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\_THE ROMANCE OF SCIENCE\_

THE MACHINERY OF THE UNIVERSE

MECHANICAL CONCEPTIONS OF

PHYSICAL PHENOMENA

BY

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PREFACE

For thirty years or more the expressions "Correlation of the Physical

Forces" and "The Conservation of Energy" have been common, yet few

persons have taken the necessary pains to think out clearly what

mechanical changes take place when one form of energy is transformed

into another.

Since Tyndall gave us his book called \_Heat as a Mode of Motion\_ neither

lecturers nor text-books have attempted to explain how all phenomena are

the necessary outcome of the various forms of motion. In general,

phenomena have been attributed to \_forces\_--a metaphysical term, which

explains nothing and is merely a stop-gap, and is really not at all

needful in these days, seeing that transformable modes of motion, easily

perceived and understood, may be substituted in all cases for forces.

In December 1895 the author gave a lecture before the Franklin Institute

of Philadelphia, on "Mechanical Conceptions of Electrical Phenomena," in

which he undertook to make clear what happens when electrical phenomena

appear. The publication of this lecture in \_The Journal of the Franklin

Institute\_ and in \_Nature\_ brought an urgent request that it should be

enlarged somewhat and published in a form more convenient for the

public. The enlargement consists in the addition of a chapter on the

"\_Contrasted Properties of Matter and the Ether\_," a chapter containing

something which the author believes to be of philosophical importance in

these days when electricity is so generally described as a phenomenon of

the ether.

A. E. DOLBEAR.

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CHAPTER I

Ideas of phenomena ancient and modern, metaphysical and

mechanical--Imponderables--Forces, invented and

discarded--Explanations--Energy, its factors, Kinetic

and Potential--Motions, kinds and transformations

of--Mechanical, molecular, and atomic--Invention of

Ethers, Faraday's conceptions.

'And now we might add something concerning a most subtle spirit

which pervades and lies hid in all gross bodies, by the force

and action of which spirit the particles of bodies attract

each other at near distances, and cohere if contiguous, and

electric bodies operate at greater distances, as well repelling

as attracting neighbouring corpuscles, and light is emitted,

reflected, inflected, and heats bodies, and all sensation is

excited, and members of animal bodies move at the command of

the will.'--NEWTON, \_Principia\_.

In Newton's day the whole field of nature was practically lying fallow.

No fundamental principles were known until the law of gravitation was

discovered. This law was behind all the work of Copernicus, Kepler, and

Galileo, and what they had done needed interpretation. It was quite

natural that the most obvious and mechanical phenomena should first be

reduced, and so the \_Principia\_ was concerned with mechanical principles

applied to astronomical problems. To us, who have grown up familiar with

the principles and conceptions underlying them, all varieties of

mechanical phenomena seem so obvious, that it is difficult for us to

understand how any one could be obtuse to them; but the records of

Newton's time, and immediately after this, show that they were not so

easy of apprehension. It may be remembered that they were not adopted in

France till long after Newton's day. In spite of what is thought to be

reasonable, it really requires something more than complete

demonstration to convince most of us of the truth of an idea, should the

truth happen to be of a kind not familiar, or should it chance to be

opposed to our more or less well-defined notions of what it is or ought

to be. If those who labour for and attain what they think to be the

truth about any matter, were a little better informed concerning mental

processes and the conditions under which ideas grow and displace others,

they would be more patient with mankind; teachers of every rank might

then discover that what is often called stupidity may be nothing else

than mental inertia, which can no more be made active by simply willing

than can the movement of a cannon ball by a like effort. We \_grow\_ into

our beliefs and opinions upon all matters, and scientific ideas are no

exceptions.

Whewell, in his \_History of the Inductive Sciences\_, says that the

Greeks made no headway in physical science because they lacked

appropriate ideas. The evidence is overwhelming that they were as

observing, as acute, as reasonable as any who live to-day. With this

view, it would appear that the great discoverers must have been men who

started out with appropriate ideas: were looking for what they found.

If, then, one reflects upon the exceeding great difficulty there is in

discovering one new truth, and the immense amount of work needed to

disentangle it, it would appear as if even the most successful have but

indistinct ideas of what is really appropriate, and that their

mechanical conceptions become clarified by doing their work. This is not

always the fact. In the statement of Newton quoted at the head of this

chapter, he speaks of a spirit which lies hid in all gross bodies, etc.,

by means of which all kinds of phenomena are to be explained; but he

deliberately abandons that idea when he comes to the study of light, for

he assumes the existence and activity of light corpuscles, for which he

has no experimental evidence; and the probability is that he did this

because the latter conception was one which he could handle

mathematically, while he saw no way for thus dealing with the other. His

mechanical instincts were more to be trusted than his carefully

calculated results; for, as all know, what he called "spirits," is what

to-day we call the ether, and the corpuscular theory of light has now no

more than a historic interest. The corpuscular theory was a mechanical

conception, but each such corpuscle was ideally endowed with qualities

which were out of all relation with the ordinary matter with which it

was classed.

Until the middle of the present century the reigning physical philosophy

held to the existence of what were called imponderables. The phenomena

of heat were explained as due to an imponderable substance called

"caloric," which ordinary matter could absorb and emit. A hot body was

one which had absorbed an imponderable substance. It was, therefore, no

heavier than before, but it possessed ability to do work proportional to

the amount absorbed. Carnot's ideal engine was described by him in terms

that imply the materiality of heat. Light was another imponderable

substance, the existence of which was maintained by Sir David Brewster

as long as he lived. Electricity and magnetism were imponderable fluids,

which, when allied with ordinary matter, endowed the latter with their

peculiar qualities. The conceptions in each case were properly

mechanical ones \_part\_ (but not all) \_of the time\_; for when the

immaterial substances were dissociated from matter, where they had

manifested themselves, no one concerned himself to inquire as to their

whereabouts. They were simply off duty, but could be summoned, like the

genii in the story of Aladdin's Lamp. Now, a mechanical conception of

any phenomenon, or a mechanical explanation of any kind of action, must

be mechanical all the time, in the antecedents as well as the

consequents. Nothing else will do except a miracle.

During the fifty years, from about 1820 to 1870, a somewhat different

kind of explanation of physical events grew up. The interest that was

aroused by the discoveries in all the fields of physical science--in

heat, electricity, magnetism and chemistry--by Faraday, Joule,

Helmholtz, and others, compelled a change of conceptions; for it was

noticed that each special kind of phenomenon was preceded by some other

definite and known kind; as, for instance, that chemical action preceded

electrical currents, that mechanical or electrical activity resulted

from changing magnetism, and so on. As each kind of action was believed

to be due to a special force, there were invented such terms as

mechanical force, electrical force, magnetic, chemical and vital forces,

and these were discovered to be convertible into one another, and the

"doctrine of the correlation of the physical forces" became a common

expression in philosophies of all sorts. By "convertible into one

another," was meant, that whenever any given force appeared, it was at

the expense of some other force; thus, in a battery chemical force was

changed into electrical force; in a magnet, electrical force was changed

into magnetic force, and so on. The idea here was the \_transformation of

forces\_, and \_forces\_ were not so clearly defined that one could have a

mechanical idea of just what had happened. That part of the philosophy

was no clearer than that of the imponderables, which had largely dropped

out of mind. The terminology represented an advance in knowledge, but

was lacking in lucidity, for no one knew what a force of any kind was.

The first to discover this and to repudiate the prevailing terminology

were the physiologists, who early announced their disbelief in a vital

force, and their belief that all physiological activities were of purely

physical and chemical origin, and that there was no need to assume any

such thing as a vital force. Then came the discovery that chemical

force, or affinity, had only an adventitious existence, and that, at

absolute zero, there was no such activity. The discovery of, or rather

the appreciation of, what is implied by the term \_absolute zero\_, and

especially of the nature of heat itself, as expressed in the statement

that heat is a mode of motion, dismissed another of the so-called forces

as being a metaphysical agency having no real existence, though standing

for phenomena needing further attention and explanation; and by

explanation is meant \_the presentation of the mechanical antecedents for

a phenomenon, in so complete a way that no supplementary or unknown

factors are necessary\_. The train moves because the engine pulls it; the

engine pulls because the steam pushes it. There is no more necessity for

assuming a steam force between the steam and the engine, than for

assuming an engine force between the engine and the train. All the

processes are mechanical, and have to do only with ordinary matter and

its conditions, from the coal-pile to the moving freight, though there

are many transformations of the forms of motion and of energy between

the two extremes.

During the past thirty years there has come into common use another

term, unknown in any technical sense before that time, namely, \_energy\_.

What was once called the conservation of force is now called the

conservation of energy, and we now often hear of forms of energy. Thus,

heat is said to be a form of energy, and the forms of energy are

convertible into one another, as the so-called forces were formerly

supposed to be transformable into one another. We are asked to consider

gravitative energy, heat energy, mechanical energy, chemical energy, and

electrical energy. When we inquire what is meant by energy, we are

informed that it means ability to do work, and that work is measurable

as a pressure into a distance, and is specified as foot-pounds. A mass

of matter moves because energy has been spent upon it, and has acquired

energy equal to the work done on it, and this is believed to hold true,

no matter what the kind of energy was that moved it. If a body moves, it

moves because another body has exerted pressure upon it, and its energy

is called \_kinetic energy\_; but a body may be subject to pressure and

not move appreciably, and then the body is said to possess potential

energy. Thus, a bent spring and a raised weight are said to possess

potential energy. In either case, \_an energized body receives its energy

by pressure, and has ability to produce pressure on another body\_.

Whether or not it does work on another body depends on the rigidity of

the body it acts upon. In any case, it is simply a mechanical

action--body A pushes upon body B (Fig. 1). There is no need to assume

anything more mysterious than mechanical action. Whether body B moves

this way or that depends upon the direction of the push, the point of

its application. Whether the body be a mass as large as the earth or as

small as a molecule, makes no difference in that particular. Suppose,

then, that \_a\_ (Fig. 2) spends its energy on \_b\_, \_b\_ on \_c\_, \_c\_ on

\_d\_, and so on. The energy of \_a\_ gives translatory motion to \_b\_, \_b\_

sets \_c\_ vibrating, and \_c\_ makes \_d\_ spin on some axis. Each of these

has had energy spent on it, and each has some form of energy different

from the other, but no new factor has been introduced between \_a\_ and

\_d\_, and the only factor that has gone from \_a\_ to \_d\_ has been

motion--motion that has had its direction and quality changed, but not

its nature. If we agree that energy is neither created nor annihilated,

by any physical process, and if we assume that \_a\_ gave to \_b\_ all its

energy, that is, all its motion; that \_b\_ likewise gave its all to \_c\_,

and so on; then the succession of phenomena from \_a\_ to \_d\_ has been

simply the transference of a definite amount of motion, and therefore of

energy, from the one to the other; for \_motion has been the only

variable factor\_. If, furthermore, we should agree to call the

translatory motion [alpha], the vibratory motion [beta], the

rotary [gamma], then we should have had a conversion of [alpha]

into [beta], of [beta] into [gamma]. If we should consider

the amount of transfer motion instead of the kind of motion, we should

have to say that the [alpha] energy had been transformed into

[beta] and the [beta] into [gamma].

[Illustration: FIG. 1.]

[Illustration: FIG. 2.]

What a given amount of energy will do depends only upon its \_form\_, that

is, the kind of motion that embodies it.

The energy spent upon a stone thrown into the air, giving it translatory

motion, would, if spent upon a tuning fork, make it sound, but not move

it from its place; while if spent upon a top, would enable the latter to

stand upon its point as easily as a person stands on his two feet, and

to do other surprising things, which otherwise it could not do. One can,

without difficulty, form a mechanical conception of the whole series

without assuming imponderables, or fluids or forces. Mechanical motion

only, by pressure, has been transferred in certain directions at certain

rates. Suppose now that some one should suddenly come upon a spinning

top (Fig. 3) while it was standing upon its point, and, as its motion

might not be visible, should cautiously touch it. It would bound away

with surprising promptness, and, if he were not instructed in the

mechanical principles involved, he might fairly well draw the conclusion

that it was actuated by other than simple mechanical principles, and,

for that reason, it would be difficult to persuade him that there was

nothing essentially different in the body that appeared and acted thus,

than in a stone thrown into the air; nevertheless, that statement would

be the simple truth.

[Illustration: FIG. 3.]

All our experience, without a single exception, enforces the proposition

that no body moves in any direction, or in any way, except when some

other body \_in contact\_ with it presses upon it. The action is direct.

In Newton's letter to his friend Bentley, he says--"That one body

should act upon another through empty space, without the mediation of

anything else by and through which their action and pressure may be

conveyed from one to another, is to me so great an absurdity that I

believe no man who has in philosophical matters a competent faculty of

thinking can ever fall into it."

For mathematical purposes, it has sometimes been convenient to treat a

problem as if one body could act upon another without any physical

medium between them; but such a conception has no degree of rationality,

and I know of no one who believes in it as a fact. If this be granted,

then our philosophy agrees with our experience, and every body moves

because it is pushed, and the mechanical antecedent of every kind of

phenomenon is to be looked for in some adjacent body possessing

energy--that is, the ability to push or produce pressure.

It must not be forgotten that energy is not a simple factor, but is

always a product of two factors--a mass with a velocity, a mass with a

temperature, a quantity of electricity into a pressure, and so on. One

may sometimes meet the statement that matter and energy are the two

realities; both are spoken of as entities. It is much more philosophical

to speak of matter and motion, for in the absence of motion there is no

energy, and the energy varies with the amount of motion; and

furthermore, to understand any manifestation of energy one must inquire

what kind of motion is involved. This we do when we speak of mechanical

energy as the energy involved in a body having a translatory motion;

also, when we speak of heat as a vibratory, and of light as a wave

motion. To speak of energy without stating or implying these

distinctions, is to speak loosely and to keep far within the bounds of

actual knowledge. To speak thus of a body possessing energy, or

expending energy, is to imply that the body possesses some kind of

motion, and produces pressure upon another body because it has motion.

