Lost Science

Eric Dollard Collection

Second Scientific Lecture-Course: Warmth Course

Lecture I

Stuttgart, March 1st, 1920.

My dear friends,

The present course of lectures will constitute a kind of continuation of the one given when I was last here. I will begin with those chapters of physics which are of especial importance for laying a satisfactory foundation for a scientific world view, namely the observations of heat relations in the world. Today I will try to lay out for you a kind of introduction to show the extent to which we can create a body of meaningful views of a physical sort within a general world view. This will show further how a foundation may be secured for a pedagogical impulse applicable to the teaching of science. Today we will therefore go as far as we can towards outlining a general introduction.

The theory of heat, so-called, has taken a form during the 19^{th} century which has given a great deal of support to a materialistic view of the world. It has done so because in heat relationships it is very easy to turn one's glance away from the real nature of heat, from its being, and to direct it to the mechanical phenomena arising from heat.

Heat is first known through sensations of cold, warmth, lukewarm, etc. But man soon learns that there appears to be something vague about these sensations, something subjective. A simple experiment which can be made by anyone shows this fact.

Imagine you have a vessel filled with water of a definite temperature, t; on the right of it you have another vessel filled with water of a temperature $t - t^1$, that is of a temperature distinctly lower than the temperature in the first vessel. In addition, you have a vessel filled with water at a temperature $t + t^1$. When now, you hold your fingers in the two outer vessels you will note by your sensations the heat conditions in these vessels. You can then plunge your fingers which have been in the outer vessels into the central vessel and you will see that to the finger which has been in the cold water the water in the central vessel will feel warm, while to the finger which has been in the warm water, the water in the central vessel will feel cold. The same temperature therefore is experienced differently according to the temperature to which one has previously been exposed. Everyone knows that when he goes into a cellar, it may feel different in winter from the way it feels in summer. Even though the thermometer stands at the same point circumstances may be such that the cellar feels warm in the winter and cool in the summer. Indeed, the subjective experience of heat is not uniform and it is necessary to set an objective standard by which to measure the heat condition of any object or location. Now, I need not here go into the elementary phenomena or take up the elementary instruments for measuring heat. It must be assumed that you are acquainted with them. I will simply say that when the temperature condition is measured with a thermometer, there is a feeling that since we measure the degree above or below

zero, we are getting an objective temperature measurement. In our thinking we consider that there is a fundamental difference between this objective determination in which we have no part and the subjective determination, where our own organization enters into the experience.

For all that the 19th century has striven to attain it may be said that this view on the matter was, from a certain point of view, fruitful and justified by its results. Now, however, we are in a time when people must pay attention to certain other things if they are to advance their way of thinking and their way of life. *From science itself* must come certain questions simply overlooked in such conclusions as those I have given. One question is this: Is there a difference, a real objective difference, between the determination of temperature by my organism and by a thermometer, or do I deceive myself for the sake of getting useful practical results when I bring such a difference into my ideas and concepts? This whole course will be designed to show why today such questions must be asked. From the principal questions it will be my object to proceed to those important considerations which have been overlooked owing to exclusive attention to the practical life. How they have been lost for us on account of the attention to technology you will see. I would like to impress you with the fact that we have completely lost our feeling for the real being of heat under the influence of certain ideas to be described presently. And, along with this loss, has gone the possibility of bringing this being of heat into relation with the human organism itself, a relation which must be all means be established in certain aspects of our life. To indicate to you in a merely preliminary way the bearing of these things on the human organism, I may call your attention to the fact that in many cases we are obliged today to measure the temperature of this organism, as for instance, when it is in a feverish condition. This will show you that the relation of the unknown being of heat to the human organism has considerable importance. Those extreme conditions as met with in chemical and technical processes will be dealt with subsequently. A proper attitude toward the relation of the unknown being of heat to the human organism has considerable importance. Those extreme conditions as met with in chemical and technical processes will be dealt with subsequently. A proper attitude toward the relation of the heat-being to the human organism cannot, however, be attained on the basis of a mechanical view of heat. The reason is, that in so doing, one neglects the fact that the various organs are quite different in their sensitiveness to this heat-being, that *the heart, the liver, the lungs differ greatly in their capacity to react to the being of heat*. Through the purely physical view of heat no foundation is laid for the real study of certain symptoms of disease, since the varying capacity to react to heat of the several organs of the body escapes attention. Today we are in no position to apply to the organic world the physical views built up in the course of the 19th century on the nature of heat. This is obvious to anyone who has an eye to see the harm done by modern physical research, so-called, in dealing with what might be designated the higher branches of knowledge of the living being. Certain questions must be asked, questions that call above everything for clear, lucid ideas. In the so-called "exact science," nothing has done more harm than the introduction of confused ideas.

What then does it really mean when I say, if I put my fingers in the right and left hand vessels and then into a vessel with a liquid of an intermediate temperature, I get different sensations? Is there really something in the conceptual realm that is different from the so-

called objective determination with the thermometer? Consider now, suppose you put thermometers in these two vessels in place of your fingers. You will then get different readings depending on whether you observe the thermometer in the one vessel or the other. If then you place the two thermometers instead of your fingers into the middle vessel, the mercury will act differently on the two. In the one it will rise; in the other it will fall. You see the thermometer does not behave differently from your sensations. For the setting up of a view of the phenomenon, there is no distinction between the two thermometers and the sensation from your finger. In both cases exactly the same thing occurs, namely a difference is shown from the immediately preceding conditions. And the thing our sensation depends on is that we do not *within ourselves* have any zero or reference point. If we had such a reference point then we would establish not merely the immediate sensation but would have apparatus to relate the temperature subjectively perceived, to such a reference point. We would then attach to the phenomenon just as we do with the thermometers something which really is not inherent in it, namely the variation from the reference point. You see, for the construction of our concept of the process there is no difference.

It is such questions as these that must be raised today if we are to clarify our ideas, or all the present ideas on these things are really confused. Do not imagine for a moment that this is of no consequence. Our whole life process is bound up with this fact that we have in us no temperature reference point. *If we could establish such a reference point within ourselves, it would necessitate an entirely different state of consciousness, a different soul life.* It is precisely because the reference point is hidden for us that we lead the kind of life we do.

You see, many things in life, in human life and in the animal organism, too, depend on the fact that we do *not* perceive certain processes. Think what you would have to do if you were obliged to experience subjectively everything that goes on in your organism. Suppose you had to be aware of all the details of the digestive process. A great deal pertaining to our condition of life rests on this fact that we do *not* bring into our consciousness certain things that take place in our organism. Among these things is that we do not carry within us a temperature reference point — we are not thermometers. A subjective-objective distinction such as is usually made is not therefore adequate for a comprehensive grasp of the physical.

It is this which has been the uncertain point in human thinking since the time of ancient Greeks. It had to be so, but it cannot remain so in the future. For the old Grecian philosophers, Zeno in particular, had already orientated human thinking about certain processes in a manner strikingly opposed to outer reality. I must call your attention to these things even at the risk of seeming pedantic. Let me recall to you the problem of Achilles and the tortoise, a problem I have often spoken about.

Let us assume we have the distance traveled by Achilles in a certain time (a). This represents the rate at which he can travel. And here we have the tortoise (s), who has a start on Achilles. Let us take the moment when Achilles gets to the point marked 1. The tortoise is ahead of him. Since the problem stated that Achilles has to cover every point covered by the tortoise, the tortoise will always be a little ahead and Achilles can never catch up. But, the way people would consider it is this. You would say, yes, I understand the problem all right, but Achilles would soon catch the tortoise. The whole thing is absurd. But if we

reason that Achilles must cover the same path as the tortoise and the tortoise is ahead, he will never catch the tortoise. Although people would say this is absurd, nevertheless the conclusion is absolutely necessary and nothing can be urged against it. It is not foolish to come to this conclusion but on the other hand, it is remarkably clever considering only the logic of the matter. It is a necessary conclusion and cannot be avoided. Now what does all this depend on? It depends on this: that as long as you think, you cannot think otherwise than the premise requires. As a matter of fact, you do not depend on thinking strictly, but instead you look at the reality and you realize that it is obvious that Achilles will soon catch the tortoise. And in doing this you uproot thinking by means of reality and abandon the pure thought process. There is no point in admitting the premises and then saying, "Anyone who thinks this way is stupid." Through thinking alone we can get nothing out of the proposition but that Achilles will never catch the tortoise. And why not? Because when we apply our thinking absolutely to reality, then our conclusions are not in accord with the facts. They cannot be. When we turn our rationalistic thought on reality it does not help us at all that we establish so-called truths which turn out not to be true. For we must conclude if Achilles follows the tortoise that he passes through each point that the tortoise passes through. Ideally this is so; in reality he does nothing of the kind. His stride is greater than that of the tortoise. He does not pass through each point of the path of the tortoise. We must, therefore, consider what Achilles really does, and not simply limit ourselves to mere thinking. Then we come to a different result. People do not bother their heads about these things but in reality they are extraordinarily important. Today especially, in our present scientific development, they are extremely important. For only when we understand that much of our thinking misses the phenomena of nature if we go from observation to so-called explanation, only in this case will we get the proper attitude toward these things.

The observable, however, is something which only needs to be described. That I can do the following for instance, calls simply for a description: here I have a ball which will pass through this opening. We will now warm the ball slightly. Now you see it does not go through. It will only go through when it has cooled sufficiently. As soon as I cool it by pouring this cold water on it, the ball goes through again. This is the observation, and it is this observation that I need only describe. Let us suppose, however, that I begin to theorize. I will do so in a sketchy way with the object merely of introducing the matter. Here is the ball; it consists of a certain number of small parts — molecules, atoms, if you like. This is not observation, but something added to observation in theory. At this moment, I have left the observed and in doing so I assume an extremely tragic role. Only those who are in a position to have insight into these things can realize this tragedy. For you see, if you investigate whether Achilles can catch the tortoise, you may indeed begin by thinking "Achilles must pass over every point covered by the tortoise and can never catch it." This may be strictly demonstrated. Then you can make an experiment. You place the tortoise ahead and Achilles or some other who does not run even so fast as Achilles, in the rear. And at any time you can show that observation furnishes the opposite of what you conclude from reasoning. The tortoise is soon caught.

When, however, you theorize about the sphere, as to how its atoms and molecules are arranged, and when you abandon the possibility of observation, you cannot in such a case look into the matter and investigate it — you can only theorize. And in this realm you will

do no better than you did when you applied your thinking to the course of Achilles. That is to say, you carry the whole incompleteness of your logic into your thinking about something which cannot be made the object of observation. This is the tragedy. We build explanation upon explanation while at the same time we abandon observation, and think we have explained things simply because we have erected hypotheses and theories. And the consequence of this course of forced reliance on our mere thinking is that this same thinking fails us the moment we are able to observe. It no longer agrees with the observation.

You will remember I already pointed out this distinction in the previous course when I indicated the boundary between kinematics and mechanics. Kinematics describes mere motion phenomena or phenomena as expressed by equations, but it is restricted to verifying the data of observation.

The moment we pass over from kinematics to mechanics where force and mass concepts are brought in, at this moment, we cannot rely on thinking alone, but we begin simply to read off what is given from observation of the phenomena. With unaided thought we are not able to deal adequately even with the simplest physical process where mass plays a role. All the 19th century theories, abandoned now to a greater or lesser extent, are of such a nature that in order to verify them it would be necessary to make experiments with atoms and molecules. The fact that they have been shown to have a practical application in limited fields makes no difference. The principle applies to the small as well as to the large. You remember how I have often in my lectures called attention to something which enters into our considerations now wearing a scientific aspect. I have often said: From what the physicists have theorized about heat relations and from related things they get certain notions about the sun. They describe what they call the "physical conditions" on the sun and make certain claims that the facts support the description. Now I have often told you, the physicists would be tremendously surprised if they could really take a trip to the sun and could see that none of their theorizing based on terrestrial conditions agreed with the realities as found on the sun. These things have a very practical value at the present, a value for the development of science in our time. Just recently news has gone forth to the world that after infinite pains the findings of certain English investigators in regard to the bending of starlight in cosmic space have been confirmed and could now be presented before a learned society in Berlin. It was rightly stated there "the investigations of Einstein and others on the theory of relativity have received a certain amount of confirmation. But final confirmation could be secured only when sufficient progress had been made to make spectrum analysis showing the behavior of the light at the time of an eclipse of the sun. Then it would be possible to see what the instruments available at present failed to determine." This was the information given at the last meeting of the Berlin Physical Society. It is remarkably interesting. Naturally the next step is to seek a way really to investigate the light of the sun by spectrum analysis. The method is to be by means of instruments not available today. Then certain things already deduced from modern scientific ideas may simply be confirmed. As you know it is thus with many things which have come along from time to time and been later clarified by physical experiments. But, people will learn to recognize the fact that it is simply *impossible for men to carry over to conditions on the sun or to the cosmic spaces what may be calculated from those heat phenomena available to observation in the terrestrial sphere*. It will be understood that the sun's corona

and similar phenomena have antecedents not included in the observations made under terrestrial conditions. Just as our speculations lead us astray when we abandon observation and theorize our way through a world of atoms and molecules, so we fall into error when we go out into the macrocosm and carry over to the sun what we have determined from observations under earth conditions. Such a method has led to the belief that the sun is a kind of glowing gas ball, but the sun is not a glowing ball of gas by any means. Consider a moment, you have matter here on the earth. All matter on the earth has a certain degree of intensity in its action. This may be measured in one way or another, be density or the like, in any way you wish, it has a definite intensity of action. This may become zero. In other words, we may have empty space. But the end is not yet. That empty space is not the ultimate condition I may illustrate to you by the following: Assume to yourselves that you had a boy and that you said, "He is a rattle-brained fellow. I have made over a small property to him but he has begun to squander it. He cannot have less than zero. He may finally have nothing, but I comfort myself with the thought that he cannot go any further once he gets to zero!" But you may now have a disillusionment. The fellow begins to get into debt. Then he does not stop at zero; the thing gets worse than zero. It has a very real meaning. As his father, you really have less if he gets into debt than if he stopped when he had nothing.

