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As it has been planned, the compilation we have begun,

Present-Day Knowledge

has as its goal to solve the task of offering to the educated person satisfactory enlightenment, teaching and stimulus in each area of science as well as in its whole from the point of view of present-day research, and we thus recommend it to the attention of the general public. At present, some two to three hundred volumes are foreseen for our collection, **each one of which will be complete in itself**, while being at the same time one stone in a whole building. In the project's planning, we have used the division into the two sections that unmistakably dominate modern scientific research as our top organizational principle. Just as the **natural sciences** and the **historical sciences** are dominant in the life of modern scientific research, like two well-situated islands that gain ever more fertile land and that draw to themselves even disciplines that are less inclined to be joined to them, these will also be the two main groups in the systematic organization of our collection, which aims at clearly reflecting this life. We will not exclude the purely abstract areas of study, which could form a third group, but they will not be examined both from the dogmatic and the historical point of view. There are two reasons for this: for part of these areas of scholarship, as for example mathematics, no knowledge other than a really complete specialist knowledge is conceivable; and for another part, such as metaphysics, positive truth can only be offered insofar as it concerns the inner history of the field of study.

Our only other comment is that we have included in the large group of historical sciences the areas of regional studies and ethnology, which are emerging as ever more important areas of scholarship and which include elements of natural science and historical ones, because the main point of view on which these sciences are based, that is their territorial boundaries, is historical.

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Volume 66

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The

Laws of the Phenomena of Nature

By

A. Pinner

Professor at the University of Berlin

With 60 Illustrations within the Text

Leipzig: **Vienna and Prague:**
G. Freytag **1888** **F. Tempsky**

Foreword

This small book, which was already written in 1884, attempts to make it possible for a larger public to understand the various phenomena of nature. Along with the desire to emphasize the unity of the basic causes of all the changes we perceive in nature, the author was led by the wish to explain mainly the presently accepted views concerning chemical changes. Therefore, the by far largest part of the book is dedicated to explaining chemical phenomena. In doing so, it became necessary to elaborate not only on the opinions in general concerning the composition of substances out of molecules and atoms, but also to go into greater detail on the theory of atoms and to explain the chemical way of writing. Hopefully, the book has succeeded in showing that this way of writing, which seems so strange and almost repulsive to us in the beginning, can be understood so easily that every non-chemist who is used to logical thinking can use it.

Berlin, December 1887. P.

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Introduction

After the thousand years of humanity's mental standstill during what we call the Middle Ages, the interest in the study of lands and peoples was stimulated and kept alive up to our day at a very broad level among the people through the great successes of outstanding individual men during the "Age of Discovery". In the same way, during our time, the "Age of Inventions", research into the laws of nature and the use of the forces of nature, which in barely a century has fundamentally transformed all our living conditions, has awakened an interest in the knowledge of nature among all classes of people. And this interest is continually kept alive both by means of ever new inventions and by the clearest possible depictions of these in popular papers.

As is generally known, the natural sciences are quite young sciences, but it is equally generally known that research into nature was and had to be the very first occupation of the human mind. For already in earliest times, because of his quite helpless position in the face of nature, the human person was dependent on protecting himself against the forces of nature that were a threat to his existence. So where and when his life was in danger because of events that did not occur every day, such as floods, being hit by lightning, etc., he had to watch closely so as to be able to choose more favorable places for his dwellings, and when such a place was not available, he had to be able to set up protective measures against the harmful forces of nature, preventing their approach when possible, but at least so as to recognize ahead of time that they were coming and not to be powerless when faced with them, or to be able to flee from them.

If we now ask how it is possible that the human being who was forced to study nature, throughout many centuries nevertheless only made small progress in getting to know it, and that the study of nature was raised to the rank of the science of nature only during the very last centuries, we find that the one and only reason is that the correct way of observing nature was only disc[illegible]