Tait and others have pointed out the fact, that what is called potential

energy must, in its nature, be kinetic. Tait says--"Now it is impossible

to conceive of a truly dormant form of energy, whose magnitude should

depend, in any way, upon the unit of time; and we are forced to conclude

that potential energy, like kinetic energy, depends (even if unexplained

or unimagined) upon motion." All this means that it is now too late to

stop with energy as a final factor in any phenomenon, that the \_form of

motion\_ which embodies the energy is the factor that determines \_what\_

happens, as distinguished from how \_much\_ happens. Here, then, are to be

found the distinctions which have heretofore been called forces; here

is embodied the proof that direct pressure of one body upon another is

what causes the latter to move, and that the direction of movement

depends on the point of application, with reference to the centre

of mass.

It is needful now to look at the other term in the product we call

energy, namely, the substance moving, sometimes called matter or mass.

It has been mentioned that the idea of a medium filling space was

present to Newton, but his gravitation problem did not require that he

should consider other factors than masses and distances. The law of

gravitation as considered by him was--Every particle of matter attracts

every other particle of matter with a stress which is proportional to

the product of their masses, and inversely to the squares of the

distance between them. Here we are concerned only with the statement

that every particle of matter attracts every other particle of matter.

Everything then that possesses gravitative attraction is matter in the

sense in which that term is used in this law. If there be any other

substance in the universe that is not thus subject to gravitation, then

it is improper to call it matter, otherwise the law should read, "Some

particles of matter attract," etc., which will never do.

We are now assured that there is something else in the universe which

has no gravitative property at all, namely, the ether. It was first

imagined in order to account for the phenomena of light, which was

observed to take about eight minutes to come from the sun to the earth.

Then Young applied the wave theory to the explanation of polarization

and other phenomena; and in 1851 Foucault proved experimentally that the

velocity of light was less in water than in air, as it should be if the

wave theory be true, and this has been considered a crucial experiment

which took away the last hope for the corpuscular theory, and

demonstrated the existence of the ether as a space-filling medium

capable of transmitting light-waves known to have a velocity of 186,000

miles per second. It was called the luminiferous ether, to distinguish

it from other ethers which had also been imagined, such as electric

ether for electrical phenomena, magnetic ether for magnetic phenomena,

and so on--as many ethers, in fact, as there were different kinds of

phenomena to be explained.

It was Faraday who put a stop to the invention of ethers, by suggesting

that the so-called luminiferous ether might be the one concerned in all

the different phenomena, and who pointed out that the arrangement of

iron filings about a magnet was indicative of the direction of the

stresses in the ether. This suggestion did not meet the approval of the

mathematical physicists of his day, for it necessitated the abandonment

of the conceptions they had worked with, as well as the terminology

which had been employed, and made it needful to reconstruct all their

work to make it intelligible--a labour which was the more distasteful as

it was forced upon them by one who, although expert enough in

experimentation, was not a mathematician, and who boasted that the most

complicated mathematical work he ever did was to turn the crank of a

calculating machine; who did all his work, formed his conclusions, and

then said--"The work is done; hand it over to the computers."

It has turned out that Faraday's mechanical conceptions were right.

Every one now knows of Maxwell's work, which was to start with Faraday's

conceptions as to magnetic phenomena, and follow them out to their

logical conclusions, applying them to molecules and the reactions of the

latter upon the ether. Thus he was led to conclude that light was an

electro-magnetic phenomenon; that is, that the waves which constitute

light, and the waves produced by changing magnetism were identical in

their nature, were in the same medium, travelled with the same velocity,

were capable of refraction, and so on. Now that all this is a matter of

common knowledge to-day, it is curious to look back no further than ten

years. Maxwell's conclusions were adopted by scarcely a physicist in

the world. Although it was known that inductive action travelled with

finite velocity in space, and that an electro-magnet would affect the

space about it practically inversely as the square of the distance, and

that such phenomena as are involved in telephonic induction between

circuits could have no other meaning than the one assigned by Maxwell,

yet nearly all the physicists failed to form the only conception of it

that was possible, and waited for Hertz to devise apparatus for

producing interference before they grasped it. It was even then so new,

to some, that it was proclaimed to be a demonstration of the existence

of the ether itself, as well as a method of producing waves short enough

to enable one to notice interference phenomena. It is obvious that Hertz

himself must have had the mechanics of wave-motion plainly in mind, or

he would not have planned such experiments. The outcome of it all is,

that we now have experimental demonstration, as well as theoretical

reason for believing, that the ether, once considered as only

luminiferous, is concerned in all electric and magnetic phenomena, and

that waves set up in it by electro-magnetic actions are capable of being

reflected, refracted, polarized, and twisted, in the same way as

ordinary light-waves can be, and that the laws of optics are applicable

to both.

CHAPTER II

PROPERTIES OF MATTER AND ETHER

Properties of Matter and Ether compared--Discontinuity

\_versus\_ Continuity--Size of atoms--Astronomical

distances--Number of atoms in the universe--Ether

unlimited--Kinds of Matter, permanent qualities

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Matter--Inertia in Matter and in Ether--Matter

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of Matter--Cohesion and chemism affected by

temperature--Shearing stress in Solids and in

Ether--Ether pressure--Sensation dependent upon

Matter--Nervous system not affected by Ether

states--Other stresses in Ether--Transformations

of Motion--Terminology.

A common conception of the ether has been that it is a finer-grained

substance than ordinary matter, but otherwise so like the latter that

the laws found to hold good with matter were equally applicable to the

ether, and hence the mechanical conceptions formed from experience in

regard to the one have been transferred to the other, and the properties

belonging to one, such as density, elasticity, etc., have been asserted

as properties of the other.

There is so considerable a body of knowledge bearing upon the

similarities and dissimilarities of these two entities that it will be

well to compare them. After such comparison one will be better able to

judge of the propriety of assuming them to be subject to identical laws.

1. MATTER IS DISCONTINUOUS.

Matter is made up of atoms having dimensions approximately determined to

be in the neighbourhood of the one fifty-millionth of an inch in

diameter. These atoms may have various degrees of aggregation;--they may

be in practical contact, as in most solid bodies such as metals and

rocks; in molecular groupings as in water, and in gases such as

hydrogen, oxygen, and so forth, where two, three, or more atoms cohere

so strongly as to enable the molecules to act under ordinary

circumstances like simple particles. Any or all of these molecules and

atoms may be separated by any assignable distance from each other. Thus,

in common air the molecules, though rapidly changing their positions,

are on the average about two hundred and fifty times their own diameter

apart. This is a distance relatively greater than the distance apart of

the earth and the moon, for two hundred and fifty times the diameter of

the earth will be 8000 × 250 = 2,000,000 miles, while the distance to

the moon is but 240,000 miles. The sun is 93,000,000 miles from the

earth, and the most of the bodies of the solar system are still more

widely separated, Neptune being nearly 3000 millions of miles from the

sun. As for the fixed stars, they are so far separated from us that, at

the present rate of motion of the solar system in its drift through

space--500 millions of miles in a year--it would take not less than

40,000 years to reach the nearest star among its neighbours, while for

the more remote ones millions of years must be reckoned. The huge space

separating these masses is practically devoid of matter; it is a vacuum.

THE ETHER IS CONTINUOUS.

The idea of continuity as distinguished from discontinuity may be gained

by considering what would be made visible by magnification. Water

appears to the eye as if it were without pores, but if sugar or salt be

put into it, either will be dissolved and quite disappear among the

molecules of the water as steam does in the air, which shows that there

are some unoccupied spaces between the molecules. If a microscope be

employed to magnify a minute drop of water it still shows the same lack

of structure as that looked at with the unaided eye. If the magnifying

power be the highest it may reveal a speck as small as the

hundred-thousandth part of an inch, yet the speck looks no different in

character. We know that water is composed of two different kinds of

atoms, hydrogen and oxygen, for they can be separated by chemical means

and kept in separate bottles, and again made to combine to form water

having all the qualities that belonged to it before it was decomposed.

If a very much higher magnifying power were available, we should

ultimately be able to see the individual water molecules, and recognize

their hydrogen and oxygen constituents by their difference in size, rate

of movements, and we might possibly separate them by mechanical methods.

What one would see would be something very different in structure from

the water as it appears to our eyes. If the ether were similarly to be

examined through higher and still higher magnifying powers, even up to

infinity, there is no reason for thinking that the last examination

would show anything different in structure or quality from that which

was examined with low power or with no microscope at all. This is all

expressed by saying that the ether is a continuous substance, without

interstices, that it fills space completely, and, unlike gases,

liquids, and solids, is incapable of absorbing or dissolving anything.

2. MATTER IS LIMITED.

There appears to be a definite amount of matter in the visible universe,

a definite number of molecules and atoms. How many molecules there are

in a cubic inch of air under ordinary pressure has been determined, and

is represented approximately by a huge number, something like a thousand

million million millions.

When the diameter of a molecule has been measured, as it has been

approximately, and found to be about one fifty-millionth of an inch,

then fifty million in a row would reach an inch, and the cube of fifty

million is 125,000,000000,000000,000000, one hundred and twenty-five

thousand million million millions. In a cubic foot there will of course

be 1728 times that number. One may if one likes find how many there may

be in the earth, and moon, sun and planets, for the dimensions of them

are all very well known. Only the multiplication table need be used, and

the sum of all these will give how many molecules there are in the solar

system. If one should feel that the number thus obtained was not very

accurate, he might reflect that if there were ten times as many it would

add but another cipher to a long line of similar ones and would not

materially modify it. The point is that there is a definite, computable

number. If one will then add to these the number of molecules in the

more distant stars and nebulæ, of which there are visible about

100,000,000, making such estimate of their individual size as he thinks

prudent, the sum of all will give the number of molecules in the visible

universe. The number is not so large but it can be written down in a

minute or two. Those who have been to the pains to do the sum say it may

be represented by seven followed by ninety-one ciphers. One could easily

compute how many molecules so large a space would contain if it were

full and as closely packed as they are in a drop of water, but there

would be a finite and not an infinite number, and therefore there is a

limited number of atoms in the visible universe.

THE ETHER IS UNLIMITED.

The evidence for this comes to us from the phenomena of light.

Experimentally, ether waves of all lengths are found to have a velocity

of 186,000 miles in a second. It takes about eight minutes to reach us

from the sun, four hours from Neptune the most distant planet, and from

the nearest fixed star about three and a half years. Astronomers tell us

that some visible stars are so distant that their light requires not

less than ten thousand years and probably more to reach us, though

travelling at the enormous rate of 186,000 miles a second. This means

that the whole of space is filled with this medium. If there were any

vacant spaces, the light would fail to get through them, and stars

beyond them would become invisible. There are no such vacant spaces, for

any part of the heavens shows stars beaming continuously, and every

increase in telescopic power shows stars still further removed than any

seen before. The whole of this intervening space must therefore be

filled with the ether. Some of the waves that reach us are not more than

the hundred-thousandth of an inch long, so there can be no crack or

break or absence of ether from so small a section as the

hundred-thousandth of an inch in all this great expanse. More than this.

No one can think that the remotest visible stars are upon the boundary

of space, that if one could get to the most distant star he would have

on one side the whole of space while the opposite side would be devoid

of it. Space we know is of three dimensions, and a straight line may be

prolonged in any direction to an infinite distance, and a ray of light

may travel on for an infinite time and come to no end provided space be

filled with ether.

How long the sun and stars have been shining no one knows, but it is

highly probable that the sun has existed for not less than 1000 million

years, and has during that time been pouring its rays as radiant energy

into space. If then in half that time, or 500 millions of years, the

light had somewhere reached a boundary to the ether, it could not have

gone beyond but would have been reflected back into the ether-filled

space, and such part of the sky would be lit up by this reflected light.

There is no indication that anything like reflection comes to us from

the sky. This is equivalent to saying that the ether fills space in

every direction away from us to an unlimited distance, and so far is

itself unlimited.

3. MATTER IS HETEROGENEOUS.

The various kinds of matter we are acquainted with are commonly called

the elements. These when combined in various ways exhibit characteristic

phenomena which depend upon the kinds of matter, the structure and

motions which are involved. There are some seventy different kinds of

this elemental matter which may be identified as constituents of the

earth. Many of the same elements have been identified in the sun and

stars, such for instance as hydrogen, carbon, and iron. Such phenomena

lead us to conclude that the kinds of matter elsewhere in the universe

are identical with such as we are familiar with, and that elsewhere the

variety is as great. The qualities of the elements, within a certain

range of temperature, are permanent; they are not subject to

fluctuations, though the qualities of combinations of them may vary

indefinitely. The elements therefore may be regarded as retaining their

identity in all ordinary experience.

THE ETHER IS HOMOGENEOUS.

One part of the ether is precisely like any other part everywhere and

always, and there are no such distinctions in it as correspond with the

elemental forms of matter.

4. MATTER IS ATOMIC.

There is an ultimate particle of each one of the elements which is

practically absolute and known as an atom. The atom retains its identity

through all combinations and processes. It may be here or there, move

fast or slow, but its atomic form persists.

THE ETHER IS NON-ATOMIC.

One might infer, from what has already been said about continuity, that

the ether could not be constituted of separable particles like masses of

matter; for no matter how minute they might be, there would be

interspaces and unoccupied spaces which would present us with phenomena

which have never been seen. It is the general consensus of opinion

among those who have studied the subject that the ether is not atomic in

structure.

5. MATTER HAS DEFINITE STRUCTURE.

Every atom of every element is so like every other atom of the same

element as to exhibit the same characteristics, size, weight, chemical

activity, vibratory rate, etc., and it is thus shown conclusively that

the structural form of the elemental particles is the same for each

element, for such characteristic reactions as they exhibit could hardly

be if they were mechanically unlike.

Of what form the atoms of an element may be is not very definitely

known. The earlier philosophers assumed them to be hard round particles,

but later thinkers have concluded that atoms of such a character are

highly improbable, for they could not exhibit in this case the

properties which the elements do exhibit. They have therefore dismissed

such a conception from consideration. In place of this hypothesis has

been substituted a very different idea, namely, that an atom is a

vortex-ring[1] of ether floating in the ether, as a smoke-ring puffed

out by a locomotive in still air may float in the air and show various

phenomena.