The same sort of thing, now, applies to the condition on the sun. It is not usually considered as empty space but the greatest possible rarefaction is thought of and a rarefied glowing gas is postulated. But what we must do is to go to a condition of emptiness and then go beyond this. *It is in a condition of negative material intensity.* In the spot where the sun is will be found a hole in space. There is less there than empty space. Therefore all the effects to be observed in the sun must be considered as attractive forces not as pressures of the like. The sun's corona, for instance, must not be thought of as it is considered by the modern physicist. It must be considered in such a way that we have the consciousness not of forces radiating outward as appearances would indicate, but of attractive force from the hole in space, from the negation of matter. Here our logic fails us. Our thinking is not valid here, for the receptive organ or the sense organ through which we perceive it is our entire body. Our whole body corresponds in this sensation to the eye in the case of light. There is no isolated organ, we respond with our whole body to the heat conditions. The fact that we may use our finger to perceive a heat condition, for instance, does not militate against this fact. The finger corresponds to a portion of the eye. While the eye therefore is an isolated organ and functions as such to objectify the world of light as color, this is not the case for heat. We are heat organs in our entirety. On this account, however, the external condition that gives rise to heat does not come to us in so isolated a form as does the condition which gives rise to light. Our eye is objectified within our organism. We cannot perceive heat in an analogous manner to light because we are one with the heat. Imagine that you could not see colors with your eye but only different degrees of brightness, and that the colors as such remained entirely subjective, were only feelings. You would never see colors; you would speak of light and dark, but the colors would evoke in you no response and it is thus with the perception of heat. *Those differences which you perceive in the case of light on account of the fact that your eye is an isolated organ, such differences you do not perceive at all in the case of heat. They live in you*. Thus when you speak of blue and red, these colors are considered as objective. When the analogous phenomenon is met in the case of heat, that

which corresponds to the blue and the red is within you. It is you yourself. Therefore you do not define it. *This requires us to adopt an entirely different method for the observation of the objective being of heat from the method we use of the objective being of light*. Nothing had so great a misleading effect on the observers of the 19th century as this general tendency to unify things schematically. You find everywhere in physiologies a "sense physiology." Just as though there were such a thing! As though there were something of which it could be said, in general, "it holds for the ear as for the eye, or even for the sense of feeling or for the sense of heat. It is an absurdity to speak of a sense physiology and to say that a sense perception is this or that. It is possible only to speak of the perception of the eye by itself, or the perception of the ear by itself and likewise of our entire organism as heat sense organ, etc. They are very different things. Only meaningless abstractions result from a general consideration of the senses. But you find everywhere the tendency towards such a generalizing of these things. Conclusions result that would be humorous were they not so harmful to our whole life. If someone says — Here is a boy, another boy has given him a thrashing. Also then it is asserted — Yesterday he was whipped by his teacher; his teacher gave him a thrashing. In both cases there is a thrashing given; there is no difference. Am I to conclude from this that the bad boy who dealt out today's whipping and the teacher who administered yesterday's are moved by the same inner motives? That would be an absurdity; it would be impossible. But now, the following experiment is carried out: it is known that when light rays are allowed to fall on a concave mirror, under proper conditions they become parallel. When these are picked up by another concave mirror distant form the first they are concentrated and focused so that an intensified light appears at the focus. The same experiment is made with so-called heat rays. Again it may be demonstrated that these too can be focused — a thermometer will show it — and there is a point of high heat intensity produced. Here we have the same process as in the case of the light; therefore heat and light are fundamentally the same sort of thing. The thrashing of yesterday and the one of today are the same sort of thing. If a person came to such a conclusion in practical life, he would be considered a fool. In science, however, as it is pursued today, he is no fool, but a highly respected individual.

It is on account of things like this that we should strive for clear and lucid concepts, and without these we will not progress. Without them physics cannot contribute to a general world view. In the realm of physics especially it is necessary to attain to these obvious ideas.

You know quite well from what was made clear to you, at least to a certain extent, in my last course, that in the case of the phenomena of light, Goethe brought some degree of order into the physics of that particular class of facts, but no recognition has been given to him.

In the field of heat the difficulties that confront us are especially great. This is because in the time since Goethe the whole physical consideration of heat has been plunged into a chaos of theoretical considerations. In the 19th century the mechanical theory of heat as it is called has resulted in error upon error. It has applied concepts verifiable only by observation to a realm not accessible to observation. Everyone who believes himself able to think, but who in reality may not be able to do so, can propose theories. Such a one is the following: a gas enclosed in a vessel consists of particles. These particles are not at rest but in a state of

continuous motion. Since these particles are in continuous motion and are small and conceived of as separated by relatively great distance, they do not collide with each other often but only occasionally. When they do so they rebound. Their motion is changed by this mutual bombardment. Now when one sums up all the various slight impacts there comes about a pressure on the wall of the vessel and through this pressure one can measure how great the temperature is. It is then asserted, "the gas particles in the vessel are in a certain state of motion, bombarding each other. The whole mass is in rapid motion, the particles bombarding each other and striking the wall. This gives rise to heat." They may move faster and faster, strike the wall harder. Then it may be asked, what is heat? It is motion of these small particles. It is quite certain that under the influence of the facts such ideas have been fruitful, but only superficially. The *entire method of thinking* rests on one foundation. A great deal of pride is taken in this so-called "mechanical theory of heat," for it seems to explain many things. For instance, it explains how when I rub my finger over a surface the effort I put forth, the pressure or work, is transformed into heat. I can turn heat back into work, in the steam engine for instance, where I secure motion by means of heat. A very convenient working concept has been built up along these lines. It is said that when we observe these things objectively going on in space, they are mechanical processes. The locomotive and the cars all move forward etc. When now, through some sort of work, I produce heat, what has really happened is that the outer observable motion has been transformed into motion of the ultimate particles. This is a convenient theory. It can be said that everything in the world is dependent on motion and we have merely transformation of observable motion into motion not observable. This latter we perceive as heat. But heat is in reality nothing but the impact and collision of the little gas particles striking each other and the walls of the vessel. The change into heat is as though the people in this whole audience suddenly began to move and collided with each other and with the walls etc. This is the Clausius theory of what goes on in a gas-filled space. This is the theory that has resulted from applying the method of the Achilles proposition to something not accessible to observation. It is not noticed that the same impossible grounds are taken as in the reasoning about Achilles and the tortoise. It is simply not as it is thought to be. Within a gas-filled space things are quite otherwise than we imagine them to be when we carry over the observable into the realm of the unobservable. My purpose today is to present this idea to you in an introductory way. From this consideration you can see that the fundamental method of thinking originated during the 19th century, begins to fail. For a large part of the method rests on the principle of calculating from observed facts by means of the differential concept. When the observed conditions in a gas-filled space are set down as differentials in accordance with the idea that we are dealing with the movements of ultimate particles, then the belief follows that by integrating something real is evolved. What must be understood is this: when we go from ordinary reckoning methods to differential equations, it is not possible to integrate forthwith without losing all contact with reality. This false notion of the relation of the integral to the differential has led the physics of the 19th century into wrong ideas of reality. It must be made clear that in certain instances one can set up differentials but what is obtained as a differential cannot be thought of as integrable without leading us into the realm of the ideal as opposed to the real. The understanding of this is of great importance in our relation to nature.

For you see, when I carry out a certain transformation period, I say that work is performed,

heat produced and from this heat, work can again be secured by reversal of this process. But the processes of the organic cannot be reversed immediately. I will subsequently show the extent to which this reversal applies to the inorganic in the realm of heat in particular. There are also great inorganic processes that are not reversible, such as the plant processes. We cannot imagine a reversal of the process that goes on in the plant from the formation of roots, through the flower and fruit formation. The process takes its course from the seed to the setting of the fruit. It cannot be turned backwards like an inorganic process. This fact does not enter into our calculations. Even when we remain in the inorganic, there are certain macrocosmic processes for which our reckoning is not valid. Suppose you were able to set down a formula for the growth of a plant. It would be very complicated, but assume that you have such a formula. Certain terms in it could never be made negative because to do so would be to disagree with reality. In the face of the great phenomena of the world I cannot reverse reality. This does not apply, however, to reckoning. If I have today an eclipse of the moon I can simply calculate how in time past in the period of Thales, for instance, there was an eclipse of the moon. That is, *in calculation only* I can reverse the process, but in reality the process is not reversible. We cannot pass from the present state of the earth to former states — to an eclipse of the moon at the time of Thales, for instance, simply by reversing the process in calculation. A calculation may be made forward or backward, but usually reality does not agree with the calculation. The latter passes over reality. It must be defined to what extent our concepts and calculations are only conceptual in their content. In spite of the fact that they are reversible, there are no reversible processes in reality. This is important since we will see that the whole theory of heat is built on questions of the following sort: to what extent within nature are heat processes reversible and to what extent are they irreversible?

Second Scientific Lecture-Course: Warmth Course

Lecture II

Stuttgart, March 2nd, 1920.

My dear friends,

Yesterday I touched upon the fact that bodies under the influence of heat expand. Today we will first consider how bodies, the solid bodies as we call them, expand when acted upon by the being of warmth. In order to impress these things upon our minds so that we can use them properly in pedagogy — and at this stage the matter is quite simple and elementary — we have set up this apparatus with an iron bar. We will heat the iron bar and make its expansion visible by noting the movements of this lever-arm over a scale. When I press here with my finger, the pointer moves upwards. (see drawing.)

You can see when we heat the rod, the pointer does move upwards which indicates for you the act that the rod expands. The pointer moves upwards at once. Also you notice that with continued heating the pointer moves more and more, showing that the expansion increases with the temperature. If instead of this rod I had another consisting of a different metal, and if we measured precisely the amount of the expansion, it would be found other than it is here. We would find that different substances expanded various amounts. Thus we would be able to establish at once that the expansion, the degree of elongation, depended on the substance. At this point we will leave out of account the fact that we are dealing with a cylinder and assume that we have a body of a certain length without breadth or thickness and turn our attention to the expansion in one direction only. To make the matter clear we may consider it as follows: here is a rod, considered simply as a length and we denote by L_o the length of the rod at the original temperature, the starting temperature. The length attained by the rod when it is heated to a temperature t, we will indicate by L. Now I said that the rod expanded to various degrees depending upon the substance of which it is composed. We can express the amount of expansion to the original length of the rod. Let us denote this relative expansion by α. Then we know the length of the rod after expansion. For the length L after expansion may be considered as made up of the original length L_o and the small addition to this length contributed by the expansion. This must be added on. Since I have denoted by α the fraction giving the ratio of the expansion and the original length, I get the expansion for a given substance by multiplying L_o by α. Also since the expansion is greater the higher the temperature, I have to multiply by the temperature t. Thus I can say the length of the rod after expansion is $L_o + L_o \alpha t$, which may be written $L_o (1 + \alpha t)$. Stated in words: if I wish to determine the length of a rod expanded by heat, I must multiply the original length by a factor consisting of 1 plus the temperature times the relative expansion of the substance under consideration. Physicists have called α the expansion coefficient of the substance considered. Now I have considered here a rod. Rods without breadth and thickness do not exist in reality. In reality bodies have three dimensions. If we proceed from the longitudinal expansion to the expansion of an assumed surface, the formula may be

changed as follows: let us assume now that we are to observe the expansion of a surface instead of simply an expansion in one dimension. There is a surface. This surface extends in two directions, and after warming both will have increased in extent. We have therefore not only the longitudinal expansion to L but also an increase in the breadth to b to consider. Taking first the original length, L_o, we have as before the expansion in this direction to L or

1. $L = L_o (1 + \alpha t)$

Considering now the breadth b_o which expands to b, I must write down:

2. $b = b_o (1 + \alpha t)$

(It is obvious that the same rule will hold here as in the case of the length.) Now you know that the area of the surface is obtained by multiplying the length by the breadth. The original area I get by multiplying b_o and L_o, and after expansion by multiplying $L_o (1 + \alpha t)$ and $b_o (1 + \alpha t)$

3. $Lb = [L_o (1 + \alpha t)] [b_o (1 + \alpha t)]$ or
4. $Lb = L_o b_o (1 + \alpha t)^2$
5. $Lb = L_o b_o (1 + 2\alpha t + \alpha^2 t^2)$

This gives the formula for the expansion of the surface. If now, you imagine thickness added to the surface, this thickness must be treated in the same manner and I can then write:

6. $Lbd = L_o b_o d_o (1 + 3\alpha t + 3\alpha^2 t^2 + \alpha^3 t^3)$

When you look at this formula I will ask you please to note the following: in the first two terms of (6) you see t raised no higher than the first power; in the third term you see the second, and in the fourth term it is raised to the third power. Note especially these last two terms of the formula for expansion. Observe that when we deal with the expansion of a three-dimensional body we obtain a formula containing the third power of the temperature. It is extremely important to keep in mind this fact that we come here upon the third power of the temperature.

Now I must always remember that we are here in the Waldorf School and everything must be presented in its relation to pedagogy. Therefore I will call your attention to the fact that the same introduction I have made here is presented very differently if you study it in the ordinary textbooks of physics. I will not well you how it is presented in the average textbook of physics. It would be said: α is a ratio. It is a fraction. The expansion is relatively very small as compared to the original length of the rod. When I have a fraction whose denominator is greater than its numerator, then when I square or cube it, I get a much smaller fraction. For if I square a third, I get a ninth and when I cube a third I get a twenty-seventh. That is, the third power is a very, very small fraction.

