for the entire operation. The zero point of the thermometer is the very definite lower limit of the temperature section that is divided into any desired number of degrees, thereby serving as a measure both for temperature stages within the section as also for higher or lower temperatures. Hence in this case also it is a very essential point. And even the absolute zero of the thermometer in no way represents pure abstract negation, but a very definite state of matter: the limit at which the last trace of independent molecular motion vanishes and matter acts only as mass. Wherever we come upon zero, it represents something very definite, and its practical application in geometry, mechanics, etc., proves that—as limit—it is more important than all the real magnitudes bounded by it.

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* See this volume, p. 221.—*Ed.*

Zero powers. Of importance in the logarithmic series: $\overset{0}{10^0}\ \overset{1}{10^1}\ \overset{2}{10^2}\ \overset{3\,\log.}{10^3}$. All variables pass somewhere through unity; hence also a constant raised to a variable power $(a^x) = 1$, if $x=0$. $a^0=1$ means nothing more than conceiving unity in its connection with the other members of the series of powers of a, only there has it any meaning and can lead to results $\left(\sum x^0 = \frac{x}{\omega}\right)$[214], otherwise not at all. From this it follows that unity also, however much it may appear identical with itself, includes within it an infinite manifoldness, since it can be the zero power of any other possible number, and that this manifoldness is not merely imaginary is proved on each occasion where unity is conceived as a determined unity, as one of the variable results of a process (as a momentary magnitude or form of a variable) in connection with this process.

* * *

$\sqrt{-1}$. The negative magnitudes of algebra are real only in so far as they are connected with positive magnitudes and only within the relation to the latter; outside this relation, taken by themselves, they are purely imaginary. In trigonometry and analytical geometry, together with the branches of higher mathematics of which these are the basis, they express a definite direction of motion, opposite to the positive direction. But the sine and tangent of the circle can be reckoned from the upper right-hand quadrant just as well as from the lower right-hand quadrant, thus directly reversing plus and minus. Similarly, in analytical geometry, abscissæ can be calculated from the periphery or from the centre of the circle, indeed in all curves they can be reckoned from the curve in the direction usually denoted as minus, [or] in any desired direction, and still give a correct rational equation of the curve. Here plus exists only as the complement of minus, and vice versa. But algebraic abstraction treats them [negative magnitudes] as real and independent, even outside the relation to a *larger*, positive magnitude.

* * *

Mathematics. To common sense it appears an absurdity to resolve a definite magnitude, e.g., a binomial expression, into an infinite series, that is, into something indefinite. But where would we be without infinite series and the binomial theorem?

* * *

Asymptotes. Geometry begins with the discovery that straight and curved are absolute opposites, that straight is absolutely inexpressible in curved, and curved in straight, that the two are incommensurable. Yet even the calculation of the circle is only possible by expressing its periphery in straight lines. For curves with asymptotes, however, straight becomes completely merged in curved, and curved in straight, just as much as the notion of parallelism: the lines are not parallel, they continually approach one another and yet never meet; the arm of the curve becomes more and more straight, without ever becoming entirely so, just as in analytical geometry the straight line is regarded as a curve of the first order with an infinitely small curvature. However large the x of the logarithmic curve may become, y can never$=0$.

* * *

Straight and curved in the differential calculus are in the last resort put as equal: in the differential triangle, the hypotenuse of which forms the differential of the arc (in the tangent method), this hypotenuse can be regarded

> "as a small, quite straight line which is at the same time the element of the arc and that of the tangent"—no matter whether the curve is regarded as composed of an infinite number of straight lines, or also, "whether one considers it as a strict curve; since the curvature at each point M is infinitely small, the last ratio of the element of the curve to that of the tangent *is evidently a ratio of equality*".*

Here, therefore, although the ratio continually *approaches* equality, but *asymptotically* in accordance with

* Italics by Engels.—*Ed.*

the nature of the curve, yet, since the contact is limited to a single *point* which has no length, it is finally assumed that equality of straight and curved has been reached. (Bossut, *Calcul différentiel et intégral*, Paris, An VI, I, p. 149.)[215] In polar curves[216] the differential imaginary abscissæ are even taken as parallel to the real abscissæ and operations based on this, although both meet at the pole; indeed, from it is deduced the similarity of two triangles, one of which has an angle precisely at the point of intersection of the two lines, the parallelism of which is the whole basis of the similarity! (Fig. 17.)[217]

When the mathematics of straight and curved lines has thus pretty well reached exhaustion a new almost infinite field is opened up by the mathematics that *conceives curved as straight* (the differential triangle) and *straight as curved* (curve of the first order with infinitely small curvature). O metaphysics!

• • •

Trigonometry. After synthetic geometry has exhausted the properties of a triangle, regarded as such, and has nothing new to say, a more extensive horizon is opened up by a very simple, thoroughly dialectical procedure. The triangle is no longer considered in and for itself but in connection with another figure, the circle. Every right-angled triangle can be regarded as belonging to a circle: if the hypotenuse $=r$, then the sides enclosing the right angle are sin and cos; if one of these sides $=r$, then the other $=$tan, the hypotenuse $=$sec. In this way the sides and angles are given quite different, definite relationships which without this relation of the triangle to the circle would be impossible to discover and use, and quite a new theory of the triangle arises, far surpassing the old and universally applicable, because every triangle can be resolved into two right-angled triangles. This development of trigonometry from synthetic geometry is a good example of dialectics, of the way in which it comprehends things in their interconnection instead of in isolation.

• • •

Identity and difference—the dialectical relation is already seen in the differential calculus, where dx is infinitely small, but yet is effective and does everything.

* * *

Molecule and differential. Wiedemann (III, p. 636)[218] puts *finite* and *molecular* distances as directly opposed to one another.

* * *

On the Prototypes of the Mathematical Infinite in the Real World[219]

Re pp. 17-18.* Concordance of Thought and Being.—The Infinite in Mathematics

The fact that our subjective thought and the objective world are subject to the same laws, and hence, too, that in the final analysis they cannot contradict each other in their results, but must coincide, governs absolutely our whole theoretical thought. It is the unconscious and unconditional premise for theoretical thought. Eighteenth-century materialism, owing to its essentially metaphysical character, investigated this premise only as regards content. It restricted itself to the proof that the content of all thought and knowledge must derive from sensuous experience, and revived the principle: *nihil est in intellectu, quod non fuerit in sensu.*[220] It was modern idealistic, but at the same time dialectical, philosophy, and especially Hegel, which for the first time investigated it also as regards *form*. In spite of all the innumerable arbitrary constructions and fantasies that we encounter here, in spite of the idealist, topsy-turvy form of its result—the unity of thought and being—it is undeniable that this philosophy proved the analogy of the processes of thought to those of nature and history and vice versa, and the validity of similar laws for all these processes, in numerous cases and in the most diverse fields. On the other hand, modern natural science has extended the principle of the origin of all thought content from ex-

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* See *Anti-Dühring*, Moscow, 1962, p. 55.—*Ed.*

perience in a way that breaks down its old metaphysical limitation and formulation. By recognising the inheritance of acquired characters, it extends the subject of experience from the individual to the genus; the single individual that must have experience is no longer necessary, its individual experience can be replaced to a certain extent by the results of the experiences of a number of its ancestors. If, for instance, among us the mathematical axioms seem self-evident to every eight-year-old child, and in no need of proof from experience, this is solely the result of "accumulated inheritance". It would be difficult to teach them by a proof to a bushman or Australian Negro.

In the present work* dialectics is conceived as the science of the most general laws of *all* motion. This implies that its laws must be valid just as much for motion in nature and human history as for the motion of thought. Such a law can be recognised in two of these three spheres, indeed even in all three, without the metaphysical philistine being clearly aware that it is one and the same law that he has come to know.

Let us take an example. Of all theoretical advances there is surely none that ranks so high as a triumph of the human mind as the discovery of the infinitesimal calculus in the last half of the seventeenth century. If anywhere, it is here that we have a pure and exclusive feat of human intelligence. The mystery which even today surrounds the magnitudes employed in the infinitesimal calculus, the differentials and infinites of various degrees, is the best proof that it is still imagined that what are dealt with here are pure "free creations and imaginations"** of the human mind, to which there is nothing corresponding in the objective world. Yet the contrary is the case Nature offers prototypes for all these imaginary magnitudes.

Our geometry takes as its starting-point space relations, and our arithmetic and algebra numerical magnitudes, which correspond to our terrestrial conditions, which there-

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* i.e., in *Anti-Dühring* (see *Anti-Dühring*, Moscow, 1962, p. 194). —*Ed.*

** Ibid., p. 57.—*Ed.*

fore correspond to the magnitude of bodies that mechanics terms masses—masses such as occur on earth and are moved by men. In comparison with these masses, the mass of the earth seems infinitely large and indeed terrestrial mechanics treats it as infinitely large. The radius of the earth$=\infty$, this is the basic principle of all mechanics in the law of falling. But not merely the earth but the whole solar system and the distances occurring in the latter in their turn appear infinitely small as soon as we have to deal with the distances reckoned in light years in the stellar system visible to us through the telescope. We have here, therefore, already an infinity, not only of the first but of the second degree, and we can leave it to the imagination of our readers to construct further infinities of a higher degree in infinite space, if they feel inclined to do so.

According to the view prevailing in physics and chemistry today, however, the terrestrial masses, the bodies with which mechanics operates, consist of molecules, of smallest particles which cannot be further divided without abolishing the physical and chemical identity of the body concerned. According to W. Thomson's calculations, the diameter of the smallest of these molecules cannot be smaller than a fifty-millionth of a millimetre.[221] But even if we assume that the largest molecule itself attains a diameter of a twenty-five-millionth of a millimetre, it still remains an infinitesimally small magnitude compared with the smallest mass dealt with by mechanics, physics, or even chemistry. Nevertheless, it is endowed with all the properties peculiar to the mass in question, it can represent the mass physically and chemically, and does actually represent it in all chemical equations. In short, it has the same properties in relation to the corresponding mass as the mathematical differential has in relation to its variables. The only difference is that what seems mysterious and inexplicable to us in the case of the differential, in the mathematical abstraction, here seems a matter of course and as it were obvious.

Nature operates with these differentials, the molecules, in exactly the same way and according to the same laws as mathematics does with its abstract differentials. Thus, for instance, the differential of $x^3=3x^2dx$, where $3xdx^2$

and dx^3 are neglected. If we put this in geometrical form, we have a cube with sides of length x, the length being increased by the infinitely small amount dx. Let us suppose that this cube consists of a sublimated element, say sulphur; and that three of the surfaces around one corner are protected, the other three being free. Let us now expose this sulphur cube to an atmosphere of sulphur vapour and lower the temperature sufficiently; sulphur will be deposited on the three free sides of the cube. We remain quite within the ordinary mode of procedure of physics and chemistry in supposing, in order to picture the process in its pure form, that in the first place a layer of the thickness of a single molecule is deposited on each of these three sides. The length x of the sides of the cube has increased by the diameter of a molecule dx. The content of the cube x^3 has increased by the difference between x^3 and x^3+3x^2dx+ $+3xdx^2+dx^3$, where dx^3, a *single* molecule, and $3xdx^2$, three rows of length $x+dx$, consisting simply of lineally arranged molecules, can be neglected with the same justification as in mathematics. The result is the same, the increase in mass of the cube is $3x^2dx$.

Strictly speaking dx^3 and $3xdx^2$ do not occur in the case of the sulphur cube, because two or three molecules cannot occupy the same space, and the cube's increase of bulk is therefore exactly $3x^2dx+3xdx+dx$. This is explained by the fact that in mathematics dx is a linear magnitude, while it is well known that such lines, without thickness or breadth, do not occur independently in nature, hence also the mathematical abstractions have unrestricted validity only in pure mathematics. And since the latter neglects $3xdx^2+dx^3$, it makes no difference.

Similarly in evaporation. When the uppermost molecular layer in a glass of water evaporates, the height of the water layer, x, is decreased by dx, and the continual flight of one molecular layer after another is actually a continued differentiation. And when the hot vapour is once more condensed to water in a vessel by pressure and cooling, and one molecular layer is deposited on another (it is permissible to leave out of account secondary circumstances that make the process an impure one) until the vessel is full, then literally an integration has been performed which differs from the mathematical one only in that the one is consciously carried out by the human brain, while the other is unconsciously carried out by nature.

But it is not only in the transition from the liquid to the gaseous state and vice versa that processes occur which are completely analogous to those of the infinitesimal calculus. When mass motion, as such, is abolished—by impact—and becomes transformed into heat, molecular motion, what is it that happens but that the mass motion is differentiated? And when the movements of the molecules of steam in the cylinder of the steam-engine become added together so that they lift the piston by a definite amount, so that they become transformed into mass motion, have they not been integrated? Chemistry dissociates molecules into atoms, magnitudes of lesser mass and spatial extension, but magnitudes of the same order, so that the two stand in definite, finite relations to one another. Hence, all the chemical equations which express the molecular composition of bodies are in their form differential equations. But in reality they are already integrated owing to the atomic weights which figure in them. For chemistry calculates with differentials, the mutual relation of the magnitudes of which is known.

Atoms, however, are in no wise regarded as simple, or in general as the smallest known particles of matter. Apart from chemistry itself, which is more and more inclining to the view that atoms are compound, the majority of physicists assert that the universal ether, which transmits light and heat radiations, likewise consists of discrete particles, which, however, are so small that they have the same relation to chemical atoms and physical molecules as these have to mechanical masses, that is to say as d^2x to dx. Here, therefore, in the now usual notion of the constitution of matter, we have likewise a differential of the second degree, and there is no reason at all why anyone, to whom it would give satisfaction, should not imagine that analogies of d^3x, d^4x, etc., also occur in nature.

Hence, whatever view one may hold of the constitution of matter, this much is certain, that it is divided up into a series of big, well-defined groups of a relatively different mass character in such a way that the members of each separate group stand to one another in definite finite mass ratios, in contrast to which those of the next group stand to them in the ratio of the infinitely large or infinitely small in the mathematical sense. The visible system of stars, the solar system, terrestrial masses, molecules and atoms, and finally ether particles, form each of them such a group. It does not alter the case that intermediate links can be found between the separate groups. Thus, between the masses of the solar system and terrestrial masses come the asteroids (some of which have a diameter no greater than, for example, that of the younger branch of the Reuss principality[222]), meteorites, etc. Thus, in the organic world the cell stands between terrestrial masses and molecules. These intermediate links prove only that there are no leaps in nature, *precisely because* nature is composed entirely of leaps.

In so far as mathematics calculates with real magnitudes, it also employs this mode of outlook without hesitation. For terrestrial mechanics the mass of the earth is regarded as infinitely large, just as for astronomy terrestrial masses and the meteorites corresponding to them are regarded as infinitely small, and just as the distances and masses of the planets of the solar system dwindle to nothing as soon as astronomy investigates the constitution of our stellar system extending beyond the nearest fixed stars. As soon, however, as the mathematicians withdraw into their impregnable fortress of abstraction, so-called pure mathematics, all these analogies are forgotten, infinity becomes something totally mysterious, and the manner in which operations are carried out with it in analysis appears as something absolutely incomprehensible, contradicting all experience and all reason. The stupidities and absurdities by which mathematicians have rather excused than explained their mode of procedure, which remarkably enough always leads to correct results, exceed the worst apparent and real fantasies, e.g., of the Hegelian philosophy of nature, about which mathematicians and natural scientists can never adequately express their horror. What they charge Hegel with doing, viz., pushing abstractions to the extreme limit, they do themselves on a far greater scale. They forget that the whole of so-called pure mathematics is concerned with abstractions, that *all* its magnitudes, strictly speaking, are imaginary, and that all abstractions when pushed to extremes are transformed into nonsense or into their opposite. Mathematical infinity is taken from reality, although unconsciously, and therefore can only be explained from reality and not from itself, from mathematical abstraction. And, as we have seen, if we investigate reality in this regard we come also upon the real relations from which the mathematical relation of infinity is taken, and even the natural analogies of the mathematical way in which this relation operates. And thereby the matter is explained.

(Hæckel's bad reproduction of the identity of thinking and being. But also *the contradiction between continuous and discrete matter*; see Hegel.)[223]

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The differential calculus for the first time makes it possible for natural science to represent mathematically *processes* and not only *states*: motion.

* * *

Application of mathematics: in the mechanics of solid bodies it is absolute, in that of gases approximate, in that of fluids already more difficult; in physics more tentative and relative; in chemistry, simple equations of the first order and of the simplest nature; in biology=0.

[Mechanics and Astronomy]

* * *

An example of the necessity of dialectical thought and of the non-rigid categories and relations in nature; the law of falling, which already in the case of a period of fall of some minutes becomes incorrect, since then the radius of the earth can no longer without error be put$=\infty$, and the attraction of the earth increases instead of remaining constant as Galileo's law of falling assumes. Nevertheless, this law is still continually taught, but the reservation omitted!

* * *

Newtonian attraction and centrifugal force—an example of metaphysical thinking: the problem not solved but only *posed*, and this preached as the solution.—Ditto Clausius' dissipation of heat.[224]

* * *

Newtonian gravitation. The best that can be said of it is that it does not explain but *pictures* the present state of planetary motion. The motion is given. Ditto the force of attraction of the sun. With these data, how is the motion to be explained? By the parallelogram of forces, by a tangential force which now becomes a necessary postulate that we *must* accept. That is to say, assuming the *eternal character* of the existing state, we need a *first impulse*, God. But neither is the existing planetary state eternal nor is the motion originally compound, but *simple rotation*, and the parallelogram of forces applied here is wrong, because it did not merely make evident the unknown magnitude, the x, that had still to be found, that is to say in so far as Newton claimed not merely to put the question but to solve it.

* * *

Newton's parallelogram of forces in the solar system is true at best *for the moment when the annular bodies separate*, because then the rotational motion comes into contradiction with itself, appearing on the one hand as attraction, and on the other hand as tangential force. As soon as the separation is complete, however, the motion is again a unity. That this separation must occur is a proof of the dialectical process.

* * *

Laplace's theory presupposes only matter in motion—rotation necessary for all bodies suspended in universal space.

* * *

Mädler, the Fixed Stars[225]

Halley, at the beginning of the eighteenth century, from the difference between the data of Hipparchus and Flamsteed on three stars, first arrived at the idea of proper motion (p. 410).—Flamsteed's British Catalogue, the first fairly accurate and comprehensive one (p. 420), then *ca.* 1750, Bradley, Maskelyne, and Lalande.

Crazy *theory of the range of light rays in the case of enormous bodies* and Mädler's calculation based on this—as crazy as anything in Hegel's *Philosophy of Nature* (pp. 424-25).

The strongest (apparent) proper motion of a star=701″ in a century=11′41″=one-third of the sun's diameter; smallest average of 921 telescopic stars 8.65″, some of them 4″.

Milky Way is a series of rings, all with a common centre of gravity (p. 434).

The Pleiades Group, and in it Alcyone, η Tauri, the centre of motion for our island universe "as far as the most remote regions of the Milky Way" (p. 448). Periods of revolution within the Pleiades Group on the average *ca.* two million years (p. 449). About the Pleiades are annular groups alternately poor in stars and rich in stars.—Secchi contests the possibility of fixing a centre at the present time.

According to Bessel, *Sirius* and *Procyon* describe an orbit about a *dark* body, as well as the general motion (p. 450).

Eclipse of Algol every 3 days, duration 8 hours, *confirmed by spectral analysis* (Secchi, p. 786).

In the region of the *Milky Way*, but deep *within* it, a dense ring of stars of magnitudes 7-11; a long way outside this ring are the concentric Milky Way rings, of which we see two. In the Milky Way, according to Herschel, *ca.* 18 million stars visible through his telescope, those lying *within* the ring being *ca.* 2 million or more, hence over 20 million in all. In addition there is always a non-resolvable glow in the Milky Way, even behind the resolved stars, hence perhaps still further rings concealed owing to perspective? (Pp. 451-52.)

Alcyone distant from the sun 573 light years. *Diameter of the Milky Way ring* of separate visible stars, at least 8,000 light years (pp. 462-63).

The *mass* of the bodies moving within the sun-Alcyone radius of 573 light years is calculated at 118 million sun masses (p. 462), not at all in agreement with the at most 2 million stars moving therein. Dark bodies? At any rate something wrong. A proof of how imperfect our observational bases still are.

For the outermost ring of the Milky Way, Mädler assumes a distance of thousands, perhaps of hundreds of thousands, of light years (p. 464).

A *beautiful argument* against the so-called absorption of light:

> "At any rate, there does exist a distance from which no further light can reach us, but the reason is quite a different one. The velocity of light is *finite*; from the beginning of creation to our day a *finite* time has elapsed, and therefore we can only become aware of the heavenly bodies up to the distance which light has travelled in this finite time!" (P. 466.)