[Footnote 1: Vortex-rings for illustration may be made by having a

wooden box about a foot on a side, with a round orifice in the middle of

one side, and the side opposite covered with stout cloth stretched tight

over a framework. A saucer containing strong ammonia water, and another

containing strong hydrochloric acid, will cause dense fumes in the box,

and a tap with the hand upon the cloth back will force out a ring from

the orifice. These may be made to follow and strike each other,

rebounding and vibrating, apparently attracting each other and being

attracted by neighbouring bodies.

By filling the mouth with smoke, and pursing the lips as if to make the

sound \_o\_, one may make fifteen or twenty small rings by snapping the

cheek with the finger.]

A vortex-ring produced in the air behaves in the most surprising manner.

[Illustration: FIG. 4.--Method of making vortex-rings and their

behaviour.]

1. It retains its ring form and the same material rotating as it

starts with.

2. It can travel through the air easily twenty or thirty feet in a

second without disruption.

3. Its line of motion when free is always at right angles to the

plane of the ring.

4. It will not stand still unless compelled by some object. If

stopped in the air it will start up itself to travel on without

external help.

5. It possesses momentum and energy like a solid body.

6. It is capable of vibrating like an elastic body, making a

definite number of such vibrations per second, the degree of

elasticity depending upon the rate of vibration. The swifter the

rotation, the more rigid and elastic it is.

7. It is capable of spinning on its own axis, and thus having rotary

energy as well as translatory and vibratory.

8. It repels light bodies in front of it, and attracts into itself

light bodies in its rear.

9. If projected along parallel with the top of a long table, it will

fall upon it every time, just as a stone thrown horizontally will

fall to the ground.

10. If two rings of the same size be travelling in the same line,

and the rear one overtakes the other, the front one will enlarge its

diameter, while the rear one will contract its own till it can go

through the forward one, when each will recover its original

diameter, and continue on in the same direction, but vibrating,

expanding and contracting their diameters with regularity.

11. If two rings be moving in the same line, but in opposite

directions, they will repel each other when near, and thus retard

their speed. If one goes through the other, as in the former case,

it may quite lose its velocity, and come to a standstill in the air

till the other has moved on to a distance, when it will start up in

its former direction.

12. If two rings be formed side by side, they will instantly collide

at their edges, showing strong attraction.

13. If the collision does not destroy them, they may either break

apart at the point of the collision, and then weld together into a

single ring with twice the diameter, and then move on as if a single

ring had been formed, or they may simply bounce away from each

other, in which case they always rebound \_in a plane\_ at right

angles to the plane of collision. That is, if they collided on their

sides, they would rebound so that one went up and the other down.

14. Three may in like manner collide and fuse into a single ring.

Such rings formed in air by a locomotive may rise wriggling in the air

to the height of several hundred feet, but they are soon dissolved and

disappear. This is because the friction and viscosity of the air robs

the rings of their substance and energy. If the air were without

friction this could not happen, and the rings would then be persistent,

and would retain all their qualities.

Suppose then that such rings were produced in a medium without friction

as the ether is believed to be, they would be permanent structures with

a variety of properties. They would occupy space, have definite form and

dimensions, momentum, energy, attraction and repulsion, elasticity; obey

the laws of motion, and so far behave quite like such matter as we know.

For such reasons it is thought by some persons to be not improbable

that the atoms of matter are minute vortex-rings of ether in the ether.

That which distinguishes the atom from the ether is the form of motion

which is embodied in it, and if the motion were simply arrested, there

would be nothing to distinguish the atom from the ether into which it

dissolved. In other words, such a conception makes the atoms of matter a

form of motion of the ether, and not a created something put into the

ether.

THE ETHER IS STRUCTURELESS.

If the ether be the boundless substance described, it is clear it can

have no form as a whole, and if it be continuous it can have no minute

structure. If not constituted of atoms or molecules there is nothing

descriptive that can be said about it. A molecule or a particular mass

of matter could be identified by its form, and is thus in marked

contrast with any portion of ether, for the latter could not be

identified in a similar way. One may therefore say that the ether is

formless.

6. MATTER IS GRAVITATIVE.

The law of gravitation is held as being universal. According to it every

particle of matter in the universe attracts every other particle. The

evidence for this law in the solar system is complete. Sun, planets,

satellites, comets and meteors are all controlled by gravitation, and

the movements of double stars testify to its activity among the more

distant bodies of the universe. The attraction does not depend upon the

kind of matter nor the arrangement of molecules or atoms, but upon the

amount or mass of matter present, and if it be of a definite kind of

matter, as of hydrogen or iron, the gravitative action is proportional

to the number of atoms.

THE ETHER IS GRAVITATIONLESS.

One might infer already that if the ether were structureless, physical

laws operative upon such material substances as atoms could not be

applicable to it, and so indeed all the evidence we have shows that

gravitation is not one of its properties. If it were, and it behaved in

any degree like atomic structures, it would be found to be denser in the

neighbourhood of large bodies like the earth, planets, and the sun.

Light would be turned from its straight path while travelling in such

denser medium, or made to move with less velocity. There is not the

slightest indication of any such effect anywhere within the range of

astronomical vision.

Gravitation then is a property belonging to matter and not to ether.

The impropriety of thinking or speaking of the ether as matter of any

kind will be apparent if one reflects upon the significance of the law

of gravitation as stated. Every particle of matter in the universe

attracts every other particle. If there be anything else in the universe

which has no such quality, then it should not be called matter, else the

law should read: Some particles of matter attract some other particles,

which would be no law at all, for a real physical law has no exceptions

any more than the multiplication table has. Physical laws are physical

relations, and all such relations are quantitative.

7. MATTER IS FRICTIONABLE.

A bullet shot into the air has its velocity continuously reduced by the

air, to which its energy is imparted by making it move out of its way. A

railway train is brought to rest by the friction brake upon the wheels.

The translatory energy of the train is transformed into the molecular

energy called heat. The steamship requires to propel it fast, a large

amount of coal for its engines, because the water in which it moves

offers great friction--resistance which must be overcome. Whenever one

surface of matter is moved in contact with another surface there is a

resistance called friction, the moving body loses its rate of motion,

and will presently be brought to rest unless energy be continuously

supplied. This is true for masses of matter of all sizes and with all

kinds of motion. Friction is the condition for the transformation of all

kinds of mechanical motions into heat. The test of the amount of

friction is the rate of loss of motion. A top will spin some time in the

air because its point is small. It will spin longer on a plate than on

the carpet, and longer in a vacuum than in the air, for it does not have

the air friction to resist it, and there is no kind or form of matter

not subject to frictional resistance.

THE ETHER IS FRICTIONLESS.

The earth is a mass of matter moving in the ether. In the equatorial

region the velocity of a point is more than a thousand miles in an hour,

for the circumference of the earth is 25,000 miles, and it turns once on

its axis in 24 hours, which is the length of the day. If the earth were

thus spinning in the atmosphere, the latter not being in motion, the

wind would blow with ten times hurricane velocity. The friction would be

so great that nothing but the foundation rocks of the earth's crust

could withstand it, and the velocity of rotation would be reduced

appreciably in a relatively short time. The air moves along with the

earth as a part of it, and consequently no such frictional destruction

takes place, but the earth rotates in the ether with that same rate, and

if the ether offered resistance it would react so as to retard the

rotation and increase the length of the day. Astronomical observations

show that the length of the day has certainly not changed so much as the

tenth of a second during the past 2000 years. The earth also revolves

about the sun, having a speed of about 19 miles in a second, or 68,000

miles an hour. This motion of the earth and the other planets about the

sun is one of the most stable phenomena we know. The mean distance and

period of revolution of every planet is unalterable in the long run. If

the earth had been retarded by its friction in the ether the length of

the year would have been changed, and astronomers would have discovered

it. They assert that a change in the length of a year by so much as the

hundredth part of a second has not happened during the past thousand

years. This then is testimony, that a velocity of nineteen miles a

second for a thousand years has produced no effect upon the earth's

motion that is noticeable. Nineteen miles a second is not a very swift

astronomical motion, for comets have been known to have a velocity of

400 miles a second when in the neighbourhood of the sun, and yet they

have not seemed to suffer any retardation, for their orbits have not

been shortened. Some years ago a comet was noticed to have its periodic

time shortened an hour or two, and the explanation offered at first was

that the shortening was due to friction in the ether although no other

comet was thus affected. The idea was soon abandoned, and to-day there

is no astronomical evidence that bodies having translatory motion in the

ether meet with any frictional resistance whatever. If a stone could be

thrown in interstellar space with a velocity of fifty feet a second it

would continue to move in a straight line with the same speed for any

assignable time.

As has been said, light moves with the velocity of 186,000 miles per

second, and it may pursue its course for tens of thousands of years.

There is no evidence that it ever loses either its wave-length or

energy. It is not transformed as friction would transform it, else there

would be some distance at which light of given wave-length and amplitude

would be quite extinguished. The light from distant stars would be

different in character from that coming from nearer stars. Furthermore,

as the whole solar system is drifting in space some 500,000,000 of miles

in a year, new stars would be coming into view in that direction, and

faint stars would be dropping out of sight in the opposite direction--a

phenomenon which has not been observed. Altogether the testimony seems

conclusive that the ether is a frictionless medium, and does not

transform mechanical motion into heat.

8. MATTER IS ÆOLOTROPIC.

That is, its properties are not alike in all directions. Chemical

phenomena, crystallization, magnetic and electrical phenomena show each

in their way that the properties of atoms are not alike on opposite

faces. Atoms combine to form molecules, and molecules arrange themselves

in certain definite geometric forms such as cubes, tetrahedra, hexagonal

prisms and stellate forms, with properties emphasized on certain faces

or ends. Thus quartz will twist a ray of light in one direction or the

other, depending upon the arrangement which may be known by the external

form of the crystal. Calc spar will break up a ray of light into two

parts if the light be sent through it in certain directions, but not if

in another. Tourmaline polarizes light sent through its sides and

becomes positively electrified at one end while being heated. Some

substances will conduct sound or light or heat or electricity better in

one direction than in another. All matter is magnetic in some degree,

and that implies polarity. If one will recall the structure of a

vortex-ring, he will see how all the motion is inward on one side and

outward on the other, which gives different properties to the two sides:

a push away from it on one side and a pull toward it on the other.

THE ETHER IS ISOTROPIC.

That is, its properties are alike in every direction. There is no

distinction due to position. A mass of matter will move as freely in one

direction as in another; a ray of light of any wave-length will travel

in it in one direction as freely as in any other; neither velocity nor

direction are changed by the action of the ether alone.

9. MATTER IS CHEMICALLY SELECTIVE.

When the elements combine to form molecules they always combine in

definite ways and in definite proportions. Carbon will combine with

hydrogen, but will drop it if it can get oxygen. Oxygen will combine

with iron or lead or sodium, but cannot be made to combine with

fluorine. No more than two atoms of oxygen can be made to unite with one

carbon atom, nor more than one hydrogen with one chlorine atom. There is

thus an apparent choice for the kind and number of associates in

molecular structure, and the instability of a molecule depends

altogether upon the presence in its neighbourhood of other atoms for

which some of the elements in the molecule have a stronger attraction

or affinity than they have for the atoms they are now combined with.

Thus iron is not stable in the presence of water molecules, and it

becomes iron oxide; iron oxide is not stable in the presence of hot

sulphur, it becomes an iron sulphide. All the elements are thus

selective, and it is by such means that they may be chemically

identified.

There is no phenomenon in the ether that is comparable with this.

Evidently there could not be unless there were atomic structures having

in some degree different characteristics which we know the ether to be

without.

10. THE ELEMENTS OF MATTER ARE HARMONICALLY RELATED.

It is possible to arrange the elements in the order of their atomic

weights in columns which will show communities of property. Newlands,

Mendeléeff, Meyer, and others have done this. The explanation for such

an arrangement has not yet been forthcoming, but that it expresses a

real fact is certain, for in the original scheme there were several gaps

representing undiscovered elements, the properties of which were

predicted from that of their associates in the table. Some of these have

since been discovered, and their atomic weight and physical properties

accord with those predicted.

With the ether such a scheme is quite impossible, for the very evident

reason that there are no different things to have relation with each

other. Every part is just like every other part. Where there are no

differences and no distinctions there can be no relations. The ether is

quite harmonic without relations.

11. MATTER EMBODIES ENERGY.

So long as the atoms of matter were regarded as hard round particles,

they were assumed to be inert and only active when acted upon by what

were called forces, which were held to be entities of some sort,

independent of matter. These could pull or push it here or there, but

the matter was itself incapable of independent activity. All this is now

changed, and we are called upon to consider every atom as being itself a

form of energy in the same sense as heat or light are forms of energy,

the energy being embodied in particular forms of motion. Light, for

instance, is a wave motion of the ether. An atom is a rotary ring of

ether. Stop the wave motion, and the light would be annihilated. Stop

the rotation, and the atom would be annihilated for the same reason. As

the ray of light is a particular embodiment of energy, and has no

existence apart from it, so an atom is to be regarded as an embodiment

of energy. On a previous page it is said that energy is the ability of

one body to act upon and move another in some degree. An atom of any

kind is not the inert thing it has been supposed to be, for it can do

something. Even at absolute zero, when all its vibratory or heat energy

would be absent, it would be still an elastic whirling body pulling upon

every other atom in the universe with gravitational energy, twisting

other atoms into conformity with its own position with its magnetic

energy; and, if such ether rings are like the rings which are made in

air, will not stand still in one place even if no others act upon it,

but will start at once by its own inherent energy to move in a right

line at right angles to its own plane and in the direction of the whirl

inside the ring. Two rings of wood or iron might remain in contact with

each other for an indefinite time, but vortex-rings will not, but will

beat each other away as two spinning tops will do if they touch ever so

gently. If they do not thus separate it is because there are other forms

of energy acting to press them together, but such external pressure will

be lessened by the rings' own reactions.

It is true that in a frictionless medium like the ether one cannot at

present see how such vortex-rings could be produced in it. Certainly not

by any such mechanical methods as are employed to make smoke-rings in

air, for the friction of the air is the condition for producing them.

However they came to be, there is implied the previous existence of the

ether and of energy in some form capable of acting upon it in a manner

radically different from any known in physical science.