α is a fraction whose denominator is usually very large. Therefore say most physics books:

if I square α to get α^2 or cube it to get α cubed with which I multiply t^3 these are very small fractions and can simply be dropped out. The average physics text says: we simply drop these last terms of the expansion formula and write $l \cdot b \cdot d$ — this is the volume and I will write is as V — the volume of an expanded body heated to a certain temperature is:

7. $V = V_o (1 + 3\alpha t)$

In this fashion is expressed the formula for the expansion of a solid body. It is simply considered that since the fraction α squared and cubed give such small quantities, these can be dropped out. You recognize this as the treatment in the physics texts. Now my friends, in doing this, the most important thing for a really informative theory of heat is stricken out. This will appear as we progress further. Expansion under the influence of heat is shown not only by solids but by fluids as well. Here we have a fluid colored so that you can see it. We will warm this colored fluid (See Figure 1). Now you notice that after a short time the colored fluid rises and from that we can conclude that fluids expand just like solids. Since the colored fluid rises, therefore fluids expand when warmed.

Now we can in the same way investigate the expansion of a gaseous body. For this purpose we have here a vessel filled simply with air. (See Figure 2). We shut off the air in the vessel and warm it. Notice that here is a tube communicating with the vessel and containing a liquid whose level is the same in both arms of the tube. When we simply warm the air in the vessel, which air constitutes a gaseous body, you will see what happens. We will warm it by immersing the vessel in water heated to a temperature of 40°. (Note: temperatures in the lectures are given in degrees Celsius.) You will see, the mercury at once rises. Why does it rise? Because the gaseous body in the vessel expands. The air streams into the tube, presses on the mercury and the pressure forces the mercury column up into the tube. From this you see that the gaseous body has expanded. We may conclude that solid, liquid and gaseous bodies all expand under the influence of the being of heat, as yet unknown to us.

Now, however, a very important matter approaches us when we proceed from the study of the expansion of solids through the expansion of liquids to the expansion of a gas. I have already stated that α, the relation of the expansion to the original length of the rod, differed for different substances. If by means of further experiments that cannot be performed here, we investigate α for various fluids, again we will find different values for various fluid substances. When however, we investigate α for gaseous bodies then a peculiar thing shows itself, namely that α is not different for various gases but that this expansion coefficient as it is called, is the same and has a constant value of about 1/273. This fact is of tremendous importance. From it we see that *as we advance from solid bodies to gases, genuinely new relations with heat appear*. It appears that different gases are related to heat simply according to their property of being gases and not according to variations in the nature of the matter composing them. The condition of being a gas is, so to speak, a property which may be shared in common by all bodies. We see indeed, that for all gases known to us on earth, the property of being a gas gathers together into a unity this property of expanding. Keep in mind now that the facts of expansion under the influence of heat oblige us to say that as we proceed from solid bodies to gases, *the different expansion values found in the case of solids are transformed into a kind of unity, or single power of expansion for gases.*

Thus if I may express myself cautiously, the solid condition may be said to be *associated with an individualization of material condition*. Modern physics pays scant attention to this circumstance. No attention is paid to it because the most important things are obscured by the fact of striking out certain values which cannot be adequately handled.

The history of the development of physics must be called in to a certain extent in order to gain insight into the things involved in a deeper insight into these matters. All the ideas current in the modern physics texts and ruling the methods by which the facts of physics are handled are really not old. They began for the most part in the 17th century and took their fundamental character from the new impulse given by a certain scientific spirit in Europe through Academia del Cimento in Florence. This was founded in 1667 and many experiments in quite different fields were carried out there, especially however, experiments dealing with heat, acoustics and tone. How recent our ordinary ideas are may be realized when we look up some of the special apparatus of the Academia del Cimento. It was there for instance, that the ground work for our modern thermometry was laid. It was at this academy that there was observed for the first time how the mercury behaves in a glass tube ending at the bottom in a closed cylinder, when the mercury filling the tube is warmed. Here, in the Academia del Cimento, it was first noticed that there is an apparent contradiction between the experiments where the expansion of liquids may be observed and another experiment. The generalization had been attained that liquids expand. But when the experiment was carried out with quicksilver it was noticed that it first fell when the tube was heated and after that began to rise. This was first explained in the 17th century, and quite simply, by saying: When heat is applied, the outer glass is heated at the start and expands. The space occupied by the quicksilver becomes greater. It sinks at first, and begins to rise only when the heat has penetrated into the mercury itself. Ideas of this sort have been current since the 17th century. At the same time, however, people were backward in a grasp of the real ideas necessary to understand physics, since this period, the Renaissance, found Europe little inclined to trouble itself with scientific concepts. It was the time set aside for the spread of Christianity. This in a certain sense, hindered the process of definite physical phenomena. For during the Renaissance, which carried with it an acquaintance with the ideas of ancient Greece, men were in somewhat the following situation. On the one hand encouraged by all and every kind of support, there arose institutions like the Academia del Cimento, where it was possible to experiment. The course of natural phenomena could be observed directly. On the other hand, people had become unaccustomed to construct concepts about things. They had lost the habit of really following things in thought. The old Grecian ideas were now taken up again, but they were no longer understood. Thus the concepts of fire or heat or as much of them as could be understood were assumed to be the same as were held by the ancient Greeks. And at this time was formed that great chasm between thought and what can be derived from the observation of experiments. This chasm has widened more and more since the 17th century. The art of experiment reached its full flower in the 19th century, but a development of clear, definite ideas did not parallel this flowering of the experimental art. And today, lacking the clear, definite ideas, we often stand perplexed before phenomena revealed in the course of time by unthinking experimentation. When the way has been found not only to experiment and to observe the outer results of the experiments but really to enter into the inner nature of the phenomena,

then only can these results be made fruitful for human spiritual development.

Note now, when we penetrate into the inner being of natural phenomena then it becomes a matter of great importance that entirely different expansion relations enter in when we proceed from solids to gases. But until the whole body of our physical concepts is extended we will not really be able to evaluate such things as we have today drawn plainly from the facts themselves. To the facts, already brought out, another one of extraordinary importance must be added.

You know that a general rule can be stated as we have already stated it, namely if bodies are warmed they expand. If they are cooled again they contract. So that in general the law may be stated: "Through heating, bodies expand; through cooling they contract." But you will recollect from your elementary physics that there are exceptions to this rule, and one exception that is of cardinal importance is the one in regard to water. When water is made to expand and contract, then a remarkable fact is come upon. If we have water at 80° say, and we cool it, it first contracts. That goes without saying, as it were. But when the water is cooled further it does not contract but expands again. Thus the ice that is formed from water — and we will speak further of this — since it is more expanded and therefore less dense than water, floats on the surface of the water. This is a striking phenomenon, that ice can float on the surface of the water! It comes about through the fact that water behaves irregularly and does not follow the general law of expansion and contraction. If this were not so, if we did not have this exception, the whole arrangement of nature would be peculiarly affected. If you observe a basin filled with water or a pond, you will see that even in the very cold winter weather, there is a coating of ice on the surface only and that this protects the underlying water from further cooling. Always there is an ice coating and underneath there is protected water. The irregularity that appears here is, to use a homely expression, of tremendous importance in the household of nature. Now the manner of forming a physical concept that we can depend on in this case must be strictly according to the principles laid down in the last course. We must avoid the path that leads to an Achilles-and-the-turtle conclusion. We must not forget the manifested facts and must experiment with the facts in mind, that is, we must remain in the field where the accessible facts are such as to enable us to determine something. Therefore, let us hold strictly to what is given and from this seek an explanation for the phenomena. We will especially hold fast to such things, given to observation, as expansion and irregularity in expansion like that of water (noting that it is associated with a fluid.) Such factual matters should be kept in mind and we must remain in the world of actualities. This is real Goetheanism.

Let us now consider this thing, which is not a theory but a demonstrable fact of the outer world. When matter passes into the gaseous condition there enters in a unification of properties for all the substances on the earth and with the passage to the solid condition there takes place an individualizing, a differentiation.

Now if we ask ourselves how it can come about that with the passage from the solid to the gaseous through the liquid state a unification takes place, we have a great deal of difficulty in answering on the basis of our available concepts. We must first, if we are to be able to remain in the realm of the demonstrable, put certain fundamental questions. We must first

ask: Whence comes the possibility for expansion in bodies, followed finally by change into the gaseous state with its accompanying unification of properties?

You have only to look in a general way at all that is to be known about the physical processes on the earth in order to come to the following conclusion: Unless the action of the sun were present, we could not have all these phenomena taking place through heat. You must give attention to the enormous meaning that the being of the sun has for the phenomena of earth. And when you consider this which is simply a matter of fact, you are obliged to say: this unification of properties that takes place in the passage from the solid through the fluid and into the gaseous state, could not happen if the earth were left to itself. Only when we go beyond the merely earthly relations can we find a firm standpoint for our consideration of these things. When we admit this, however, we have made a very far reaching admission. For by putting the way of thinking of the Academia del Cimento and all that went with it in place of the above mentioned point of view, the old concepts still possible in Greece were robbed of all their super-earthly characteristics. And you will soon see, that purely from the facts, without any historical help, we are going to come back to these concepts. It will perhaps be easier to win way into your understanding if I make a short historical sketch at this time.

I have already said that the real meaning of those ideas and concepts of physical phenomena that were still prevalent in ancient Greece have been lost. Experimentation was started and without the inner thought process still gone through in ancient Greece, ideas and concepts were taken up parrot-fashion, as it were. Then all that the Greeks included in these physical concepts was forgotten. The Greeks had not simply said, “Solid, liquid, gaseous,” but what they expressed may be translated into our language as follows:

Whatever was *solid* was called in ancient Greek *earth*;
Whatever was *fluid* was called in ancient Greece *water*;
Whatever was *gaseous* was called in ancient Greece *air*.

It is quite erroneous to think that we carry our own meaning of the words earth, air and water over into old writings where Grecian influence was dominant, and assume that the corresponding words have the same meaning there. When in old writings, we come across the word *water* we must translate it by our word *fluid*; the word *earth* by our words *solid bodies*. Only in this way can we correctly translate old writings. But a profound meaning lies in this. The use of the word *earth* to indicate *solid bodies* implied especially that this solid condition falls under the laws ruling on the planet earth. (As stated above, we will come upon these things in following lectures from the fact themselves; they are presented today in this historical sketch simply to further your understanding of the matter.)

Solids were designated as earth because it was desired to convey this idea: When a body is solid it is under the influence of the earthly laws in every respect. On the other hand, when a body was spoken of as *water*, then it was not merely under the earthly laws but influenced by the entire planetary system. The forces active in fluid bodies, in water, spring not merely from the earth, but from the planetary system. The forces of Mercury, Mars, etc. are active in all that is fluid. But they act in such a way that they are oriented according to the relation

of the planets and show a kind of resultant in the fluid.

The feeling was, thus, that only solid bodies, designated as earth, were under the earthly system of laws; and that when a body melted it was influenced from outside the earth. And when a gaseous body was called *air*, the feeling was that such a body was under the unifying influence of the sun, (these things are simply presented historically at this point,) this body was lifted out of the earthly and the planetary and stood under the unifying influence of the sun. Earthly air being were looked upon in this way, that their configuration, their inner arrangement and substance were principally the field for unifying forces of the sun.

You see, ancient physics had a cosmic character. It was willing to take account of the forces actually present in fact. For the Moon, Mercury, Mars, etc. are facts. But people lost the sources of this view of things and were at first not able to develop a need for new sources. Thus they could only conceive that since solid bodies in their expansion and in their whole configuration fell under the laws of the earth, that liquid and gaseous bodies must do likewise. You might say that it would never occur to a physicist to deny that the sun warmed the air, etc. He does not, indeed do this, but since he proceeds from concepts such as I characterized yesterday, which delineate the action of the sun according to ideas springing from observations on the earth, he therefore explains the sun in terrestrial terms instead of explaining the terrestrial in solar terms.

The essential thing is that the consciousness of certain things was completely lost in the period extending from the 15th to the 17th centuries. The consciousness that our earth is a member of the whole solar system and that consequently every single thing on the earth had to do with the whole solar system was lost. Also there was lost the feeling that the solidity of bodies arose, as it were, because the earthly emancipated itself from the cosmic, that it tore itself free to attain independent action while the gaseous, for example, the air, remained in its behavior under the unifying influence of the sun as it affected the earth as a whole. It is this which has led to the necessity of explaining things terrestrially which formerly received a cosmic explanation. Since man no longer sought for planetary forces acting when a solid body changes to a fluid, as when ice becomes fluid — changes to water — since the forces were no longer sought in the planetary system, they had to be placed within the body itself. It was necessary to rationalize and to theorize over the way in which the atoms and molecules were arranged in such a body. And to these unfortunate molecules and atoms had to be ascribed the ability from within to bring about the change from solid to liquid, from liquid to gas. Formerly such a change was considered as acting through the spatially given phenomena from the cosmic regions beyond the earth. It is in this way we must understand the transition of the concepts of physics as shown especially in the crass materialism of the Academia del Cimento which flowered in the ten year period between 1657 and 1667. You must picture to yourselves that this crass materialism arose through the gradual loss of ideas embodying the connection between the earthly and the cosmos beyond the earth. Today the necessity faces us again to realize this connection. It will not be possible, my friends, to escape from materialism unless we cease being Philistines just in this field of physics. The narrow-mindedness comes about just because we go from the concrete to the abstract, for no one loves abstractions more than the Philistine. He wishes to explain everything by a few

formulae, a few abstract ideas. But physics cannot hope to advance if she continues to spin theories as has been the fashion ever since the materialism of the Academia del Cimento. We will only progress in such a field as that of the understanding of heat if we seek again to establish the connection between the terrestrial and the cosmic through wider and more comprehensive ideas than modern materialistic physics can furnish us.