Thus it came about that hardly a single natural phenomenon could be interpreted correctly, that the observation of nature remained very superficial, and that the most preposterous hypotheses were set up to explain the natural processes. Only very late and to begin with timidly, often turning aside from the right path and getting lost on muddled wrong tracks, people began to leave the answering of questions concerning the nature of the human being and the causes of his mental powers, the questions concerning the principle of order in the world and such like to later times and to seek the causes of the simplest natural phenomena first of all by seeking to bring about the conditions that gave rise to them, and thus to bring about the phenomena themselves. So people tried to imitate the natural processes in small things, and thus, with the help of experiments and not just through the observation of natural events that occur daily without our influence, they collected for the time being a large number of irrefutable facts, and gradually they recognized the connection between these. By following this path, results were attained faster than was to be expected. These revealed to us in a most surprising way and yet most clearly not only what the mighty forces of nature are, but above all, they taught us to utilize these forces for our own purposes in ways that, in former times, the most audacious thinkers could hardly have imagined. Thus, once it had been led onto the right track, the exploration of nature gave not only what was of highest interest, not only the highest satisfaction of the human being's inborn desire to know, but also the highest reward through the total transformation of his living conditions. And if we consider that we are really at the beginning of getting to know nature, that every solution of any kind of a problem immediately stimulates new problems, the solution of which is reserved for later times, then the joyful perspective opens up for us that the human race is advancing both in its mental development and in its physical well-being, is becoming ever more noble, both mentally and physically.

Very soon after the right path for getting to know the natural phenomena had been taken, after recognizing that reflection alone, speculation, is not capable of discovering the causes for the constantly occurring changes in nature, but rather, that only experimenting can bring us closer to this goal, our entire way of seeing nature was also transformed, our ideas about what nature and its changes are, were given a different foundation.

For we find that among the Greeks, the civilized nation whose view of nature we know more precisely and that alone had an influence on the development of the human race in all branches of human knowledge throughout all of the Middle Ages, the same basic mistake recurs almost constantly in their general view of nature. In this, only the natural things as such, that is to say, expressed in one short word, only matter, its substance and its various forms of being visible were looked at, whereas the powers dwelling within matter, that bring about the variety in the visible forms, were considered to be insignificant and were hardly taken into consideration. And one consequence of this point of view was that Aristotle included also fire among his four elements, the first three of which can be considered to be the three states, so the most conspicuous visible forms of matter [(earth, water, air)[1]]. Aristotle considered fire to be an equal material state, but according to our present-day point of view, fire stands in no relation to the

[1] Earth = the solid state, Water = the liquid state, Air = the gaseous state.

other three. Of course, Aristotle's four elements were not supposed to express the states of matter in the present-day sense, since no gase ot

On the Nature of Matter

All our experience of the nature of matter forces us to assume that no body, no matter what it is like, can form an uninterrupted mass. Otherwise we could neither explain the division of matter nor its expansion through heating or its contraction through cooling etc. Rather, we are obliged to assume that all matter consists of very small particles that are separate from one another and that are called mass particles. The technical name for mass particles is the diminutive of *moles* (mass), *molecula*, which we can anglicize and make into *molecule* (like the word particle from *particula*). So the first theorem can be reached: *Every type of matter is made up of molecules that are separated from one another by spaces between them*. Of course, the tools we have to help us do not enable us to observe molecules directly, so we are entirely in the dark as to their shape. We are even obliged to assume that molecules are so utterly tiny that, even by improving the microscopes, for example, we will never get to the point of being able to make these mass particles materially visible. However, the shape of molecules is completely irrelevant for all of our examinations.

In the same way, we know nothing certain about the absolute size of the molecules. People have expressed the most varied speculative possibilities, but because of the lack of certainty in the prerequisites on which this speculation is based, we shall not take it into consideration. However, the following frequently used allegory can give an idea of how small we have to imagine the molecules. Let us think of some object the size of a pea, for example a small glass bead that is then magnified so much that the little bead ultimately has the circumference of our earth. Comparably, if the individual glass molecules were magnified to an equal extent, they would be the size of a pea.