There is good spectroscopic evidence that in some way elements of

different kinds are now being formed in nebulæ, for the simplest show

the presence of hydrogen alone. As they increase in complexity other

elements are added, until the spectrum exhibits all the elements we know

of. It has thus seemed likely either that most of what are called

elements are composed of molecular groupings of some fundamental

element, which by proper physical methods might be decomposed, as one

can now decompose a molecule of ammonia or sulphuric acid, or that the

elements are now being created by some extra-physical process in those

far-off regions. In either case an atom is the embodiment of energy in

such a form as to be permanent under ordinary physical circumstances,

but of which, if in any manner it should be destroyed, only the form

would be lost. The ether would remain, and the energy which was embodied

would be distributed in other ways.

THE ETHER IS ENDOWED WITH ENERGY.

The distinction between energy in matter and energy in the ether will be

apparent, on considering that both the ether and energy in some form

must be conceived as existing independent of matter; though every atom

were annihilated, the ether would remain and all the energy embodied in

the atoms would be still in existence in the ether. The atomic energy

would simply be dissolved. One can easily conceive the ether as the same

space-filling, continuous, unlimited medium, without an atom in it. On

this assumption it is clear that no form of energy with which we have to

deal in physical science would have any existence in the ether; for

every one of those forms, gravitational, thermal, electric, magnetic, or

any other--all are the results of the forms of energy in matter. If

there were no atoms, there would be no gravitation, for that is the

attraction of atoms upon each other. If there were no atoms, there could

be no atomic vibration, therefore no heat, and so on for each and all.

Nevertheless, if an atom be the embodiment of energy, there must have

been energy in the ether before any atom existed. One of the properties

of the ether is its ability to distribute energy in certain ways, but

there is no evidence that of itself it ever transforms energy. Once a

given kind of energy is in it, it does not change; hence for the

apparition of a form of energy, like the first vortex-ring, there must

have been not only energy, but some other agency capable of transforming

that energy into a permanent structure. To the best of our knowledge

to-day, the ether would be absolutely helpless. Such energy as was

active in forming atoms must be called by another name than what is

appropriate for such transformations as occur when, for instance, the

mechanical energy of a bullet is transformed into heat when the target

is struck. Behind the ether must be assumed some agency, directing and

controlling energy in a manner totally different from any agency, which

is operative in what we call physical science. Nothing short of what is

called a miracle will do--an event without a physical antecedent in any

way necessarily related to its factors, as is the fact of a stone

related to gravity or heat to an electric current.

Ether energy is an endowment instead of being an embodiment, and implies

antecedents of a super-physical kind.

12. MATTER IS AN ENERGY TRANSFORMER.

As each different kind of energy represents some specific form of

motion, and \_vice versâ\_, some sort of mechanism is needful for

transforming one kind into another, therefore molecular structure of

one kind or another is essential. The transformation is a mechanical

process, and matter in some particular and appropriate form is the

condition of its taking place. If heat appears, then its antecedent has

been some other form of motion acting upon the substance heated. It may

have been the mechanical motion of another mass of matter, as when a

bullet strikes a target and becomes heated; or it may be friction, as

when a car-axle heats when run without proper oiling to reduce friction;

or it may be condensation, as when tinder is ignited by condensing the

air about it; or chemical reactions, when molecular structure is changed

as in combustion, or an electrical current, which implies a dynamo and

steam-engine or water-power. If light appears, its antecedent has been

impact or friction, condensation or chemical action, and if electricity

appears the same sort of antecedents are present. Whether the one or the

other of these forms of energy is developed, depends upon what kind of a

structure the antecedent energy has acted upon. If radiant energy,

so-called, falls upon a mass of matter, what is absorbed is at once

transformed into heat or into electric or magnetic effects; \_which\_ one

of these depends upon the character of the mechanism upon which the

radiant energy acts, but the radiant energy itself, which consists of

ether-waves, is traceable back in every case to a mass of matter having

definite characteristic motions.

One may therefore say with certainty that every physical phenomenon is a

change in the direction, or velocity, or character, of the energy

present, and such change has been produced by matter acting as a

transformer.

THE ETHER IS A NON-TRANSFORMER.

It has already been said that the absence of friction in the ether

enables light-waves to maintain their identity for an indefinite time,

and to an indefinitely great distance. In a uniform, homogeneous

substance of any kind, any kind of energy which might be in it would

continue in it without any change. Uniformity and homogeneity imply

similarity throughout, and the necessary condition for transformation is

unlikeness. One might not look for any kind of physical phenomenon which

was not due to the presence and activity of some heterogeneity.

As a ray of light continues a ray of light so long as it exists in free

ether, so all kinds of radiations, of whatever wave-length, continue

identical until they fall upon some mechanical structure called matter.

Translatory motion continues translatory, rotary continues rotary, and

vibratory continues to be vibratory, and no transforming change can

take place in the absence of matter. The ether is helpless.

13. MATTER IS ELASTIC.

It is commonly stated that certain substances, like putty and dough, are

inelastic, while some other substances, like glass, steel, and wood, are

elastic. This quality of elasticity, as manifested in such different

degrees, depends upon molecular combinations; some of which, as in glass

and steel, are favourable for exhibiting it, while others mask it, for

the ultimate atoms of all kinds are certainly highly elastic.

The measure of elasticity in a mass of matter is the velocity with which

a wave-motion will be transmitted through it. Thus the elasticity of the

air determines the velocity of sound in it. If the air be heated, the

elasticity is increased and the sound moves faster. The rates of such

sound-conduction range from a few feet in a second to about 16,000, five

times swifter than a cannon ball. In such elastic bodies as vibrate to

and fro like the prongs of a tuning-fork, or give sounds of a definite

pitch, the rate of vibration is determined by the size and shape of the

body as well as by their elementary composition. The smaller a body is,

the higher its vibratory rate, if it be made of the same material and

the form remains the same. Thus a tuning-fork, that may be carried in

the waistcoat-pocket, may vibrate 500 times a second. If it were only

the fifty-millionth of an inch in size, but of the same material and

form, it would vibrate 30,000,000000 times a second; and if it were made

of ether, instead of steel, it would vibrate as many times faster as the

velocity of waves in the ether is greater than it is in steel, and would

be as many as 400,000000,000000 times per second. The amount of

displacement, or the amplitude of vibration, with the pocket-fork might

be no more than the hundredth of an inch, and this rate measured as

translation velocity would be but five inches per second. If the fork

were of atomic magnitude, and should swing its sides one half the

diameter of the atom, or say the hundred-millionth of an inch, the

translational velocity would be equivalent to about eighty miles a

second, or a hundred and fifty times the velocity of a cannon ball,

which may be reckoned at about 3000 feet.

That atoms really vibrate at the above rate per second is very certain,

for their vibrations produce ether-waves the length of which may be

accurately measured. When a tuning-fork vibrates 500 times a second, and

the sound travels 1100 feet in the same interval, the length of each

wave will be found by dividing the velocity in the air by the number of

vibrations, or 1100 ÷ 500 = 2.2 feet. In like manner, when one knows

the velocity and wave-length, he may compute the number of vibrations by

dividing the velocity by the wave-length. Now the velocity of the waves

called light is 186,000 miles a second, and a light-wave may be one

forty thousandth of an inch long. The atom that produces the wave must

be vibrating as many times per second as the fifth thousandth of an inch

is contained in 186,000 miles. Reducing this number to inches we have

186,000 × 5280 × 12

------------------- = 400,000,000,000,000, nearly.

1/40,000

This shows that the atoms are minute elastic bodies that change their

form rapidly when struck. As rapid as the change is, yet the rate of

movement is only one-fifth that of a comet when near the sun, and is

therefore easily comparable with other velocities observed in masses of

matter.

These vibratory motions, due to the elasticity of the atoms, is what

constitutes heat.

THE ETHER IS ELASTIC.

The elasticity of a mass of matter is its ability to recover its

original form after that form has been distorted. There is implied that

a stress changes its shape and dimensions, which in turn implies a

limited mass and relative change of position of parts and some degree

of discontinuity. From what has been said of the ether as being

unlimited, continuous, and not made of atoms or molecules, it will be

seen how difficult, if not impossible, it is to conceive how such a

property as elasticity, as manifested in matter, can be attributed to

the ether, which is incapable of deformation, either in structure or

form, the latter being infinitely extended in every direction and

therefore formless. Nevertheless, certain forms of motion, such as

light-waves, move in it with definite velocity, quite independent of how

they originate. This velocity of 186,000 miles a second so much exceeds

any movement of a mass of matter that the motions can hardly be

compared. Thus if 400 miles per second be the swiftest speed of any mass

of matter known--that of a comet near the sun--the ether-wave moves

186,000 ÷ 400 = 465 times faster than such comet, and 900,000 times

faster than sound travels in air. It is clear that if this rate of

motion depends upon elasticity, the elasticity must be of an entirely

different type from that belonging to matter, and cannot be defined in

any such terms as are employed for matter.

If one considers gravitative phenomena, the difficulty is enormously

increased. The orbit of a planet is never an exact ellipse,

on account of the perturbations produced by the planetary

attractions--perturbations which depend upon the direction and distance

of the attracting bodies. These, however, are so well known that slight

deviations are easily noticed. If gravitative attraction took any such

appreciable time to go from one astronomical body to another as does

light, it would make very considerable differences in the paths of the

planets and the earth. Indeed, if the velocity of gravitation were less

than a million times greater than that of light, its effects would have

been discovered long ago. It is therefore considered that the velocity

of gravitation cannot be less than 186000,000000 miles per second. How

much greater it may be no one can guess. Seeing that gravitation is

ether-pressure, it does not seem probable that its velocity can be

infinite. However that may be, the ability of the ether to transmit

pressure and various disturbances, evidently depends upon properties so

different from those that enable matter to transmit disturbances that

they deserve to be called by different names. To speak of the elasticity

of the ether may serve to express the fact that energy may be

transmitted at a finite rate in it, but it can only mislead one's

thinking if he imagines the process to be similar to energy transmission

in a mass of matter. The two processes are incomparable. No other word

has been suggested, and perhaps it is not needful for most scientific

purposes that another should be adopted, but the inappropriateness of

the one word for the different phenomena has long been felt.

14. MATTER HAS DENSITY.

This quality is exhibited in two ways in matter. In the first, the

different elements in their atomic form have different masses or atomic

weights. An atom of oxygen weighs sixteen times as much as an atom of

hydrogen; that is, it has sixteen times as much matter, as determined by

weight, as the hydrogen atom has, or it takes sixteen times as many

hydrogen atoms to make a pound as it takes of oxygen atoms. This is

generally expressed by saying that oxygen has sixteen times the density

of hydrogen. In like manner, iron has fifty-six times the density, and

gold one hundred and ninety-six. The difference is one in the structure

of the atomic elements. If one imagines them to be vortex-rings, they

may differ in size, thickness, and rate of rotation; either of these

might make all the observed difference between the elements, including

their density. In the second way, density implies compactness of

molecules. Thus if a cubic foot of air be compressed until it occupies

but half a cubic foot, each cubic inch will have twice as many molecules

in it as at first. The amount of air per unit volume will have been

doubled, the weight will have been doubled, the amount of matter as

determined by its weight will have been doubled, and consequently we say

its density has been doubled.

If a bullet or a piece of iron be hammered, the molecules are compacted

closer together, and a greater number can be got into a cubic inch when

so condensed. In this sense, then, density means the number of molecules

in a unit of space, a cubic inch or cubic centimeter. There is implied

in this latter case that the molecules do not occupy all the available

space, that they may have varying degrees of closeness; in other words,

matter is discontinuous, and therefore there may be degrees in density.

THE ETHER HAS DENSITY.

It is common to have the degree of density of the ether spoken of in the

same way, and for the same reason, that its elasticity is spoken of. The

rate of transmission of a physical disturbance, as of a pressure or a

wave-motion in matter, is conditioned by its degree of density; that is,

the amount of matter per cubic inch as determined by its weight; the

greater the density the slower the rate. So if rate of speed and

elasticity be known, the density may be computed. In this way the

density of the ether has been deduced by noting the velocity of light.

The enormous velocity is supposed to prove that its density is very

small, even when compared with hydrogen. This is stated to be about

equal to that of the air at the height of two hundred and ten miles

above the surface of the earth, where the air molecules are so few that

a molecule might travel for 60,000,000 miles without coming in collision

with another molecule. In air of ordinary density, a molecule can on the

average move no further than about the two-hundred-and-fifty-thousandth

of an inch without such collision. It is plain the density of the ether

is so far removed from the density of anything we can measure, that it

is hardly comparable with such things. If, in addition, one recalls the

fact that the ether is homogeneous, that is all of one kind, and also

that it is not composed of atoms and molecules, then degree of

compactness and number of particles per cubic inch have no meaning, and

the term density, if used, can have no such meaning as it has when

applied to matter. There is no physical conception gained from the study

of matter that can be useful in thinking of it. As with elasticity, so

density is inappropriately applied to the ether, but there is no

substitute yet offered.

15. MATTER IS HEATABLE.

So long as heat was thought to be some kind of an imponderable thing,

which might retain its identity whether it were in or out of matter,

its real nature was obscured by the name given to it. An imponderable

was a mysterious something like a spirit, which was the cause of certain

phenomena in matter. Heat, light, electricity, magnetism, gravitation,

were due to such various agencies, and no one concerned himself with the

nature of one or the other. Bacon thought that heat was a brisk

agitation of the particles of substances, and Count Rumford and Sir

Humphrey Davy thought they proved that it could be nothing else, but

they convinced nobody. Mayer in Germany and Joule in England showed that

quantitative relations existed between work done and heat developed, but

not until the publication of the book called \_Heat as a Mode of Motion\_,

was there a change of opinion and terminology as to the nature of heat.