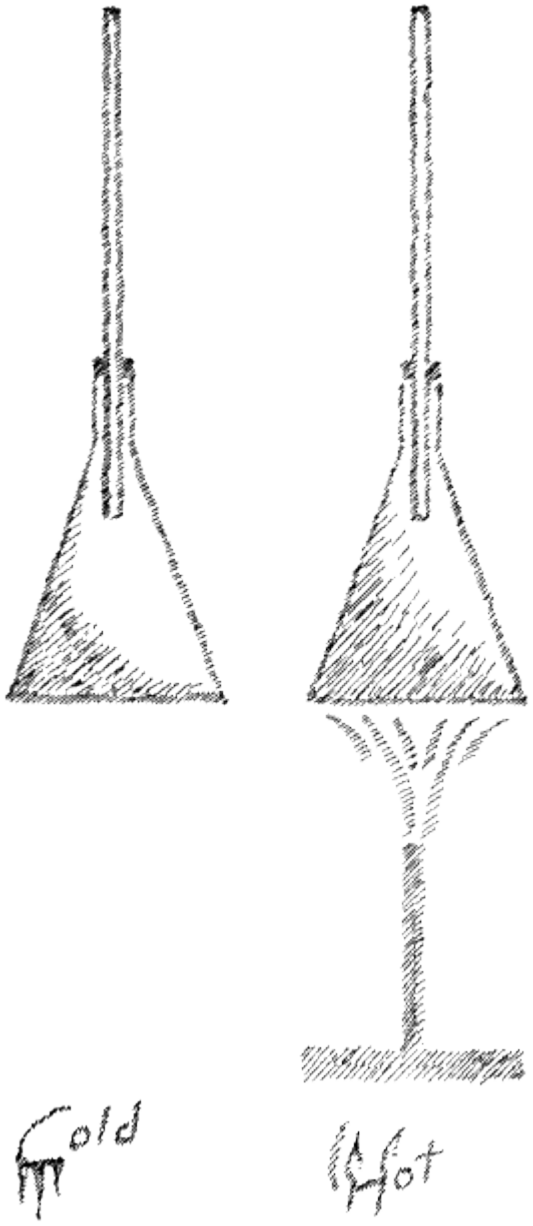


Figure 1

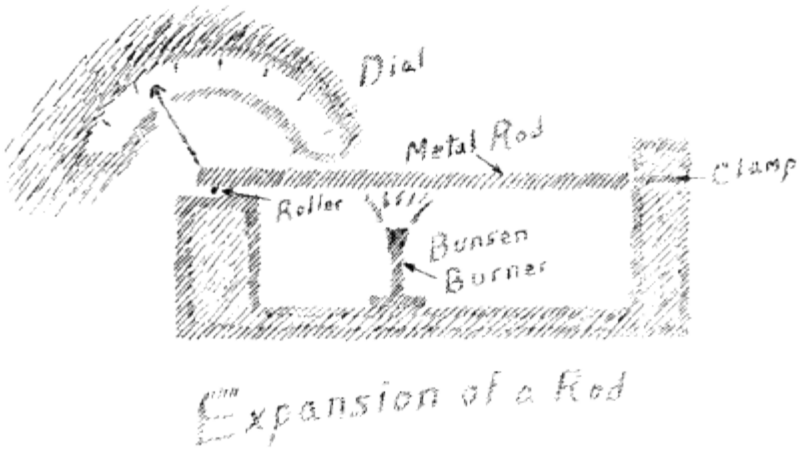


Figure 1a

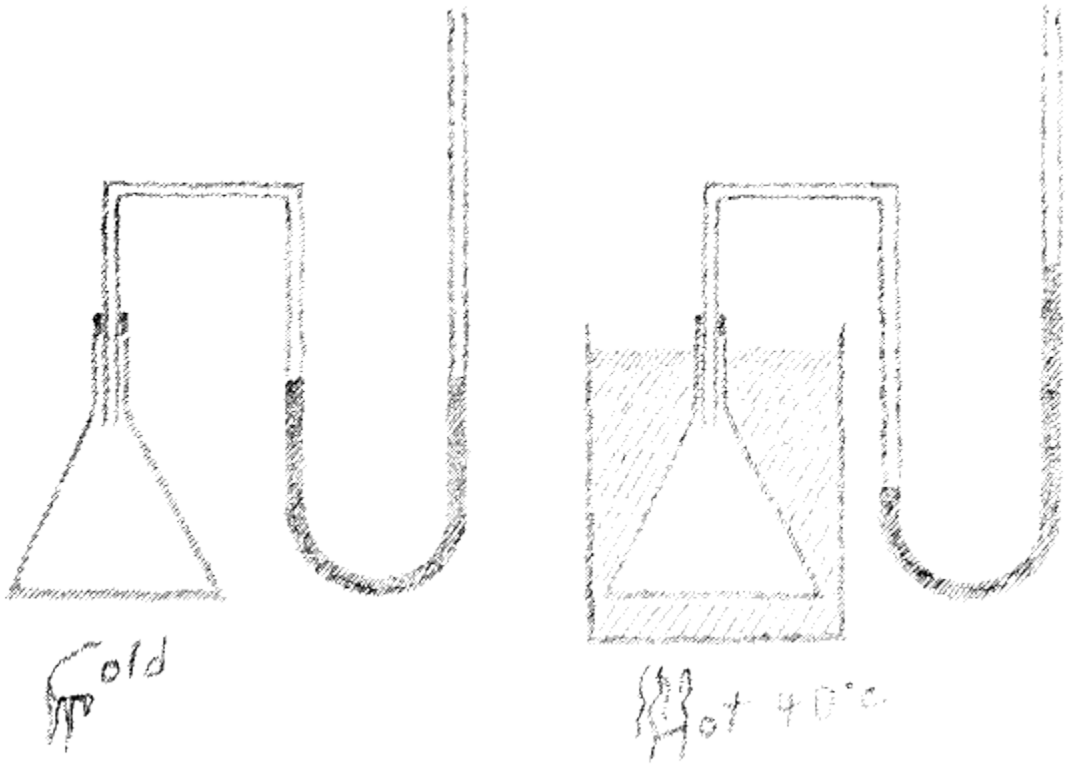


Figure 2

Second Scientific Lecture-Course: Warmth Course

Lecture III

Stuttgart, March 3rd, 1920.

My dear friends,

Today in order to press toward the goal of the first of these lectures, we will consider some of the relations between the being of heat and the so-called state of aggregation. By this state of aggregation I mean what I referred to yesterday as called in the ancient view of the physical world, earth, water, air. You are acquainted with the fact that earth, water, and air, or as they are called today, solid, fluid, and gaseous bodies may be transformed one into another. In this process however, a peculiar phenomenon shows itself so far as heat relations are concerned. I will first describe the phenomenon and then we will demonstrate it in a simple fashion. If we select any solid body and heat it, it will become warmer and warmer and finally come to a point where it will go over from the solid to the fluid condition. By means of a thermometer we can determine that as the body absorbs heat, its temperature rises. At the moment when the body begins to melt, to become fluid, the thermometer ceases rising. It remains stationary until the entire body has become fluid, and only begins to rise again when all of the solid is melted. Thus we can say: during the process of melting, the thermometer shows no increase in temperature. It must not be concluded from this however, that no heat is being absorbed. For if we discontinue heating, the process of melting will stop. (I will speak more of this subsequently.) Heat must be added in order to bring about melting, but the heat does not show itself in the form of an increase in temperature on the thermometer. The instrument begins to show an increase in temperature only when the melting has entirely finished, and the liquid formed from the solid begins to take up the heat. Let us consider this phenomenon carefully. For you see, this phenomenon shows discontinuity to exist in the process of temperature rise. We will collect a number of such facts and these can lead us to a comprehensive view of heat unless we go over to some reasoned-out theory. We have prepared here this solid body, sodium thiosulphate, which solid we will melt. You see here a temperature of about 25° C. Now we will proceed to heat this body and I will request someone to come up and watch the temperature to verify the fact that while the body is melting the temperature does not rise.(Note: The thermometer went to 48° C. which is the melting point of sodium thiosulphate, and remained there until the substance had melted.) Now the thermometer rises rapidly, since the melting is complete, although it remained stationary during the entire process of melting.

Suppose we illustrate this occurrence in a simple way, as follows: The temperature rise we will consider as a line sloping upward in this fashion (Fig. 1). Assume we have raised the temperature to the melting point as it is called. So far as the thermometer shows, the temperature again rises. It can be shown that through this further temperature rise, with its corresponding addition of heat, the liquid in question expands. Now if we heat such a melted body further, the temperature rises again from the point at which melting took place (dotted line.) It rises as long as the body remains fluid. We can then come upon another point at which the liquid begins to boil. Again we have the same phenomenon as before. The thermometer shows no further temperature rise until the entire liquid is vaporized. At the moment when the fluid has vaporized, we would find by holding the thermometer in the vapor that it again shows a temperature rise (dot-dash line.) You can see here that during vaporizing the instrument does not rise. There I find a second place where the thermometer

remains stationary. (Note: the thermometer remained at 100° C. in a vessel of boiling water.)

Now I will ask you to add to the fact I have brought before you, another which you will know well from ordinary experience. If you consider solids, which form our starting point, you know that they hold their shape of themselves, whatever form is given them they maintain. If I place a solid here before you it remains as it is. If you select a fluid, that is, a body that has by the application of heat been made to go through the melting point, you know that I cannot handle it piece by piece, but it is necessary to place it in a vessel, and it takes the form of the vessel, forming a horizontal upper surface. (Fig. 3) If I select a gas — a body that has been vaporized by passing through the boiling point, I cannot keep it in an open vessel such as I use for the liquid, it will be lost. Such a gas or vapor I can hold only in a vessel closed in on all sides, otherwise the gas spreads out in all directions. (Fig. 4) This holds, at least for superficial observation, and we will consider the matter first in this way. And now I would ask you to make the following consideration of these things with me. We make this consideration in order to bring facts together so that we can reach a general conception of the nature of heat. Now have we determined the rise in temperature? We have determined it by means of the expansion of quicksilver. The expansion has taken place in space. And since at our ordinary temperature quicksilver is a liquid, we must keep clear in our minds that it is confined in a vessel, and the three dimensional expansion is summed up so that we get an expansion in that direction. By reducing the expansion of quicksilver in three dimensions to a single dimension, we have made this expansion measure the temperature rise.

Let us proceed from this observation which we have laid out as a fundamental and consider the following: Assume a line (Fig. 5) Naturally, a line can only exist in thought. And suppose on this line there lie a number of points a, b, c, d, etc. If you wish to reach these points you can remain in the line. If, for instance, you are at this point (a) you can reach c by passing along the line. You can pass back again and again reach the point a. In brief, if I desire to reach the points a, b, c, d, I can do so and remain entirely in the line. The matter is otherwise when we consider the point e or the point f. You cannot remain in the line if you wish to reach point e or f. You must go outside to reach these points. You have to move along the line and then out of it to get to these points.

Now assume you have a surface, let us say the surface of the blackboard, and again I locate on the surface of this board a number of points; (a,) (b,) (c,) (d.) (Fig. 6) In order to reach these points you may remain always in the surface of the blackboard. If you are at this point (x) you may trace your way to each of these points over a path that does not leave the blackboard. You cannot, however, if you wish to remain in the surface of the board, reach this point which is at a distance in front of the board. In this case you must leave the surface. This consideration leads to a view of the dimensionality of space from which one can say: To reach points in one dimension, movement in this single direction suffices, for those in two dimensions movement in two dimensions gives access to them. It is however, not possible to reach points outside a single dimension without leaving this dimension and likewise one cannot pass through points in three dimensions by moving about in a single plane. What is involved when I consider the points e and f in relation to the single dimension represented by points a, b, c, and d? Imagine a being who was able to observe only one dimension and who had no idea of a second or third dimension. Such a being would move in his one dimension

just as you do in three dimensional space. If such a being carried the point a to the position b and the point then slipped off to e, at that moment the content of the point would simply vanish from the single dimension of the being. It would no longer exist for this being from the moment it left the single dimension of which he is aware. Likewise the points outside a surface would not exist for a being aware only of two dimensions. When a point dropped out of the plane, such a being would have no way of following it; the point would disappear form his space realm. What kind of a geometry would a unidimensional being have? He would have a one-dimensional geometry. He would be able to speak only of distance and the like, of the laws relating to such things as they applied in a single dimension. A two-dimensional being would be able to speak of the laws of plane figures and would have a two-dimensional geometry. We men have at the outset a three-dimensional geometry. A being with a unidimensional geometry would have no possibility of understanding what a point does when it leaves the single dimension. A being with a two-dimensional geometry would be unable to follow the motion of a point that left a surface and moved out in front of it as we supposed was the case when the point left a surface and moved out in front of it as we supposed was the case when the point left the surface of the blackboard. We men — I state again — have a three-dimensional geometry. Now I may just as well do what I am obliged to do on account of the reducing of the three-dimensional expansion of the quicksilver to a single dimension. I may draw two lines in two directions so as to form a system of axes, thus giving as in Fig. 7 an axis of abscissae and an axis of ordinates. At right angles to the plane of these two, suppose we have a third line which we will call a space line. (Referring again to the temperature rise diagram – *tr*). Just as soon as I come either to the melting point or the boiling point, at that moment I am not in a position to proceed with the line (Fig. 8). Theoretically or hypothetically there is no possibility of continuing the line. Let us assume that we can say, the rise of temperature is represented by this line. We can proceed along it and still have a point of connection with our ordinary world. But we do not as a matter of fact have such a point of connection. For when I draw this temperature curve and come to the melting or boiling point, I can only continue the curve from the same point (x, x in Fig. 8). I had reached when the body had begun to melt or vaporize. You can see from this, that in regard to the melting or boiling point, I am in a position not different from that of the one-dimensional being when a point moves out of his first dimension into the second dimension, or of the two-dimensional being when a point disappears for him into the third dimension. When the point comes back again and starts from the same place, or as in Fig. 5 when the point moves out to one side and returns, then it is necessary to continue the line on in its one dimension. Considered simply as an observed phenomenon, when the temperature rise disappears at the melting and boiling point, it is as though my temperatures curve were broken, and I had to proceed after a time from the same point. But what is happening to the heat during this interruption falls outside the realm in which I draw my curve. Formally speaking, I may say that I can draw this on the space line. There is, at first considered — note I say at first — an analogy present between the disappearance of the point a from the first and into the second dimension and what happens to the temperature as shown by the thermometer when the instrument stands still at the melting point and the boiling point.