When we divide an object, we are separating the material molecules from one another. The individual parts of the object no longer have the shape of the undivided object, though they do still possess all its characteristics. Of course, our mechanical tools are not able by far to split an object to the point of its molecules. Under a strong magnifying microscope, the finest powder that we produce from a solid object, the tiniest drops that we can produce from sprinkled liquid appear as a mass of coarse grains or as large drops, which we perceive immediately as being divisible into smaller parts. Since the various forms of matter, even in their most finely divided state, still maintain their essential characteristics, we are justified in assuming that even the infinitely tiny particles, and that is to say nothing other than each individual molecule, for example of glass, of water, of iron, of mercury, etc. must also possess the essential characteristics of glass, water, iron, mercury. So are molecules themselves still divisible? Since we have to think of molecules as being the tiniest particles of which any kind of matter consists, the obvious answer to the above question is: molecules are not divisible, and that is why in the past they were called atoms (from the Greek word *atomos*, “indivisible”). However, as we shall see later, the molecules are also not simple homogenous particles, but are almost always made up of even smaller particles, but these no longer have the characteristics that we perceive in the respective form of matter. For example, glass molecules are made up of a quite large number of even smaller particles, which however no longer have the characteristics of glass and which we are not able to depict in their free state. As will be shown further on, we do have a considerable number of tools to help us divide the glass molecules, but the minute the division occurs, the particles unite in a different way, and we again get molecules made up of the same particles but with entirely different characteristics to those of the glass molecules. That is to say, from the glass, we get a row of different forms of matter. Later, we shall discuss in detail this fact, which seems strange when observed superficially. For the moment, we only mention here that the small particles, which make up the molecules, are now called atoms. Any change that we observe in any form of matter must have been brought about by some cause. These causes are called forces in the broadest sense of the word. A cause or a force must have been active if the stone does not remain in the place where it was laid; a force must be active if the water in an open container gradually evaporates, is transformed into steam; a force must be active if at sunrise, light spreads over the surface of the earth, if clouds are formed, gather together, if lightning flashes from the cloud and there is crashing thunder. We have to ascribe it to some kind of forces when the stone gradually crumbles away from the building, when steel rusts, when the shiny metal surface becomes dull and nondescript. Every change that we observe more closely in the respective state of nature that surrounds us or in the individual forms of matter, that is to say, all of nature's phenomena, are brought about through forces that are at work in the most varied ways. But in every case, when we can discover the ways and means by which these forces are at work, we find that they cause movement, whether this movement includes the entire mass ~~of a~~n object~~ ~~as such, or that the molecules of an object or finally the atoms in the molecules are made to move. Mainly for the sake of easier comprehension, we distinguish between those forces that cause the total mass of matter to move, mechanical forces, and those that give movement to the molecules, which are the physical forces, and finally those that bring the atoms in the molecules into movement, which we call chemical forces.

Everywhere in nature we find such moving forces at work. We no longer see anything marvelous in the fact that the moon is in constant movement around the earth, that the earth is in eternal movement around its axis and around the sun. Also, the fact that even the sun and all the fixed stars in our firmament are not standing still but are rather moving uninterruptedly – something that was recognized only very late – does not strike us as marvelous. But it is more difficult for us to grasp the idea that the extremely tiny particles of every earthly form of matter are in uninterrupted movement, like the large bodies in the heavens that we not inappropriately might call the molecules of the universe. The molecules of a piece of glass, a drop of water, etc. are not lying quietly next to each other, but are in constant movement, even though this is happening within immeasurably small boundaries. Of course, we cannot directly see these movements of the molecules, but all of our experiences of the most varied phenomena in nature force us to assume such constantly occurring molecular movement.

The question as to where the moving forces in nature come from is just as futile, at least for the natural sciences, as that concerning the origin of matter. Our task is simply to examine the laws according to which these forces work and to derive nature’s individual phenomena from them.

Thus we can, for example, immediately attribute the most obvious difference in the forms in which matter appears to us, their state, to molecular movement. As we know, all forms of matter which we are able to perceive are either solid or liquid or in the form of air, and as can be observed best with water, we are almost always able to get one and the same form of matter both in its solid state as well as in its liquid and its air-like (or better, gaseous) state. But we know of the heavenly bodies that the planets, for example, only move around a certain point in a closed path, in circular ellipses, because there a special force between them and the sun is at work, the force of attraction (gravitation). The minute this force ceased to work, the planets would fly into space in a straight line, in the direction of the tangent. In **Figure 1**, the disc **S** is the sun, point **P** is the planet, and the circular line is the planet’s path; the line **ab** is the tangent of the circle and shows the direction in which the planet would fly away if the sun’s force of attraction ceased to work on it just when it was in the place marked by **P**. It would fly away in this direction (**ab**) and with the same constant speed until it hit some obstacle, from which it would ricochet. It would then fly back in a straight line until it again hit an obstacle. Thus, its originally circular or elliptical movement is transformed into a straight line the minute the sun’s force of attraction loses its effect on it. Exactly the same law must also rule over the smallest particles of matter, the molecules. When the molecules in any object attract one another, every one of them will move around a certain point, whether in a circular or an elliptical path, whereas, as soon as this mutual attraction ceases or is lacking, those same molecules will move away in a straight line until they bump into some resistance and ricochet, when they will then swing into the opposite direction until they hit a second point of resistance.