For twenty years after that it was common to hear the expressions heat,

and radiant heat, to distinguish between phenomena in matter and what is

now called radiant energy radiations, or simply ether-waves. Not until

the necessity arose for distinguishing between different forms of

energy, and the conditions for developing them, did it become clear to

all that a change in the form of energy implied a change in the form of

motion that embodied it. The energy called heat energy was proved to be

a vibratory motion of molecules, and what happened in the ether as a

result of such vibrations is no longer spoken of as heat, but as ether

waves. When it is remembered that the ultimate atoms are elastic bodies,

and that they will, if free, vibrate in a periodic manner when struck or

shaken in any way, just as a ball will vibrate after it is struck, it is

easy to keep in mind the distinction between the mechanical form of

motion spent in striking and the vibratory form of the motion produced

by it. The latter is called heat; no other form of motion than that is

properly called heat. It is this alone that represents temperature, the

rate and amplitude of such atomic and molecular vibrations as constitute

change, of form. Where molecules like those in a gas have some freedom

of movement between impacts, they bound away from each other with

varying velocities. The path of such motion may be long or short,

depending upon the density or compactness of the molecules, but such

changes in position are not heat for a molecule any more than the flight

of a musket ball is heat, though it may be transformed into heat on

striking the target.

This conception of heat as the rapid change in the form of atoms and

molecules, due to their elasticity, is a phenomenon peculiar to matter.

It implies a body possessing form that may be changed; elasticity, that

its changes may be periodic, and degrees of freedom that secure space

for the changes. Such a body may be heated. Its temperature will depend

upon the amplitude of such vibrations, and will be limited by the

maximum amplitude.

THE ETHER IS UNHEATABLE.

The translatory motion of a mass of matter, big or little, through the

ether, is not arrested in any degree so far as observed, but the

internal vibratory motion sets up waves in the ether, the ether absorbs

the energy, and the amplitude is continually lessened. The motion has

been transferred and transformed; transferred from matter to the ether,

and transformed from vibratory to waves travelling at the rate of

186,000 miles per second. The latter is not heat, but the result of

heat. With the ether constituted as described, such vibratory motion as

constitutes heat is impossible to it, and hence the characteristic of

heat-motion in it is impossible; it cannot therefore be heated. The

space between the earth and the sun may have any assignable amount of

energy in the form of ether waves or light, but not any temperature. One

might loosely say that the temperature of empty spaces was absolute

zero, but that would not be quite correct, for the idea of temperature

cannot properly be entertained as applicable to the ether. To say that

its temperature was absolute zero, would serve to imply that it might be

higher, which is inadmissible.

When energy has been transformed, the old name by which the energy was

called must be dropped. Ether cannot be heated.

16. MATTER IS INDESTRUCTIBLE.

This is commonly said to be one of the essential properties of matter.

All that is meant by it, however, is simply this: In no physical or

chemical process to which it has been experimentally subjected has there

been any apparent loss. The matter experimented upon may change from a

solid or liquid to a gas, or the molecular change called chemical may

result in new compounds, but the weight of the material and its atomic

constituents have not appreciably changed. That matter cannot be

annihilated is only the converse of the proposition that matter cannot

be created, which ought always to be modified by adding, by physical or

chemical processes at present known. A chemist may work with a few

grains of a substance in a beaker, or test-tube, or crucible, and after

several solutions, precipitations, fusions and dryings, may find by

final weighing that he has not lost any appreciable amount, but how much

is an appreciable amount? A fragment of matter the ten-thousandth of an

inch in diameter has too small a weight to be noted in any balance, yet

it would be made up of thousands of millions of atoms. Hence if, in the

processes to which the substance had been subjected, there had been the

total annihilation of thousands of millions of atoms, such phenomenon

would not have been discovered by weighing. Neither would it have been

discovered if there had been a similar creation or development of new

matter. All that can be asserted concerning such events is, that they

have not been discovered with our means of observation.

The alchemists sought to transform one element into another, as lead

into gold. They did not succeed. It was at length thought to be

impossible, and the attempt to do it an absurdity. Lately, however,

telescopic observation of what is going on in nebulæ, which has already

been referred to, has somewhat modified ideas of what is possible and

impossible in that direction. It is certainly possible roughly to

conceive how such a structure as a vortex-ring in the ether might be

formed. With certain polarizing apparatus it is possible to produce rays

of circularly polarized light. These are rays in which the motion is an

advancing rotation like the wire in a spiral spring. If such a line of

rotations in the ether were flexible, and the two ends should come

together, there is reason for thinking they would weld together, in

which case the structure would become a vortex-ring and be as durable as

any other. There is reason for believing, also, that somewhat similar

movements are always present in a magnetic field, and though we do not

know how to make them close up in the proper way, it does not follow

that it is impossible for them to do so.

The bearing of all this upon the problem of the transmutation of

elements is evident. No one now will venture to deny its possibility as

strongly as it was denied a generation ago. It will also lead one to be

less confident in the theory that matter is indestructible. Assuming the

vortex-ring theory of atoms to be true, if in any way such a ring could

be cut or broken, there would not remain two or more fragments of a ring

or atom. The whole would at once be dissolved into the ether. The ring

and rotary energy that made it an atom would be destroyed, but not the

substance it was made of, nor the energy which was embodied therein. For

a long time philosophers have argued, and commonsense has agreed with

them, that an atom which could not be ideally broken into two parts was

impossible, that one could at any rate think of half an atom as a real

objective possibility. This vortex-ring theory shows easily how possible

it is to-day to think what once was philosophically incredible. It shows

that metaphysical reasoning may be ever so clear and apparently

irrefragable, yet for all that it may be very unsound. The trouble does

not come so much from the logic as from the assumption upon which the

logic is founded. In this particular case the assumption was that the

ultimate particles of matter were hard, irrefragable somethings, without

necessary relations to anything else, or to energy, and irrefragable

only because no means had been found of breaking them.

The destructibility or indestructibility of the ether cannot be

considered from the same standpoint as that for matter, either ideally

or really. Not ideally, because we are utterly without any mechanical

conceptions of the substance upon which one can base either reason or

analogy; and not really, because we have no experimental evidence as to

its nature or mode of operation. If it be continuous, there are no

interspaces, and if it be illimitable there is no unfilled space

anywhere. Furthermore, one might infer that if in any way a portion of

the ether could be annihilated, what was left would at once fill up the

vacated space, so there would be no record left of what had happened.

Apparently, its destruction would be the destruction of a substance,

which is a very different thing from the destruction of a mode of

motion. In the latter, only the form of the motion need be destroyed to

completely obliterate every trace of the atom. In the former, there

would need to be the destruction of both substance and energy, for it is

certain, for reasons yet to be attended to, that the ether is saturated

with energy.

One may, without mechanical difficulties, imagine a vortex-ring

destroyed. It is quite different with the ether itself, for if it were

destroyed in the same sense as the atom of matter, it would be changed

into something else which is not ether, a proposition which assumes the

existence of another entity, the existence for which is needed only as a

mechanical antecedent for the other. The same assumption would be needed

for this entity as for the ether, namely, something out of which it was

made, and this process of assuming antecedents would be interminable.

The last one considered would have the same difficulties to meet as the

ether has now. The assumption that it was in some way and at some time

created is more rational, and therefore more probable, than that it

either created itself or that it always existed. Considered as the

underlying stratum of matter, it is clear that changes of any kind in

matter can in no way affect the quantity of ether.

17. MATTER HAS INERTIA.

The resistance that a mass of matter opposes to a change in its position

or rate and direction of movement, is called inertia. That it should

actively oppose anything has been already pointed out as reason for

denying that matter is inert, but inertia is the measure of the reaction

of a body when it is acted upon by pressure from any source tending to

disturb its condition of either rest or motion. It is the equivalent of

mass, or the amount of matter as measured by gravity, and is a fixed

quantity; for inertia is as inherent as any other quality, and belongs

to the ultimate atoms and every combination of them. It implies the

ability to absorb energy, for it requires as much energy to bring a

moving body to a standstill as was required to give it its forward

motion.

Both rotary and vibratory movements are opposed by the same property. A

grindstone, a tuning-fork, and an atom of hydrogen require, to move them

in their appropriate ways, an amount of energy proportionate to their

mass or inertia, which energy is again transformed through friction into

heat and radiated away.

One may say that inertia is the measure of the ability of a body to

transfer or transform mechanical energy. The meteorite that falls upon

the earth to-day gives, on its impact, the same amount of energy it

would have given if it had struck the earth ten thousand years ago. The

inertia of the meteor has persisted, not as energy, but as a factor of

energy. We commonly express the energy of a mass of matter by

\_mv\_^{2}/2, where \_m\_ stands for the mass and \_v\_ for its velocity. We

might as well, if it were as convenient, substitute inertia for mass,

and write the expression \_iv\_^{2}/2, for the mass, being measured by its

inertia, is only the more common and less definitive word for the same

thing. The energy of a mass of matter is, then, proportional to its

inertia, because inertia is one of its factors. Energy has often been

treated as if it were an objective thing, an entity and a unity; but

such a conception is evidently wrong, for, as has been said before, it

is a product of two factors, either of which may be changed in any

degree if the other be changed inversely in the same degree. A cannon

ball weighing 1000 pounds, and moving 100 feet per second, will have

156,000 foot-pounds of energy, but a musket ball weighing an ounce will

have the same amount when its velocity is 12,600 feet per second.

Nevertheless, another body acting upon either bullet or cannon ball,

tending to move either in some new direction, will be as efficient

while those bodies are moving at any assignable rate as when they are

quiescent, for the change in direction will depend upon the inertia of

the bodies, and that is constant.

The common theory of an inert body is one that is wholly passive, having

no power of itself to move or do anything, except as some agency outside

itself compels it to move in one way or another, and thus endows it with

energy. Thus a stone or an iron nail are thought to be inert bodies in

that sense, and it is true that either of them will remain still in one

place for an indefinite time and move from it only when some external

agency gives them impulse and direction. Still it is known that such

bodies will roll down hill if they will not roll up, and each of them

has itself as much to do with the down-hill movement as the earth has;

that is, it attracts the earth as much as the earth attracts it. If one

could magnify the structure of a body until the molecules became

individually visible, every one of them would be seen to be in intense

activity, changing its form and relative position an enormous number of

times per second in undirected ways. No two such molecules move in the

same way at the same time, and as all the molecules cohere together,

their motions in different directions balance each other, so that the

body as a whole does not change its position, not because there is no

moving agency in itself, but because the individual movements are

scattering, and not in a common direction. An army may remain in one

place for a long time. To one at a distance it is quiescent, inert. To

one in the camp there is abundant sign of activity, but the movements

are individual movements, some in one direction and some in another, and

often changing. The same army on the march has the same energy, the same

rate of individual movement; but all have a common direction, it moves

as a whole body into new territory. So with the molecules of matter. In

large masses they appear to be inert, and to do nothing, and to be

capable of doing nothing. That is only due to the fact that their energy

is undirected, not that they can do nothing. The inference that if

quiescent bodies do not act in particular ways they are inert, and

cannot act in any kind of a way, is a wrong inference. An illustration

may perhaps make this point plainer. A lump of coal will be still as

long as anything if it be undisturbed. Indeed, it has thus lain in a

coal-bed for millions of years probably, but if coal be placed where it

can combine with oxygen, it forthwith does so, and during the process

yields a large amount of energy in the shape of heat. One pound of coal

in this way gives out 14,000 heat units, which is the equivalent of

11,000,000 foot-pounds of work, and if it could be all utilized would

furnish a horse-power for five and a half hours. Can any inert body

weighing a pound furnish a horse-power for half a day? And can a body

give out what it has not got? Are gunpowder and nitro-glycerine inert?

Are bread and butter and foods in general inert because they will not

push and pull as a man or a horse may? All have energy, which is

available in certain ways and not in others, and whatever possesses

energy available in any way is not an ideally inert body. Lastly, how

many inert bodies together will it take to make an active body? If the

question be absurd, then all the phenomena witnessed in bodies, large or

small, are due to the fact that the atoms are not inert, but are

immensely energetic, and their inertia is the measure of their rates of

exchanging energy.

THE ETHER IS CONDITIONALLY POSSESSED OF INERTIA.

A moving mass of matter is brought to rest by friction, because it

imparts its motion at some rate to the body it is in contact with.

Generally the energy is transformed into heat, but sometimes it appears

as electrification. Friction is only possible because one or both of the

bodies possess inertia. That a body may move in the ether for an

indefinite time without losing its velocity has been stated as a reason

for believing the ether to be frictionless. If it be frictionless, then

it is without inertia, else the energy of the earth and of a ray of

light would be frittered away. A ray of light can only be transformed

when it falls upon molecules which may be heated by it. As the ether

cannot be heated and cannot transform translational energy, it is

without inertia for \_such\_ a form of motion and its embodied energy.

It is not thus with other forms of energy than the translational. Atomic

and molecular vibrations are so related to the ether that they are

transformed into waves, which are conducted away at a definite rate.

This shows that such property of inertia as is possessed by the ether is

selective and not like that of matter, which is equally "inertiative"

under all conditions. Similarly with electric and magnetic phenomena, it

is capable of transforming the energy which may reside as stress in the

ether, and other bodies moving in the space so affected meet with

frictional resistance, for they become heated if the motion be

maintained. On the other hand, there is no evidence that the body which

produced the electric or magnetic stress suffers any degree of friction

on moving in precisely the same space. A bar magnet rotating on its

longitudinal axis does not disturb its own field, but a piece of iron

revolving near the magnet will not only become heated, but will heat the

stationary magnet. Much experimental work has been done to discover, if

possible, the relation of a magnet to its ether field. As the latter is

not disturbed by the rotation of the magnet, it has been concluded that

the field does not rotate; but as every molecule in the magnet has its

own field independent of all the rest, it is mechanically probable that

each such field does vary in the rotation, but among the thousands of

millions of such fields the average strength of the field does not vary

within measurable limits. Another consideration is that the magnetic

field itself, when moved in space, suffers no frictional resistance.

There is no magnetic energy wasted through ether inertia. These

phenomena show that whether the ether exhibits the quality called

inertia depends upon the kind of motion it has.

18. MATTER IS MAGNETIC.

The ordinary phenomenon of magnetism is shown by bringing a piece of

iron into the neighbourhood of a so-called magnet, where it is attracted

by the latter, and if free to move will go to and cling to the magnet. A

delicately suspended magnetic needle will be affected appreciably by a

strong magnet at the distance of several hundred feet. As the strength

of such action varies inversely as the square of the distance from the

magnet, it is evident there can be no absolute boundary to it. At a

distance from an ordinary magnet it becomes too weak to be detected by

our methods, not that there is a limit to it. It is customary to think

of iron as being peculiarly endowed with magnetic quality, but all kinds

of matter possess it in some degree. Wood, stone, paper, oats, sulphur,

and all the rest, are attracted by a magnet, and will stick to it if the

magnet be a strong one. Whether a piece of iron itself exhibits the

property depends upon its temperature, for near 700 degrees it becomes

as magnetically indifferent as a piece of copper at ordinary

temperature. Oxygen, too, at 200 degrees below the zero of Centigrade

adheres to a magnet like iron.