Now we have to bring another phenomenon in connection with this. Please note that in this linking together of phenomena we make progress, not in elaborating some kind of theory, but in bringing together phenomena so that they naturally illuminate each other. This is the

distinction between the physics of Goethe that simply places phenomena side by side so that they throw light on each other, and modern physics which tends to go over into theories, and to add thought-out elaborations to the facts. For atoms and molecules are nothing else but fancies added to the facts.

Let us now consider another phenomenon along with this disappearance of the temperature recorded by the thermometer during the process of melting. This other phenomenon meets us when we look at yesterday's formula. This formula was written:

$$V - V_o (1 + 3\alpha t + 3\alpha^2 t^2 + \alpha^3 t^3)$$

You remember that I said yesterday you should pay especial attention to the last two terms. It is especially important for us at this time to consider t^3, the third power of the temperature. Imagine for a moment ordinary space. In this ordinary space you speak in mathematical terms of length, breadth, and thickness. These are actually the three dimensions of space. Now when we warm a rod, as we did yesterday, we can observe the expansion of this rod. We can also note the temperature of this rod. There is one thing we cannot bring about. We cannot bring it about that the rod while it is expanding, does not give off heat to its surroundings, that it does not stream out or radiate heat. This we cannot prevent. It is impossible for us *to think* — note the word — of a propagation of heat in one dimension. We can indeed think of a space extension in one dimension as one does in geometry in the case of a line. *But we cannot under any circumstances imagine heat propagated along a line*. When we consider this matter we cannot say that the propagation of heat is to be thought of as represented in space in reality by the line that I have drawn here. (Fig. 1) This curve does not express for me the whole process involved in the heat. Something else is active besides what I can deduce from the curve. And the activity of this something changes the entire nature and being of what is shown by this curve, which I am using as a symbol which may be considered equally well as a purely arithmetical or geometrical fact.

We have, thus, a peculiar situation. When we try to grasp the heat condition, in so far as the temperature shows this condition, by means of an ordinary geometrical line, we find it cannot be done. Now this has another bearing. Imagine for a moment that I have a line. This line has a certain length: l (Fig. 9) I square this line, and then I can represent this l^2 by a square surface. Assume that I obtain l^3 then I can represent the third power by a cube, a solid body. But suppose I obtain the fourth power, l^4. How can I represent that? I can pass over from the line to the surface, from the surface to the solid, but what can I do by following this same method if I wish to represent the fourth power? I cannot do anything if I remain in our three-dimensional space. The mathematical consideration shows this. But we have seen that the heat condition in so far as it is revealed by temperature is not expressible in space terms. There is something else in it. If there were not, we could conceive of the heat condition passing along a rod as confined entirely to the rod. This, however, is impossible. The consequence of this is that when I really wish to work in this realm, I ought not to look upon the powers of 't' in the same manner as the powers of a quantity measured in space. I cannot think about the powers of 't' in the same way as those of 'l' or of any other mere space quantity. When, for instance, and I will consider this tomorrow hypothetically, when I have the first power and find it not expressible as a line, then the second power t^2 cannot be

expressed as a surface and certainly the third power t^3 cannot be expressed as a solid. In purely mathematical space, it is only after I have obtained the third power that I get outside of ordinary space, but in this other case I am quite outside of ordinary space in the case of the second power and the third as well.

Therefore, you must realize that you have to conceive of t as different entirely in its nature from space quantities. You must consider t as something already squared, as a second power and the squared t you must think of as of the third power, the cubed t as of the fourth power. This takes us out of ordinary space. Consider now how this gives our formula a very special aspect. For the last member, which is in this super-space, forces me to go out of ordinary space. In such a case when I confine myself to reckoning I must go beyond three dimensional space for the last member of the formula. There is such a possibility in purely mathematical formulae.

When you observe a triangle and determine that it has three angles, you are dealing, at the start, with a conceived triangle. Since merely thinking about it is not enough to satisfy your senses, you draw it, but the drawing adds nothing to your idea. You have given, the sum of the angles is 180, or a right-angled triangle — the square of the hypotenuse equals the sum of the squares of the other two sides. These things are handled as I now handle the power of 't.'

Let us now go back and see what we have established as fact. This is the way it is done in geometry. It is always true that when I observe an actual triangle in bridge construction or elsewhere, the abstract idea verifies itself. What I have thought of in the abstract 't' has at first a similarity with melting and vaporizing. (We will gradually get nearer to the essence of the reality.) Melting and vaporizing I could not express in terms of the three dimensions of space. The only way I could force them into the curve was to stop and then continue again. In order to prove the hypothesis that I made for you, it was necessary, in the case of the third power, the cube of the temperature, to go outside of three-dimensional space.

You see, I am showing you how we must, as it were, break a path if we wish to place together those phenomena which simply by being put side by side illustrate the being of heat and enable us to attain to an understanding similar to that reached in the preceding course of lectures on light.

The physicist Crookes approached this subject from entirely different hypotheses. It is significant that his considerations led him to a result similar to the one we have arrived at tentatively and whose validity we will establish in the next lectures. He also concluded the temperature changes had essentially to do with a kind of fourth dimension in space. It is important at this time to give attention to these things because the relativists, with Einstein at their head, feel obliged when they go outside of three-dimensional space, to consider time as the fourth dimension. Thus, in the Einstein formulae, everywhere one finds time as the fourth dimension. Crookes, on the other hand, considered the gain or loss of heat as the fourth dimension. So much for this side-light on historical development.

To these phenomena I would ask you now to add what I have formerly emphasized. I have said: An ordinary solid may be handled and it will keep its form, (Fig. 2). That is, it has a

determinate boundary. A fluid must be poured into a vessel, (Fig. 3). It always forms a flat upper surface and for the rest takes the shape of the vessel. This is not so for a gas or vaporous body which extends itself in every direction. In order to hold it, I must put it into a vessel closed on all sides, (Fig. 4). This completely closed vessel gives it its form. Thus, in the case of a gas, I have a form only when I shut it in a vessel closed on all sides. The solid body possesses a form simply by virtue of the fact that it is a solid body. It has a form of itself, as it were. Considering the fluid as an intermediate condition, we will note that the solid and gaseous bodies may be described as opposites. The solid body provides for itself that which I must add to the gaseous body, namely the completely surrounding boundary.

Now, however, a peculiar thing occurs in the case of a gas. When you put a gas into a smaller volume (Fig. 10), using the same amount of gas but contracting the walls all around, you must use pressure. You have to exert pressure. This means nothing else but that you have to overcome the pressure of the gas. You do it by exerting pressure on the walls which give form to the gas. We may state the matter thus: that a gas which has the tendency to spread out in all directions is held together by the resistance of the bounding walls. This resistance is there of itself in the case of the solid body. So that, without any theorizing, but simply keeping in mind the quite obvious facts, I can define a polaric contrast between a gas and a solid body in the following way: *That which I must add to the gas from the outside is present of itself in the solid.* But now, if you cool the gas, you can pass back again to the boiling point and get a liquid from the vapor, and if you cool further to the melting point, you can get the solid from the liquid. That is to say, you are able by processes connected with the heat state to bring about a condition such that you no longer have to build the form from the outside, but the creation of form takes place of itself from within. Since I have done nothing but bring about a change in the heat condition, it is self-evident that form is related in some way to changes in the heat state. In a solid, something is present which is not present in a gas. If we hold a wall up against a solid, the solid does not of itself exert pressure against the wall unless we ourselves bring this about. When, however, we enclose a gas in a vessel, the gas presses against the solid wall. You see, we come upon the concept of pressure and have to bring this creation of pressure into relation with the heat condition. We have to say to ourselves: it is necessary to find the exact relation between the form of solid bodies, the diffusing tendency of gases and the opposition of the boundary walls that oppose this diffusion. When we know this relation we can hope really to press forward into the relation between heat and corporeality.