That light, decreasing in intensity according to the square of the distance, must reach a point where it is no longer visible to our eyes, however much the latter may be strengthened and equipped, is quite obvious, and suffices for refuting the view of Olbers that only light absorption is capable of explaining the darkness of the sky that nevertheless is filled in all directions with shining stars to an infinite distance. That is not to say that there does not exist a distance at which the ether *allows no further light to penetrate*.

* * *

Nebulæ. Of all forms, strictly circular, elliptical, or irregular and jagged. All degrees of resolvability, merging into total non-resolvability, where only a thickening towards the centre can be distinguished. In some of the resolvable nebulæ, up to ten thousand stars are perceptible, the middle mostly denser, very rarely a central star of greater brilliance. Rosse's giant telescope has, however, resolved many of them. Herschel I enumerates 197 star aggregations and 2,300 nebulæ, to which must be added those catalogued by Herschel II in the southern heavens.

The irregular ones *must be distant island universes*, since masses of vapour can only exist in equilibrium in globular or ellipsoidal form. Most of them, moreover, are only just visible even through the most powerful telescopes. At any rate the circular ones *can* be vapour masses: there are 78 of them among the above 2,500. Herschel assumes 2 million, Mädler—on the assumption of a true diameter equal to 8,000 light years—30 million light years distant from us. Since the distance of each astronomical system of bodies from the next one amounts to at least a hundredfold the diameter of the system, the distance of our island universe from the next one would be *at least* 50 times 8,000 light years=400,000 light years, in which case with the several thousands of nebulæ we get far beyond Herschel I's 2 million ([Mädler, *loc cit*., p. 485-] 492).

Secchi:

> The resolvable nebulæ give a continuous and an ordinary stellar spectrum. The nebulæ proper, however, "in part give a continuous spectrum like the nebula in Andromeda, but mostly they give a spectrum consisting of one or only very few bright lines, like the nebulæ in Orion, in Sagittarius, in Lyra, and the majority of those that are known by the name of *planetary* (circular) nebulæ (p. 787).

(The nebula in Andromeda according to Mädler, p. 495, is unresolvable.—The nebula in Orion is irregular, flocculent and, as it were, puts out arms, p. 495.—Those of Lyra are ring-shaped, only slightly elliptical, p. 498.)

Huggins found in the spectrum of Herschel's nebula No. 4374, three bright lines, "from this it follows immediately that this nebula does not consist of an aggregate of separate stars, but is a *true* nebula*, a glowing substance in the gaseous state" [p. 787].

The lines belong to nitrogen (I) and hydrogen (I), the third is unknown. Similarly for the nebula in Orion. Even nebulæ that contain gleaming points (Hydra, Sagittarius) have these bright lines, so that star masses in course of aggregation are still not solid or liquid (p. 789). The nebula in Lyra has only a nitrogen line (p. 789).—The densest place of the nebula in Orion is 1°, its whole extension 4° [pp. 790-91].

* * *

Secchi: *Sirius*:

"Eleven years later (subsequent to Bessel's calculation, Mädler, p. 450) ... not only was the satellite of Sirius discovered in the form of a self-luminous star of the sixth magnitude, but it was also shown that its orbit coincides with that calculated by Bessel. Since then the orbit also for Procyon and its companion has been determined by Auwers, although the satellite itself has not yet been seen" (p. 793).

Secchi: Fixed stars:

"Since the fixed stars, with the exception of two or three, have no perceptible parallax, they are at least" some 30 light years distant from us (p. 799).

According to Secchi, the stars of the 16th magnitude (still distinguishable in Herschel's big telescope) are 7,560 light years distant, those distinguishable in Rosse's telescope are at least 20,900 light years distant (p. 802).

Secchi (p. 810) himself asks:

When the sun and the whole system are extinct, "are there forces in nature which can reconvert the dead system into its original state of glowing nebula and reawaken it to new life? We do not know."

* Italics by Engels.—*Ed.*

* * *

Secchi and the Pope.

* * *

Descartes discovered that the ebb and flow of tides are caused by the attraction of the moon. He also discovered simultaneously with Snell the basic law of the refraction of light* and this in a form peculiar to himself and different from that of Snell.

* * *

Mayer, *Mechanische Theorie der Wärme,* p. 328. *Kant has already stated* that the ebb and flow of tides exert a retarding pressure on the rotating earth. (Adam's calculation that the duration of the sidereal day is now increasing by 1/100 second in 1,000 years.)[227]

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* Note in the margin of the manuscript: "Contested by Wolf, p. 325."[226]—*Ed.*

[Physics]

* * *

Impact and friction. Mechanics regards the effect of impact as *taking place in a pure form.* But in reality things are different. On every impact part of the mechanical motion is transformed into heat, and friction is nothing more than a form of impact that continually converts mechanical motion into heat (fire by friction known from primeval times).

* * *

The consumption of kinetic energy as such in the field of dynamics is always of a twofold nature and has a twofold result: (1) the kinetic work done, production of a corresponding quantity of potential energy, which, however, is always less than the applied kinetic energy; (2) overcoming—besides gravity—frictional and other resistances that convert the remainder of the used-up kinetic energy into *heat.*—Likewise on reconversion: according to the way this takes place, a part of the loss through friction, etc., is dissipated as heat—and that is all very ancient!

* * *

The first, naïve outlook is as a rule more correct than the later, metaphysical one. Thus already *Bacon* (and after him Boyle, Newton, and almost all the Englishmen) said heat is motion[228] (Boyle even said molecular motion). It was only in the eighteenth century that the caloric theory arose in France and became more or less accepted on the Continent.

* * *

Conservation of energy. The *quantitative* constancy of motion was already enunciated by Descartes, and indeed almost in the same words as now by? (Clausius, Robert Mayer?) On the other hand, the transformation of the *form* of motion was only discovered in 1842 and this, not the law of quantitative constancy, is what is new.

* * *

Force and conservation of force. The passages of J. R. Mayer in his two first papers* to be cited against Helmholtz.

* * *

Force.**—Hegel (*Geschichte der Philosophie*, I, S. 208) says.

> "It is better to say that a magnet has a *soul*" (as Thales expresses it) "than that it has an attracting *force;* force is a kind of property that, *separable from matter,* is put forward as a predicate—while soul, on the other hand, is *this movement itself, identical with the nature of matter*."

* * *

Hegel's conception of force and its manifestation, of cause and effect as identical, is proved in the change of form of matter, where the equivalence is proved mathematically. This had already been recognised in measurement: force is measured by its manifestation, cause by effect.

* * *

Force. If any kind of motion is transferred from one body to another, then one can regard the motion, *in so far as it transfers itself*, i.e., is active, as the cause of motion, *in so far as the latter becomes transferred*, i.e., is passive, and then this cause, the active motion, appears as *force* and the passive as its *manifestation*. From the law of the in-

* See this volume, pp. 77-79.—*Ed.*

** Engels used this note in the Chapter "Basic Forms of Motion" (see this volume, pp. 80-81). All italics are by Engels.—*Ed.*

destructibility of motion, it follows automatically that the force is exactly as great as its manifestation, since indeed it is *the same motion* in both cases. Motion that transfers itself, however, is more or less quantitatively determinable, because it appears in two bodies, of which one can serve as a unit of measurement in order to measure the motion in the other. The measurability of motion gives the category *force* its value, otherwise it has none. Hence the more this is the case, the more are the categories of force and its manifestation usable in research. Hence this is so especially in mechanics, where one resolves the forces still further, regarding them as compound, and thereby often arriving at new results, although one should not forget that this is merely a mental operation; by applying the analogy of forces that are really compound, as expressed in the parallelogram of forces, to forces that are really simple, the latter still do not thereby really become compound. Similarly in statics. Then, again, in the transformation of other forms of motion into mechanical motion (heat, electricity, magnetism in the attraction of iron), where the original motion can be measured by the mechanical effect produced. But here, where various forms of motion are considered simultaneously, the limitation of the category or abbreviation, *force*, already stands revealed. No regular physicist any longer terms electricity, magnetism, or heat mere *forces,* any more than *substances* or *imponderabilia.* When we know into how much mechanical motion a definite quantity of heat motion is converted, we still do not know anything of the nature of heat, however much the examination of these transformations may be necessary for investigating this nature of heat. To conceive heat as a form of motion is the latest advance of physics, and by so doing the category of force is sublated in it: in certain connections—those of transition—they* can appear as forces and so be measured. Thus heat is measured by the expansion of a body on warming. If heat did not pass here from one body to the other—the measuring rod—i.e., if the heat of the body acting as a measuring rod did not alter,

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* i.e., the various forms of motion: mechanical motion, heat, electricity, etc.—*Ed.*

there could be no talk of measurement, of a change of magnitude. One says simply: heat expands a body, whereas to say: heat has the force to expand a body, would be a mere tautology, and to say: heat is the force which expands bodies, would not be correct, since 1. expansion, e.g., in gases, is produced also by other means, and 2. heat is not exhaustively characterised in this way.

Some chemists speak also of chemical force, as the force that makes and maintains compounds. Here, however, there is no real transference, but a combination of the motion of various bodies into a single whole, and so "force" here reaches its limit. It is, however, still measurable by the heat production, but so far without much result. Here it becomes a phrase, as everywhere where, instead of investigating the uninvestigated forms of motion, one *invents* a so-called force for their explanation (as, for instance, explaining the floating of wood in water by a buoyancy force —the refraction of light by a refractive force, etc.), in which case as many forces are obtained as there are unexplained phenomena, the external phenomenon being indeed merely translated into an internal phrase.[229] (Attraction and repulsion are easier to excuse; here a number of phenomena inexplicable to the physicist are embraced under a common name, which gives an inkling of an inner connection.)

Finally in organic nature the category of force is completely inadequate and yet continually applied. True, it is possible to characterise the action of the muscles, in accordance with its mechanical effect, as muscular force, and also to measure it. One can even conceive of other measurable functions as forces, e.g., the digestive capacity of various stomachs, but one quickly arrives *ad absurdum* (e.g., nervous force), and in any case one can speak here of forces only in a very restricted and figurative sense (the ordinary phrase: to regain one's forces). This misuse, however, has led to speaking of a vital force. If by this is meant that the form of motion in the organic body is different from the mechanical, physical, or chemical form, and contains them all sublated in itself, then it is a very lax manner of expression, and especially so because the force—presupposing transference of motion—appears here as something pumped into the organism from outside, not as inherent in it and inseparable from it, and therefore this vital force has been the last refuge of all supernaturalists.

The defect: (1) Force usually treated as having independent existence. (Hegel, *Naturphilosophie,* S. 79.)[230]

(2) *Latent, dormant* force—this to be explained from the relation of motion and rest (inertia, equilibrium), where also arousing of forces to be dealt with.

* * *

Force (see above). The transference of motion takes place, of course, only in the presence of *all* the various conditions, which are often multiple and complex, especially in machines (the steam-engine, the shotgun with lock, trigger, percussion cap, and gunpowder). If *one* of them is missing, then the transference does not take place until this condition is supplied. In that case one can imagine this as if the force must first be *aroused* by the introduction of this last condition, as if it lay *latent* in a body, the so-called carrier of force (gunpowder, charcoal), whereas in reality not only this body but all the other conditions must be present in order to evoke precisely this special transference.—

The notion of force comes to us quite automatically in that we possess in our own body means for transferring motion, which within certain limits can be brought into action by our will; especially the muscles of the arms through which we produce mechanical change of place and motion of other bodies, lifting, carrying, throwing, hitting, etc., resulting in definite useful effects. The motion is here apparently *produced*, not transferred, and this gives rise to the notion of force in general *producing motion*. That muscular force is also merely transference has only now been proved physiologically.

* * *

Force. The negative side also has to be analysed: the resistance which is opposed to the transference of motion.

* * *

Radiation of heat into universal space. All the hypotheses cited by Lavrov of the renewal of extinct heavenly bodies (p. 109)[231] *involve loss of motion*. The heat once radiated, i.e., the infinitely greater part of the original motion, is and remains lost. Helmholtz says, up to now, $\frac{453}{454}$. Hence one finally arrives after all at the exhaustion and cessation of motion. The question is only finally solved when it has been shown how the heat radiated into space becomes *utilisable* again. The theory of the transformation of motion puts this question categorically, and it cannot be got over by postponing the answer or by evasion. That, however, with the posing of the question the conditions for its solution are simultaneously given—*c'est autre chose*. The transformation of motion and its indestructibility were first discovered hardly thirty years ago, and it is only quite recently that the consequences have been further elaborated and worked out. The question as to what becomes of the apparently lost heat has, as it were, only been *nettement posée* since 1867 (Clausius).[232] No wonder that it has not yet been solved; it may still be a long time before we arrive at a solution with our small means. But it will be solved, just as surely as it is certain that there are no miracles in nature and that the original heat of the nebular ball is not communicated to it miraculously from outside the universe. The general assertion that *the total amount (die Masse) of motion is infinite*, and hence inexhaustible, is of equally little assistance in overcoming the difficulties of each individual case; it too does not suffice for the revival of extinct universes, except in the cases provided for in the above hypotheses, which are always bound up with loss of force and are therefore only temporary cases. The cycle has not been traced and will not be until the possibility of the re-utilisation of the radiated heat is discovered.

* * *

Clausius—if correct—proves that the universe has been created, *ergo* that matter is creatable, *ergo* that it is destructible, *ergo* that also force, or motion, is creatable and destructible, *ergo* that the whole theory of the "conservation of force" is nonsense, *ergo* that all his conclusions from it are also nonsense.

* * *

Clausius' second law, etc., however it may be formulated, shows energy as lost, qualitatively if not quantitatively. *Entropy cannot be destroyed by natural means but it can certainly be created.* The world clock has to be wound up, then it goes on running until it arrives at a state of equilibrium from which only a miracle can set it going again. The energy expended in winding has disappeared, at least qualitatively, and can only be restored by an *impulse from outside*. Hence, an impulse from outside was necessary at the beginning also, hence, the quantity of motion, or energy, existing in the universe was not always the same, hence, energy must have been created, i.e., it must be creatable, and therefore destructible. *Ad absurdum*!

* * *

Conclusion for Thomson, Clausius, Loschmidt: *The reversion consists in repulsion repelling itself and thereby returning out of the medium into extinct heavenly bodies.* But just therein lies also the proof that repulsion is the really *active* aspect of motion, and attraction the *passive* aspect.

* * *

In the motion of gases—in the process of evaporation—the motion of masses passes directly into molecular motion. Here, therefore, the transition has to be made.

* * *

States of aggregation—nodal points where quantitative change is transformed into qualitative.

* * *

Cohesion—already negative in gases—transformation of attraction into *repulsion*, the latter only real in gas and ether (?).

* * *

At absolute 0° no gas is possible, all motion of the molecules ceases; the slightest pressure, and hence their own attraction, forces them together. *Consequently, a permanent gas is an impossibility.*

* * *

mv^2 has been proved also for gas molecules by the kinetic theory of gases. Hence there is the same law for molecular motion as for the motion of masses: the difference between the two is here abolished.

* * *

The kinetic theory has to show how molecules that strive upwards can at the same time exert a downward pressure and—assuming the atmosphere as more or less permanent in relation to universal space—how in spite of gravity they can move to a distance from the centre of the earth, but nevertheless, at a certain distance, although the force of gravity has decreased according to the *square* of the distance, are yet compelled by this force to come to a stop or to return.

* * *

The kinetic theory of gases:

"In a perfect gas ... the molecules are already so far distant from one another that their mutual interaction can be neglected." (Clausius, p. 6.)[233]

What fills up the spaces between them? Ditto ether.[234] Hence here *the postulate of a matter that is not articulated into molecular or atomic cells.*

* * *

The character of mutual opposites belonging to theoretical development; from the *horror vacui*[235] the transition was made at once to absolutely empty universal space, only afterwards the *ether*.

* * *

Ether. If the ether offers resistance at all, it must also offer resistance to *light*, and so at a certain distance be impenetrable to light. That however ether *propagates* light, being its *medium*, necessarily involves that it should also offer resistance to light, otherwise light could not set it in vibration.—This the solution of the controversial questions raised by Mädler* and mentioned by Лавров [Lavrov].[236]

* * *

Light and darkness are certainly the most conspicuous and definite opposites in nature; they have always served as a rhetorical phrase for religion and philosophy from the time of the fourth Gospel[237] to the *lumières* of the eighteenth century.

Fick,[238] p. 9: "the law long ago rigidly demonstrated in physics... that the form of motion called radiant heat is identical in all essential respects with the form of motion that we call *light*."** Clerk Maxwell,[239] p. 14: "These rays (of radiant heat) have all the physical properties of rays of light and are capable of reflection, etc.... Some of the heat-rays are identical with the rays of light, while other kinds of heat-rays make no impression upon our eyes."

Hence there exist *dark* light-rays, and the famous opposition between light and darkness disappears from natural science as an absolute opposition. Incidentally, the deepest darkness and the brightest, most glaring light have the same effect of *dazzling* our eyes, and in this way are *for us* identical.

The fact is, the sun's rays have different effects according to the length of the vibration: those with the greatest wave-length communicate heat, those with medium wave-

* See this volume, pp. 275-276.—*Ed*.
** Italics by Engels.—*Ed*.

length, light, and those with the shortest wave-length, chemical action (Secchi, p. 632 et seq.), the maxima of the three actions being closely approximated, the *inner* minima of the outer groups of rays, as regards their action, coming within the light-ray group.[240] What is light and what is non-light depends on the structure of the eye. Night animals may be able to see even a part, not of the heat-rays, but of the chemical rays, since their eyes are adapted for shorter wave-lengths than ours. The difficulty disappears if one assumes, instead of three kinds, only a single kind of ray (and scientifically we know only *one* and everything else is a premature conclusion), which has different, but within narrow limits compatible, effects according to the wave-length.

* * *

Hegel constructs the theory of light and colour out of pure thought, and in so doing falls into the *grossest empiricism* of home-bred philistine experience (although with a certain justification, since this point had not been cleared up at that time), e.g., where he adduces against Newton the mixtures of colours used by painters (p. 314, below).[241]

* * *

Electricity. In regard to Thomson's cock-and-bull stories, cf. Hegel, pp. 346-47, where there is exactly the same thing.*—On the other hand, Hegel already conceives frictional electricity quite clearly as *tension*, in contrast to the fluid theory and the electrical matter theory (p. 347).

* * *

When Coulomb says that "*particles* of electricity repel each other inversely as the square of their distance", Thomson calmly takes this as proved (p. 358).[242] Ditto (p. 366) the hypothesis that electricity consists of two fluids, positive and negative, whose particles repel each other. It is

* See this volume, pp. 115-16.—*Ed.*

said (p. 360) that electricity in a charged body is retained merely by the pressure of the atmosphere. Faraday put the seat of electricity in the opposed poles of the atoms (or molecules, there is still confusion about it), and thus for the first time expressed the idea that electricity is not a fluid but a form of motion, a "force" (p. 378). What old Thomson cannot get into his head at all is that it is precisely the spark that is of a *material* nature!

Already in 1822, Faraday had discovered that the momentary induced current—the first as well as the second, reversed current—"participates more of the current produced by the discharge of the Leyden jar than that produced by the voltaic battery"—herein lay the whole secret (p. 385).

The *spark* has been the subject of all sorts of cock-and-bull stories, which are now known to be special cases or illusions: the spark from a positive body is said to be a "pencil of rays, brush, or cone", the point of which is the point of discharge; the negative spark, on the other hand, is said to be a "*star*" (p. 396). A short spark is said to be always white, a long one usually reddish or purplish. (Wonderful nonsense of Faraday on the spark, p. 400.)* The spark drawn from the prime conductor [of an electric machine] by a metal sphere is said to be white, by the hand—purple, by aqueous moisture—red (p. 405). The spark, i.e., light, is said to be "not inherent in electricity but merely the result of the compression of the air. That air is violently and suddenly *compressed* when an electric spark passes through it" is proved by the experiment of Kinnersley in Philadelphia, according to which the spark produces "*a sudden rarefaction of the air in the tube*",** and drives the water into the tube (p. 407). In Germany, 30 years ago, Winterl and others believed that the spark, or electric light, was "of the same nature with *fire*"** and arises by the union of two electricities. Against which Thomson seriously proves that the place where the two electricities unite is precisely that where the light is least, and that it is two-thirds from the positive and one-third

* See this volume, p. 116.—*Ed.*

** Italics by Engels.—*Ed.*

from the negative end! (Pp. 409-10.) That fire is here still something quite *mythical* is obvious.