In this as in so many other particulars, how a piece of matter behaves

depends upon its temperature, not that the essential qualities are

modified in any degree, but temperature interferes with atomic

arrangement and aggregation, and so disguises their phenomena.

As every kind of matter is thus affected by a magnet, the manifestations

differing but in degree, it follows that all kinds of atoms--all the

elements--are magnetic. An inherent property in them, as much so as

gravitation or inertia; apparently a quality depending upon the

structure of the atoms themselves, in the same sense as gravitation is

thus dependent, as it is not a quality of the ether.

An atom must, then, be thought of as having polarity, different

qualities on the two sides, and possessing a magnetic field as extensive

as space itself. The magnetic field is the stress or pressure in the

ether produced by the magnetic body. This ether pressure produced by a

magnet may be as great as a ton per square inch. It is this pressure

that holds an armature to the magnet. As heat is a molecular condition

of vibration, and radiant energy the result of it, so is magnetism a

property of molecules, and the magnetic field the temporary condition in

the ether, which depends upon the presence of a magnetic body. We no

longer speak of the wave-motion in the ether which results from heat, as

heat, but call it radiation, or ether waves, and for a like reason the

magnetic field ought not to be called magnetism.

THE ETHER IS NON-MAGNETIC.

A magnetic field manifests itself in a way that implies that the ether

structure, if it may be said to have any, is deformed--deformed in such

a sense that another magnet in it tends to set itself in the plane of

the stress; that is, the magnet is twisted into a new position to

accommodate itself to the condition of the medium about it. The new

position is the result of the reaction of the ether upon the magnet and

ether pressure acting at right angles to the body that produced the

stress. Such an action is so anomalous as to suggest the propriety of

modifying the so-called third law of motion, viz., action and reaction

are equal and opposite, adding that sometimes action and reaction are at

right angles.

There is no condition or property exhibited by the ether itself which

shows it to have any such characteristic as attraction, repulsion, or

differences in stress, except where its condition is modified by the

activities of matter in some way. The ether itself is not attracted or

repelled by a magnet; that is, it is not a magnetic body in any such

sense as matter in any of its forms is, and therefore cannot properly be

called magnetic.

It has been a mechanical puzzle to understand how the vibratory motions

called heat could set up light waves in the ether seeing that there is

an absence of friction in the latter. In the endeavour to conceive it,

the origin of sound-waves has been in mind, where longitudinal air-waves

are produced by the vibrations of a sounding body, and molecular impact

is the antecedent of the waves. The analogy does not apply. The

following exposition may be helpful in grasping the idea of such

transformation and change of energy from matter to the ether.

Consider a straight bar permanent magnet to be held in the hand. It has

its north and south poles and its field, the latter extending in every

direction to an indefinite distance. The field is to be considered as

ether stress of such a sort as to tend to set other magnets in it in new

positions. If at a distance of ten feet there were a delicately-poised

magnet needle, every change in the position of the magnet held in the

hand would bring about a change in the position of the needle. If the

position of the hand magnet were completely reversed, so the south pole

faced where the north pole faced before, the field would have been

completely reversed, and the poised needle would have been pushed by the

field into an opposite position. If the needle were a hundred feet away,

the change would have been the same except in amount. The same might be

said if the two were a mile apart, or the distance of the moon or any

other distance, for there is no limit to an ether magnetic field.

Suppose the hand magnet to have its direction completely reversed once

in a second. The whole field, and the direction of the stress, would

necessarily be reversed as often. But this kind of change in stress is

known by experiment to travel with the speed of light, 186,000 miles a

second; the disturbance due to the change of position of the magnet will

therefore be felt in some degree throughout space. In a second and a

third of a second it will have reached the moon, and a magnet there will

be in some measure affected by it. If there were an observer there with

a delicate-enough magnet, he could be witness to its changes once a

second for the same reason one in the room could. The only difference

would be one of amount of swing. It is therefore theoretically possible

to signal to the moon with a swinging magnet. Suppose again that the

magnet should be swung twice a second, there would be formed two waves,

each one half as long as the first. If it should swing ten times a

second, then the waves would be one-tenth of 186,000 miles long. If in

some mechanical way it could be rotated 186,000 times a second, the wave

would be but one mile long. Artificial ways have been invented for

changing this magnet field as many as 100 million times a second, and

the corresponding wave is less than a foot long. The shape of a magnet

does not necessarily make it weaker or stronger as a magnet, but if the

poles are near together the magnetic field is denser between them than

when they are separated. The ether stress is differently distributed for

every change in the relative positions of the poles.

A common U-magnet, if struck, will vibrate like a tuning-fork, and gives

out a definite pitch. Its poles swing towards and away from each other

at uniform rates, and the pitch of the magnet will depend upon its size,

thickness, and the material it is made of.

Let ten or fifteen ohms of any convenient-sized wire be wound upon the

bend of a commercial U-magnet. Let this wire be connected to a telephone

in its circuit. When the magnet is made to sound like a tuning-fork, the

pitch will be reproduced in the telephone very loudly. If another magnet

with a different pitch be allowed to vibrate near the former, the pitch

of the vibrating body will be heard in the telephone, and these show

that the changing magnetic field reacts upon the quiescent magnet, and

compels the latter to vibrate at the same rate. The action is an ether

action, the waves are ether waves, but they are relatively very long. If

the magnet makes 500 vibrations a second, the waves will be 372 miles

long, the number of times 500 is contained in 186,000 miles. Imagine the

magnet to become smaller and smaller until it was the size of an atom,

the one-fifty-millionth of an inch. Its vibratory rate would be

proportionally increased, and changes in its form will still bring about

changes in its magnetic field. But its magnetic field is practically

limitless, and the number of vibrations per second is to be reckoned

as millions of millions; the waves are correspondingly short,

small fractions of an inch. When they are as short as the

one-thirty-seven-thousandth of an inch, they are capable of affecting

the retina of the eye, and then are said to be visible as red light. If

the vibratory rate be still higher, and the corresponding waves be no

more than one-sixty-thousandth of an inch long, they affect the retina

as violet light, and between these limits there are all the waves that

produce a complete spectrum. The atoms, then, shake the ether in this

way because they all have a magnetic hold upon the ether, so that any

disturbance of their own magnetism, such as necessarily comes when they

collide, reacts upon the ether for the same reason that a large magnet

acts thus upon it when its poles approach and recede from each other. It

is not a phenomenon of mechanical impact or frictional resistance, since

neither are possible in the ether.

19. MATTER EXISTS IN SEVERAL STATES.

Molecular cohesion exists between very wide ranges. When strong, so if

one part of a body is moved the whole is moved in the same way, without

breaking continuity or the relative positions of the molecules, we call

the body a solid. In a liquid, cohesion is greatly reduced, and any part

of it may be deformed without materially changing the form of the rest.

The molecules are free to move about each other, and there is no

definite position which any need assume or keep. With gases, the

molecules are without any cohesion, each one is independent of every

other one, collides with and bounds away from others as free elastic

particles do. Between impacts it moves in what is called its free path,

which may be long or short as the density of the gas be less or greater.

These differing degrees of cohesion depend upon temperature, for if the

densest and hardest substances are sufficiently heated they will become

gaseous. This is only another way of saying that the states of matter

depend upon the amount of molecular energy present. Solid ice becomes

water by the application of heat. More heat reduces it to steam; still

more decomposes the steam molecules into oxygen and hydrogen molecules;

and lastly, still more heat will decompose these molecules into their

atomic state, complete dissociation. On cooling, the process of

reduction will be reversed until ice has been formed again.

Cohesive strength in solids is increased by reduction of temperature,

and metallic rods become stronger the colder they are.

No distinction is now made between cohesion and chemical affinity, and

yet at low temperatures chemical action will not take place, which

phenomenon shows there is a distinction between molecular cohesion and

molecular structure. In molecular structure, as determined by chemical

activity, the molecules and atoms are arranged in definite ways which

depend upon the rate of vibrations of the components. The atoms are set

in definite positions to constitute a given molecule. But atoms or

molecules may cohere for other reasons, gravitative or magnetic, and

relative positions would be immaterial. In the absence of temperature, a

solid body would be solider and stronger than ever, while a gaseous mass

would probably fall by gravity to the floor of the containing vessel

like so much dust. The molecular structure might not be changed, for

there would be no agency to act upon it in a disturbing way.

THE ETHER HAS NO CORRESPONDING STATES.

Degrees of density have already been excluded, and the homogeneity and

continuity of the ether would also exclude the possibility of different

states at all comparable with such as belong to matter. As for cohesion,

it is doubtful if the term ought to be applied to such a substance. The

word itself seems to imply possible separateness, and if the ether be a

single indivisible substance, its cohesion must be infinite and is

therefore not a matter of degree. The ether has sometimes been

considered as an elastic solid, but such solidity is comparable with

nothing we call solid in matter, and the word has to be defined in a

special sense in order that its use may be tolerated at all. In addition

to this, some of the phenomena exhibited by it, such as diffraction and

double refraction, are quite incompatible with the theory that the ether

is an elastic solid. The reasons why it cannot be considered as a liquid

or gas have been considered previously.

The expression \_states of matter\_ cannot be applied to the ether in any

such sense as it is applied to matter, but there is one sense when

possibly it may be considered applicable. Let it be granted that an atom

is a vortex-ring of ether in the ether, then the state of being in ring

rotation would suffice to differentiate that part of the ether from the

rest, and give to it a degree of individuality not possessed by the

rest; and such an atom might be called a state of ether. In like manner,

if other forms of motion, such as transverse waves, circular and

elliptical spirals, or others, exist in the ether, then such movements

give special character to the part thus active, and it would be proper

to speak of such states of the ether, but even thus the word would not

be used in the same sense as it is used when one speaks of the states of

matter as being solid, liquid, and gaseous.

20. SOLID MATTER CAN EXPERIENCE A SHEARING STRESS, LIQUIDS AND GASES

CANNOT.

A sliding stress applied to a solid deforms it to a degree which depends

upon the stress and the degree of rigidity preserved by the body. Thus

if the hand be placed upon a closed book lying on the table, and

pressure be so applied as to move the upper side of the book but not the

lower, the book is said to be subject to a shearing stress. If the

pressing hand has a twisting motion, the book will be warped. Any solid

may be thus sheared or warped, but neither liquids nor gases can be so

affected. Molecular cohesion makes it possible in the one, and the lack

of it, impossible in the others. The solid can maintain such a

deformation indefinitely long, if the pressure does not rupture its

molecular structure.

THE ETHER CAN MAINTAIN A SHEARING STRESS.

The phenomena in a magnetic field show that the stress is of such a sort

as to twist into a new directional position the body upon which it acts

as exhibited by a magnetic needle, also as indicated by the transverse

vibrations of the ether waves, and again by the twist given to plane

polarized light when moving through a magnetic field. These are all

interpreted as indicative of the direction of ether stress, as being

similar to a shearing stress in solid matter. The fact has been adduced

to show the ether to be a solid, but such a phenomenon is certainly

incompatible with a liquid or gaseous ether. This kind of stress is

maintained indefinitely about a permanent magnet, and the mechanical

pressure which may result from it is a measure of the strength of the

magnetic field, and may exceed a thousand pounds per square inch.

21. OTHER PROPERTIES OF MATTER.

There are many secondary qualities exhibited by matter in some of its

forms, such as hardness, brittleness, malleability, colour, etc., and

the same ultimate element may exhibit itself in the most diverse ways,

as is the case with carbon, which exists as lamp-black, charcoal,

graphite, jet, anthracite and diamond, ranging from the softest to the

hardest of known bodies. Then it may be black or colourless. Gold is

yellow, copper red, silver white, chlorine green, iodine purple. The

only significance any or all of such qualities have for us here is that

the ether exhibits none of them. There is neither hardness nor

brittleness, nor colour, nor any approach to any of the characteristics

for the identification of elementary matter.

22. SENSATION DEPENDS UPON MATTER.

However great the mystery of the relation of body to mind, it is quite

true that the nervous system is the mechanism by and through which all

sensation comes, and that in our experience in the absence of nerves

there is neither sensation nor consciousness. The nerves themselves are

but complex chemical structures; their molecular constitution is said to

embrace as many as 20,000 atoms, chiefly carbon, hydrogen, oxygen, and

nitrogen. There must be continuity of this structure too, for to sever a

nerve is to paralyze all beyond. If all knowledge comes through

experience, and all experience comes through the nervous system, the

possibilities depend upon the mechanism each one is provided with for

absorbing from his environment, what energies there are that can act

upon the nerves. Touch, taste, and smell imply contact, sound has

greater range, and sight has the immensity of the universe for its

field. The most distant but visible star acts through the optic nerve to

present itself to consciousness. It is not the ego that looks out

through the eyes, but it is the universe that pours in upon the ego.

Again, all the known agencies that act upon the nerves, whether for

touch or sound or sight, imply matter in some of its forms and

activities, to adapt the energy to the nervous system. The mechanism

for the perception of light is complicated. The light acts upon a

sensitive surface where molecular structure is broken up, and this

disturbance is in the presence of nerve terminals, and the sensation is

not in the eye but in the sensorium. In like manner for all the rest; so

one may fairly say that matter is the condition for sensation, and in

its absence there would be nothing we call sensation.

THE ETHER IS INSENSIBLE TO NERVES.

The ether is in great contrast with matter in this particular. There is

no evidence that in any direct way it acts upon any part of the nervous

system, or upon the mind. It is probable that this lack of relation

between the ether and the nervous system was the chief reason why its

discovery was so long delayed, as the mechanical necessities for it even

now are felt only by such as recognize continuity as a condition for the

transmission of energy of whatever kind it may be. Action at a distance

contradicts all experience, is philosophically incredible, and is

repudiated by every one who once perceives that energy has two

factors--substance and motion.