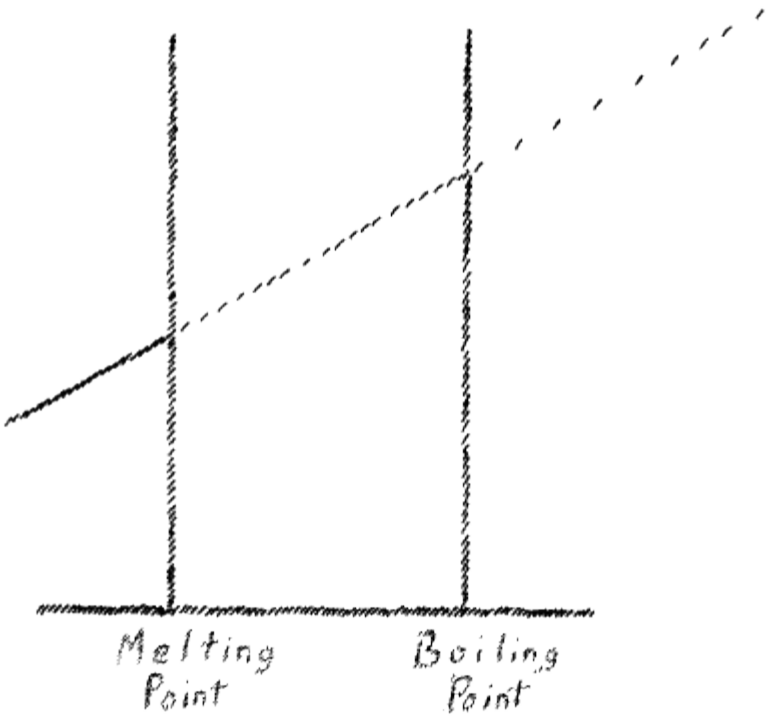


Figure 1

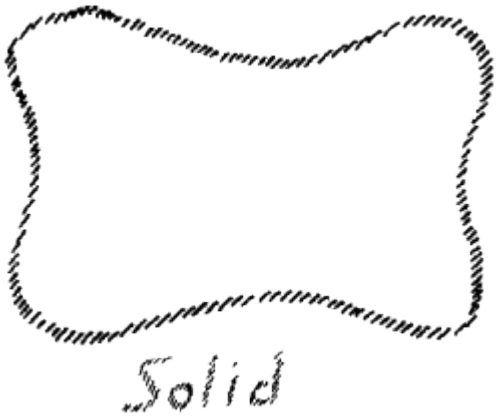


Figure 2

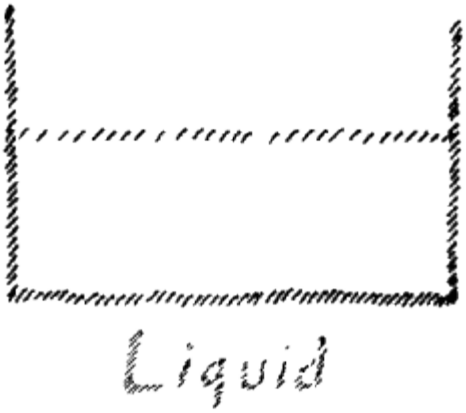


Figure 3

Figure 4

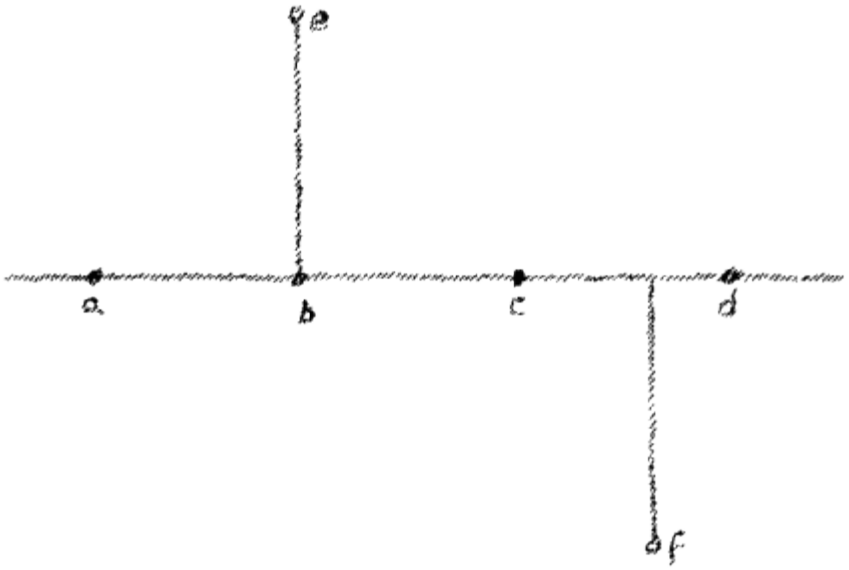


Figure 5

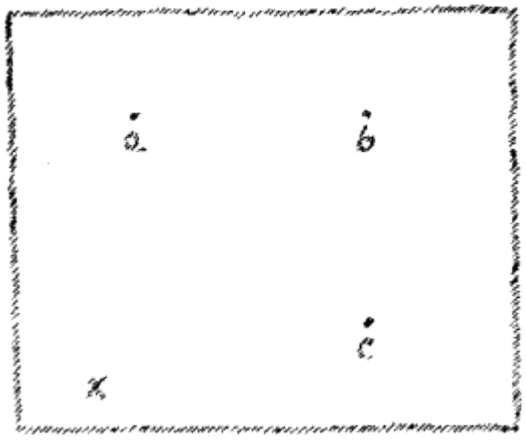


Figure 6

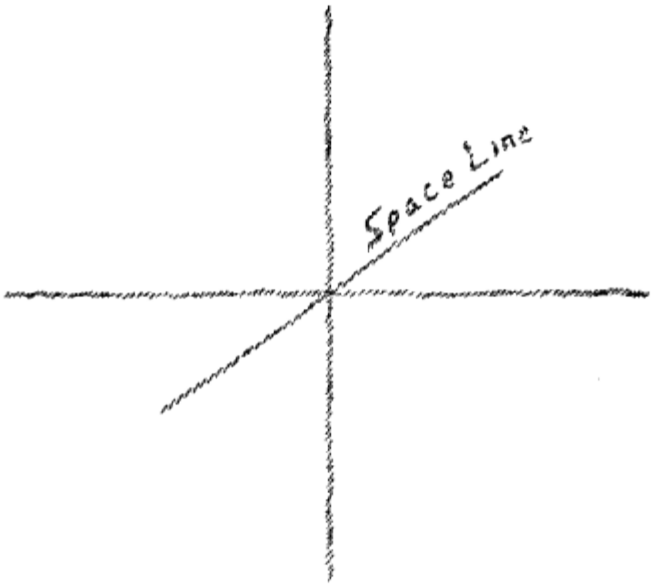


Figure 7

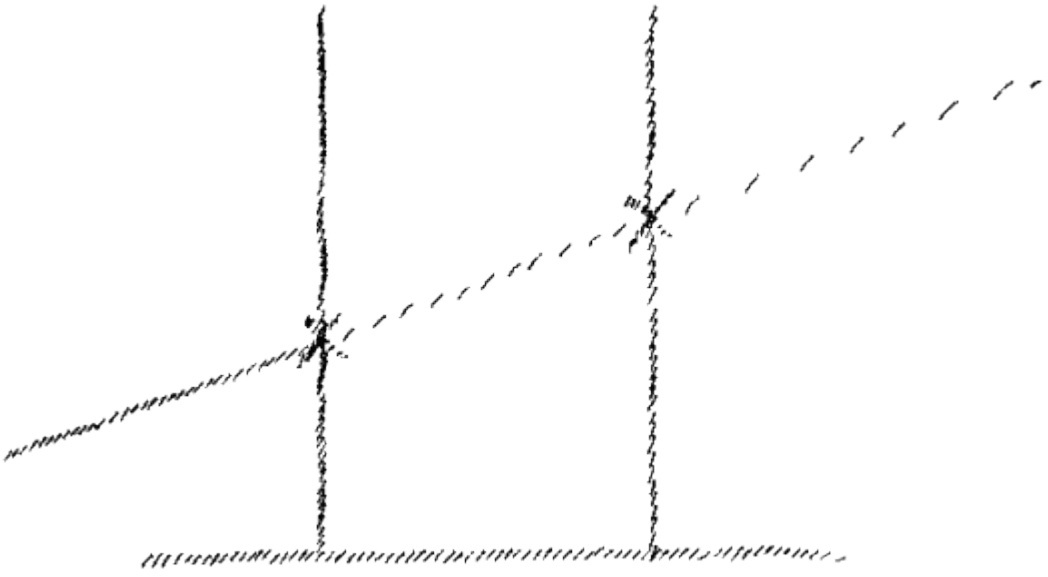


Figure 8

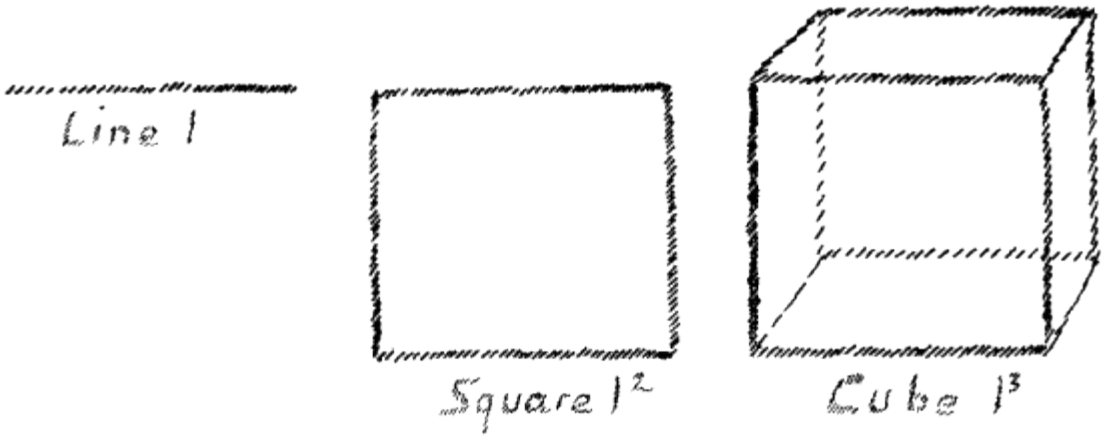


Figure 9

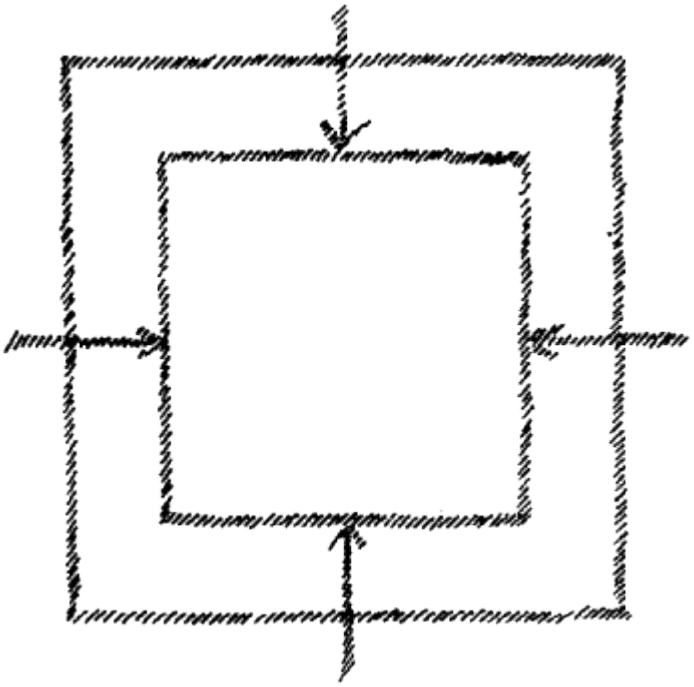


Figure 10

Second Scientific Lecture-Course: Warmth Course

Lecture IV

Stuttgart, March 4th, 1920.

My dear friends,

You will perhaps have noticed that in our considerations here, we are striving for a certain particular goal. We are trying to place together a series of phenomena taken from the realm of heat in such a manner that the real nature of warmth may be obvious to us from these phenomena. We have become acquainted in a general way with certain relations that meet us from within the realm of heat, and we have in particular observed the relation of this realm of the expansionability of bodies. We have followed this with an attempt to picture to ourselves mentally the nature of form in solid bodies, fluids and gaseous bodies. I have also spoken of the relation of heat to the changes produced in bodies in going from the solid to the fluid and from the fluid to the gaseous or vaporous condition. Now I wish to bring before you certain relations which come up when we have to do with gases or vapors. We already know that these are so connected with heat that by means of this we bring about the gaseous condition, and again, by appropriate change of temperature that we can obtain a liquid from a gas. Now you know that when we have a solid body, we cannot by any means interpenetrate this solid with another. The observation of such simple elementary relations is of enormous importance if we really wish to force our way through to the nature of heat. The experiment I will carry out here will show that water vapor produced here in this vessel passes through into this second vessel. And now having filled the second vessel with water vapor, we will produce in the first vessel another vapor whose formation you can follow by reason of the fact that it is colored. (The experiment was carried out.) You see that in spite of our having filled the vessel with water vapor, the other vapor goes into the space filled with the water vapor. That is, a gas does not prevent another gas from penetrating the space it occupies. We may make this clear to ourselves by saying that gaseous or vaporous bodies may to a certain extent interpenetrate each other.

I will now show you another phenomenon which will illustrate one more relation of heat to certain facts. We have here in the left hand tube, air which is in equilibrium with the outer air with which we are always surrounded. I must remind you that this outer air surrounding us is always under a certain pressure, the usual atmospheric pressure, and it exerts this pressure on us. Thus, we can say that air inside the left hand tube is under the same pressure as the outer air itself, which fact is shown by the similar level of mercury in the right and left hand tubes. You can see that on both right and left hand sides the mercury column is at the same height, and that since here on the right the tube is open to the atmosphere the air in the closed tube is at atmospheric pressure. We will now alter the conditions by bringing pressure on the air in the left hand tube, ($2 \times p$). By doing this we have added to the usual atmospheric pressure, the pressure due to the higher mercury column. That is, we have simply added the weight of the mercury from here to here. (Fig. 1b from a to b). By thus increasing the pressure exerted on this air by the pressure corresponding to the weight of the mercury column, the volume of the air in the left hand tube is, as you can see, made smaller. We can therefore say when we increase the pressure on the gas its volume decreases. We must extend this and consider it a general phenomenon that the space occupied by a gas and the pressure exerted on it have an inverse ratio to each other. The greater the pressure the smaller the volume, and the greater the volume the smaller must be the pressure acting on

the gas. We can express this in the form of an equation where the volume V_1 divided by the volume V_2 equals the pressure P_2 divided by the pressure P_1.

$V_1 : V_2 = P_2 : P_1$

From which it follows:

$V_1 * P_1 = V_2 * P_2$

This expresses a relatively general law (we have to say relative and will see why later.) This may be stated as follows: volume and pressure of gases are so related that the volume-pressure product is a constant at constant temperature. As we have said, such phenomena as these must be placed side by side if we are to approach the nature of heat. And now, since our considerations are to be thought of as a basis for pedagogy we must consider the matter from two aspects. On the one hand, we must build up a knowledge of the method of thinking of modern physics and one the other, we must become acquainted with what must happen if we are to throw aside certain obstacles that modern physics places in the path to a real understanding of the nature of heat.

Please picture vividly to ourselves that when we consider the nature of heat we are necessarily dealing at the same time with volume increases, that is with changes in space and with alterations of pressure. In other words, mechanical facts meet us in our consideration of heat. I have to speak repeatedly in detail of these things although it is not customary to do this. Space changes, pressure changes. Mechanical facts meet us.

Now for physics, these facts that meet us when we consider heat are purely and simply mechanical facts. These mechanical occurrences are, as it were, the milieu in which heat is observed. The being of heat is left, so to speak, in the realm of the unknown and attention is focused on the mechanical phenomena which play themselves out under its influence. Since the perception of heat is alleged to be purely a subjective thing, the expansion of mercury, say, accompanying change of heat condition and of sensation of heat, is considered as something belonging in the realm of the mechanical. The dependence of gas pressure, for instance, on the temperature, which we will consider further, is thought of as essentially mechanical and the being of heat is left out of consideration. We saw yesterday that there is a good reason for this. For we saw that when we attempt to calculate heat, difficulties arise in the usual calculations and that we cannot, for example, handle the third power of the temperature in the same way as the third power of an ordinary quantity in space. And since modern physics has not appreciated the importance of the higher powers of the temperature, it has simply stricken them out of the expansion formulae I mentioned to you in former lectures.

Now you need only consider the following. You need consider only that in the sphere of outer nature heat always appears in external mechanical phenomena, primarily in space phenomena. Space phenomena are there to begin with and in them the heat appears. This it is, my dear friends, that constrains us to think of heat as we do of lines in space and that leads us to proceed from the first power of extension in space to the second power of the

extension.

When we observe the first power of the extension, the line, and we wish to go over to the second power, we have to go out of the line. That is, we must add a second dimension to the first. The standard of measurement of the second power has to be thought of as entirely different from that of the first power. We have to proceed in an entirely similar fashion when we consider a temperature condition. The first power is, so to speak, present in the expansion. Change of temperature and expansion are so related that they may be expressed by rectilinear coordination (Fig. 2). I am obliged, when I wish to make the graph representing change in expansion with change in temperature, to add the axis of abscissae to the axis of ordinates. But this makes it necessary to consider what is appearing as temperature not as a first power but as a second power, and the second power as a third. When we deal with the third power of the temperature, we can no longer stay in our ordinary space. A simple consideration, dealing it is true with rather subtle distinctions, will show you that in dealing with the heat manifesting itself as the third power, we cannot limit ourselves to the three directions of space. It will show you how, the moment we deal with the third power, we are obliged, so far as heat effects are concerned, to go out of space.

In order to explain the phenomena, modern physics sets itself the problem of doing so and remaining within the three dimensional space.