With the same seriousness Thomson quotes the experiments of Dessaignes, according to which, with a rising barometer and falling temperature, glass, amber, silk, etc., become negatively electrified on being plunged into mercury, but positively electrified if the barometer is falling and the temperature rising, and in summer always become positive in impure, and always negative in pure, mercury; that in summer gold and various other metals become positive on warming and negative on cooling, the reverse being the case in winter; that they are "highly electric" with a high barometer and northerly wind, positive if the temperature is rising, negative if falling, etc. (p. 416).

How matters stood in regard to *heat*: "In order to produce thermo-electric effects, it is not necessary to apply heat. Any thing *which alters the temperature** in one part of the chain ... occasions a deviation in the declination of the magnet." For instance, the cooling of a metal by ice or evaporation of ether! (P. 419.)

The electro-chemical theory (p. 438) is accepted as "at least exceedingly ingenious and plausible".

Fabroni and Wollaston had already long ago, and Faraday recently, asserted that voltaic electricity is the simple consequence of chemical processes, and Faraday had even given the correct explanation of the shifting of atoms taking place in the liquid, and established that the quantity of electricity is to be measured by the quantity of the electrolytic product.

With the help of Faraday, Thomson arrives at the law

> "that every atom must be naturally surrounded by the same quantity of electricity, *so that in this respect heat and electricity resemble each other*"!* [P. 454.]

* * *

Static and dynamic electricity. Static or frictional electricity is the putting into a state of tension of the electricity *already existing* in nature in the *form* of electricity but in an equilibrated, neutral state. Hence the removal of this

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* Italics by Engels.—*Ed.*

tension—if and in so far as the electricity during propagation can be conducted—also occurs at one stroke, by a spark, which re-establishes the neutral state.

Dynamic or voltaic electricity, on the other hand, is electricity produced by the conversion of chemical motion into electricity. Under certain definite conditions, it is produced by the solution of zinc, copper, etc. Here the tension is not acute, but chronic. At every moment new + and — electricity is produced from some other form of motion, and not already existing ± electricity separated into + and —. The process is a continuous one, and therefore too its result, electricity, does not take the form of instantaneous tension and discharge, but of a continuous current which can be reconverted at the poles into the chemical motion from which it arose, a process that is termed electrolysis. In this process, as well as in the production of electricity by chemical combination (in which electricity is liberated instead of heat, and in fact as much electricity as under other circumstances heat is set free, Guthrie, p. 210),[243] the current can be traced in the liquid (exchange of atoms in adjacent molecules—this is the current).

This electricity, being of the nature of a current, for that very reason cannot be directly converted into static electricity. By means of induction, however, neutral electricity already existing as such can be de-neutralised. In the nature of things the induced electricity has to follow that which induces it, and therefore must likewise be of a flowing character. On the other hand, this obviously gives the possibility of condensing the current and of converting it into static electricity, or rather into a higher form that combines the property of a current with that of tension. This is solved by Ruhmkorff's machine. It provides an inductional electricity, which achieves this result.

* * *

A pretty example of the dialectics of nature is the way in which according to present-day theory the *repulsion of like* magnetic poles is explained by the *attraction of like* electric currents. (Guthrie, p. 264.)

* * *

Electro-chemistry. In describing the effect of the electric spark in chemical decomposition and synthesis, Wiedemann declares that this is more the concern of chemistry.[244] In the same case the chemists declare that it is rather a matter which concerns physics. Thus at the point of contact of molecular and atomic science, both declare themselves incompetent, while it is precisely *at this point that the greatest results are to be expected*.

* * *

Friction and impact produce an *internal* motion of the bodies concerned, molecular motion, differentiated as warmth, electricity, etc., according to circumstances. *This motion, however, is only temporary: cessante causa cessat effectus*. At a definite stage they all become transformed into a *permanent molecular change*, a *chemical change*.

[Chemistry]

* * *

The motion of an actual *chemically uniform matter*—ancient as it is—fully corresponds to the childish view, widely held even up to Lavoisier, that the chemical affinity of two bodies depends on each one containing a common third body. (Kopp, *Entwickelung,* p. 105.)[245]

* * *

How old, convenient methods, adapted to previously customary practice, become transferred to other branches and there are a hindrance: in chemistry, the calculation of the composition of compounds in percentages, which was the most suitable method of all for making it impossible to discover the laws of constant proportion and multiple proportion in combination, and indeed did make them undiscoverable for long enough.

* * *

The new epoch begins in chemistry with atomistics (hence Dalton, not Lavoisier, is the father of modern chemistry), and correspondingly in physics with the molecular theory (in a different form, but essentially representing only the other side of this process, with the discovery of the transformation of the forms of motion). The new atomistics is distinguished from all previous to it by the fact that it does not maintain (idiots excepted) that matter is *merely* discrete, but that the discrete parts at various stages (ether atoms, chemical atoms, masses, heavenly bodies) are various *nodal points* which determine the various *qualitative* modes of existence of matter in general—right down to weightlessness and repulsion.

* * *

Transformation of quantity into quality: the simplest example *oxygen* and *ozone*, where 2:3 produces quite different properties, even in regard to smell. Chemistry likewise explains the other allotropic bodies merely by a difference in the number of atoms in the molecule.

* * *

The significance of *names*. In organic chemistry the significance of a body, hence also its name, is no longer determined merely by its composition, but rather by its position in the *series* to which it belongs. If we find, therefore, that a body belongs to such a series, its old name becomes an obstacle to understanding it and must be replaced by a *series name* (paraffins, etc.).

[Biology]

* * *

Reaction. Mechanical, physical (alias heat, etc.) reaction is exhausted with each occurrence of reaction. Chemical reaction alters the composition of the reacting body and is only renewed if a further quantity of the latter is added. Only the *organic* body reacts *independently*—of course within its sphere of power (sleep), and assuming the supply of nourishment—but this supply of nourishment is effective only after it has been assimilated, not immediately as at lower stages, so that here the organic body has an *independent* power of reaction, the new reaction must be *mediated* by it.

* * *

Life and death. Already no physiology is held to be scientific if it does not consider death as an essential element of life (note, Hegel, *Enzyklopädie*, I, pp. 152-53),[246] the *negation* of life as being essentially contained in life itself, so that life is always thought of in relation to its necessary result, death, which is always contained in it in germ. The dialectical conception of life is nothing more than this. But for anyone who has once understood this, all talk of the immortality of the soul is done away with. Death is either the dissolution of the organic body, leaving nothing behind but the chemical constituents that formed its substance, or it leaves behind a vital principle, more or less the soul, that then survives *all* living organisms, and not only human beings. Here, therefore, by means of dialectics, simply becoming clear about the nature of life and death suffices to abolish an ancient superstition. Living means dying.

* * *

*Generatio aequivoca.** All investigations hitherto amount to the following: in fluids containing organic matter in decomposition and accessible to the air, lower organisms arise, Protista, Fungi, Infusoria. Where do they come from? Have they arisen by *generatio aequivoca*, or from germs brought in from the atmosphere? Consequently the investigation is limited to a quite narrow field, to the question of plasmogony.[247]

The assumption that new living organisms can arise by the decomposition of others belongs essentially to the epoch of immutable species. At that time men found themselves compelled to assume the origin of all organisms, even the most complicated, by original generation from non-living materials, and if they did not want to resort to the aid of an act of creation, they easily arrived at the view that this process is more readily explicable given a formative material already derived from the organic world; no one any longer believed in the production of a mammal directly from inorganic matter by chemical means.

This assumption, however, directly conflicts with the present state of science. By the analysis of the process of decomposition in dead organic bodies chemistry proves that at each successive step this process necessarily produces products that are more and more dead, that are more and more close to the inorganic world, products that are less and less capable of being used by the organic world, and that this process can be given another direction, such utilisation being able to occur only when these products of decomposition are absorbed early enough in an appropriate, already existing, organism. It is precisely the most essential vehicle of cell-formation, protein, that decomposes first of all, and so far it has never been built up again.

Still more. The organisms whose original generation from organic fluids is the question at issue in these investigations, while being of a comparatively low order, are nevertheless definitely differentiated, bacteria, yeasts, etc., with a life-cycle composed of various phases and in part, as in the case of the Infusoria, equipped with fairly

* Spontaneous generation.—*Ed.*

well developed organs. They are all at least unicellular. But ever since we have been acquainted with the structureless Monera, it has become foolish to desire to explain the origin of even a single cell directly from dead matter instead of from structureless living protein, to believe it is possible by means of a little stinking water to force nature to accomplish in twenty-four hours what it has cost her thousands of years to bring about.

Pasteur's experiments[248] in this direction are useless; for those who believe in this possibility he will never be able to prove the impossibility by these experiments alone, but they are important because they furnish much enlightenment on these organisms, their life, their germs, etc.

* * *

Moriz Wagner, Naturwissenschaftliche Streitfragen, I

Augsburger Allgemeine Zeitung, Beilage,
October 6, 7, 8, 1874][249]

Liebig's statement to Wagner towards the end of his life (1868):

> "We may only assume that life is just as old and just as eternal as matter itself, and the whole controversial point about the origin of life seems to me to be disposed of by this simple assumption. In point of fact, why should not organic life be thought of as present from the very beginning just as much as carbon and *its compounds* (!),* or as the whole of uncreatable and indestructible matter in general, and the forces that are eternally bound up with the motion of matter in space?"

Liebig said further (Wagner believes November 1868)

> that he, too, regards the hypothesis that organic life has been "imported" on to our planet from universal space as "acceptable".

Helmholtz (Preface to Thomson's *Handbuch der theoretischen Physik*, German edition, part II):

> "It appears to me to be a fully correct procedure, *if all our efforts fail to cause the production of organisms from non-living matter*, to

* Italics by Engels.—*Ed.*

raise the question whether life has ever arisen, whether it is not just as old as matter, and whether its germs have not been transported from one heavenly body to another and have developed wherever they have found favourable soil."[250]

Wagner:

"The fact that matter is indestructible and imperishable, that it... can by no force be reduced to nothing, *suffices for the chemist to regard it also as 'uncreatable'**.... But, according to the now prevailing view (?), life is regarded merely as a 'property' inherent in certain simple elements, of which the lowest organisms consist, and which, as a matter of course, must be as old, i.e., as originally existing, as these basic stuffs *and their compounds** (!!) themselves. In this sense one could also speak of vital force, as Liebig does (*Chemische Briefe*, 4th edition), namely as 'a formative principle in and together with the physical forces',[251] hence not acting outside of matter. This vital force as a 'property of matter', however, manifests itself... only under appropriate conditions which have existed since eternity at innumerable points in infinite space, but which in the course of the different periods of time must often enough have changed their place in space." Hence no life is possible on the ancient fluid earth or the present-day sun, but the glowing bodies have enormously expanded atmospheres, consisting, according to recent views, of the same materials that fill all space in extremely rarefied form and are attracted by bodies. The rotating nebular mass from which the solar system developed, reaching beyond the orbit of Neptune, contained "also all water (!) dissolved in vaporous form in an atmosphere richly impregnated with carbonic *acid* (!)* up to immeasurable heights, and with that also the basic materials for the existence (?) of the lowest organic germs"; in it there prevailed "most varied degrees of temperature in most varied regions, and hence the assumption is *fully justified** that at all times the conditions necessary for organic life were somewhere to be found. According to this the atmospheres of the heavenly bodies, like those of the rotating cosmic nebular masses, would have to be regarded as the permanent repositories of the living form, as the eternal breeding grounds of organic germs."—In the Andes, below the equator, the smallest living Protista with their invisible germs are still present in masses in the atmosphere up to 16,000 feet. Perty says that they are "almost omnipresent". They are only absent where the glowing heat kills them. For them (*Vibrionidæ*, etc.) existence is conceivable "also in the vapour belt of *all** heavenly bodies, wherever the appropriate conditions are to be found".

"According to Cohn, bacteria are... so extremely minute that 633 million can find room in a cubic millimetre, and 636,000 million weigh only a gram. The micrococci are even smaller", and perhaps they are not the smallest. But being very varied in shape, "the *Vibrionidæ*... sometimes globular, sometimes ovoid, sometimes rod-shaped or spiral" (already possess, therefore, a form that is of con-

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* Italics by Engels.—*Ed.*

siderable importance). "Hitherto no valid objection has been raised against the well-founded hypothesis that all the multifarious, more highly organised living beings of both natural kingdoms *could** have developed and *must** have developed in the course of very long periods of time from such, *or similar**, extremely simple(!!), neutral, primordial beings, hovering between plants and animals... on the basis of individual variability and the capacity for hereditary transmission of newly acquired characters to the offspring on alteration of the physical conditions of the heavenly bodies and on spatial separation of the individual varieties produced."

Worth noting is the proof how much of a dilettante Liebig was in biology, although the latter is a science bordering on chemistry.

He read Darwin for the first time in 1861, and only much later the important biological and palæontological-geological works subsequent to Darwin. Lamarck he had "never read". "Similarly the important palæontological special researches which appeared even before 1859, of L. v. Buch, d'Orbigny, Münster, Klipstein, Hauer, and Quenstedt on the fossil Cephalodos, that throw such remarkable light on the genetic connection of the various creations, remained completely unknown to him. All the above-mentioned scientists were... driven by the force of facts, almost against their will, to the Lamarckian hypothesis of descent", and this indeed *before* Darwin's book. "The theory of descent, therefore, had already quietly struck roots in the views of those scientists who had concerned themselves more closely with the comparative study of fossil organisms.... As early as 1832, in *Über die Ammoniten und ihre Sonderung in Familien*, and in 1848 in a paper read before the Berlin Academy, L. v. Buch very definitely introduced in the science of petrifacts (!) 'the Lamarckian idea of the typical relationship of organic forms as a sign of their common descent'." In 1848 he based himself on his investigation of the ammonites for the declaration: "that the disappearance of old forms and the appearance of new ones is not a consequence of the total destruction of organic creations, but *that the formation of new species out of older forms has most probably only resulted from altered conditions of life*".*

Comments. The above hypothesis of "eternal life" and of importation presupposes:

1. The eternal existence of protein.

2. The eternal existence of the original forms from which everything organic can develop. Both are inadmissible.

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* Italics by Engels.—*Ed.*

Ad. 1.—Liebig's assertion that carbon compounds are just as eternal as carbon itself, is doubtful, if not false.

(*a*) Is carbon simple? If not, it is as such not eternal.

(*b*) The compounds of carbon are eternal in the sense that under the same conditions of mixture, temperature, pressure, electric potential, etc., they are always reproduced. But that, for instance, only the simplest carbon compounds, CO_2 or CH_4, should be eternal in the sense that they exist at all times and more or less in all places, and not rather that they are continually produced anew and pass out of existence again—in fact, out of the elements and into the elements—has hitherto not been asserted. If living protein is eternal in the same sense as other carbon compounds, then it must not only continually be dissolved into its elements, as is well known to happen, but it must also continually be produced anew from the elements and without the collaboration of previously existing protein—and that is the exact opposite of the result at which Liebig arrives.

(*c*) Protein is the most unstable carbon compound known to us. It decomposes as soon as it loses the capacity of carrying out the functions peculiar to it, which we call life, and it is inherent in its nature that this incapacity should sooner or later make its appearance. And it is just this compound which is supposed to be eternal and able to endure all the changes of temperature, pressure, lack of nourishment, and air, etc., in space, although even its upper temperature limit is so low—less than 100° *C*! The conditions for the existence of protein are infinitely more complicated than those of any other known carbon compound, because not only physical and chemical functions, but in addition nutritive and respiratory functions, enter, requiring a medium which is narrowly delimited, physically and chemically—and is it this medium that one must suppose has maintained itself from eternity under all possible changes? Liebig "prefers, *ceteris paribus*, the simpler of two hypotheses", but a thing may appear very simple and yet be very complicated.

The assumption of innumerable continuous series of living protein bodies, tracing their descent from one another through all eternity, and which under all circumstances always leave sufficient over for the stock to remain well assorted, is the most complicated assumption possible.

Moreover, the atmospheres of the heavenly bodies, and especially nebular atmospheres, were originally glowing hot and therefore no place for protein bodies; hence in the last resort space must serve as the great reservoir—a reservoir in which there is neither air nor nourishment, and with a temperature at which certainly no protein can function or maintain itself!

Ad. 2.—The vibrios, micrococci, etc., which are referred to here, are beings already considerably differentiated—protein granules that have excreted an outer membrane, but *no nucleus*. The series of protein bodies capable of development, however, forms *a nucleus first of all* and becomes a cell—the cell membrane is then a further advance (*Amœba Sphærococcus*). Hence the organisms under consideration here belong to a series which, by all previous analogy, proceeds barrenly into a blind alley, and they cannot be numbered among the ancestors of the higher organisms.

What Helmholtz says of the sterility of attempts to produce life artificially is pure childishness. Life is the mode of existence of protein bodies, the essential element of which consists in *continual metabolic interchange with the natural environment outside them*, and which ceases with the cessation of this metabolism, bringing about the decomposition of the protein.* If success is ever attained in preparing protein bodies chemically, they will undoubtedly exhibit the phenomena of life and carry out metabolism, however weak and short-lived they may be. But it is certain that such bodies could *at most* have the form of the very crudest Monera, and probably much lower forms, but by no means the form of organisms that have become differentiated by an evolution lasting thousands of years, and in which the cell membrane has become separated

* Such metabolism can also occur in the case of inorganic bodies and in the long run it occurs everywhere, since chemical reactions take place, even if extremely slowly, everywhere. The difference, however, is that inorganic bodies are destroyed by this metabolism, while in organic bodies it is the necessary condition for their existence. [*Note by Engels.*]

from the contents and a definite inherited form assumed. So long, however, as we know no more of the chemical composition of protein than we do at present, and therefore for probably another hundred years to come cannot think of its artificial preparation, it is ridiculous to complain that all our efforts, etc., have failed!

Against the above assertion that metabolism is the characteristic activity of protein bodies may be put the objection of the growth of Traube's "artificial cells."[252] But here there is merely unaltered absorption of a liquid by endosmosis, while metabolism consists in the absorption of substances, the chemical composition of which is altered, which are assimilated by the organism, and the residua of which are excreted together with the decomposition products of the organism itself resulting from the life process.* The significance of Traube's "cells" lies in the fact that they show endosmosis and growth as two things which can be produced also in inorganic nature and without any carbon.

The newly arisen protein granule must have had the capacity of nourishing itself from oxygen, carbon dioxide, ammonia, and some of the salts dissolved in the surrounding water. Organic nutritive substances were not present, for the granules surely could not devour one another. This proves how high above them are the present-day Monera, even without nuclei, living on diatoms, etc., and therefore presupposing a whole series of differentiated organisms.

* * *

Dialectics of Nature—references.

Nature No. 294 et seq. Allman on Infusoria.[253] Unicellular character, important.

Croll on Ice Periods and Geological Time.[254]

Nature No. 326, Tyndall on *Generatio*.[255] Specific decay and fermentation experiments.

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* *N.B.*—Just as we have to speak of invertebrate vertebrates, so also here the unorganised, formless, undifferentiated granule of protein is termed an organism—*dialectically* this is permissible because just as the vertebral column is implicit in the notochord so in the protein granule on its first origin the whole infinite series of higher organisms lies included "*in itself*" as if in embryo. [*Note by Engels.*]

* * *

Protista. 1. Non-cellular, begin with a simple granule of protein which extends and withdraws pseudopodia in one form or another, including the Monera. The Monera of the present day are certainly very different from the original forms, since for the most part they live on organic matter, swallowing diatoms and Infusoria (i.e., bodies higher than themselves and which only arose after them), and, as Hæckel's plate I[256] shows, have a developmental history and pass through the form of non-cellular ciliate swarmspores.

The tendency towards form which characterises all protein bodies is already evident here. This tendency is more prominent in the non-cellular *Foraminifera*, which excrete highly artistic shells (anticipating colonies? corals, etc.) and anticipate the higher molluscs in form just as the tubular Algæ (*Siphoneæ*) anticipate the trunk, stem, root, and leaf form of higher plants, although they are merely structureless protein. Hence *Protamœba* is to be separated from *Amœba*.*

2. On the one hand there arises the distinction of skin (ectosarc) and medullary layer (endosarc) in the sun animalcule *Actinophrys sol* (Nicholson,[257] p. 49). The epidermal layer puts out pseudopodia (in *Protomyxa aurantiaca,* this stage is already a transitional one, see Hæckel, plate I). Along this line of evolution protein does not appear to have got very far.