In solid bodies, the molecules have a strong attraction towards one another. That is why it is only possible to separate the molecules from one another by using more or less great force. In particular, the earth’s force of attraction, its gravity, on the individual mass particles is not able to overcome their mutual attraction. With liquid bodies, on the other hand, the mutual attraction between the molecules is very small and is already cancelled by gravity, so that when a liquid is poured out of a container, the part that comes out of the container separates itself from the rest and falls to the ground. In the gaseous bodies, finally, the mutual attraction of the molecules is completely destroyed; every molecule moves freely as far as it is able. Thus, the movement of the molecules in solid and liquid bodies occurs in small closed paths around a position of equilibrium, whereas in gaseous bodies it occurs in straight lines and as far as possible, that is to say, until the molecules bump into and ricochet away from each other or until they finally hit the walls of the container and are thrown back from there, thus continuing the same game in the opposite direction.

We can easily derive the main differences between the three states from the various kinds of molecular movement in solid, liquid and gaseous matter. Since the molecules attract one another in solid and liquid matter and swing in limited paths, if all the other conditions remain the same, the distance between the molecules must remain unchanged except for the path of oscillation, which can be disregarded. Therefore, a thousand molecules must take up the double space of five hundred and half that of two thousand. That is saying nothing other than that solid and liquid matter always fill up only a certain space and half of the mass half of the space, etc.

In contrast, gaseous matter must behave differently. Here, the molecules move freely; when there are no other obstacles, every molecule swings through the entire space. Consequently, a gaseous body cannot occupy any space of its own, but must rather fill every space that is offered it. If we bring a liter of a gaseous body, for example air, into a large space, for example a space that can hold a thousand liters and that is free of air, the gas will spread out into the entire space in a very short time. In every corner and spot, we will find a corresponding part of air, one thousandth of the amount that was previously in a space of the same size.

Similarly, another phenomenon that we can observe daily can be derived from the different forms of the molecules' mutual attraction. Solid bodies do not mix. It is true that we can mix two kinds of powder, but the little grains of powder from the one object will always lie next to the little grains of the other, and with an equipped eye they can easily be distinguished from one another. On the other hand, with liquids, where the mutual attraction of the molecules is very slight, a real mixture can occur, although this is not a necessity. The mixing of two liquids depends on whether the attraction of the molecules of the one liquid to the molecules of the other liquid is greater than the mutual attraction of the molecules among themselves in each of the two liquids. If we shake water and alcohol together, we get a completely homogenous liquid; even if we magnify it very greatly, we cannot perceive any difference between the individual particles of the liquid. But if we shake water and oil together, we don't need much effort to observe the little drops of water next to the small drops of oil. In this case, the two liquids are behaving like two solid bodies. – However, with gaseous matter, a real mixture and mutual penetration must always occur, since there is no mutual molecular attraction here that has to be overcome. So if we mix two kinds of gas in whatever proportion to one another, we will find exactly the same proportion of the two gasses in every part of the space where the gas mixture is.

It was said above that we are not able to observe the molecular movements directly, but indirectly, we can also perceive these movements. If, under a strong microscope, we look closely at a drop of water on which there are a few grains of dust, we can note that the solid grains are constantly moving slightly back and forth as if they were trembling. This trembling motion of the grains of dust can be observed best when there is no external reason for it, when there is perfect quiet in the place of observation. The movement is caused by the constant movement of the water molecules that are bumping into the little grains of dust and finally cause them to move as well. In addition, in a dark room with a ray of direct sunlight coming in through a small opening, we can observe even with our naked eye how small solid particles move back and forth in the intensely lit stripe. For there are great amounts of such solid particles everywhere in our air, most of which are the germs of lower organisms. Air molecules are constantly hitting these small particles and thus gradually setting them into motion. The movement of this so-called sun dust – which incidentally is just as present in places that are entirely free of dust, as for example in the middle of a forest – can also be best observed when there is not the slightest draft. It can then be seen moving up and down in a straight line.