You see, here we have an important point where physical science has to cross a kind of Rubicon to a higher view of the world. And one is obliged to emphasize the fact that since so little attempt is made to attain clarity at this point, a corresponding lack enters into the comprehensive world view.

Imagine to yourselves that physicists would so present these matters to their students as to show that one must leave ordinary space in which mechanical phenomena play when heat phenomena are to be observed. In such a case, these teachers of physics would call forth in their students, who are intelligent people since they find themselves able to study the subject, the idea that a person cannot really know it without leaving the three dimensional space. Then it would be much easier to place a higher world-view before people. For people in general, even if they were not students of physics, would say, “We cannot form a judgment on the matter, but those who have studied know that the human being must rise through the physics of space to other relations than the purely spatial relations.” Therefore so much depends on our getting into this science such ideas as those put forth in our considerations here. Then what is investigated would have an effect on a spiritually founded world view among people in general quite different from what it has now. The physicist announces that he explains all phenomena by means of purely mechanical facts. This causes people to say, “Well, there are only mechanical facts in space. Life must be a mechanical thing, soul phenomena must be mechanical and spiritual things must be mechanical.” “Exact sciences” will not admit the possibility of a spiritual foundation for the world. And “exact science” works as an especially powerful authority because they are not familiar with it. What people know, they pass their own judgment on and do not permit it to exercise such an authority. What they do not know they accept on authority. If more were done to popularize the so-called “rigidly exact science,” the authority of some of those who sit

entrenched in possession of this exact science would practically disappear.

During the course of the 19th century there was added to the facts that we have already observed, another one of which I have spoken briefly. This is that mechanical phenomena not only appear in connection with the phenomena of heat, but that heat can be transformed into mechanical phenomena. This process you see in the ordinary steam locomotive where heat is applied and forward motion results. Also mechanical processes, friction and the like, can be transformed back again into heat since the mechanical processes, as it is said, bring about the appearance of heat. Thus mechanical processes and heat processes may be mutually transformed into each other.

We will sketch the matter today in a preliminary fashion and go into the details pertaining to this realm in subsequent lectures.

Further, it has been found that not only heat but electrical and chemical processes may be changed into mechanical processes And from this has been developed what has been called during the 19th century the "mechanical theory of heat."

This mechanical theory of heat has as its principal postulate that heat and mechanical effects are mutually convertible one into the other. Now suppose we consider this idea somewhat closely. I am unable to avoid for you the consideration of these elementary things of the realm of physics. If we pass by the elementary things in our basic consideration, we will have to give up attaining any clarity in this realm of heat. We must therefore ask the questions: what does it really mean then when I say: Heat as it is applied in the steam engine shows itself as motion, as mechanical work? What does it mean when I draw from this idea: through heat, mechanical work is produced in the external world? Let us distinguish clearly between what we can establish as fact and the ideas which we add to these facts. We can establish the fact that a process subsequently is revealed as mechanical work, or shows itself as a mechanical process. Then the conclusion is drawn that the heat process, the heat as such, has been changed into a mechanical thing, into work.

Well now, my dear friends, if I come into this room and find the temperature such that I am comfortable, I may think to myself, perhaps unconsciously without saying it in words: In this room it is comfortable. I sit down at the desk and write something. Then following the same course of reasoning as has given rise to the mechanical theory of heat, I would say: I came into the room, the heat condition worked on me and what I wrote down is a consequence of this heat condition. Speaking in a certain sense I might say that if I had found the place cold like a cellar, I would have hurried out and would not have done this work of writing. If now I add to the above the conclusion that the heat conducted to me has been changed into the work I did, then obviously something has been left out of my thinking. I have left out all that which can only take place through myself. If I am to comprehend the whole reality I must insert into my judgment of it this which I have left out. The question now arises: When the corresponding conclusion is drawn in the realm of heat, by assuming that the motion of the locomotive is simply the transformed heat from the boiler, have I not fallen into the error noted above? That is, have I not committed the same fallacy as when I speak of a transformation of heat into an effect which can only take place

because I myself am part of the picture? It may appear to be trivial to direct attention to such a thing as this, but it is just these trivialities that have been completely forgotten in the entire mechanical theory of heat. What is more, enormously important things depend on this. Two things are bound together here. First, when we pass over from the mechanical realm into the realm where heat is active we really have to leave three dimensional space, and then we have to consider that when external nature is observed, we simply do not have that which is interpolated in the case, where heat is changed over into my writing. When heat is changed into my writing, I can note from observation of my external bodily nature that something has been interpolated in the process. Suppose however, that I simply consider the fact that I must leave three dimensional space in order to relate the transformation of heat into mechanical effects. Then I can say, perhaps the most important factor involved in this change plays its part outside of three dimensional space. In the example that concerned myself which I gave you, the manner in which I entered into the process took place outside of three dimensions. And when I speak of simple transformation of heat into work I am guilty of the same superficiality as when I consider transformation of heat into a piece of written work and leave myself out.

This, however, leads to a very weighty consequence. For it requires me to consider in external nature even lifeless inorganic nature, a being not manifested in three dimensional space. This being, as it were, rules behind the three dimensions. Now this is very fundamental in relation to our studies of heat itself.

Since we have outlined the fundamentals of our conception of the realm of heat, we may look back again on something we have already indicated, namely on man's own relation to heat. We may compare the perception of heat to perception in other realms. I have already called attention to the fact that, for instance, when we perceive light, we note this perception of light to be bound up with a special organ. This organ is simply inserted into our body and we cannot, therefore, speak of being related to color and light with our whole organism, but our relation to it concerns a part of us only. Likewise with acoustical or sound phenomena, we are related to them with a portion of our organism, namely the organ of hearing. To the being of heat we are related through our entire organism. This fact, however, conditions our relation to the being of heat. We are related to it with our entire organism. And when we look more closely, when we try, as it were, to express these facts in terms of human consciousness, we are obliged to say, “We are really ourselves this heat being. In so far as we are men moving around in space, we are ourselves this heat being.” Imagine the temperature were to be raised a couple of hundred degrees; at that moment we could no longer be identical with it, and the same thing applies if you imagine it lowered several hundred degrees. Thus the heat condition belongs to that in which we continually live, but do not take up into our consciousness. We experience it as independent beings, but we do not experience it consciously. Only when some variation from the normal condition occurs, does it take conscious form.

Now with this fact a more inclusive one may be connected. It is this. You may say to yourselves when you contact a warm object and perceive the heat condition by means of your organism, that you can do it with the tip of your tongue, with the tip of your finger, you can do it with other parts of your organism: with the lobes of your ears, let us say. In

fact, you can perceive the heat condition with your entire organism. But there is something else you can perceive with your entire organism. You can perceive anything exerting pressure. And here again, you are not limited strictly as you are in the case of the eye and color perception to a certain member of your entire organism. If would be very convenient if our heads, at least, were an exception to this rule of pressure perception; we would not then be made so uncomfortable from a rap on the head.

We can say there is an inner kinship between the nature of our relationship to the outer world perceived as heat and perceived as pressure. We have today spoken of pressure volume relations. We come back now to our own organism and find an inner kinship between our relation to heat and to pressure. Such a fact must be considered as a groundwork for what will follow.

But there is something else that must be taken into account as a preliminary to further observations. You know that in the most popular text books of physiology, a good deal of emphasis is laid on the fact that we have certain organs within our bodies by means of which we perceive the usual sense qualities. We have the eye for color, the ear for found, the organ of taste for certain chemical processes, etc. We have spread over our entire organism, as it were, the undifferentiated heat organ, and the undifferentiated pressure organ.

Now, usually, attention is drawn to the fact that there are certain other things of which we are aware but for which we have no organs. Magnetism and electricity are known to us only through their effects and stand, as it were, outside of us, not immediately perceived. It is said sometimes that if we imagine our eyes were electrically sensitive instead of light sensitive, then when we turned them towards a telegraph wire we would perceive the streaming electricity in it. Electricity would be known not merely by its effects, but like light and color, would be immediately perceived. We cannot do this. We must therefore say: electricity is an example of something for whose immediate perception we have no organ. There are aspects of nature, thus, for which we have organs and aspects of nature for which we do not have organs. So it is said.

The question is whether perhaps a more unbiased observer would not come to a different conclusion from those whose view is expressed above. You all know, my dear friends, that what we call our ordinary passive concepts through which we apprehend the world, are closely bound up with the impressions received through the eye, the ear and somewhat less so with taste and smell impressions. If you will simply consider language, you may draw from it the summation of your conceptual life, and you will become aware that the words themselves used to represent our ideas are residues of our sense impressions. Even when we speak the very abstract word *Sein* (being), the derivation is from *Ich habe gesehen*, (I have seen.) What I have seen I can speak of as possessing "being." In "being" there is included "what has been seen." Now without becoming completely materialistic (and we will see later why it is not necessary to become so,) it may be said that our conceptual world is really a kind of residue of seeing and hearing and to a lesser extent of smelling and tasting. (Those last two enter less into our higher sense impressions.) Through the intimate connection between our consciousness and our sense impressions, this consciousness is enabled to take

up the passive concept world.

But within the soul nature, from another side, comes the will, and you remember how I have often told you in these anthroposophical lectures that man is really asleep so far as his will is concerned. He is, properly considered, awake only in the passive conceptual realm. What you will, you apprehend, only through these ideas or concepts. You have the idea. I will raise this glass. Now, in so far as your mental act contains ideas, it is a residue of sense impressions. You place before yourself in thought something which belongs entirely in the realm of the seen, and when you think of it, you have an image of something seen. Such an immediately derived image you cannot create from a will process proper, from what happens when you stretch out your arm and actually grasp the glass with your hand and raise it. That act is entirely outside of your consciousness. You are not aware of what happens between your consciousness and the delicate processes in your arm. Our unconsciousness of it is as complete as our unconsciousness between falling asleep and waking up. But something really is there and takes place, and can its existence be denied simply because it does not enter our consciousness? Those processes must be intimately bound up with us as human beings, because after all, it is we who raise the glass. Thus we are led in considering our human nature from that which is immediately alive in consciousness to will processes taking place, as it were, outside of consciousness. (Fig. 3) Imagine to yourselves that everything above this line is in the realm of consciousness. What is underneath is in the realm of will and is outside of consciousness. Starting from this point we proceed to the outer phenomena of nature and find our eye intimately connected with color phenomena, something which we can consciously apprehend; we find our ear intimately connected with sound, as something we can consciously apprehend. Tasting and smelling are, however, apprehended in a more dreamlike way. We have here something which is in the realm of consciousness and yet is intimately bound up with the outer world.

If now, we go to magnetic and electrical phenomena, the entity which is active in these is withdrawn from us in contrast with those phenomena of nature which have immediate connection with us through certain organs. This entity escapes us. Therefore, say the physicists and physiologists: we have no organ for it; it is cut off from us. It lies outside us. (Fig. 3 above) We have realms that we approach when we draw near the outer world — the realms of light and heat. How do electrical phenomena escape us? We can trace no connection between them and any of our organs. Within us we have the results of our working over of light and sound phenomena as residues in the form of ideas. When, however, we plunge down (Fig. 3 below), our own being disappears from us into will.

I will now tell you something a bit paradoxical, but think it over until tomorrow. Imagine we were not living men, but living rainbows, and that our consciousness dwelt in the green portion of the spectrum. On the one side we would trail off into unconsciousness in the yellow and red and this would escape us inwardly like our will. If we were rainbows, we would not perceive green, because that we are in our beings, we do not perceive immediately; we live it. We would touch the border of the real inner when we tried, as it were, to pass from the green to the yellow. We would say: I, as a rainbow, approach my red portion, but cannot take it up as a real inner experience; I approach my blue-violet, but it escapes me. If we were thinking rainbows, we would thus live in the green and have on the

one side a blue-violet pole and on the other side a yellow-red pole. Similarly, we now as men are placed with our consciousness between what escapes us as external natural phenomena in the form of electricity and as inner phenomena in the form of will.