3. On the other hand, the *nucleus* and *nucleolus* become differentiated in the protein—naked *Amœbæ*. From now on the development of form proceeds apace. Similarly, the development of the young cell in the organism, cf. *Wundt*[258] on this (at the beginning). In *Amœba Sphærococcus*, as in *Protomyxa*, the formation of the cell membrane is only a transitional phase, but even here there is already the beginning of the circulation in the contractile vacuole. [Hæckel, p. 380.] Sometimes we find either a shell of sand grains stuck together (*Difflugia*, Nicholson, p. 47) as in

* Note in the margin of the manuscript, opposite this paragraph: "Individualisation small, they divide and also fuse."—*Ed.*

worms and insect larvæ, sometimes a genuinely excreted shell. Finally,

4. *The cell with a permanent cell membrane*. According to Hæckel (p. 382), out of this has arisen, depending on the hardness of the cell membrane, either plant, or in the case of a soft membrane, animal (? it certainly cannot be conceived so generally). With the cell membrane, definite and at the same time plastic form makes its appearance. Here again a distinction between simple cell membrane and excreted shell. But (in contrast to No. 3) the *putting out of pseudopodia* stops with this cell membrane and this shell. Repetition of earlier forms (ciliate swarm-spores) and diversity of form. The transition is provided by the *Labyrinthuleæ* (Hæckel, p. 385), which deposit their pseudopodia outside and creep about in this network with alteration of the normal spindle shape kept within definite limits. The *Gregarinæ* anticipate the mode of life of higher *parasites*—some are already no longer single cells but *chains* of cells (Hæckel, p. 451), but only containing 2-3 cells—a weak beginning. The highest development of unicellular organisms is in the Infusoria, in so far as these are *really* unicellular. Here a considerable differentiation (see Nicholson). Once again colonies and zoophytes[259] (*Epistylis*). Among unicellular plants likewise a high development of form (*Desmidiaceæ*, Hæckel, p. 410).*

5. The next advance is the union of several cells into *one* body, no longer colony. First of all, the *Katallaktæ* of Hæckel, *Magosphæra Planula* (Hæckel, p. 384), where the union of the cells is only a phase in development. But here also there are already no pseudopodia (whether there are any as a transitional phase Hæckel does not state exactly). On the other hand, the *Radiolaria*, also undifferentiated masses of cells, have retained their pseudopodia and have developed to the highest extent the geometric regularity of the shell, which plays a part even among the genuinely noncellular rhizopods. The protein surrounds itself, so to speak, with its crystalline form.

6. *Magosphæra Planula* forms the transition to the true

* Note in the margin of the manuscript opposite this passage: "Rudiment of higher differentiation."—*Ed.*

Planula and *Gastrula*, etc. Further details in Hæckel (p. 452 et seq.).[260]

* * *

Bathybius.[261] The stones in its flesh are proof that the original form of protein, still lacking any differentiation of form, already bears within it the germ of and capacity for skeletal formation.

* * *

The individual. This concept also has been dissolved into something purely relative. Cormus, colony, tapeworm—on the other hand, cell and metamere as individuals in a certain sense (anthropogeny and morphology).[262]

* * *

The whole of organic nature is one continuous proof of the identity or inseparability of form and content. Morphological and physiological phenomena, form and function, mutually determine one another. The differentiation of form (the cell) determines differentiation of substance into muscle, skin, bone, epithelium, etc., and the differentiation of substance in turn determines difference of form.

* * *

Repetition of morphological forms at all stages of evolution: cell forms (the two essential ones already in *Gastrula*) —metamere formation at a certain stage: annelids, arthropods, vertebrates. In the tadpoles of amphibians the primitive form of ascidian larvæ is repeated.—Various forms of marsupials, which recur among placentals (even counting only existing marsupials).

* * *

For the entire evolution of organism the law of acceleration according to the square of the distance in time from the point of departure is to be accepted. Cf. Hæckel, *Schöp-*

fungsgeschichte and *Anthropogenie*, the organic forms corresponding to the various geological periods. The higher, the more rapid the process.

* * *

The Darwinian theory to be demonstrated as the practical proof of Hegel's account of the inner connection between necessity and chance.*

* * *

The struggle for existence. Above all this must be strictly limited to the struggles resulting from plant and animal *over-population*, which do in fact occur at certain stages of plant and lower animal life. But one must keep sharply distinct from it the conditions in which species alter, old ones die out and newly evolved ones take their place, *without* this over-population: e.g., on the migration of animals and plants into new regions where new conditions of climate, soil, etc., bring about the alteration. If *there* the individuals which become adapted survive and develop into a new species by continually increasing adaptation, while the other more stable individuals die away and finally die out, and with them the imperfect intermediate stages, then this can and does proceed *without any Malthusianism*, and if the latter should occur here at all it makes no change to the process, at most it can accelerate it.

Similarly with the gradual alteration of the geographical, climatic, etc., conditions in a given region (drying up of Central Asia for instance). Whether the members of the animal or plant population there exert pressure on one another is a matter of indifference; the process of evolution of the organisms that is determined by this alteration proceeds all the same.—It is the same for sexual selection, in which case, too, Malthusianism is quite unconcerned.

Hence also Hæckel's "adaptation and heredity" can bring about the whole process of evolution, without need for selection and Malthusianism.

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* See this edition, pp. 217-21.—*Ed.*

Darwin's mistake lies precisely in lumping together in "natural selection" *or* the "survival of the fittest"[263] two absolutely separate things:

1. Selection by the pressure of over-population, where perhaps the strongest survive in the first place, but can also be the weakest in many respects.

2. Selection by greater capacity of adaptation to altered circumstances, where the survivors are better suited to these *circumstances*, but where this adaptation as a whole can mean regress just as well as progress (for instance adaptation to parasitic life is *always* regress).

The main thing: that each advance in organic evolution is at the same time a regression, fixing *one-sided* evolution and excluding the possibility of evolution in many other directions.

This, however, *a basic law*.

* * *

The struggle for life.[264] Until Darwin, what was stressed by his present adherents was precisely the harmonious co-operative working of organic nature, how the plant kingdom supplies animals with nourishment and oxygen, and animals supply plants with manure, ammonia, and carbonic acid. Hardly was Darwin recognised before these same people saw everywhere nothing but *struggle*. Both views are justified within narrow limits, but both are equally one-sided and prejudiced. The interaction of bodies in non-living nature includes both harmony and collisions, that of living bodies conscious and unconscious co-operation as well as conscious and unconscious struggle. Hence, even in regard to nature, it is not permissible one-sidedly to inscribe only "struggle" on one's banners. But it is absolutely childish to desire to sum up the whole manifold wealth of historical evolution and complexity in the meagre and one-sided phrase "struggle for existence." That says less than nothing.

The whole Darwinian theory of the struggle for existence is simply the transference from society to organic nature of Hobbes' theory of *bellum omnium contra omnes*[265] and of the bourgeois economic theory of competition, as well as the Malthusian theory of population. When once this feat has been accomplished (the unconditional justification for which, especially as regards the Malthusian theory, is still very questionable), it is very easy to transfer these theories back again from natural history to the history of society, and altogether too naïve to maintain that thereby these assertions have been proved as eternal natural laws of society.

Let us accept for a moment the phrase "struggle for existence", for argument's sake. The most that the animal can achieve is to *collect*; man *produces*, he prepares the means of life, in the widest sense of the words, which without him nature would not have produced. This makes impossible any unqualified transference of the laws of life in animal societies to human society. Production soon brings it about that the so-called struggle for existence no longer turns on pure means of existence, but on means of enjoyment and development. Here—where the means of development are socially produced—the categories taken from the animal kingdom are already totally inapplicable. Finally, under the capitalist mode of production, production reaches such a high level that society can no longer consume the means of life, enjoyment and development that have been produced, because for the great mass of producers access to these means is artificially and forcibly barred; and therefore every ten years a crisis restores the equilibrium by destroying not only the means of life, enjoyment and development that have been produced, but also a great part of the productive forces themselves. Hence the so-called struggle for existence assumes the form: to *protect* the products and productive forces produced by bourgeois capitalist society against the destructive, ravaging effect of this capitalist social order, by taking control of social production and distribution out of the hands of the ruling capitalist class, which has become incapable of this function, and transferring it to the producing masses—and that is the socialist revolution.

The conception of history as a series of class struggles is already much richer in content and deeper than merely reducing it to weakly distinguished phases of the struggle for existence.

* * *

Vertebrates. Their essential character: *the grouping of the whole body about the nervous system.* Thereby the development of self-consciousness, etc., becomes possible. In all other animals the nervous system is a secondary affair, here it is the basis of the whole organisation; the nervous system, when developed to a certain extent—by posterior elongation of the head ganglion of the worms—takes possession of the whole body and organises it according to its needs.

* * *

When Hegel makes the transition from life to cognition by means of propagation (reproduction),[266] there is to be found in this the germ of the theory of evolution, that, organic life once given, it must evolve by the development of the generations to a genus of thinking beings.

* * *

What Hegel calls reciprocal action is the *organic body*, which, therefore, also forms the transition to consciousness, i.e., from necessity to freedom, to the idea. See *Logik*, II, conclusion.[267]

* * *

Rudiments in nature. Insect states (the ordinary ones do not go beyond purely natural conditions), here even a social rudiment. Ditto productive animals with tools (bees, etc , beavers), but still only subsidi y things and without total effect.—Even earlier: colonies of corals and Hydrozoa, where the individual is at most an intermediate stage and the fleshy community mostly a stage of the full development. See Nicholson.[268]—Similarly, the Infusoria, the highest, and in part very much differentiated, form which a *single* cell can achieve.

* * *

Work.—The mechanical theory of heat has transferred this category from economics into physics (for *physiologically* it is still a long way from having been scientifically determined), but in so doing it becomes defined in quite a different way, as seen even from the fact that only a very slight, subordinate part of economic work (lifting of loads, etc.) can be expressed in kilogram-metres. Nevertheless, there is an inclination to re-transfer the thermodynamical definition of work to the sciences from which the category was derived, with a different determination. For instance, without further ado, to identify it crudely with physiological work, as in Fick and Wislicenus' Faulhorn experiment,[269] in which the lifting of a human body, of say 60 kgs., to a height of say 2,000 metres, i.e., 120,000 kilogram-metres, is supposed to express the *physiological* work done. In the physiological work done, however, it makes an enormous difference *how* this lifting is effected: whether by positive lifting of the load, by mounting vertical ladders, or whether along a road or stair with 45° slope (=militarily impracticable terrain), or along a road with a slope of 1/18, hence a length of about 36 kms. (but this is questionable, if the same time is allowed in all cases). At any rate, however, in all practicable cases a forward motion also is combined with the lifting, and indeed where the road is quite level this is fairly considerable and as physiological work it cannot be put equal to zero. In some places there even appears to be not a little desire to re-import the thermodynamical category of work back into economics (as with the Darwinists and the struggle for existence), the result of which would be nothing but nonsense. Let someone try to convert any skilled labour into kilogram-metres and then to determine wages on this basis! Physiologically considered, the human body contains organs which in their totality, *from one aspect*, can be regarded as a thermodynamical machine, where heat is supplied and converted into motion. But even if one presupposes constant conditions as regards the other bodily organs, it is questionable whether physiological work done, even lifting, can be at once fully expressed in kilogram-metres, since within the body *internal* work is performed at the same time which does not appear in the result. For the body is not a steam-engine, which only undergoes friction and wear and tear. Physiological work is only possible with continued chemical changes in the body itself, depending also on the process of respiration and the work of the heart. Along with every muscular contraction or relaxation, chemical changes occur in the nerves and muscles, and these changes cannot be treated as parallel to those of coal in a steam-engine. One can, of course, compare two instances of physiological work that have taken place under otherwise identical conditions, but one cannot measure the physical work of a man according to the work of a steam-engine, etc.; their external results, yes, but not the processes themselves without considerable reservations.

(All this has to be thoroughly revised.)

[Titles and Tables of Contents of the Folders[270]]

[First Folder]

Dialectics and Natural Science

[Second Folder]

The Investigation of Nature and Dialectics

1) Notes: a) On the Prototypes of the Mathematical Infinite in the Real World

b) On the "Mechanical" Conception of Nature

c) On Nägeli's Incapacity to Know the Infinite

2) Old Preface to [Anti]-Dühring. On Dialectics

<3) Natural Science and the Spirit World>*

4) The Part Played by Labour in the Transition from Ape to Man

<5) Basic Forms of Motion>*

6) Omitted from *Feuerbach*

[Third Folder]

Dialectics of Nature

1) Basic Forms of Motion
2) Two Measures of Motion
3) Electricity and Magnetism
4) Natural Science and the Spirit World
5) Old Introduction
6) Tidal Friction

[Fourth Folder]

Mathematics and Natural Science

Miscellaneous

* This heading is crossed out in the manuscript, for Engels decided to transfer it to the third folder.

Notes

[Plan Outlines]

[1] This plan was compiled after June 1878—since it mentions the old preface to [*Anti*]-*Dühring* written in May-June 1878, and a pamphlet by Haeckel entitled, *Freie Wissenschaft und freie Lehre* (*Free Science and Free Teaching*), published in June 1878—and before 1880, since there is no mention in it of such chapters of *Dialectics of Nature* as "Basic Forms of Motion", "Heat", and "Electricity", which were written in 1880-82. A comparison of the reference to the German bourgeois Darwinists Haeckel and Schmidt contained in point 11 of this plan with Engels's letter to Lavrov dated August 10, 1878, gives grounds for assuming that the present outline was written in August 1878. p. 17

[2] This refers to the "Old Preface to [*Anti*]-*Dühring*. On Dialectics" (see pp. 40-49 of this edition). p. 17

[3] This refers to: (1) E. Du Bois-Reymond's paper "Über die Grenzen des Naturerkennens" ("Limits of the Knowledge of Nature") at the 45th Congress of German Natural Scientists and Physicians, Leipzig, August 14, 1872 (first published in Leipzig in 1872); and (2) K. Nägeli's paper "Die Schranken der naturwissenschaftlichen Erkenntnis" ("Limits of Natural Scientific Knowledge") at the 50th Congress of German Natural Scientists and Physicians, Munich, September 20, 1877 (published as a supplement to the Congress *Bulletin*). p. 18

[4] The reference is to the mechanicist views of the adherents of natural scientific materialism, of which Ernst Haeckel was a typical exponent. Cf. the note "On the 'Mechanical' Conception of Nature" (see pp. 251-56 of this edition). p. 18

[5] Plastidules was the name Haeckel gave to the smallest particles of living protoplasm, each of which, according to his theory, is a protein molecule of highly complex structure and possesses a kind of elementary "soul".

The problem of the "soul of the plastidule", the existence of embryonic consciousness in elementary living organisms, and the relationship between consciousness and its material substratum were discussed at the 50th Congress of German Natural Scientists and Physicians held in Munich in September 1877. Haeckel, Nägeli and Virchow, who addressed the Congress plenary meetings on September 18, 20 and 22, dealt with the problem at considerable length. Haeckel devoted one chapter in his pamphlet *Freie Wissenschaft und freie Lehre* (*Free Science and Free Teaching*) to the defence of his views on the matter against Virchow's attacks. p. 18

6 Engels has in mind Virchow's paper "Die Freiheit der Wissenschaft im modernen Staat" ("Freedom of Science in the Modern State"), which proposed restricting the teaching of science. Virchow was opposed by Haeckel, who published his pamphlet *Freie Wissenschaft und freie Lehre.* p. 18

7 In July-August 1878 Engels proposed to criticise bourgeois Darwinists attacking socialism. The idea was prompted by the news that Oskar Schmidt was going to read a paper entitled "Darwinismus und Socialdemocratie" ("Darwinism and Social-Democracy") at the 51st Congress of German Natural Scientists and Physicians in Kassel (September 1878). Engels read the news in the magazine *Nature* of July 18, 1878 (Vol. XVIII, No. 455, p. 316). After the Congress Schmidt's paper was published in pamphlet form (Oskar Schmidt, *Darwinismus und Socialdemocratie*, Bonn, 1878). About August 10, 1878, Engels received Haeckel's pamphlet *Freie Wissenschaft und freie Lehre* (Stuttgart, 1878), which tried to exonerate Darwinism from the accusation of being linked with the socialist movement and quoted some of Schmidt's statements. He wrote to Schmidt on July 19 and to Lavrov on August 10, 1878, telling them of his intention to answer those statements. p. 18

8 Helmholtz, *Populäre wissenschaftliche Vorträge* (*Popular Scientific Lectures*), Zweites Heft, Braunschweig, 1871. Helmholtz speaks about the physical concept of "work" chiefly on pp. 137-79. Engels examines the category of "work" in his "The Measure of Motion.—Work" (see pp. 98-102 of this edition). p. 18

9 This outline is fundamentally a plan for the chapter "Basic Forms of Motion". On the other hand, there is a whole group of chapters—interconnected as to subject and period—that correspond to it, namely, "Basic Forms of Motion", "The Measure of Motion.—Work", "Tidal Friction", "Heat" and "Electricity". All these chapters were written between 1880 and 1882. The outline was written earlier—probably in 1880. p. 19

[Articles and Chapters]

Introduction

10 In Engels's list of contents of the third folder of materials for *Dialectics of Nature* this "Introduction" is called the "Old Introduction". The text of this "Introduction" contains two passages

which make it possible to fix the date at which it was written. On page 31 Engels says that the cell "is a discovery not yet forty years old". Bearing in mind that in a letter to Marx dated July 14, 1858, Engels mentions 1836 as the approximate date of the discovery of the cell, we can draw a conclusion that the "Introduction" was written before 1876. On the other hand, on page 33 Engels writes that "it is only about ten years ago that the fact became known that completely structureless protein exercises all the essential functions of life", having in mind, probably, Ernst Haeckel's Monera, which he first described in his *Generelle Morphologie der Organismen* (*General Morphology of Organisms*), which was published in 1866. So, the "Introduction" was written approximately in 1876. The original outline of this "Introduction" was written by Engels at the end of 1874 (see pp. 192-95 of this edition). Thus, there are grounds for the conclusion that the "Introduction" was written in 1875 or 1876. The first part of the "Introduction" may have been written in 1875 and the second, in the first half of 1876.
p. 20

11 Engels is referring to Luther's choral "Ein' feste Burg ist unser Gott" ("God is our firm stronghold"). In the second book of his work *Zur Geschichte der Religion und Philosophie in Deutschland* (*On the History of Religion and Philosophy in Germany*), Heine calls the choral the "Marseillaise of Reformation". p. 22

12 It was on the day of his death, May 24 (Old Style), 1543, that Copernicus received a copy of his book, *De revolutionibus orbium coelestium* (*The Revolutions of Heavenly Orbs*), in which he set out the heliocentric system of the world and which had just come off the press. p. 22

13 Eighteenth-century chemists attributed combustion to the presence in combustible bodies of phlogiston, a substance which those bodies were supposed to give off in burning. As it was known, however, that metals heated in air become heavier, the proponents of the phlogistic theory endowed phlogiston with a physically absurd negative weight. This theory was proved untenable by Lavoisier, the French chemist, who correctly explained the process of combustion as the reaction of a burning substance combining with oxygen. The useful part which the phlogistic theory played in its day is noted by Engels at the end of his "Old Preface to [*Anti*]-*Dühring*" (see pp. 48-49 of this edition). He deals with this theory in detail in his preface to Volume II of *Capital*. p. 23

14 Kant's nebular hypothesis, which considers the solar system to have been formed out of a nebula, is set out in I. Kant, *Allgemeine Naturgeschichte und Theorie des Himmels, oder Versuch von der Verfassung und dem mechanischen Ursprunge des ganzen Weltgebäudes nach Newtonischen Grundsätzen abgehandelt* (*Universal Natural History, and Theory of the Heavens, or A Tentative Description of the Structure and Mechanical Origin of the Universe According*

to Newtonian Principles), Königsberg und Leipzig, 1755. The book was published anonymously.

The hypothesis of the formation of the solar system advanced by Laplace was first stated in the closing chapter of his work *Exposition du système du monde* (*An Exposition of the System of the World*), t. I-II, Paris, l'an IV de la République Francaise [1796]. In the sixth, posthumous edition of the book (1835), the last to be prepared for the press in Laplace's lifetime, the hypothesis is set out in the form of the seventh, and last, note to the work.

In 1864 the British astronomer William Huggins proved spectroscopically the existence in outer space of heated gaseous matter similar to the original nebula mentioned in the nebular hypothesis of Kant and Laplace. Huggins made extensive use of spectral analysis, a method developed by G. Kirchhoff and R. Bunsen in 1859. p. 26

15 Engels has in mind the idea expressed by Newton in the conclusion to the second edition of his fundamental work *Mathematical Principles of Natural Philosophy*, Vol. II, Book III, "General Scholium". "Hitherto," wrote Newton, "we have explained the phaenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power...." After listing some properties of gravity, Newton continued: "But hitherto I have not been able to discover the cause of those properties of gravity from phaenomena, and I frame no hypotheses; for whatever is not deduced from the phaenomena is to be called an *hypothesis*; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phaenomena, and afterwards rendered general by induction."