The table given below presents a list of twenty-two of the known

properties of matter contrasted with those exhibited by the ether. In

none of them are the properties of the two identical, and in most of

them what is true for one is not true for the other. They are not simply

different, they are incomparable.

From the necessities of the case, as knowledge has been acquired and

terminology became essential for making distinctions, the ether has been

described in terms applicable to matter, hence such terms as mass,

solidity, elasticity, density, rigidity, etc., which have a definite

meaning and convey definite mechanical conceptions when applied to

matter, but have no corresponding meaning and convey no such mechanical

conceptions when applied to the ether. It is certain that they are

inappropriate, and that the ether and its properties cannot be described

in terms applicable to matter. Mathematical considerations derived from

the study of matter have no advantage, and are not likely to lead us to

a knowledge of the ether.

Only a few have perceived the inconsistency of thinking of the two in

the same terms. In his \_Grammar of Science\_, Prof. Karl Pearson says,

"We find that our sense-impressions of hardness, weight, colour,

temperature, cohesion, and chemical constitution, may all be described

by the aid of the motions of a single medium, which itself is conceived

to have no hardness, weight, colour, temperature, nor indeed elasticity

of the ordinary conceptual type."

None of the properties of the ether are such as one would or could have

predicted if he had had all the knowledge possessed by mankind. Every

phenomenon in it is a surprise to us, because it does not follow the

laws which experience has enabled us to formulate for matter. A

substance which has none of the phenomenal properties of matter, and is

not subject to the known laws of matter, ought not to be called matter.

Ether phenomena and matter phenomena belong to different categories, and

the ends of science will not be conserved by confusing them, as is done

when the same terminology is employed for both.

There are other properties belonging to the ether more wonderful, if

possible, than those already mentioned. Its ability to maintain enormous

stresses of various kinds without the slightest evidence of

interference. There is the gravitational stress, a direct pull between

two masses of matter. Between two molecules it is immeasurably small

even when close together, but the prodigious number of them in a bullet

brings the action into the field of observation, while between such

bodies as the earth and moon or sun, the quantity reaches an astonishing

figure. Thus if the gravitative tension due to the gravitative

attraction of the earth and moon were to be replaced by steel wires

connecting the two bodies to prevent the moon from leaving its orbit,

there would be needed four number ten steel wires to every square inch

upon the earth, and these would be strained nearly to the breaking

point. Yet this stress is not only endured continually by this pliant,

impalpable, transparent medium, but other bodies can move through the

same space apparently as freely as if it were entirely free. In addition

to this, the stress from the sun and the more variable stresses from the

planets are all endured by the same medium in the same space and

apparently a thousand or a million times more would not make the

slightest difference. Rupture is impossible.

Electric and magnetic stresses, acting parallel or at right angles to

the other, exist in the same space and to indefinite degrees, neither

modifying the direction nor amount of either of the others.

These various stresses have been computed to represent energy, which if

it could be utilized, each cubic inch of space would yield five hundred

horse-power. It shows what a store-house of energy the ether is. If

every particle of matter were to be instantly annihilated, the universe

of ether would still have an inexpressible amount of energy left. To

draw at will directly from this inexhaustible supply, and utilize it for

the needs of mankind, is not a forlorn hope.

The accompanying table presents these contrasting properties for

convenient inspection.

CONTRASTED PROPERTIES OF MATTER AND THE ETHER.

MATTER. ETHER.

1. Discontinuous Continuous

2. Limited Unlimited

3. Heterogeneous Homogeneous

4. Atomic Non-atomic

5. Definite structure Structureless

6. Gravitative Gravitationless

7. Frictionable Frictionless

8. Æolotropic Isotropic

9. Chemically selective ----

10. Harmonically related ----

11. Energy embodied Energy endowed

12. Energy transformer Non-transformer

13. Elastic Elastic?

14. Density Density?

15. Heatable Unheatable

16. Indestructible? Indestructible

17. Inertiative Inertiative conditionally

18. Magnetic ----

19. Variable states ----

20. Subject to shearing stress

in solid Shearing stress maintained

21. Has Secondary qualities ----

22. Sensation depends upon Insensible to nerves

CHAPTER III

Antecedents of Electricity--Nature of what is

transformed--Series of transformations for the

production of light--Positive and negative

Electricity--Positive and negative twists--Rotations

about a wire--Rotation of an arc--Ether a

non-conductor--Electro-magnetic waves--Induction

and inductive action--Ether stress and atomic

position--Nature of an electric current--Electricity

a condition, not an entity.

So far as we have knowledge to-day, the only factors we have to consider

in explaining physical phenomena are: (1) Ordinary matter, such as

constitutes the substance of the earth, and the heavenly bodies; (2) the

ether, which is omnipresent; and (3) the various forms of motion, which

are mutually transformable in matter, and some of which, but not all,

are transformable into ether forms. For instance, the translatory motion

of a mass of matter can be imparted to another mass by simple impact,

but translatory motion cannot be imparted to the ether, and, for that

reason, a body moving in it is not subject to friction, and continues

to move on with velocity undiminished for an indefinite time; but the

vibratory motion which constitutes heat is transformable into

wave-motion in the ether, and is transmitted away with the speed of

light. The kind of motion which is thus transformed is not even a

to-and-fro swing of an atom, or molecule, like the swing of a pendulum

bob, but that due to a change of form of the atoms within the molecule,

otherwise there could be no such thing as spectrum analysis. Vibratory

motion of the matter becomes undulatory motion in the ether. The

vibratory motion we call heat; the wave-motion we call sometimes radiant

energy, sometimes light. Neither of these terms is a good one, but we

now have no others.

It is conceded that it is not proper to speak of the wave-motion in the

ether as \_heat\_; it is also admitted that the ether is not heated by the

presence of the wave--or, in other words, the temperature of the ether

is absolute zero. Matter only can be heated. But the ether waves can

heat other matter they may fall on; so there are three steps in the

process and two transformations--(1) vibrating matter; (2) waves in the

ether; (3) vibration in other matter. Energy has been transferred

indirectly. What is important to bear in mind is, that when a form of

energy in matter is transformed in any manner so as to lose its

characteristics, it is not proper to call it by the same name after as

before, and this we do in all cases when the transformation is from one

kind in matter to another kind in matter. Thus, when a bullet is shot

against a target, before it strikes it has what we call mechanical

energy, and we measure that in foot-pounds; after it has struck the

target, the transformation is into heat, and this has its mechanical

equivalent, but is not called mechanical energy, nor are the motions

which embody it similar. The mechanical ideas in these phenomena are

easy to grasp. They apply to the phenomena of the mechanics of large and

small bodies, to sound, to heat, and to light, as ordinarily considered,

but they have not been applied to electric phenomena, as they evidently

should be, unless it be held that such phenomena are not related to

ordinary phenomena, as the latter are to one another.

When we would give a complete explanation of the phenomena exhibited by,

say, a heated body, we need to inquire as to the antecedents of the

manifestation, and also its consequents. Where and how did it get its

heat? Where and how did it lose it? When we know every step of those

processes, we know all there is to learn about them. Let us undertake

the same thing for some electrical phenomena.

First, under what circumstances do electrical phenomena arise?

(1) \_Mechanical\_, as when two different kinds of matter are subject to

friction.

(2) \_Thermal\_, as when two substances in molecular contact are heated at

the junction.

(3) \_Magnetic\_, as when any conductor is in a changing magnetic field.

(4) \_Chemical\_, as when a metal is being dissolved in any solution.

(5) \_Physiological\_, as when a muscle contracts.

[Illustration: FIG. 5.--Frictional electrical machine.]

Each of these has several varieties, and changes may be rung on

combinations of them, as when mechanical and magnetic conditions

interact.

(1) In the first case, ordinary mechanical or translational energy is

spent as friction, an amount measurable in foot-pounds, and the factors

we know, a pressure into a distance. If the surface be of the same kind

of molecules, the whole energy is spent as heat, and is presently

radiated away. If the surfaces are of unlike molecules, the product is a

compound one, part heat, part electrical. What we have turned into the

machine we know to be a particular mode of motion. We have not changed

the amount of matter involved; indeed, we assume, without specifying and

without controversy, that matter is itself indestructible, and the

product, whether it be of one kind or another, can only be some form of

motion. Whether we can describe it or not is immaterial; but if we agree

that heat is vibratory molecular motion, and there be any other kind of

a product than heat, it too must also be some other form of motion. So

if one is to form a conception of the mechanical origin of electricity,

this is the only one he can have--transformed motion.

[Illustration: FIG. 6.--Thermo-pile.]

[Illustration: FIG. 7.--Dynamo.]

(2) When heat is the antecedent of electricity, as in the thermo-pile,

that which is turned into the pile we know to be molecular motion of a

definite kind. That which comes out of it must be some equivalent

motion, and if all that went in were transformed, then all that came out

would be transformed, call it by what name we will and let its amount be

what it may.

(3) When a conductor is moved in a magnetic field, the energy spent is

measurable in foot-pounds, as before, a pressure into a distance. The

energy appears in a new form, but the quantity of matter being

unchanged, the only changeable factor is the kind of motion, and that

the motion is molecular is evident, for the molecules are heated.

Mechanical or mass motion is the antecedent, molecular heat motion is

the consequent, and the way we know there has been some intermediate

form is, that heat is not conducted at the rate which is observed in

such a case. Call it by what name one will, some form of motion has been

intermediate between the antecedent and the consequent, else we have

some other factor of energy to reckon with than ether, matter and

motion.

(4) In a galvanic battery, the source of electricity is chemical action;

but what is chemical action? Simply an exchange of the constituents of

molecules--a change which involves exchange of energy. Molecules capable

of doing chemical work are loaded with energy. The chemical products of

battery action are molecules of different constitution, with smaller

amounts of energy as measured in calorics or heat units. If the results

of the chemical reaction be prevented from escaping, by confining them

to the cell itself, the whole energy appears as heat and raises the

temperature of the cell. If a so-called circuit be provided, the energy

is distributed through it, and less heat is spent in the cell, but

whether it be in one place or another, the mass of matter involved is

not changed, and the variable factor is the motion, the same as in the

other cases. The mechanical conceptions appropriate are the

transformation of one kind of motion into another kind by the mechanical

conditions provided.

[Illustration: FIG. 8.--Galvanic Battery.]

(5) Physiological antecedents of electricity are exemplified by the

structure and mode of operation of certain muscles (Fig. 9, \_a\_) in the

torpedo and other electrical animals. The mechanical contraction of them

results in an electrical excitation, and, if a proper circuit be

provided, in an electric current. The energy of a muscle is derived from

food, which is itself but a molecular compound loaded with energy of a

kind available for muscular transformation. Bread-and-butter has more

available energy, pound for pound, than has coal, and can be substituted

for coal for running an engine. It is not used, because it costs so much

more. There is nothing different, so far as the factors of energy go,

between the food of an animal and the food of an engine. What becomes of

the energy depends upon the kind of structure it acts on. It may be

changed into translatory, and the whole body moves in one direction; or

into molecular, and then appears as heat or electrical energy.

If one confines his attention to the only variable factor in the energy

in all these cases, and traces out in each just what happens, he will

have only motions of one sort or another, at one rate or another, and

there is nothing mysterious which enters into the processes.

We will turn now to the mode in which electricity manifests itself, and

what it can do. It may be well to point out at the outset what has

occasionally been stated, but which has not received the philosophical

attention it deserves--namely, that electrical phenomena are reversible;

that is, any kind of a physical process which is capable of producing

electricity, electricity is itself able to produce. Thus to name a few:

If mechanical motion develops electricity, electricity will produce

mechanical motion; the movement of a pith ball and an electric motor are

examples. If chemical action can produce it, it will produce chemical

action, as in the decomposition of water and electro-plating. As heat

may be its antecedent, so will it produce heat. If magnetism be an

antecedent factor, magnetism may be its product. What is called

induction may give rise to it in an adjacent conductor, and, likewise,

induction may be its effect.

[Illustration: FIG. 9.--Torpedo.]

[Illustration: FIG. 10.--Dynamo and Motor.]

Let us suppose ourselves to be in a building in which a steam-engine is

at work. There is fuel, the furnace, the boiler, the pipes, the engine

with its fly-wheel turning. The fuel burns in the furnace, the water is

superheated in the boiler, the steam is directed by the pipes, the

piston is moved by the steam pressure, and the fly-wheel rotates

because of proper mechanism between it and the piston. No one who has

given attention to the successive steps in the process is so puzzled as

to feel the need of inventing a particular force, or a new kind of

matter, or any agency, at any stage of the process, different from the

simple mechanical ones represented by a push or a pull. Even if he

cannot see clearly how heat can produce a push, he does not venture to

assume a genii to do the work, but for the time is content with saying

that if he starts with motion in the furnace and stops with the motion

of the fly-wheel, any assumption of any other factor than some form of

motion between the two would be gratuitous. He can truthfully say that

he understands the \_nature\_ of that which goes on between the furnace

and the wheel; that it is some sort of motion, the particular kind of

which he might make out at his leisure.

Suppose once more that, across the road from an engine-house, there was

another building, where all sorts of machines--lathes, planers, drills,

etc.--were running, but that the source of the power for all this was

out of sight, and that one could see no connection between this and the

engine on the other side of the street. Would one need to suppose there

was anything mysterious between the two--a force, a fluid, an immaterial

something? This question is put on the supposition that one should not

be aware of the shaft that might be between the two buildings, and that

it was not obvious on simple inspection how the machines got their

motions from the engine. No one would be puzzled because he did not know

just what the intervening mechanism might be. If the boiler were in the

one building, and the engine in the other with the machines, he could

see nothing moving between them, even if the steam-pipes were of glass.

If matter of any kind were moving, he could not see it there. He would

say there \_must\_ be something moving, or pressure could not be

transferred from one place to the other.

Substitute for the furnace and boiler a galvanic battery or a dynamo;

for the machines of the shop, one or more motors with suitable wire

connections. When the dynamo goes the motors go; when the dynamo stops

the motors stop; nothing can be seen to be turning or moving in any way

between them. Is there any necessity for assuming a mysterious agency,

or a force of a \_nature\_ different from the visible ones at the two ends

of the line? Is it not certain that the question is, How does the motion

get from one to the other, whether there be a wire or not? If there be a

wire, it is plain that there is motion in it, for it is heated its whole

length, and heat is known to be a mode of motion, and every molecule

which is thus heated must have had some antecedent motions. Whether it

be defined or not, and whether it be called by one name or another, are

quite immaterial, if one is concerned only with the \_nature\_ of the

action, whether it be matter or ether, or motion or abracadabra.