With reference to this statement of Newton's, Hegel said, in his *Enzyklopädie der philosophischen Wissenschaften im Grundrisse*, Heidelberg, 1817 (*Encyclopaedia of the Philosophical Sciences*), § 98, Addendum 1: "Newton ... gave physics an express warning to beware of metaphysics...." p. 26

16 Grove's book *The Correlation of Physical Forces* was first published in 1846. It is based on a lecture which Grove read in the London Institute in January 1842 and which was published shortly afterwards. Engels used its 3rd edition, published in London in 1855. p. 28

17 *Amphioxus* (the lancet fish)—a small fish-like animal (about 5 centimetres in length), which occurs in a number of seas and oceans (the Indian Ocean, Pacific Ocean off the shores of the Malayan Archipelago and Japan, the Mediterranean, Black Sea, etc.) and which is a transitional form between invertebrates and vertebrates.

Lepidosiren (an Amazon mudfish) belongs to the order of the lung fishes, or Dipnoi, which have both lungs and gills; it occurs in South America. p. 29

[18] *Ceratodus* (the barramunda)—a fish having lungs and gills, occurs in Australia. *Archaeopteryx*—an extinct animal, is the most ancient representative of the birds, at the same time possessing certain features of the reptiles.

Here Engels uses H. A. Nicholson's *A Manual of Zoology*, first published in 1870. In working on *Dialectics of Nature*, he used one of the early editions of the book, published not later than 1874. p. 30

[19] In 1759 C. F. Wolff published his thesis "Theoria generationis" ("The Theory of Generation") refuting the doctrine of preformation and furnishing scientific proof in support of the theory of epigenesis.

Preformation implies that the adult organism is pre-formed in the germ cell. From the metaphysical point of view of preformism, which prevailed among the biologists in the seventeenth and eighteenth centuries, every part of the adult organism is present already in the germ cell in reduced form, so that development means the purely quantitative growth of organs already there, while development in the proper sense of the term, that is, new formation, or epigenesis, does not take place at all. The theory of epigenesis was advanced and elaborated by a number of outstanding biologists, from Wolff to Darwin. p. 30

[20] *On the Origin of Species* appeared on November 24, 1859. p. 30

[21] E. Haeckel, *Natürliche Schöpfungsgeschichte. Gemeinverständliche wissenschaftliche Vorträge über die Entwickelungslehre im Allgemeinen und diejenige von Darwin, Goethe und Lamarck im Besonderen* (*A History of Natural Creation. Popular scientific lectures on the theory of development in general and those of Darwin, Goethe and Lamarck in particular*), 4. Aufl., Berlin, 1873. The book was first published in Berlin in 1868.

Protista (Gr. *prōtistos*—first), according to Haeckel's classification, a vast group of primitive organisms comprising both the unicellular and non-cellular ones and forming a third branch of organic life, in addition to the flora and fauna.

Monera (Gr. *monērēs*—single), according to Haeckel, non-nuclear and structureless blobs of protein performing all vital functions: alimentation, movement, reaction to stimuli, and reproduction. Haeckel distinguished between original Monera, which are dead now and which came into being archigonously, that is, by spontaneous generation, and modern Monera, which still live. The former were the starting point for the development of the three branches of organic life. Historically, the cell developed from archigonous Monera. The latter belong to the Protista branch, and form its first and most primitive class. Modern Monera are represented, according to Haeckel, by various species of Protamoeba primitiva, Protomyxa aurantiaca, and Bathybius Haeckelii.

The terms Protista and Monera were coined by Haeckel in 1866 in his book *Generelle Morphologie der Organismen (General Morphology of Organisms)* but did not become established in science. Today the organisms which Haeckel regarded as Protista are classified either as plants or as animals. The existence of Monera has not been confirmed. Nevertheless, the general idea of cellular organisms developing from pre-cellular forms and the idea of original organisms differentiating into plants and animals have gained universal recognition in science. p.30

22 Here and further down, Engels quotes from J. H. Mädler, *Der Wunderbau des Weltalls, oder populäre Astronomie* (*The Miraculous Structure of the Universe, or Popular Astronomy*), 5. Aufl., Berlin, 1861, and A. Secchi, *Die Sonne* (*The Sun*), Braunschweig, 1872.

In the second part of the "Introduction" Engels uses his excerpts from the two books, made probably in January and February 1876 (see pp. 274-78 of this edition). p. 31

23 *Eozoon canadense*—a fossil found in Canada, which was regarded as the remains of ancient primitive organisms. In 1878 Möbius refuted the view of the organic origin of this fossil. p. 33

24 Mephistopheles's words in Goethe's *Faust*: "Alles was entsteht, ist wert, daß es zugrunde geht" (Part I, Scene 3). p. 35

OLD PREFACE TO [ANTI]-DÜHRING. On Dialectics

25 This is the heading of this article in the list of contents of the second folder, where it was put by Engels when grouping the materials for *Dialectics of Nature*. The actual manuscript of the article has only the one word "Preface" as a heading, but in the right-hand top corner of the first page there is in addition a note in brackets "Dühring, Revolution in Science". The article was written in May or in the early part of June 1878 as a preface to the first edition of [*Anti*]-*Dühring*. However, Engels decided to replace this long preface by a shorter one.

The new preface was dated June 11, 1878. Its content is in the main almost identical with the deleted pages of the "Old Preface" used in the new one. p. 40

26 The Sixth World Industrial Exhibition, opened in Philadelphia on May 10, 1876, was dedicated to the centenary of the U.S.A. (July 4, 1776). Germany was among the forty countries represented at the exhibition. However, Professor F. Reuleaux, Director of the Berlin Industrial Academy, appointed by the German Government to preside over the German committee of judges, had to admit that German industry was lagging considerably behind those of other countries and that its watchword was "cheap but rotten". His statement gave rise to numerous press comments.

In particular, *Der Volksstaat* carried between July and September a series of articles dealing with the scandalous fact. p. 41

[27] *Tageblatt der 50. Versammlung deutscher Naturforscher und Aerzte in München 1877*, Beilage, S. 18. p. 41

[28] Engels has in mind Virchow's statement at the 50th Congress of German Natural Scientists and Physicians in Munich, September 22, 1877. See R. Virchow, *Die Freiheit der Wissenschaft im modernen Staat*, Berlin, 1877, S. 13. p. 42

[29] A. Kekulé, *Die wissenschaftlichen Ziele und Leistungen der Chemie*, Bonn, 1878, S. 13-15. p. 44

[30] *Holde Hindernisse* (charming obstacles), a phrase from Heine's cycle *Neuer Frühling*, "Prologue". p. 45

[31] K. Marx, *Capital*, Vol. I, Moscow, 1959, p. 19. p. 48

[32] K. Marx, *Capital*, Vol. I, Moscow, 1959, p. 20. p. 48

[33] Engels has in mind the mathematician Jean Baptiste Joseph Fourier, the author of the treatise *Théorie analytique de la chaleur (Analytical Theory of Heat)*, Paris, 1822, and S. Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance (Reflections on the Motive Power of Fire and on Machines Capable of Generating This Power)*, Paris, 1824. The function *C* mentioned by Engels further down occurs in a note on pp. 73-79 of Carnot's book. p. 48

Natural Science in the Spirit World

[34] This heading was given to the article on the first page of the manuscript. In the list of contents to the third folder, in which Engels put it, it reads: "Natural Science and the Spirit World". The article was probably written in the first half of 1878. This can be concluded from the fact that in the article (see p. 58 of this edition) Engels speaks of reports about Zöllner's "experiments" with the tying of knots on a string that had both ends sealed to the table as of the "latest reports". Zöllner carried on these "experiments" in Leipzig on December 17, 1877.

Engels's article remained unpublished during his lifetime. In 1898 it was published in the Social-Democratic yearbook *Illustrier Neue Welt-Kalender für das Jahr 1898*, Hamburg, 1898, S. 56-59. p. 50

[35] This refers to *Instauratio magna (The Great Instalment)*, an encyclopaedic work planned by Francis Bacon, particularly to its third part, *Phaenomena universi, sive Historia naturalis et experimentalis ad condendam philosophiam (Natural Phenomena, or*

Natural and Experimental History as a Possible Basis for Philosophy). Bacon carried out his plan only in part. The material that was to go into the third part of his work was published in London in 1622-23, under the general title *Historia naturalis et experimentalis* (*Natural and Experimental History*). p. 50

36 Newton's best-known theological work is *Observations on the Prophecies of Daniel and Apocalypse of St. John*, published posthumously in 1733. p. 50

37 A. R. Wallace, *On Miracles and Modern Spiritualism*, London, Burns, 1875. The pages of this book, quoted by Engels in this article, are given in square brackets. p. 51

38 *Mesmerism*—the unscientific theory of "animal magnetism", so named after F. A. Mesmer (1734-1815), an Austrian physician. It became widespread in the late eighteenth century and was one of the early forerunners of spiritualism. p. 51

39 *Phrenology*—a vulgar materialist theory advanced in the early nineteenth century by F. J. Gall, an Austrian physician, maintains that every mental faculty of man has an organ of its own, and is localised in specific sections of the cerebrum. The development of a particular mental faculty gives rise to the growth of the relevant organ and to the formation of a hump on the corresponding section of the skull, so that the conformation of the skull allegedly indicates the mental characteristics of the person concerned. The pseudo-scientific deductions of phrenology were widely used by various charlatans, including spiritualists. p. 51

40 *Barataria* (Spanish *barato*—"cheap"), the name of a non-existent island, denotes in *Don Quixote* a small town of which Sancho Panza was appointed the imaginary governor. p. 51

41 Here Engels used the book: J. N. Maskelyne, *Modern Spiritualism. A short account of its rise and progress with some exposures of so-called spirit media*, London, 1876. p. 54

42 *The Echo*, a bourgeois-liberal newspaper published in London from 1868 till 1907. p. 55

43 J. N. Maskelyne, op. cit., pp. 99-101. p. 55

44 The radiometer was invented by Crookes in 1874. The German word *Lichtmühle* literally means "light mill", a revolving apparatus which works by light- or heat-rays. Thallium was discovered by Crookes in 1861. p. 55

45 J. N. Maskelyne, op. cit., pp. 141-42. p. 56

46 This and the two subsequent quotations are taken from William Crookes's article "The Last of 'Katie King'".

The Spiritualist—a weekly published by the English spiritualists in London from 1869 to 1882. In 1874 it changed its title to *The Spiritualist Newspaper*. p. 56

47 J. N. Maskelyne, op. cit., pp. 144-45. p. 57

48 Ch. M. Davies, *Mystic London*, London, Tinsley Brothers, 1875, p. 319. p. 57

49 J. N. Maskelyne, op. cit., pp. 118-19, 142-44, 146-53. p. 57

50 This refers to the Commission for the Investigation of Spiritualist Phenomena, set up by the Physical Society at St. Petersburg University on May 6, 1875; it completed its work on March 21, 1876. The Commission consisted of D. I. Mendeleyev and other prominent scientists. It proposed to the persons disseminating spiritualism in Russia—A. N. Aksakov, A. M. Butlerov and N. P. Wagner—that they provide information on "genuine" spiritualist phenomena. It came to the conclusion that "spiritualist phenomena arise from unconscious movements or deliberate deception", and that "the spiritualist doctrine is superstition", and it published its conclusions in the newspaper *Golos* (*Voice*) on March 25, 1876. D. I. Mendeleyev published the materials of the Commission under the heading *Materials for a Judgement about Spiritualism* (St. Petersburg, 1876). p. 58

51 This is the beginning of the Pamina and Papageno duet in Mozart's opera *The Magic Flute* (Act I, Scene 18). The lyric of this duet is punned on in the next sentence. p. 59

52 Engels is hinting at the reactionary attacks against Darwinism which were particularly widespread in Germany after the Paris Commune of 1871. Even an important scientist like Virchow, who had previously supported Darwinism, proposed in 1877 at a meeting of natural scientists in Munich that the teaching of Darwinism be banned, asserting that Darwinism was closely connected with the socialist movement and therefore dangerous for the existing social order. (R. Virchow, *Die Freiheit der Wissenschaft im modernen Staat*, Berlin, 1877, S. 12.). p. 59

53 In 1870 the Dogma of the Infallibility of the Pope was proclaimed in Rome. The German Catholic theologian Döllinger refused to accept this dogma. Ketteler, Bishop of Mainz, was also at first against proclaiming the new dogma; but very quickly he reconciled himself of it and became its zealous defender. p. 60

54 These words are taken from the letter written by the biologist Thomas Huxley to the London Dialectical Society, which had invited him to take part in the work of the committee to study spiritualist phenomena. Huxley declined the invitation, making a num-

ber of ironical remarks about spiritualism. Huxley's letter, dated January 29, 1869, is given on page 389 of Davies's book *Mystic London* (1875) mentioned above. p. 61

Dialectics

55 This was the heading of the article as given on the first page of the manuscript. On the fifth and ninth pages of the manuscript the words "Dialectical Laws" are written in the top margins. The article remained unfinished. It was written in 1879, but not before September of that year (it quotes the end of the second volume of Roscoe and Schorlemmer's *Ausführliches Lehrbuch der Chemie*, the second part of which was published in 1879, but there is no mention of the discovery of scandium, which Engels could not have failed to mention in connection with the discovery of gallium if he had written the article after 1879, the year scandium was discovered). p. 62

56 H. Heine, "Ueber den Denunzianten. Eine Vorrede zum dritten Theile des *Salons*", Hamburg, 1837, S. 15. p. 63

57 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 108, Addendum. For *Dialectics of Nature* Engels used the edition G. W. F. Hegel, *Werke (Works)*, Bd. VI, 2. Aufl., Berlin, 1843, S. 217. p. 65

58 Hegel, *Wissenschaft der Logik* (*Science of Logic*), Book I, Section III, Ch. 2, Observation on "Examples of Nodal Lines of Measure-Relations; *natura non facit saltum*". In working on *Dialectics of Nature*, Engels used the edition G. W. F. Hegel, *Werke*, Bd. III, 2. Aufl., Berlin, 1841, S. 433. p. 65

59 H. E. Roscoe und C. Schorlemmer, *Ausführliches Lehrbuch der Chemie*, Bd. II, Braunschweig, 1879, S. 823. p. 67

60 The periodic law was discovered by D. I. Mendeleyev in 1869. In 1870-71, Mendeleyev gave a detailed description of the several missing numbers of the periodic system. He suggested using Sanskrit numerals to denote those elements (as, *eka*—"one"), prefixing each numeral to the name of the preceding known element, which was to be followed by the appropriate missing member of the same group. Gallium the first element predicted by Mendeleyev, was discovered in 1875. p. 68

61 In the comedy *Le Bourgeois Gentilhomme*. p. 68

Basic Forms of Motion

62 This heading appears in the list of contents of the third folder of *Dialectics of Nature*. p. 69

63 Engels has in mind Vol. I of Kant's *Collected Works*, edited by Hartenstein (I. Kant, *Sämmtliche Werke*, in chronologischer Reihenfolge herausgegeben von G. Hartenstein, Band I, Leipzig, 1867). On page 22 of this edition is Paragraph 10 of Kant's work *Gedanken von der wahren Schätzung der lebendigen Kräfte* (*Thoughts on the Correct Appraisal of Live Forces*). The basic thesis of this paragraph states: "The threefold measurement is apparently based on the fact that substances in the existing world act on one another in such a way that the strength of the action is inversely proportional to the square of the distance." p. 71

64 H. Helmholtz, *Über die Erhaltung der Kraft*, Berlin, 1847, Abschn. I u. II. p. 71

65 This refers to the general amount of motion, of motion in its quantitative determination in general. "Quantity of motion" in the special sense of *mv* is indicated in Germany by the word *Bewegungsgrösse*. However, here and in the text that follows Engels uses the expression *Bewegungsmenge*, which we give in round brackets to avoid confusion with the magnitude *mv*. Instead of the expression "Bewegungsmenge", Engels sometimes uses the expression "die Masse der Bewegung", also in the sense of the general amount of every kind of motion. p. 71

66 Italics by Engels. p. 78

67 Engels has in mind J. R. Mayer's works *Notes on the Forces of Inorganic Nature* (published in 1842) and *Organic Motion in Its Connection with Metabolism* (published in 1845). The two works were included in the book J. R. Mayer, *Die Mechanik der Wärme in gesammelten Schriften (Heat Mechanics. Collected Writings)*, 2. Aufl., Stuttgart, 1874. Engels used this edition in working on *Dialectics of Nature*. p. 79

68 Engels most probably has in mind Hegel's observation to the paragraph on the "Formal Ground" in volume two of the *Science of Logic*. In this observation Hegel ridicules the "formal method of explanation from tautological grounds". "This manner of explaining," Hegel writes, "is favoured because it is so easy to see and understand; nothing is easier to see and understand, for instance, than that a plant has its ground in vegetative--that is, in plant-productive—force." "If the question why somebody goes to town is answered by the ground that there is an attractive force in the town which draws him there", this style of answer is no less senseless than the explanation by means of a "vegetative force". Moreover, Hegel remarks, "every science, and especially physical science, is full of tautologies of this kind, which in a manner constitute a prerogative of science". p. 80

69 Hegel, *Lectures on the History of Philosophy*, Vol. I, Part I, 1, "Thales". In working on *Dialectics of Nature*, Engels used the edition G. W. F. Hegel, *Werke*, Bd. XIII, Berlin, 1833, S. 208. p. 81

The Measure of Motion.—Work

70 Engels gives this heading on the title page and first page of the manuscript of this article. In Engels's list of contents to the third folder, this article is entitled "Two Measures of Motion". It was apparently written in 1880 or 1881. p. 87

71 H. Suter, *Geschichte der mathematischen Wissenschaften*, Th. II, Zürich, 1875, S. 367. p. 88

72 See Kant, *Thoughts on the Correct Appraisal of Live Forces*, § 92 (I. Kant, *Sämmtliche Werke*, Bd. I, Leipzig, 1867, S. 98-99).

Acta Eruditorum—the first German scientific journal, was founded by Professor O. Mencke. It was published in Latin in Leipzig from 1682 to 1782. In 1732 its title was changed to *Nova Acta Eruditorum*. Leibniz was an active contributor. p. 88

73 The title page of the first edition of this work of Kant's, published in Königsberg, gives 1746 as the year of publication. It is obvious, however—in particular from the dedication, which is dated April 22, 1747—that the book was completed and published in 1747. p. 88

74 D'Alembert, *Traité de dynamique*, Paris, 1743. p. 89

75 In September 1686 and June 1687, the French abbé Catelan published two articles in the magazine *Nouvelles de la République des Lettres* in which he defended Descartes's measure of motion (*mv*) against Leibniz. Leibniz's articles in reply appeared in the same journal, in February and September 1687 respectively.

Nouvelles de la République des Lettres, a scientific journal published by Pierre Bayle in Rotterdam from 1684 to 1687. H. Basnage de Beauval continued its publication till 1709, under the title of *Histoire des ouvrages des Savants*. p. 91

76 This refers to an anecdote about an uneducated Prussian non-commissioned officer who could never understand when to use the dative case "*mir*" and when the accusative case "*mich*". (Berliners often confuse these two forms.) In order not to have to worry about this question, he adopted the decision: when on duty always use "*mir*", when off duty always use "*mich*". p. 92

77 W. Thomson and P. G. Tait, *Treatise on Natural Philosophy*, Vol. 1, Oxford, 1867. "Natural philosophy" here means theoretical physics. p. 92

78 G. Kirchhoff, *Vorlesungen über mathematische Physik. Mechanik* (*Lectures on Mathematical Physics. Mechanics*), 2. Aufl., Leipzig, 1877. p. 92

[79] Helmholtz, *Über die Erhaltung der Kraft (On the Conservation of Energy)*, Berlin, 1847, S. 9. p. 92.

[80] Engels calculates the velocity of a falling body according to the formula $v = \sqrt{2gh}$ where v is the velocity, g—the acceleration due to gravity and h—the height from which the body falls. p. 94

[81] *Rolf Krake*—the Danish battleship which on the night of June 28-29, 1864, lay off the coast of Alsen Island, its assignment being to prevent the Prussian troops from crossing to the island. This refers to a battle during the Danish war of 1864, in which Denmark was opposed by Prussia and Austria. p. 96

[82] According to more exact measurements, the mechanical equivalent of heat is now taken to equal 426.9 kilogram-metres. p. 96

[83] Engels is referring to the lecture "Force" delivered by P. G. Tait at the 46th Congress of the British Association for the Advancement of Science in Glasgow, on September 8, 1876. The lecture was published in *Nature* No. 360, on September 21, 1876.

Nature. A Weekly Illustrated Journal of Science has been published in London ever since 1869. p. 99

[84] A. Naumann, *Handbuch der allgemeinen und physikalischen Chemie*, Heidelberg, 1877, S. 7. p. 101

[85] R. Clausius, *Die mechanische Wärmetheorie*, 2. Aufl., Bd. I, Braunschweig, 1876, S. 18. p. 101

Tidal Friction

[86] The first line of the heading figures on Engels's title page preceding this article; the second line on the first page of the article itself. In the list of contents of the third folder this article is entitled "Tidal Friction". The article was written apparently in 1880 or 1881. p. 103

[87] Previous to this Thomson and Tait were speaking of the direct resistances to the motion of bodies, such as that which air offers to the flight of a rifle bullet. p. 103

[88] Engels is quoting Kant's work "Investigation of the Question Whether the Earth in Its Rotation about Its Axis Has Suffered Any Change from the First Period of Its Origin, the Rotation Which Causes the Alteration of Day and Night, and How Can It Be Asserted" (I. Kant, *Sämmtliche Werke*, published by Hartenstein, Bd. I, Leipzig, 1867, S. 185). p. 105

[89] *Ibid.*, S. 182-83. p. 105

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Heat

[90] The chapter is unfinished. It was written not earlier than the end of April 1881 and not later than mid-November 1882. The first date is suggested by the fact that in the second part of the chapter Engels quotes from *The Correspondence of Leibniz and Huyghens with Papin*, published by E. Gerland in Berlin in April 1881. The second date is deduced from a comparison of the end of the first part of the chapter with Engels's letter to Marx dated November 23, 1882. The comparison shows that the chapter was written before the letter (see Note 91). p. 109

[91] In a letter to Marx dated November 23, 1882, Engels introduced an important correction into the question of the measure of such a form of motion as electricity. He proceeded from the solution of the problem of the twofold measure of mechanical motion, given by him in the chapter "The Measure of Motion.—Work", and from Wilhelm Siemens's speech published in *Nature* No. 669, August 24, 1882. The speech was made at the 52nd Congress of the British Association for the Advancement of Science in Southampton. Siemens proposed introducing the watt, a new unit of electricity expressing the active power of electric current. This is why, in the letter, mentioned above, Engels defined the distinction between the volt and the watt, two units of electricity as one between the measure of the quantity of electric motion in cases when it does not turn into other forms of motion and the same measure in cases when it does. p. 110

[92] Joshua, 5. p. 111

[93] *Leibnizens und Huyghens' Briefwechsel mit Papin, nebst der Biographie Papin's und einigen zugehörigen Briefen und Aktenstücken,* bearbeitet von E. Gerland, Berlin, 1881 (*The Correspondence of Leibniz and Huyghens with Papin, Together with the Biography of Papin and Some Letters and Documents Connected with It,* compiled by E. Gerland). p. 112

[94] Th. Thomson, *An Outline of the Science of Heat and Electricity,* 2nd ed., London, 1840, p. 281. The first edition appeared in London in 1830. p. 113

Electricity

[95] G. Wiedemann, *Die Lehre vom Galvanismus und Elektromagnetismus* (Theory of Galvanism and Electromagnetism), 2. Aufl., Braunschweig, 1872-74. The work consists of three volumes: Vol. I, *The Theory of Galvanism*, Vol. II, Section 1, *Electrodynamics, Electromagnetism and Diamagnetism*, and Vol. II, Section 2, *Induction*, and Concluding Chapter. It was first published in two

volumes in Braunschweig in 1861-63. A third edition, entitled *The Theory of Electricity*, in four volumes, was brought out in the same town in 1882-85. p. 114

96 Engels is quoting from a review of the book by Mascart and Joubert, *Electricity and Magnetism*. The review, signed *G. C.*, appeared in *Nature* No. 659, June 15, 1882. The reference to *Nature* of June 15, 1882 shows that the article was written by Engels in 1882. In Engels's list of contents to the third folder this article is headed "Electricity and Magnetism". p. 114

97 Thomson gives this quotation from Faraday on page 400 of the second edition of his book. The quotation is taken from Faraday's work *Experimental Researches in Electricity*, 12th Series, published in the journal of the Royal Society, *Philosophical Transactions*, 1838, p. 105. Thomson does not quote the passage accurately. The relevant passage reads: "as if a metallic wire had been put into the place of the discharging particle". p. 116

98 G. W. F. Hegel, *Werke*, Bd. VII, Abt. I, Berlin, 1842, S. 346, 348, 349. p. 116

99 Subsequently it was established in Einstein's relativity theory (1905), by generalising new experimental data, primarily Michaelson's experiment (1881), that the velocity of light propagation in a vacuum (*c*) is a universal physical constant and signifies speed limit. The velocity of propagation of electrically charged particles is always less than *c*. p. 119

100 Engels describes the experiments of Favre according to Wiedemann's book (Volume II, Part 2, pp. 521-22). p. 122

101 See Note 82. p. 123

102 Here and further down, Engels cites the results of thermochemical measurements by J. Thomsen from A. Naumann, *Handbuch der allgemeinen und physikalischen Chemie* (*A Manual of General and Physical Chemistry*), Heidelberg, 1877, pp. 639-46. p. 132

103 In a number of places Wiedemann speaks of "atoms of hydrochloric acid", meaning molecules of this acid. p. 134

104 *Annalen der Physik und Chemie*, a scientific journal, published in Leipzig from 1824 to 1899, first (till 1877) under the editorship of J. C. Poggendorff and then (from 1877) of G. Wiedemann. It appeared once in four months. p. 137

105 Refers to an anecdote about an old Major in the army who, having heard from one of the "one-year" conscripts that he was a Doctor of Philosophy, and not wanting to trouble himself with distin-

guishing between a doctor of philosophy and a doctor of medicine, declared: "It is all the same to me, sawbones is sawbones." p. 145

106 Here Engels uses the word *"Gewichtsteil"* ("part by weight"), but as before he is referring to equivalents. p. 148

107 Here and further down, Engels cites the results of Poggendorff's experiments from Wiedemann's book, Vol. I, pp. 368-72. p. 148

108 This result of Berthelot's thermochemical measurements is cited by Engels from A. Naumann's *Handbuch der allgemeinen und physikalischen Chemie*, Heidelberg, 1877, p. 652. p. 152

109 This refers to the difference between the internal diameter of the barrel and the diameter of the projectile. p. 154

110 The results of the measurements of electromotive force experimentally obtained by Raoult, Wheatstone, Beetz and Joule, are cited by Engels in this paragraph from Wiedemann's book, Vol. I, pp. 390, 375, 385 and 376. p. 158

111 The words "*iterum Crispinus*", given in brackets, are Engels's. They mean "again Crispin!" and are the words with which Juvenal begins his IV Satire in which (in the first part) he scourges Crispin, one of the courtiers of the Roman Emperor Domitian. In a figurative sense the words mean "again the same person!" or "again the same theme!" p. 158

112 *Experimentum crucis*, literally "experiment of the cross", from the Baconian *instantia crucis*; a decisive experiment, which definitely confirms the correctness of one of the proposed explanations of a particular phenomenon and excludes all other explanations. (See Fr. Bacon, *Novum Organum*, Book II, Aphorism XXXVI.) p. 159

113 The words "third in the alliance" ("der dritte im Bunde") are taken from Schiller's ballad "Die Bürgschaft", Verse 20. The tyrant Dionysius asks to be admitted to the alliance of the two faithful friends. p. 164

The Part Played by Labour in the Transition from Ape to Man

114 This was the heading which Engels gave to the article in the list of contents of the second folder of materials for *Dialectics of Nature*. The article was originally written by Engels as the introduction to a more extensive work entitled *The Three Basic Forms of Slavery*. Later Engels altered this title to *The Enslavement of the Worker. Introduction*. Since, however, this work remained unfinished, Engels finally gave to its introductory portion the heading *The Part Played by Labour in the Transition from Ape to Man*, which

is in conformity with the bulk of the manuscript of this work. The article was apparently written in June 1876. Evidence for this assumption is the letter of W. Liebknecht to Engels, dated June 10, 1876, in which Liebknecht writes, among other things, that he is impatiently awaiting Engels's work "The Three Basic Forms of Slavery", promised by him for the newspaper *Volksstaat*. Only in 1896 the article was published in the magazine *Die Neue Zeit* (Jahrgang XIV, Bd. 2, S. 545-54). p. 170

115 See Charles Darwin, *The Descent of Man, and Selection in Relation to Sex* (Vol. I, London, 1871), Ch. VI, "On the Affinities and Genealogy of Man". p. 170

116 Engels is referring to the testimony of Labeo Notker, a German monk (c. 952-1022), quoted in J. Grimm, *Deutsche Rechtsalterthümer* (*Antiquities of German Law*), Göttingen, 1828, S. 488. Engels quotes Notker in his unfinished work *A History of Ireland*. p. 176

117 With regard to the effect of man's activity on plant life and climate, Engels uses C. Fraas, *Klima und Pflanzenwelt in der Zeit* (*Climate and Plant Life in Time*), Landshut, 1847. Marx called Engels's attention to this book in a letter dated March 25, 1868. p. 180

118 Engels is referring to the economic crisis of 1873. In Germany the crisis began with a "terrific crash" in May 1873, foreshadowing a crisis that dragged on till the late seventies. p. 183

[Notes and Fragments]

[From the History of Science]

119 G. W. F. Hegel, *Werke*, Bd. XIII, Berlin, 1833. p. 186

120 Regarding the work *De placitis philosophorum*, it was subsequently proved that it did not come from Plutarch but some other unknown author (the so-called "Pseudo-Plutarch"). It derives from Aetius who lived in about the year 100 of our era. p. 187

121 Genesis, Ch. 2, Verse 7. p. 188

122 This note is written in Marx's handwriting and consists of quotations (from Tauchnitz editions) in Greek from Aristotle's *Metaphysica* and from the compilatory work of Diogenes Laertius, *Lives and Opinions of Famous Philosophers*. The note dates from before June 1878 since it contains quotations about Epicurus which were used by Engels in the Old Preface to [*Anti*]-*Dühring* (see this edition, p. 44). All the italicised words in the quotations are Marx's. p. 189

[123] In the latest editions of *Metaphysica*, Book IX is called Book X. p. 190

[124] R. Wolf, *Geschichte der Astronomie* (*History of Astronomy*), München, 1877. For Mädler's book, see Note 22. p. 190

[125] This fragment constitutes the original outline of the Introduction (see this edition, pp. 20-39). p. 192

[126] The Declaration of Independence, adopted on July 4, 1776, at the Philadelphia congress of delegates from thirteen English colonies in North America, proclaimed the secession of these colonies from England and the establishment of an independent republic, the United States of America. p. 193

[127] This is the heading of the fragment given in the list of contents of the second folder of materials for *Dialectics of Nature*. The fragment consists of four pages of the original manuscript of *L. Feuerbach*, numbered 16, 17, 18 and 19. At the top of page 16 is written in Engels's handwriting: "*Aus 'Ludwig Feuerbach'*." This fragment was part of the second chapter of *L. Feuerbach* and was intended to follow immediately after the description of the three principal "limitations" of the French materialists of the eighteenth century. On finally revising the manuscript of *L. Feuerbach*, Engels removed these four pages and replaced them by another text, but the basic contents of these pages left out of the second chapter (on the three great discoveries in natural science of the nineteenth century) were reproduced in an abbreviated form in the fourth chapter of *L. Feuerbach*. Since Engels's *L. Feuerbach* was originally printed in the April and May issues of the magazine *Die Neue Zeit* for 1886, it can be considered that this fragment dates from the first quarter of 1886. On the first page of the fragment the text begins in the middle of a sentence. The beginning of the sentence, restored according to the text of *L. Feuerbach* printed in *Die Neue Zeit*, is given in square brackets. p. 195

[128] This quotation is given in Starcke's book *Ludwig Feuerbach*, Stuttgart, 1885, on pp. 154-55. It is taken from Feuerbach's work *Die Unsterblichkeitsfrage vom Standpunkt der Anthropologie* (*The Question of Immortality from the Standpoint of Anthropology*) which was written in 1846. (See Ludwig Feuerbach's *Sämtliche Werke*, Bd. III, Leipzig, 1847, S. 331.) p. 199

[129] Engels has in mind Feuerbach's aphorisms published posthumously in K. Grün, *Ludwig Feuerbach in seinem Briefwechsel und Nachlass sowie in seiner philosophischen Charakterentwicklung* (*Ludwig Feuerbach in His Correspondence and Legacy, as well as in His Philosophical Development*), Bd. II, Leipzig und Heidelberg, 1874, S. 308. The aphorisms are quoted on p. 166 of Starcke's book. Cf. Frederick Engels, *Ludwig Feuerbach and the End of Classical German Philosophy*, Ch. II. p. 199

130 "*Sire, je n'avais pas besoin de cette hypothèses*"—the words of Laplace in answer to Napoleon's question why he had made no mention of God in his work on celestial mechanics. p. 200

131 Engels is referring to Tyndall's opening speech at the 44th meeting of the British Association for the Advancement of Science in Belfast, August 19, 1874 (published in *Nature* No. 251 of August 20, 1874). In a letter to Marx dated September 21, 1874, Engels gives a more detailed characterisation of this speech. p. 200

132 Ignorance is no argument, says Spinoza in his *Ethics* (Part One, Addendum), as he opposes the exponents of the clerical-teleological view on nature, who gave the "will of God" as the cause of causes of all phenomena and had no other argument left them but the assertion that they knew no other causes. p. 201

[Natural Science and Philosophy]

133 The fragment headed "Büchner" was written before the other parts of *Dialectics of Nature*. It is the opening note of the first folder of the manuscript. The fragment is apparently a synopsis of a work planned by Engels against Büchner as an exponent of vulgar materialism and social Darwinism. Judging by the content of the fragment and by Engels's marginal notes in his copy of Büchner's book *Der Mensch und seine Stellung in der Natur* (*Man and His Place in Nature*), a second edition of which appeared late in 1872, Engels proposed to criticise primarily this work of Büchner's. The laconical comment we find in W. Liebknecht's letter to Engels dated February 8, 1873—"As for Büchner, go ahead!"—seems to suggest that Engels had just informed Liebknecht of his plan. It is therefore safe to assume that this fragment was written early in 1873. p. 202

134 Engels is quoting the following passage from the Preface to the second edition of Hegel's *Encyclopaedia of the Philosophical Sciences*: "Lessing said in his time that people treat Spinoza like a dead dog." Hegel had in mind a conversation between Lessing and Jacobi on June 7, 1780, during which Lessing had said: "Why, people still talk of Spinoza as if he were a dead dog." See F. H. Jacobi, *Werke*, Bd. IV, Abt. I, Leipzig, 1819, S. 68.

Hegel deals in detail with the French materialists in Volume III of his *History of Philosophy*. p. 202

135 The reference is to L. Büchner, *Der Mensch und seine Stellung in der Natur in Vergangenheit, Gegenwart und Zukunft* (*Man and His Place in Nature in the Past, Present and Future*), 2. Aufl., Leipzig, 1872. On pp. 170-171 of his book, Büchner says that as mankind gradually develops there arrives the moment when nature in man becomes aware of itself and when man stops submitting

passively to the blind laws of nature to become their master, that is, when quantity becomes quality, to use Hegel's phrase. In his copy of Büchner's book, Engels marked this passage with a stroke and commented: "*Umschlag!*" ("A reversal!") p. 201

136 Engels has in mind the limitation of Newton's philosophical views, his one-sided over-estimation of the method of induction and his negative attitude to hypotheses, expressed by him in the well-known words "*Hypotheses non fingo*" ("I do not invent hypotheses"). See Note 15. p. 205

137 At the present time it is considered to be beyond doubt that Newton arrived at the discovery of the differential and integral calculus independently of and earlier than Leibniz, but Leibniz, who made this discovery also independently, gave it a more perfect form. Already within two years of writing the present fragment Engels expressed a more accurate view on this question (see this edition, p. 258). p. 205

138 Engels has in mind the following passage from Hegel's *Logik* in *Enzyklopädie der philosophischen Wissenschaften (Encyclopaedia of the Philosophical Sciences*), § 5, Note: "Everybody allows that to know any other science you must have first studied it, and that you can only claim to express a judgement upon it in virtue of such knowledge. Everybody allows that to make a shoe you must have learnt and practised the craft of the shoemaker.... For philosophy alone, it seems to be imagined, such study, care, and application are not in the least requisite." p. 205

139 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 6, Observation: "This divorce between idea and reality is especially dear to the analytic understanding which looks upon its own abstractions, dreams though they are, as something true and real, and prides itself on the imperative 'ought', which it takes especial pleasure in prescribing even on the field of politics. As if the world had waited on it to learn how it ought to be, and was not!" p. 205

140 Ibid., observation to § 20. p. 205

141 Ibid., addendum to § 21. p. 205

142 The reference is to Hegel's argument on the transition from a naïvely unsophisticated state to a state of reflection, both in the history of society and in the development of the individual: "But the truth is that... the awakening of consciousness follows from the very nature of man: and the same history repeats itself in every son of Adam" (*Encyclopaedia of the Philosophical Sciences*, § 24, Addendum 3). p. 206

143 A "mathematical poem" is the term applied by W. Thomson to the book of the French mathematician Jean Baptiste Joseph

Fourier *Théorie analytique de la chaleur* (*Analytical Theory of Heat*), Paris, 1822. See the appendix to the book of Thomson and Tait *A Treatise on Natural Philosophy*, Vol. I, Oxford, 1867, p. 713. In the synopsis of this book made by Engels this passage is copied out and underlined. p. 206

144 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 130, Observation; *Science of Logic*, Book II, Section II, Chapter 1, "Note on the Porosity of Matter". p. 206

145 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 103, Addendum. Here Hegel is polemising with those physicists who explained the differences of the specific gravity of bodies by saying that "a body, with a specific gravity twice that of another, contains within the same space twice as many material parts (atoms) as the other". p. 206

146 R. Owen, *On the Nature of Limbs*, London, 1849, p. 86. p. 206

147 E. Haeckel, *Natürliche Schöpfungsgeschichte* (*Natural History of Creation*), 4. Aufl., Berlin, 1873. p. 207

148 On page 26 of his book Hofmann gives the following quotation from Rosenkranz's book *System der Wissenschaft. Ein philosophisches Encheiridion*, Königsberg, 1850: "... Platinum is ... basically only a paradox of silver, wishing to occupy already the highest stage of metallicity. This belongs only to gold..." (§ 475, S. 301).

Hofmann speaks of the "services" of the Prussian King Frederick-William III in organising the sugar-beet industry on pages 5-6 of his book. p. 207

149 In Engels's manuscript the surname Cassini is given in the plural (die Cassinis). Four astronomers named Cassini are known in the history of French science: 1) Giovanni Domenico Cassini (1625-1712), first director of the Paris Observatory, who emigrated from Italy; 2) his son Jacques Cassini (1677-1756); 3) the son of the last-named, César Francois Cassini (1714-1784), and 4) his son Jacques Dominique Cassini (1748-1845). All four consecutively held the office of director of the Paris Observatory (from 1669 to 1793). The first three upheld incorrect, anti-Newtonian notions of the shape of the earth, and only the last was compelled, under the influence of more accurate measurements of its volume and shape, to admit that Newton was correct in inferring that the globe is compressed along the axis of its rotation. p. 207

150 Th. Thomson, *An Outline of the Sciences of Heat and Electricity*, 2nd edition, London, 1840. p. 208

151 E. Haeckel, *Anthropogenie oder Entwickelungsgeschichte des Menschen*, Leipzig, 1874, S. 707-08. p. 208

[152] Haeckel (*Natürliche Schöpfungsgeschichte*, 4. Aufl., Berlin, 1873, pp. 89-94) stresses the contradiction in Kant's *Critique of the Teleological Faculty of Judgement* (second part) between the "mechanical methods of explanation" and teleology, Haeckel depicting the latter, in opposition to Kant, as the doctrine of external aims, of external expediency. Hegel, however, who examines this same *Critique of the Teleological Faculty of Judgement* in his *History of Philosophy*, Vol. III, Part III, Chapter 4, paragraph on Kant (*Werke*, Bd. XV, Berlin, 1836, S. 603), put in the foreground Kant's conception of "inner expediency", according to which in organic beings "everything is purpose and reciprocally also means". (Quotation from Kant, given by Hegel.) p. 208

[153] Hegel, *Science of Logic*, Book III, Section II, Chapter 3. In working on *Dialectics of Nature*, Engels used the edition G. W. F. Hegel, *Werke*, Bd. V, 2. Aufl., Berlin, 1841. p. 209

[154] Ibid., Section III, Chapter 1. p. 209

[155] That is, taking "metaphysics" not in its old meaning—not as Newton did, for example (see Note 15), who regarded it as philosophical thought in general, but in its modern meaning, that is, as the metaphysical method of thought. p. 210

[Dialectics]

[a] General Questions of Dialectics. The Fundamental Laws of Dialectics

[156] *Compsognathus*—an extinct animal of the order of dinosaurs, belonging to the class of reptiles, but according to the structure of the pelvis and hind extremities closely related to the birds (H. A. Nicholson, *A Manual of Zoology*, 5th ed., Edinburgh and London, 1878, p. 545).