Once more: suppose we have a series of active machines. (Fig. 11.) An

arc lamp, radiating light-waves, gets its energy from the wire which is

heated, which in turn gets its energy from the electric current; that

from a dynamo, the dynamo from a steam-engine; that from a furnace and

the chemical actions going on in it. Let us call the chemical actions A,

the furnace B, the engine C, the dynamo D, the electric lamp E, the

ether waves F. (Fig. 12.)

[Illustration: FIG. 11.]

The product of the chemical action of the coal is molecular motion,

called heat in the furnace. The product of the heat is mechanical motion

in the engine. The product of the mechanical motion is electricity in

the dynamo. The product of the electric current in the lamp is

light-waves in the ether. No one hesitates for an instant to speak of

the heat as being molecular motion, nor of the motions of the engine as

being mechanical; but when we come to the product of the dynamo, which

we call electricity, behold, nearly every one says, not that he does not

know what it is, but that no one knows! Does any one venture to say he

does not know what heat is, because he cannot describe in detail just

what goes on in a heated body, as it might be described by one who saw

with a microscope the movements of the molecules? Let us go back for a

moment to the proposition stated early in this book, namely, that if any

body of any magnitude moves, it is because some other body in motion and

in contact with it has imparted its motion by mechanical pressure.

Therefore, the ether waves at F (Fig. 11) imply continuous motions of

some sort from A to F. That they are all motions of ordinary matter from

A to E is obvious, because continuous matter is essential for the

maintenance of the actions. At E the motions are handed over to the

ether, and they are radiated away as light-waves.

[Illustration: FIG. 12.]

[Illustration: FIG. 13.]

A puzzling electrical phenomenon has been what has been called its

duality-states, which are spoken of as positive and negative. Thus, we

speak of the positive plate of a battery and the negative pole of a

dynamo; and another troublesome condition to idealize has been, how it

could be that, in an electric circuit, there could be as much energy at

the most remote part as at the source. But, if one will take a limp

rope, 8 or 10 feet long, tie its ends together, and then begin to twist

it at any point, he will see the twist move in a right-handed spiral on

the one hand, and in a left-handed spiral on the other, and each may be

traced quite round the circuit; so there will be as much twist, as much

motion, and as much energy in one part of the rope as in any other; and

if one chooses to call the right-handed twist positive, and the

left-handed twist negative, he will have the mechanical phenomenon of

energy-distribution and the terminology, analogous to what they are in

an electric conductor. (Fig. 13.) Are the cases more dissimilar than the

mechanical analogy would make them seem to be?

Are there any phenomena which imply that rotation is going on in an

electric conductor? There are. An electric arc, which is a current in

the air, and is, therefore, less constrained than it is in a conductor,

rotates. Especially marked is this when in front of the pole of a

magnet; but the rotation may be noticed in an ordinary arc by looking at

it with a stroboscope disk, rotated so as to make the light to the eye

intermittent at the rate of four or five hundred per second. A ray of

plane polarized light, parallel with a wire conveying a current, has its

plane of vibration twisted to the right or left, as the current goes

one way or the other through the wire, and to a degree that depends upon

the distance it travels; not only so, but if the ray be sent, by

reflection, back through the same field, it is twisted as much more--a

phenomenon which convinces one that rotation is going on in the space

through which the ray travels. If the ether through which the ray be

sent were simply warped or in some static stress, the ray, after

reflection, would be brought back to its original plane, which is not

the case. This rotation in the ether is produced by what is going on in

the wire. The ether waves called light are interpreted to imply that

molecules originate them by their vibrations, and that there are as many

ether waves per second as of molecular vibrations per second. In like

manner, the implication is the same, that if there be rotations in the

ether they must be produced by molecular rotation, and there must be as

many rotations per second in the ether as there are molecular rotations

that produce them. The space about a wire carrying a current is often

pictured as filled with whorls indicating this motion (Fig. 14), and one

must picture to himself, not the wire as a whole rotating, but each

individual molecule independently. But one is aware that the molecules

of a conductor are practically in contact with each other, and that if

one for any reason rotates, the next one to it would, from frictional

action, cause the one it touched to rotate in the opposite direction,

whereas, the evidence goes to show that all rotation is in the same

direction.

[Illustration: FIG. 14.]

How can this be explained mechanically? Recall the kind of action that

constitutes heat, that it is not translatory action in any degree, but

vibratory, in the sense of a change of form of an elastic body, and

this, too, of the atoms that make up the molecule of whatever sort. Each

atom is so far independent of every other atom in the molecule that it

can vibrate in this way, else it could not be heated. The greater the

amplitude of vibration, the more free space to move in, and continuous

contact of atoms is incompatible with the mechanics of heat. There must,

therefore, be impact and freedom alternating with each other in all

degrees in a heated body. If, in any way, the atoms themselves \_were\_

made to rotate, their heat impacts not only would restrain the

rotations, but the energy also of the rotation motion would increase the

vibrations; that is, the heat would be correspondingly increased, which

is what happens always when an electric current is in a conductor. It

appears that the cooler a body is the less electric resistance it has,

and the indications are that at absolute zero there is no resistance;

that is, impacts do not retard rotation, but it is also apparent that

any current sent through a conductor at that temperature would at once

heat it. This is the same as saying that an electric current could not

be sent through a conductor at absolute zero.

So far, mechanical conceptions are in accordance with electrical

phenomena, but there are several others yet to be noted. Electrical

phenomena has been explained as molecular or atomic phenomena, and there

is one more in that category which is well enough known, and which is so

important and suggestive, that the wonder is its significance has not

been seen by those who have sought to interpret electrical phenomena.

The reference is to the fact that electricity cannot be transmitted

through a vacuum. An electric arc begins to spread out as the density of

the air decreases, and presently it is extinguished. An induction spark

that will jump two or three feet in air cannot be made to bridge the

tenth of an inch in an ordinary vacuum. A vacuum is a perfect

non-conductor of electricity. Is there more than one possible

interpretation to this, namely, that electricity is fundamentally a

molecular and atomic phenomenon, and in the absence of molecules cannot

exist? One may say, "Electrical \_action\_ is not hindered by a vacuum,"

which is true, but has quite another interpretation than the implication

that electricity is an ether phenomenon. The heat of the sun in some way

gets to the earth, but what takes place in the ether is not

heat-transmission. There is no heat in space, and no one is at liberty

to say, or think, that there can be heat in the absence of matter.

When heat has been transformed into ether waves, it is no longer heat,

call it by what name one will. Formerly, such waves were called

heat-waves; no one, properly informed, does so now. In like manner, if

electrical motions or conditions in matter be transformed, no matter

how, it is no longer proper to speak of such transformed motions or

conditions as electricity. Thus, if electrical energy be transformed

into heat, no one thinks of speaking of the latter as electrical. If the

electrical energy be transformed into mechanical of any sort, no one

thinks of calling the latter electrical because of its antecedent. If

electrical motions be transformed into ether actions of any kind, why

should we continue to speak of the transformed motions or energy as

being electrical? Electricity may be the antecedent, in the same sense

as the mechanical motion of a bullet may be the antecedent of the heat

developed when the latter strikes the target; and if it be granted that

a vacuum is a perfect non-conductor of electricity, then it is

manifestly improper to speak of any phenomenon in the ether as an

electrical phenomenon. It is from the failure to make this distinction

that most of the trouble has come in thinking on this subject. Some have

given all their attention to what goes on in matter, and have called

that electricity; others have given their attention to what goes on in

the ether, and have called that electricity, and some have considered

both as being the same thing, and have been confounded.

Let us consider what is the relation between an electrified body and the

ether about it.

When a body is electrified, the latter at the same time creates an ether

stress about it, which is called an electric field. The ether stress may

be considered as a warp in the distribution of the energy about the body

(Fig. 15), by the new positions given to the molecules by the process of

electrification. It has been already said that the evidence from other

sources is that atoms, rather than molecules, in larger masses, are what

affect the ether. One is inclined to inquire for the evidence we have as

to the constitution of matter or of atoms. There is only one hypothesis

to-day that has any degree of probability; that is, the vortex-ring

theory, which describes an atom as being a vortex-ring of ether in the

ether. It possesses a definite amount of energy in virtue of the motion

which constitutes it, and this motion differentiates it from the

surrounding ether, giving it dimensions, elasticity, momentum, and the

possibility of translatory, rotary, vibratory motions, and combinations

of them. Without going further into this, it is sufficient, for a

mechanical conception, that one should have so much in mind, as it will

vastly help in forming a mechanical conception of reactions between

atoms and the ether. An exchange of energy between such an atom and the

ether is not an exchange between different kinds of things, but between

different conditions of the same thing. Next, it should be remembered

that all the elements are magnetic in some degree. This means that they

are themselves magnets, and every magnet has a magnetic field unlimited

in extent, which can almost be regarded as a part of itself. If a magnet

of any size be moved, its field is moved with it, and if in any way the

magnetism be increased or diminished, the field changes correspondingly.

[Illustration: FIG. 15.]

Assume a straight bar electro-magnet in circuit, so that a current can

be made intermittent, say, once a second. When the circuit is closed and

the magnet is made, the field at once is formed and travels outwards at

the rate of 186,000 miles per second. When the current stops, the field

adjacent is destroyed. Another closure develops the field again, which,

like the other, travels outwards; and so there may be formed a series of

waves in the ether, each 186,000 miles long, with an electro-magnetic

antecedent. If the circuit were closed ten times a second, the waves

would be 18,600 miles long; if 186,000 times a second, they would be but

one mile long. If 400 million of millions times a second, they would be

but the forty-thousandth of an inch long, and would then affect the eye,

and we should call them light-waves, but the latter would not differ

from the first wave in any particular except in length. As it is proved

that such electro-magnetic waves have all the characteristics of light,

it follows that they must originate with electro-magnetic action, that

is, in the changing magnetism of a magnetic body. This makes it needful

to assume that the atoms which originate waves are magnets, as they are

experimentally found to be. But how can a magnet, not subject to a

varying current, change its magnetic field? The strength or density of a

magnetic field depends upon the form of the magnet. When the poles are

near together, the field is densest; when the magnet is bent back to a

straight bar, the field is rarest or weakest, and a change in the form

of the magnet from a U-form to a straight bar would result in a change

of the magnetic field within its greatest limits. A few turns of

wire--as has been already said--wound about the poles of an ordinary

U-magnet, and connected to an ordinary magnetic telephone, will enable

one, listening to the latter, to hear the pitch of the former loudly

reproduced when the magnet is struck like a tuning-fork, so as to

vibrate. This shows that the field of the magnet changes at the same

rate as the vibrations.

Assume that the magnet becomes smaller and smaller until it is of the

dimensions of an atom, say for an approximation, the fifty-millionth of

an inch. It would still have its field; it would still be elastic and

capable of vibration, but at an enormously rapid rate; but its vibration

would change its field in the same way, and so there would be formed

those waves in the ether, which, because they are so short that they can

affect the eye, we call light. The mechanical conceptions are

legitimate, because based upon experiments having ranges through nearly

the whole gamut as waves in ether.

The idea implies that every atom has what may be loosely called an

electro-magnetic grip upon the whole of the ether, and any change in the

former brings some change in the latter.

Lastly, the phenomenon called induction may be mechanically conceived.

It is well known that a current in a conductor makes a magnet of the

wire, and gives it an electro-magnetic field, so that other magnets in

its neighbourhood are twisted in a way tending to set them at right

angles to the wire. Also, if another wire be adjacent to the first, an

electric current having an opposite direction is induced in it. Thus:

Consider a permanent magnet A (Fig. 15), free to turn on an axis in the

direction of the arrow. If there be other free magnets, B and C, in

line, they will assume such positions that their similar poles all point

one way. Let A be twisted to a position at right angles, then B will

turn, but in the opposite direction, and C in similar. That is, if A

turn in the direction of the hands of a clock, B and C will turn in

opposite directions. These are simply the observed movements of large

magnets. Imagine that these magnets be reduced to atomic dimensions, yet

retaining their magnetic qualities, poles and fields. Would they not

evidently move in the same way and for the same reason? If it be true,

that a magnet field always so acts upon another as to tend by rotation

to set the latter into a certain position, with reference to the stress

in that field, then, \_wherever there is a changing magnetic field, there

the atoms are being adjusted by it\_.

[Illustration: FIG. 16.]

Suppose we have a line of magnetic needles free to turn, hundreds or

thousands of them, but disarranged. Let a strong magnetic field be

produced at one end of the line. The field would be strongest and best

conducted along the magnet line, but every magnet in the line would be

compelled to rotate, and if the first were kept rotating, the rotation

would be kept up along the whole line. This would be a mechanical

illustration of how an electric current travels in a conductor. The

rotations are of the atomic sort, and are at right angles to the

direction of the conductor.

That which makes the magnets move is inductive magnetic ether stress,

but the advancing motion represents mechanical energy of rotation, and

it is this motion, with the resulting friction, which causes the heat in

a conductor.

What is important to note is, that the action in the ether is not

electric action, but more properly the result of electro-magnetic

action. Whatever name be given to it, and however it comes about, there

is no good reason for calling any kind of ether action electrical.

Electric action, like magnetic action, begins and ends in matter. It is

subject to transformations into thermal and mechanical actions, also

into ether stress--right-handed or left-handed--which, in turn, can

similarly affect other matter, but with opposite polarities.

In his \_Modern Views of Electricity\_, Prof. O. J. Lodge warns us, quite

rightly, that perhaps, after all, there is no such \_thing\_ as

electricity--that electrification and electric energy may be terms to be

kept for convenience; but if electricity as a term be held to imply a

force, a fluid, an imponderable, or a thing which could be described by

some one who knew enough, then it has no degree of probability, for

spinning atomic magnets seem capable of developing all the electrical

phenomena we meet. It must be thought of as a \_condition\_ and not as an

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