On *Archaeopteryx* see Note 18. p. 212

[157] Engels is referring to multiplication by budding or division among coelenterates. p. 212

[158] Hegel, *Encyclopaedia of the Philosophical Sciences*, § 135, Addendum: "The limbs and organs, for instance, of an organic body are not merely parts of it: it is only in their unity that they are what they are, and they are unquestionably affected by that unity, as they also in turn affect it. These limbs and organs become mere parts, only when they pass under the hands of the anatomist, whose occupation, be it remembered, is not with the living body but with the corpse." p. 213

[159] Op. cit., § 126, Addendum. p. 214

[160] Op. cit., § 117, Addendum. p. 214

[161] Op. cit., § 115, Note. Here Hegel says that the very form of judgement speaks of the distinction between the subject and the predicate. p. 215

[162] This refers in all probability to the book by Clausius *Die mechanische Wärmetheorie*, 2-te umgearbeitete Auflage, I. Band, Braunschweig, 1876. Pages 87-88 of this book speak of the "positive and negative quantities of heat". p. 216

[163] Engels has in mind J. Grimm's *Geschichte der deutschen Sprache* (*A History of the German Language*), 4. Aufl., Leipzig, 1880, first published in Leipzig in 1848. He speaks of the Frankish dialect in greater detail in his work *The Frankish Dialect,* written in 1881-82. This note must have been written about 1881. p. 217

[164] *Kismet*, in Moslem, chiefly Turkish, usage, means destiny or fate. p. 219

[165] This refers to Darwin's *The Origin of Species by Means of Natural Selection* (1859). p. 220

[166] A quotation from Heine's satirical poem "Disputation" (*Romanzero*, Vol. III, 1851), which depicts a mediaeval dispute between a Catholic Capuchin monk and a learned Jewish Rabbi, who in the course of the dispute appeals to the Jewish religious book *Tausves Jontof*. The Capuchin's reply is to send the *Tausves Jontof* to the devil. Thereupon the indignant Rabbi cries out in a frenzy: "*Gilt nichts mehr der 'Tausves Jontof'. Was soll gelten? Zeter! Zeter!*" ("If the *Tausves Jontof* has no longer authority, then what shall prevail? Help! Help!") p. 221

[167] G. W. F. Hegel, *Werke,* Bd. III, 2. Aufl., Berlin, 1841. The underscoring in the quotations is by Engels. p. 221

[168] The reference is to the following passage from Hegel's Preface to *Phänomenologie des Geistes (Phenomenology of Mind):* "The bud disappears when the blossom breaks through, and we might say that the former is refuted by the latter; in the same way, when the fruit comes the blossom may be explained to be a false form of the plant's existence, for the fruit appears as its true nature in place of the blossom." Engels is quoting from G. W. F. Hegel, *Werke*, Bd. II, 2. Aufl., Berlin, 1841. p. 221

b) Dialectical Logic and the Theory of Knowledge. On the "Limits of Knowledge"

[169] *Dido*—the name of Engels's dog, which he mentioned in his letters to Marx dated April 16, 1865, and August 10, 1866. p. 222

170 Hegel explains the correspondence between the division of logic into three parts (the doctrine of being, doctrine of essence, and doctrine of notion) and the four-member classification of judgements as follows: "the different species of judgement derive their features from the universal forms of the logical idea itself. If we follow this clue, it will supply us with three chief kinds of judgement parallel to the stages of Being, Essence and Notion. The second of these kinds, as required by the character of Essence, which is the stage of differentiation, must be doubled." (Hegel, *Encyclopaedia of the Philosophical Sciences*, § 171. Addendum.) p. 223

171 Here the definitions *singulär, partikulär* and *universell* stand for individual, particular, and universal in the sense of formal logic, as distinct from the dialectical categories of *Einzelnes, Besonderes* and *Allgemeines* (single, special, and general). p. 223

172 Engels gives the pages of the whole chapter on judgement in the third book of Hegel's *Science of Logic.* p. 224

173 I.e., the whole of the third part of Hegel's *Science of Logic*. p. 226

174 On pages 75-77 of the fourth edition of his *Natural History of Creation* (Berlin, 1873), Haeckel relates how Goethe discovered the existence of the intermaxillary bone in man. In Haeckel's opinion, Goethe arrived first of all at the inductive proposition: "All mammals have an intermaxillary bone", from which he drew the deductive conclusion: "Therefore, man also has such a bone", following which this conclusion was confirmed by experimental data (by the discovery of the intermaxillary bone in the human embryo and in occasional atavistic cases in adults). Engels says that the induction of which Haeckel speaks is incorrect because it was contradicted by the proposition, considered correct, that the mammal "man" has no intermaxillary bone. p. 226

175 Engels is obviously referring to the two main works of Whewell: *History of the Inductive Sciences* (three volumes, London, 1837) and *Philosophy of the Inductive Sciences* (two volumes, London, 1840).

The manuscript has: "*die bloss mathematisch[en] umfass[en]d*." The word "umfassend" is used here obviously in the sense of "comprising" the purely mathematical sciences, which, according to Whewell, are sciences of pure reason that investigate the "conditions of all theory" and in this sense occupy, as it were, a central position in the "geography of the intellectual world." In *Philosophy of the Inductive Sciences* (Vol. I, Book II), Whewell gives a brief outline of the "philosophy of the pure sciences", regarding geometry, theoretical arithmetic and algebra as its main components. In his *History of the Inductive Sciences* Whewell counterposes the "inductive sciences" (mechanics, astronomy, physics, chemistry, mineralogy, botany, zoology, physiology, geology) to the "deductive" sciences (geometry, arithmetic, algebra). p. 227

[176] In the formula U—I—P, U denotes the Universal, I—the Individual, P—the Particular. This formula is used by Hegel in analysing the logical essence of inductive conclusions. See Hegel, *Science of Logic*, Book III, Section I, Chapter 3, paragraph "The Syllogism of Induction". Hegel's proposition—mentioned by Engels further down—that inductive conclusion is in effect problematic occurs in the same place. p. 227

[177] H. A. Nicholson, *A Manual of Zoology*, 5th ed., Edinburgh and London, 1878, pp. 283-85, 363-70, 481-84. p. 227

[178] Hegel, *Encyclopaedia of the Philosophical Sciences*, § 39: "Mere experience affords perceptions of changes *succeeding each other*. . but it presents no *necessary* connexion." p. 229

[179] Spinoza, *Ethics*, Part I, definitions 1 and 3, and theorem 6. p. 231

[180] See Note 16. p. 232

[181] This heading is given in the list of contents drawn up by Engels for the second folder of materials for *Dialectics of Nature*. This note is devoted to a critical analysis of the basic theses put forward by the botanist Nägeli in his lecture to the Munich Congress of German Natural Scientists and Physicians on September 20, 1877. Nägeli's lecture was entitled "Die Schranken der naturwissenschaftlichen Erkenntnis" ("The Limits of Natural-Scientific Knowledge"). Engels quotes it according to the Appendix to the congress report (*Tageblatt der 50. Versammlung deutscher Naturforscher und Aerzte in München 1877*. Beilage, September 1877). This edition was supplied to Engels in all probability by K. Schorlemmer, who attended the Congress. p. 232

[182] Engels is referring to the discovery of oxygen in 1774 by Joseph Priestley, who did not even guess that he had discovered a new chemical element and that this discovery would lead to a revolution in chemistry. Engels speaks in more detail about this discovery in his preface to the second volume of Marx's *Capital*. p. 234

[183] Cf. Hegel, *Encyclopaedia of the Philosophical Sciences*, § 13, Note: "When the universal is made a mere form and co-ordinated with the particular, it sinks into a particular itself. Even common sense in every-day matters is above the absurdity of setting a universal *beside* the particulars. Would any one, who wished for fruit, reject cherries, pears, and grapes, on the ground that they were cherries, pears, or grapes, and not fruit?" p. 236

[184] This reference is to Hegel's *Science of Logic*, in the section on Quantity. Hegel mentions astronomy and says it is admirable not because of the bad infinity of immeasurable distances, time and the immeasurable multitude of stars, but "rather because of those *relations of measure* and those *laws* which reason recognises in

these objects; for they are the infinity of reason and those others the infinity of unreason". Hegel, *Science of Logic*, Vol. I, Part II, Chapter 2, Note: "High Opinion of Infinite Progress." p. 238

185 This is a quotation, slightly modified by Engels, from the treatise *Della moneta (On Money)* of the Italian economist Galiani. This same quotation was used by Marx in Volume I of *Capital*. Marx and Engels used the Custodi edition *Scrittori classici italiani di economia politica*. Parte moderna, Tomo III, Milano, 1803, p. 156. p. 238

186 The words "so also $\frac{1}{r^2}$" were added subsequently by Engels. It is possible that Engels has in mind the number π, which has a quite definite meaning, but which cannot be expressed by a finite decimal or an ordinary fraction. If the area of a circle is taken as 1, the formula $\pi r^2 = 1$ gives: $\pi, = \frac{1}{r^2}$ (where r is the radius of the circle). p. 238

187 Engels is referring to the following passage in Hegel's *Philosophy of Nature*: "The sun serves the planet, just as in general sun, moon, comets, stars are merely significations of the earth" (§ 280, Addendum). p. 239

188 Engels is referring to George Romanes's review of Sir John Lubbock's book *Ants, Bees, and Wasps*, London, 1882. The review appeared in the British journal *Nature* No. 658, of June 8, 1882. The passage which interested Engels, that ants are "very sensitive to the ultra-violet rays", occurs on page 122 of Vol. XXVI of *Nature*. p. 239

189 Engels is referring to A. von Haller's poem "Falschheit der menschlichen Tugenden", in which Haller asserted: "No mortal mind can Nature's inner secrets tell, too happy only if he knows the outer shell." Goethe, in his poem "Allerdings" (1820) opposed Haller's assertion, pointing out that Nature is a single unity and cannot be divided, as is done by Haller, into an unknowable inner kernel and an outer shell accessible to man. Hegel mentions this argument between Goethe and Haller twice in his *Encyclopaedia of the Philosophical Sciences* (§ 140, Note, and § 246, Addendum). p. 241

190 Hegel, *Science of Logic*, Book II, Section I, Chapter 1, Paragraph "Show", and Section II ("Appearance") which contains a special paragraph on thing-in-itself ("Thing-in-Itself and Existence") and an observation ("The Thing-in-Itself of Transcendental Idealism"). p. 241

191 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 124, Observation and Addendum. p. 241

192 Hegel, *Science of Logic*, Book III, Section III, Chapter 2. p. 242

[Forms of Motion of Matter. Classification of the Sciences]

193 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 128, Addendum. p. 243

194 Op. cit., § 98, Addendum 1: "...attraction is as essential a part of matter as repulsion." p. 244

195 See Hegel, *Science of Logic*, Book I, Section II, Chapter 1, Observation on Kant's antinomy of the indivisibility and infinite divisibility of time, space and matter. p. 245

196 Hegel, *Naturphilosophie* (*Philosophy of Nature*), § 261, Addendum. p. 245

197 The idea of the preservation of the quantity of motion was expressed by Descartes in his *Le Traité de la Lumière* (*Treatise on Light*), first part of the work *Le Monde* (*The World*), written in 1630-33 and published posthumously in 1664, and in his letter to Debeaune dated April 30, 1639. This proposition is given in its most complete form in R. Des-Cartes, *Principia Philosophiae (Principles of Philosophy),* Amstelodami, 1644, Pars secunda, XXXVI. p. 245

198 Grove, *The Correlation of Physical Forces* (see Note 16). On pp. 20-29 Grove speaks of the "indestructibility of force" when mechanical motion is converted into a "state of tension" and into heat. p. 246

199 This note was written on the same sheet as "Outline of Part of the Plan" and is a conspectus of ideas developed by Engels in the chapter "Basic Forms of Motion" (see this edition, pp. 19 and 69-86). p. 247

200 Grove, *The Correlation of Physical Forces* (see Note 16). By "affections of matter" Grove means "heat, light, electricity, magnetism, chemical affinity, and motion" (p. 15) and by "motion" he means mechanical motion or displacement. p. 248

201 This outline was written on the first sheet of the first folder of *Dialectics of Nature*. As regards its contents, it coincides with Engels's letter to Marx dated May 30. 1873. This letter begins with the words: "This morning in bed the following dialectical ideas about natural science came into my head." The exposition of these ideas is more definite in the letter than in the present outline. It may be inferred that the outline was written before the letter, on the same day, May 30, 1873. Not counting the fragment on Büchner (see this edition, pp. 202-07), which was written shortly before this outline, all the other chapters and fragments of *Dialectics of Nature* were written later, i.e., after May 30, 1873. p. 248

202 A. Comte set out this system of classification of the sciences in his main work *A Course of Positive Philosophy*, first published in Paris in 1830-42. The question of classification of the sciences is specially dealt with in the second lecture, in Volume I of the book, headed "An Exposition of the Plan of This Course, or General Considerations Concerning the Hierarchy of the Positive Sciences". See A. Comte, *Cours de philosophie positive*, t. I, Paris 1830. p. 250

203 Engels is referring to the third part of Hegel's *Science of Logic*, first published in 1816. In his *Philosophy of Nature*, Hegel denotes these three main divisions of natural science by the terms "mechanics", "physics" and "organics". p. 250

204 This note is one of those three larger notes (*Noten*) which Engels put in the second folder of materials for *Dialectics of Nature* (the smaller notes were put in the first and fourth folders). Two of these notes—"On the Prototypes of the Mathematical Infinite in the Real World" and "On the 'Mechanical' Conception of Nature"—are Notes or Addenda to [*Anti*]-*Dühring*, in which Engels elaborates some very important ideas that were only outlined, or stated in brief, in various parts of [*Anti*]-*Dühring*. The third note, "Nägeli's Inability to Cognise the Infinite", has nothing to do with [*Anti*]-*Dühring*. The first two notes were in all probability written in 1885. In any case, they cannot date from earlier than mid-April 1884, when Engels decided to prepare for the press a second, enlarged edition of [*Anti*]-*Dühring*, or later than late September 1885, when Engels finished and sent to the publisher his Preface to the second edition of the book. Engels's letters to Bernstein and Kautsky in 1884 and to Schlüter in 1885 indicate that he planned to write a series of Addenda and Appendices of a natural-scientific character to various passages in [*Anti*]-*Dühring*, with a view to giving them at the end of the second edition of the book. But owing to being extremely busy with other matters (above all with his work on the second and third volumes of Marx's *Capital*); Engels was prevented from carrying out his intention. He only managed to make a rough outline of two "notes" or "addenda", to pp. 17-18 and p. 46 of the text of the first edition of [*Anti*]-*Dühring*. The present notice is the second of these "notes".

The heading "On the 'Mechanical' Conception of Nature" was given by Engels in his list of contents of the second folder of *Dialectics of Nature*. The sub-heading "Note 2 to p. 46": "the various forms of motion and the sciences dealing with them" occurs at the beginning of this notice. p. 251

205 A. Kekulé, *Die wissenschaftlichen Ziele und Leistungen der Chemie*, Bonn, 1878, S. 12. p. 251

206 This refers to an item in *Nature* No. 420, November 15, 1877, summarising A. Kekulé's speech on October 18, 1877, when he took the office of rector at the University of Bonn. In 1878 the speech was published in pamphlet form, under the title *The Scientific Aims and Achievements of Chemistry*. p. 251

207 E. Haeckel, *Die Perigenesis der Plastidule oder die Wellenzeugung der Lebensteilchen. Ein Versuche zur mechanischen Erklärung der elementaren Entwickelungs-Vorgänge*, Berlin, 1876, S. 13. p. 252

208 *The Lothar Meyer curve* shows the relation between the atomic weights of the elements and their atomic volumes. It was constructed by L. Meyer who dealt with it in his article "Die Natur der chemischen Elemente als Funktion ihrer Atomgewichte", which appeared in 1870 in the journal *Annalen der Chemie und Pharmacie*.

The discovery of the correlation between the atomic weights of the elements and their physical and chemical properties was made by the great Russian scientist D. I. Mendeleyev, who was the first to formulate the periodic law of the chemical elements in his article "The Correlation of the Properties of the Elements and Their Atomic Weights", published in March 1869, i.e., a year prior to L. Meyer's article, in the *Journal of Russian Chemical Society*. Meyer, too, was close to establishing the periodic law when he learned about Mendeleyev's discovery. The curve made by him graphically illustrated the law discovered by Mendeleyev, except that it expressed the law in external and, unlike Mendeleyev, one-sided terms. Mendeleyev went much farther than Meyer in his conclusions. On the basis of the periodic law discovered by him, Mendeleyev predicted the existence and specific properties of chemical elements still unknown at that time; whereas L. Meyer in his subsequent works revealed a lack of understanding of the nature of the periodic law. p. 253

209 See Note 183. p. 255

210 E. Haeckel, *Natürliche Schöpfungsgeschichte*, 4. Aufl., Berlin, 1873, S. 538, 543, 588; *Anthropogenie*, Leipzig, 1874, S. 460, 465, 492. p. 255

211 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 99, Addendum. p. 255

212 This fragment was written on a separate sheet marked *Noten* (*Notes*). It may be an original outline of the Second Note to [*Anti*]-*Dühring* headed "On the 'Mechanical' Conception of Nature" (see this edition, pp. 251-55). p. 255

[Mathematics]

213 In the former case, Engels has in mind Hegel's remark that in arithmetic, thought moves in "thoughtlessness" (*Science of Logic*, Book I, Section II, Chapter 2, Observation on the employment of numerical determinations to express philosophic concepts); in the latter case, Hegel's statement that "already the natural numer-

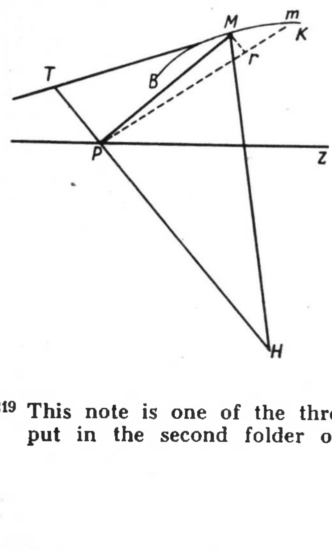
ical system exemplifies a nodal line of qualitative moments, which manifest themselves in the merely external progression", etc. (ibid., Section III, Chapter 2, Observation on examples of nodal lines of measure-relations; *natura non facit saltum*). p. 259

214 This expression occurs in the book by Bossut, referred to by Engels in the fragment "Straight and Curved". In the chapter on "Integral Calculation with Finite Differences", Bossut examines first of all the following problem: "To integrate or sum the whole-number steps of a variable magnitude x." Bossut assumes that the difference $\triangle x$ is constant and he denotes it by the Greek letter ω. Since the sum of $\triangle x$ or of ω is equal to x, the sum of $\omega\times 1$ or of ωx° is also equal to x. Bossut writes this equation in the form $\Sigma\omega x^{\circ}=x$. Bossut then takes out the constant ω and puts it before the summation sign, obtaining the expression $\omega\Sigma x^{\circ}=x$, from which he obtains the equation $\Sigma x^{\circ}=\frac{x}{\omega}$. This last equation is then used by Bossut to find the magnitudes Σx, Σx^2, Σx^3, etc., for solving other problems. See Bossut, *Traités de Calcul différentiel et de Calcul intégral*, t. I, Paris, 1798, p. 38. p. 263

215 Ch. Bossut, *Traités de Calcul différentiel et de Calcul intégral*, t. I, Paris, an VI (1798), p. 149. p. 265

216 This is how Bossut terms the curves considered in the system of polar co-ordinates. p. 265

217 Engels has in mind Fig. 17 and explanation to it on pp. 148-51 of Bossut's *Treatise*. This figure has the following form: *BMK* is the curve. *MT* is its tangent. *P* is the pole or origin of the co-ordinates. *PZ* is the polar axis. *PM* is the ordinate of the point *M* (Engels calls it "real abscissa"; nowadays it is called the radius-vector). *Pm* is the ordinate of point *m* lying infinitely close to *M* (Engels calls this radius-vector the "differential imaginary abscissa"). *MH*, perpendicular to the tangent *MT*. *TPH*, perpendicular to the ordinate *PM*. *Mr*, the curve described by the radius *PM*. As *MPm* is an infinitesimal angle, *PM* and *Pm* are considered parallel. The triangles *Mrm* and *TPM*, as also the triangles *Mrm* and *MPH*, are regarded as similar. p. 265



218 See Note 95. p. 266

219 This note is one of the three larger notes (*Noten*) which Engels put in the second folder of materials for *Dialectics of Nature*.

(See Note 204.) It was written originally as the first sketch of a commentary note to pp. 17-18 of the first edition of *[Anti]-Dühring*. The heading "On the Prototypes of the Mathematical Infinite in the Real World" was given by Engels in the list of contents of the second folder of *Dialectics of Nature*. The sub-heading "To pp. 17-18; Concordance of Thought and Being.—The Infinite in Mathematics" stands at the beginning of the note. p. 266

220 *Nihil est in intellectu, quod non fuerit in sensu* (nothing is in the mind which has not been in the senses), the fundamental tenet of sensualism. The content of this formula goes back to Aristotle (see his *Posterior Analytics*). p. 266

221 This figure is given in an article by William Thomson, entitled "The Size of Atoms", which was first published in the journal *Nature* No. 22, of March 31, 1870, and afterwards reprinted as an appendix in the second edition of *Treatise on Natural Philosophy* by Thomson and Tait (Vol. I, Part II, new ed., Cambridge, 1883, pp. 501-52). p. 268

222 One of the dwarf states forming part of the German Empire since 1871. p. 271

223 Here Engels possibly has in mind Haeckel's psychophysical monism and his views on the structure of matter. In *Die Perigenesis der Plastidule* (*The Perigenesis of the Plastidule*), which Engels quotes in his Second Note to [*Anti*]-*Dühring* (see present edition, p. 252), Haeckel affirms, for example, that the elementary "soul" is inherent not only in "plastidules", or protoplasm molecules, but also in atoms, and that all atoms are "animate" and possess "sensation" and "volition". In the same book Haeckel describes atoms as something absolutely discrete, absolutely indivisible and absolutely inalterable, while along with discrete atoms he recognises the existence of ether as something absolutely continuous (op. cit., Berlin, 1876, S. 38-40).

Engels mentions in his note "The Divisibility of Matter" (see present edition, p. 245) how Hegel deals with the contradiction of contnuity and discreteness of matter. p. 272

[Mechanics and Astronomy]

224 Engels is referring to Clausius's lecture "On the Second Law of the Mechanical Theory of Heat", delivered in Frankfort-on-Main, September 23, 1867, at the 41st Congress of German Natural Scientists and Physicians, and published in book form in Braunschweig the same year. p. 273

225 This and the two following notes consist of extracts from the following books: J. H. Mädler, *Der Wunderbau des Weltalls, oder*

Populäre Astronomie, 5. Auflage, Berlin, 1861. (Sections IX and X); A. Secchi, *Die Sonne*, Braunschweig, 1872, Part III. Engels made use of these extracts in 1876 in the second part of Introduction to *Dialectics of Nature*. (See this edition, pp. 31-40). p. 274

226 Engels is referring to Rudolf Wolf's book *Geschichte der Astronomie*, München, 1877 (see Note 124). On p. 325 of this book Wolf asserts that the law of the refraction of light was discovered not by Descartes but by Snell who formulated it in his unpublished works, from which Descartes subsequently (after Snell's death) took it. p. 288

227 Engels is referring to Julius Robert Mayer's book *Die Mechanik der Wärme in gesammelten Schriften*, 2. Auflage, Stuttgart, 1874, S. 328, 330. p. 288

[Physics]

228 Francis Bacon, *Novum Organum* (Francis Bacon, *The New Organon*), Book II, Aphorism XX, published in London in 1620. p. 279

229 Cf. Hegel's remark that force "has no other content than the phenomenon itself" and that this content expresses itself only "in the form of into-reflected determination or force", the result being an "empty tautology" (Hegel, *Science of Logic*, Book II, Section I, Ch. 3, Observation on the formal method of explanation from tautological grounds). p. 282

230 G. W. F. Hegel, *Philosophy of Nature*, § 266, Observation. p. 283

231 Engels is referring to Lavrov's book *Опыт истории мысли* (*Attempt at a History of Thought*), Vol. 1, published anonymously in St. Petersburg in 1875. On page 109 of this book in the chapter "The Cosmic Basis of the History of Thought", Lavrov writes: "Dead suns with their dead systems of planets and satellites continue their motion in space as long as they do not fall into a new nebula in process of formation. Then the remains of the dead world become material for hastening the process of formation of the new world." In a footnote Lavrov quotes the opinion of Zöllner that the state of torpor of extinct heavenly bodies "can be ended only by external influences, e.g., by the heat evolved on collision with some other body." p. 284

232 See Note 224. p. 284

233 See Note 224. p. 286

234 Engels is evidently referring to page 16 of the above pamphlet, where Clausius incidentally mentions the ether as existing *outside* the heavenly bodies. Here again, on p. 6, it is a question of the

same ether, though not outside bodies but in the interstices between the most minute constituent particles of the bodies. p. 286

235 *Horror vacui*, abhorrence of a vacuum. The view, dating from Aristotle, that "nature abhors the void", that is, does not allow a vacuum to form, prevailed in natural science till the mid-seventeenth century. This "abhorrence" was given, among other things, as the reason why the water rises in a piston. In 1643 Torricelli discovered atmospheric pressure and thereby refuted the Aristotelian notion of the impossibility of a vacuum. p. 287

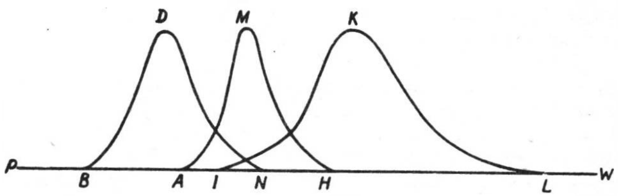
236 Engels wrote Lavrov's name in Russian characters. Engels is referring to Lavrov's book *Опыт истории мысли* (See Note 231). In the chapter "The Cosmic Basis of the History of Thought", Lavrov mentions the views of various scientists (Albers, V. Struve) on the extinction of light coming from very great distances (pp. 103-04). p. 287

237 Gospel according to St. John, I. p. 287

238 Fick, *Die Naturkräfte in ihrer Wechselbeziehung* (*The Interaction of Natural Forces*), Würzburg, 1869. p. 287

239 Maxwell, *Theory of Heat*, Fourth Edition, London, 1875, pp. 87, 185. p. 287

240 Engels is referring to the diagram on page 632 of Secchi's book, showing the relationship between the length of the wave and the intensity of the thermal, luminar and chemical actions of the sun-rays, the main portion of which is reproduced below:



The curve *BDN* represents the intensity of heat radiation, from the longest wave heat-rays (at point *B*) to the shortest wave rays (at point *N*). The curve *AMH* represents the intensity of light radiation, from the longest wave rays (at point *A*) to the shortest wave rays (at point *H*). The curve *IKL* represents the intensity of chemical rays, from the longest wave rays (at point *I*) to the shortest wave rays (at point *L*). In all three cases the intensity of the rays is shown by the distance of the point on the curve from the line *PW*. p. 288

241 Engels is referring to Hegel's *Philosophy of Nature*, Berlin edition, 1842, § 320, Addendum. p. 288

242 Here and further on Engels quotes from Th. Thomson's book, *An Outline of the Sciences of Heat and Electricity*, 2nd edition, London, 1840. Engels made use of these quotations in the chapter "Electricity". p. 288

243 Here and in the following note Engels is referring to the book of the British physicist Frederick Guthrie *Magnetism and Electricity*, London and Glasgow, 1876. On page 210 Guthrie writes: "The strength of the current is proportional to the amount of zinc dissolved in the battery that is oxidised, and is proportional to the heat which the oxidation of that zinc would liberate." p. 291

244 See Wiedemann, *Die Lehre von Galvanismus und Elektromagnetismus*, III, Braunschweig, 1874, S. 418 (see Note 95). p. 292

[Chemistry]

245 H. Kopp, *Die Entwickelung der Chemie in der neueren Zeit*, 1. Abt., München, 1871, S. 105. p. 293

[Biology]

246 Hegel, *Encyclopaedia of the Philosophical Sciences*, § 81, Addendum 1: "...life as such bears in it the embryo of death." p. 295

247 *Plasmogony* was the term Haeckel used to denote the hypothetical origin of organisms when the organism arises within some organic liquid, in contrast to *autogeny*, i.e., the direct origin of living protoplasm from inorganic matter. p. 296

248 Engels is referring to the experiments on spontaneous generation carried out by Pasteur in 1860. By these experiments Pasteur proved that micro-organisms (bacteria, yeasts, infusoria) in any nutritive (organic) medium develop only from germs already present in the medium or which reach it from outside. Pasteur concluded that the spontaneous generation of micro-organisms, and spontaneous generation in general, is not possible. p. 297

249 The extracts from Wagner's article are taken from the Augsburg *Allgemeine Zeitung* of 1874, pp. 4333, 4334, 4351 and 4370.

Die Allgemeine Zeitung was a conservative daily founded in 1798. It appeared in Augsburg from 1810 to 1882. p. 297

250 W. Thomson and P. G. Tait, *Handbuch der theoretischen Physik*, Autorisierte deutsche Übersetzung von Dr. H. Helmholtz und G. Wertheim. 1. Band, 2. Teil, Braunschweig, 1874, S. XI. Engels quotes from Wagner's article. p. 298

251 See Liebig, *Chemische Briefe*, 4-te umgearbeitete und vermehrte Auflage, I. Band, Leipzig und Heidelberg, 1859, S. 373. p. 298

252 *Traube's artificial cells*, inorganic formations representing replicas of living cells and capable of reproducing metabolism and growth and serving to investigate various aspects of vital phenomena. They were created by M. Traube, a German chemist and physiologist, through mixing colloidal solutions. Traube reported on his experiments at the 47th Congress of German Natural Scientists and Physicians in Breaslau on September 23, 1874. Marx and Engels had a high opinion of Traube's discovery (see Marx's letter to P. L. Lavrov dated June 18, 1875, and W. A. Freund, dated January 21, 1877). p. 302

253 Engels is referring to Allman's paper "Recent Progress in Our Knowledge of the Ciliate Infusoria", delivered to the Linnaeus Society on May 24, 1875, and printed in Nos. 294, 295 and 296 of the British journal *Nature* (of June 17 and 24 and July 1, 1875). p. 302

254 Engels is referring to the review of Croll's book *Climate and Time in Their Geological Relations; a Theory of Secular Changes of the Earth's Climate*, London, 1875, printed in *Nature* Nos. 294, 295 (of June 17 and 24, 1875) and signed J. F. B. p. 302

255 Engels is referring to Tyndall's article "On the Optical Deportment of the Atmosphere in Reference to the Phenomena of Putrefaction and Infection" which was an abstract of a paper read before the Royal Society on January 13, 1876. The article was published under the heading "Professor Tyndall on Germs" in *Nature* Nos. 326 and 327 of January 27 and February 3, 1876. p. 302

256 Haeckel, *Natürliche Schöpfungsgeschichte*, 4. Aufl., Berlin, 1873. Plate I occurs between pp. 168 and 169 of this edition and the letterpress to it on p. 664. p. 303

257 Engels is referring to the book of Nicholson, *A Manual of Zoology*. (See Note 18.) p. 303

258 Engels is most probably referring to Wilhelm Wundt's *Lehrbuch der Physiologie des Menschen*. It was first published in Erlangen in 1865. A second and a third edition appeared in the same town in 1868 and 1873. p. 303

259 *Zoophytes* (Pflanzentiere, animal plants)—a term applied from the sixteenth century onwards to a group of invertebrates, mostly the sponges and coelenterates, possessing certain characteristics that were considered indicative of plants (such as a sessile way of life). The zoophytes were therefore regarded as forms intermediate

between plants and animals. In the mid-nineteenth century the term became a synonym for coelenterate. It is no longer used. p. 304

260 In the fourth edition of his book *Natürliche Schöpfungsgeschichte* Haeckel enumerates the following first five stages of development of the embryo in multi-cellular animals: *Monerula, Ovulum, Morula, Planula* and *Gastrula*, which, according to him, correspond to the five initial stages of the development of animal life as a whole. In the later editions of the book, Haeckel substantially altered this scheme, but his basic idea, to which Engels gave a positive appraisal, the idea of the parallelism between the individual development of an organism (autogeny) and the development of a particular form in the course of evolution (phylogeny) has become firmly established in science. p. 305

261 The word "bathybius" means "living in the depths". In 1868 Huxley described a sticky slime, dredged from the bottom of the ocean, which he regarded as primitive, structureless living matter—protoplasm. In honour of Haeckel, he named this—as he thought—simplest living organism *Bathybius Haeckelii*. Haeckel considered the bathybius as species of modern, still living Monera. Afterwards it was demonstrated that the bathybius has nothing in common with protoplasm and is an inorganic form. Haeckel speaks of bathybius and the small calcareous modules enclosed in it on pp. 165-66, 306, 379 of the fourth edition of his *Natürliche Schöpfungsgeschichte*, Berlin, 1873. p. 305

262 In the first volume of his *Generelle Morphologie der Organismen*, Berlin, 1866, Haeckel deals in four large chapters (VIII-XI) with the concept of the organic individual, and with the morphological and physiological individuality of organisms. He also considers the notion of individual in a number of passages of *Anthropogenie oder Entwickelungsgeschichte des Menschen* (*Anthropology, or A History of the Evolution of Man*), Leipzig, 1874. He divides organic individuals into six classes or orders: plastids, organs, antimeres, metameres, individuals, and cormuses. The individuals of the first order are pre-cellular organic forms of the Monera (cytode) type and cells, they are "elementary organisms". The individuals of each order, beginning with the second, consist of individuals of the preceding order. The individuals of the fifth order are, in the case of superior animals, "individuals" in the narrow sense of the term.

Cormus—a morphological individual of the sixth order representing a colony of individuals of the fifth order. The series of marine lucifers may serve as an example.

Metamere—a morphological individual of the fourth order, the recurrent limb of the individual of the fifth order. The segments of the tapeworm may serve as an example. p. 305

263 "Natural Selection; or the Survival of the Fittest", is the title of Chapter IV of Darwin's *The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*". p. 307

264 The contents of this note are almost identical with those of Engels's letter to Lavrov of November 12, 1875. p. 307

265 *Bellum omnium contra omnes* (a war of all against all), an expression used by T. Hobbes in his writings *De cive* (*Of the Citizen*), a "Preface to the Reader", and *Leviathan*, Chapters XIII and XIV. p. 307

266 Hegel, *Science of Logic*, Book III, Section III, Chapter 1. p. 309

267 Engels is referring to the end of the second part of Hegel's *Logic* (*Science of Logic*, Book II, Section III, Chapter 3, "Reciprocity", and *Encyclopaedia of the Philosophical Sciences*, Part I, Section II, "Reciprocity"). Here Hegel himself mentions the living organism as an instance of interaction: "...individual organs and functions likewise prove to be in a relation of interaction towards each other." (*Encyclopaedia*, § 156, Addendum.) p. 309

268 H. A. Nicholson, *A Manual of Zoology*, 5th edition, Edinburgh and London, 1878, pp. 32, 102. p. 309

269 A peak in the Berne Alps, Switzerland. p. 310

270 The headings of the four folders and the list of contents made by Engels for the second and third folders of materials for *Dialectics of Nature* were written in his closing years, in any case not earlier than 1886, for the list of contents of the second folder includes the fragment "Omitted from *Feuerbach*", which was written early in 1886. p. 312

Index of Contents of the Folders*

[First Folder]

Dialectics and Natural Science

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* Notes and fragments from one and the same sheet of the manuscript are bracketed together. The numbers on the left indicate the pagination of Engels's manuscript. Asterisks refer to the notes made in preparation for the writing of *Anti-Dühring*. The relevant pages in this volume are given in brackets on the right.

103) Application of mathematics (p. 272).
104) The differential calculus... (p. 272).

* "Slavery"

105) That positive and negative are equivalent ... (p. 216).
106) Chance and necessity (pp. 217-221).

* Fourier, *New Industrial and Social World.*

107) Polarisation (p. 217).
108) Polarity (p. 217).
109) Another example of polarity in Haeckel (pp. 208-209).
110) Valuable self-criticism of the Kantian *thing-in-itself* (p. 242).
111) When Hegel makes the transition from life to cognition... (p. 309).
112) According to Hegel, infinite progress is a barren waste (pp. 237-238).
113) Quantity and quality (pp. 258-259).
114) Number (p. 259).
115) Mathematics (p. 264).
116) Conservation of energy (p. 280).
117) At absolute 0° no gas is possible (p. 286).
118) mv^2 has been proved also for gas molecules (p. 286).
119) $\sqrt{-1}$. The negative magnitudes of algebra (p. 283).
120) The transformation of quantity into quality (p. 213).
121) Identity and difference (p. 216).
122) Just as Fourier is a mathematical poem (p. 206).
123) Hegel's conception of force and its manifestation, of cause and effect as identical... (p. 280).
124) The evolution of a concept, or of a conceptual relation ... in the history of thought (p. 222).
125) Abstract and concrete (p. 222).
126) The significance of *names* (p. 294).
127) In the first place, Kekulé (pp. 255-256).

[Second Folder]

The Investigation of Nature and Dialectics

[Contents of the second folder] (p. 312).

1) On the Prototypes of the Mathematical Infinite in the Real World (pp. 266-272).
2) On the "Mechanical" Conception of Nature (pp. 251-255).
3) On Nägeli's Incapacity to Know the Infinite (pp. 232-236).
4) Old Preface to [*Anti*]-*Dühring*. On Dialectics (pp. 40-49).
5) The Part Played by Labour in the Transformation from Ape to Man (pp. 170-183).
6) Omitted from "*Feuerbach*" (pp. 195-200).

* "Modern socialism" (the most important passages of this rough outline differing from Chapter One of the Introduction are given in footnotes to [*Anti*]-*Dühring*).

[Third Folder]

Dialectics of Nature

[Fourth Folder]

Mathematics and Natural Science Miscellaneous

Chronological List of Chapters and Fragments*

1873

1874

* The list includes those fragments and articles the dates of which have been established more or less accurately. The dates of the remaining 62 fragments could not be established because of insufficient data; most of them were written between July 1878 and March 1883. The figures in brackets indicate the corresponding pages of the present edition.

22) Bad infinity (p. 237).
23) Simple and compound (p. 214).
24) Primordial matter (p. 243).
25) The incorrect *theory of porosity* ... is presented by Hegel as a pure *figment of the mind* (p. 206).
26) Force (pp. 280-283).
27) The indestructibility of motion in *Descartes*'s principle (pp. 245-246).
28) Its essence (of motion) is to be the immediate unity of space and time (p. 245).
29) Force (see above) (p. 283).
30) Motion and equilibrium (pp. 246-247).
31) Causality (pp. 230-231).
32) Newtonian gravitation (pp. 273-274).
33) Force (p. 283).
34) Reciprocal action (pp. 231-232).
35) The indestructibility of motion (p. 246).
36) Mechanical motion (pp. 247-248).
37) The divisibility of matter (p. 245).
38) Natural-scientific thought (p. 207).
39) Induction and deduction (p. 226).
40) In *Oken*... the nonsense ... is evident (p. 207).
41) *Causae finales* and *efficientes* (p. 208).
42) God is nowhere treated worse than by the natural scientists who believe in him (pp. 200-201).
43) Rudiments in nature (p. 309).
44) Unity of nature and mind (p. 222).
45) Classification of the sciences (pp. 249-250).
46) Protista (pp. 303-305).
47) The individual (p. 305).
48) Repetition of morphological forms at all stages of evolution (p. 305).
49) For the entire evolution of organisms (pp. 305-306).
50) The whole of organic nature is one continuous proof of the identity or inseparability of form and content (p. 305).
51) The kinetic theory of gases (p. 286).
52) The law of identity (pp. 215-216).
53) Natural scientists believe that they free themselves from philosophy by ignoring it or abusing it (pp. 209-210).
54) Historical (pp. 192-195).
55) The character of mutual opposition belonging to theoretical development (p. 287).
56) *Generatio aequivoca* (pp. 296-297).
57) Force (p. 280).
58) Haeckel, *Anthropogenie*, p. 707 (p. 208).
59) Mayer, *Mechanische Theorie der Wärme* (p. 278).
60) An example of the necessity of dialectical thought ... the law of falling (p. 273).
61) Moriz Wagner, *Naturwissenschaftliche Streitfragen* (pp. 297-302).

1875

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