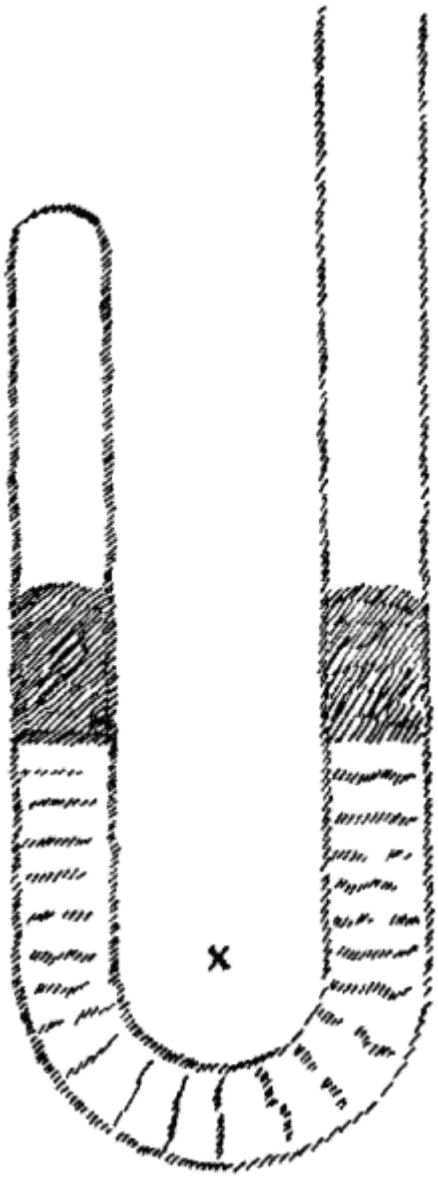


Figure 1a

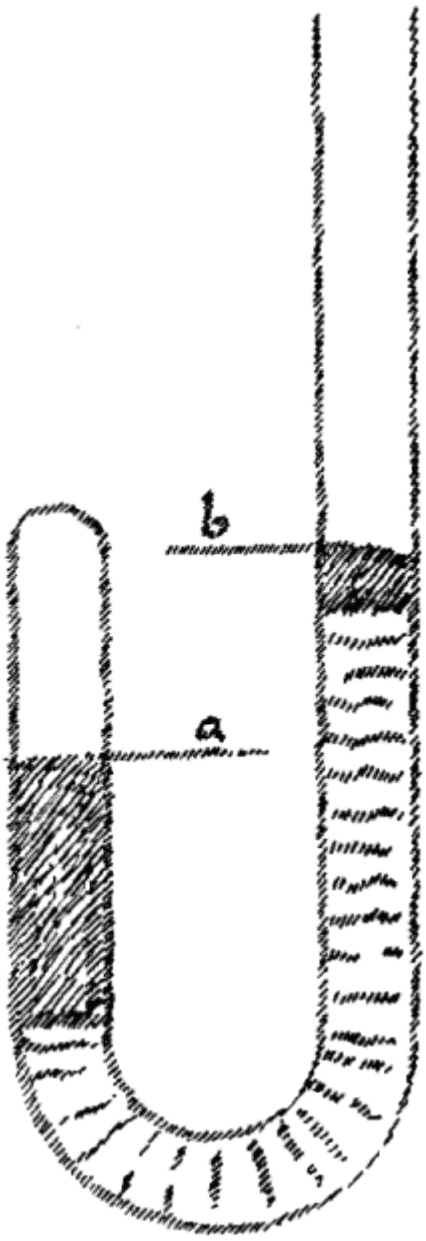


Figure 1b

Figure 2

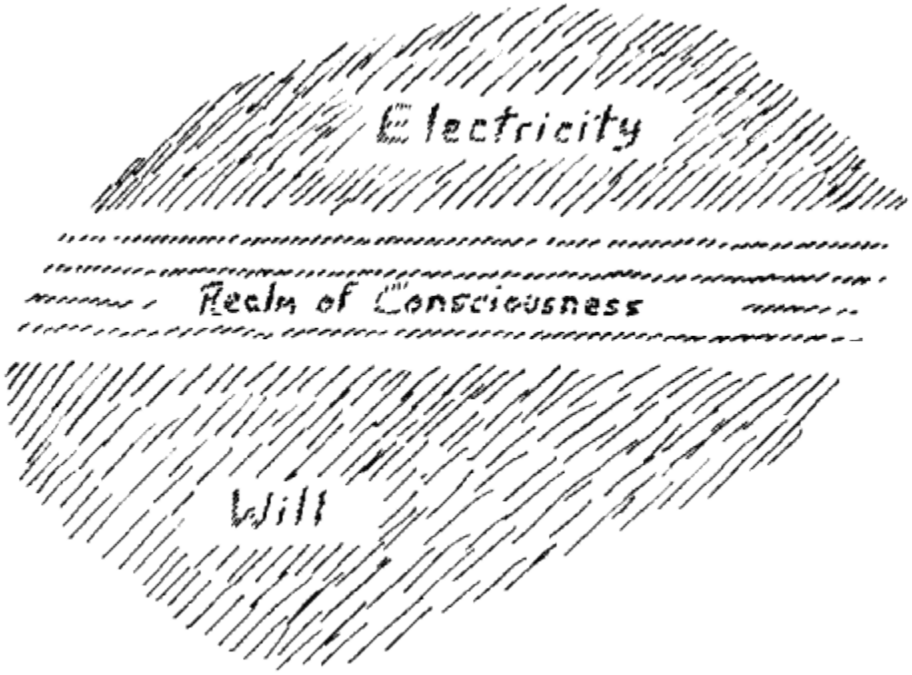


Figure 3

Second Scientific Lecture-Course: Warmth Course

Lecture V

Stuttgart, March 5th, 1920.

My dear friends,

I would have liked to carry out for you today some experiments to round out the series of facts that lead us to our goal. It is not possible to do so, however, and I must accordingly arrange my lecture somewhat differently from the way I intended. The reason for this is partly that the apparatus is not in working order and partly because we lack alcohol today, just as we lacked ice yesterday.

We will therefore take up in more detail the things that were begun yesterday. I will ask you to consider all these facts that were placed before you for the purpose of obtaining a survey of the relationships of various bodies to the being of heat. You will realize that certain typical phenomena meet us. We can say: These phenomena carry the impress of certain relations involving the being of heat, at first unknown to us. Heat and pressure exerted on a body or the state of aggregation that a body assumes according to its temperature, also the extent of space occupied, the volume, are examples. We are able on the one side, to see how a solid body melts, and can establish the fact that during the melting of the solid, no rise in temperature is measurable by the thermometer or any other temperature-measuring instrument. The temperature increase stands still, as it were, during the melting. On the other hand, we can see the change from a liquid to a gas, and there again we find the disappearance of the temperature increase and its reappearance when the whole body has passed into the gaseous condition. These facts make up a series that you can demonstrate for yourselves, and that you can follow with your eyes, your senses and with instruments. Yesterday, also, we called attention to certain inner experiences of the human being himself which he has under the influence of warmth and also under the influence of other sense qualities such as light and tone. But we saw that magnetism and electricity were not really sense impressions, at least not immediate sense impressions, because as ordinary physics says, there is no sense organ for these entities. We say, indeed, that so far as electrical and magnetic properties are concerned we come to know them through determining their effects, the attraction of bodies for instance, and the many other effects of electrical processes. But we have no immediate sense perception of electricity and magnetism as we have for tone and light.

We then noted particularly, and this must be emphasized, *that our own passive concepts, by which we represent the world, are really a kind of distillation of the higher sense impressions.* Wherever you make an examination you will find these higher concepts and will be able to convince yourselves that they are the distilled essence of the sense impressions. I illustrated this yesterday in the case of the concept of being. You can get echoes of tone in the picture of the conceptual realm, and you can everywhere see showing through how these concepts have borrowed from light . But there is one kind of concept where you cannot do this, as you will soon see. You cannot do it in the realm of the mathematical concepts. In so far as they are purely mathematical, there is no trace of the

tonal or the visible. Now we must deceive ourselves here. Man is thinking of tone when he speaks of the wave number of sound vibrations. Naturally I do not refer to this sort of thing. I mean all that is obtained from pure mathematics. Such things, for instance, as the content of the proposition of Pythagoras, that the sum of the angles of a triangle is 180°, or that the whole is greater than the part, etc. The basis of our mathematical concepts does not relate itself to the seen or the heard, but *it relates itself in the last analysis to our will impulse*. Strange as it may seem to you at first, you will always find this fact when you look at these things from the psychological point of view, as it were. The human being who draws a triangle (the drawn triangle is only an externalization) is attaining in *concept to an unfolding of the will around the three angles*. There is an unfolding of action around three angles as shown by the motion of the hand or by walking, by turning of the body. The thing that you have within you as a will-concept, that in reality you carry into the pure mathematical concept. That is the essential distinction between mathematical concepts and other concepts. This is the distinction about which Kant and other philosophers waged such controversy. You can distinguish the inner determination of mathematical concepts. This distinction arises from the fact that mathematical concepts are so rigidly bound up with our own selves, that we carry our will nature into them. Only what subsists in the sphere of the will is brought into mathematical operations. This is what makes them seem so certain to us. What is not felt to be so intimately bound up with us, but is simply felt through an organ placed in a certain part of our make-up, that appears uncertain and empirical. This is the real distinction. Now, I wish to call your attention to a certain fact. When we dip down into the sphere of will, whence came, in a vague and glimmering way, the abstractions which make up the sum of our pure arithmetical and geometrical concepts, we enter the unknown region where the will rules, a region as completely unknown to us in the inner sense, as electricity and magnetism are in the outer sense. Yesterday I endeavored to illustrate this by asking you to imagine yourselves living, thinking rainbows with your consciousness in the green, in consequence of which you did not perceive the green but perceived the colors on each side of it, fading into the unknown. I compared the *red to the dipping down inwardly into the unknown sphere of the will and the blue-violet to the outward extension into the spheres of electricity and magnetism and the like*.

Now I am inserting at this point in our course this psychological-physiological point of view, as it might be called, because it is very essential for the future that people should be led back again to the relation of the human being to physical observations. Unless this relationship is established, the confusion that reigns at present cannot be eliminated. We will see this as we follow further the phenomena of heat. But it is not so easy to establish this relationship in the thinking of today. The reason is just this, that modern man cannot easily bridge the gap between what he perceives as outer space phenomena in the world, or better, as outer sense phenomena and what he experiences within. In these modern times there is such a pronounced dualism between all which we experience as knowledge of the outer world and what we experience inwardly, that it is extraordinarily difficult to bridge this gap, But the gap must be bridged if physics is to advance. To this end we must use the intuitive faculties rather than the rational when we relate something external to what goes on within man himself. Thus we can begin to grasp how we must orient ourselves, in observing phenomena so difficult as those arising from heat. Let me call your attention to

the following:

Suppose you learn a poem by heart. You will, as you learn it, first find it necessary to become acquainted with the ideas that underlie the poem. At first you will always have the tendency, when you recite the poem, to let those ideas unroll in your mind. But you know that the more frequently you recite the poem, especially when there is a lapse of time between the recitations, the less intensely you are obliged to think of the ideas. There may come a time when it is not necessary to think at all, but simply to reel off the recitation mechanically. We never actually reach this point; do not wish to, in fact, but we approach the condition asymptotically as it were. Our feelings as human beings prevent us from reaching this stage of purely mechanical repetition, but it is thinkable that we would get to the point where we needed to think not at all, but when we spoke the first line the rest of the poem would follow without any thinking about it. You recognize the similarity between such a condition and the approach of the hyperbola to its asymptotes. But this leads us to the conception that when we speak a poem we are dealing with two different activities working simultaneously in our organism. We are dealing with a mechanical reeling-off of certain processes, and along with this go the processes included in our soul concepts. On the one hand, we have what we can properly speak of as playing itself out mechanically in space, and on the other hand, we have a soul process which is entirely non-spatial in nature.

When now, you fasten your attention simply on that which reels itself off mechanically, and you do this in thought, for instance, if you imagine you recited a poem in an unknown language, then you have simply the mechanical process. The instant you accompany this mechanical process with thinking, then you have an inner soul activity that cannot be brought out into space. You cannot express in space the thinking with which a man accompanies the recitation, as you can the mechanical processes of actual speaking, of the pronouncing of words.

Let me give you an analogy. When we follow the heating of a solid body up to the time it arrives at its melting point, the temperature becomes higher. We can see this on the thermometer. When the body begins to melt, the thermometer stands still until the melting is complete. There is an analogy between what we can follow with the thermometer, the outer physical process, and what we can follow physically in the spoken word. And there is *an analogy also between what escapes us, and lies in the concepts of the reciter and what happens to the heat while the melting goes on*. Here you see, we have an example where we can, by analogy, at least bridge the gap between an outer observation and something in the human being. In other realms than that of speech we do not have such ready examples to bridge the gap. This is because in speech there is, on the one hand, the possibility imaginable, at least, that a person could mechanically speak out something learned by heart. Or on the other hand, that the person would not speak at all but simply think about it and thus remove it entirely from the realm of space. In other spheres we do not have the opportunity to make this cleavage and see precisely how one activity passes over into another. Especially is this difficult when we wish to follow the nature of heat. In this case we have to set out to investigate physiologically and psychologically how heat behaves when we have taken it up into ourselves.

Yesterday, by way of illustration, I said to you: "I go into a room that is comfortably warmed, I sit down and write." I cannot so directly find the inter-relationships between what I experience or feel when I go into the warm room. What goes on within me parallels the outer warmth, when I write my thoughts down. But I cannot determine the relationship so readily as I can between speaking something and thinking about it. Thus it is difficult to find the something within that corresponds to the outer sensation of warmth. It is a question of gradually approaching the concepts that will lead us further in this direction and in this connection I want to call your attention to something you know from your anthroposophy.

You know, when we make the attempt to extend our thinking by meditation, to increase its inner intensity, and so to work with our thoughts that we come again and again into the condition where we know we are using soul-forces without the help of the body, we notice a certain thing. We notice that in order to do this, our entire inner soul life has to change. With ordinary abstract thoughts man cannot enter the higher region of human soul life. There thoughts become picture-like and they have to be translated out of the imaginative element in order to get them into abstract form, if they are to be brought into the outer world which is not grasped by the imaginative element. But you need to understand a method of looking at these things, such as is presented, for instance, in my *Occult Science*. In this book the endeavor is to be as true to the facts as possible, and it is this which has so disturbed the people who are only able to think abstractly. For the attempt must be made to get things over into picture form, as I have done to some extent in the description of the Saturn and Sun states. There you will find purely picture concepts mixed in with the others. It is very hard for people to go over into the pictures, because these things cannot be put into the abstract form. The reason for this is that when we think abstractly, when we move within the narrow confines of concepts, in which people today are so much at home, and especially so in the realm of natural science, when we do this we are using ideas completely dependent on our bodies. We cannot, for instance, do without our bodies when we set out to think through the things set forth as laws in the physics books. There we must think in such a way that we use our bodies as instruments. When we rise to the sphere of the imagination, then the abstract ideas must be completely altered, because our inner soul life no longer uses the physical body.

Now you can take what I might call a comprehensive view of the realm of imaginative thought. This realm of imaginative thought has in us nothing to do with what is tied up in our outer corporeality. We rise to a region where we live as beings of soul and spirit without dependence on our corporeality. In other words, the *instant we enter the realm of the imaginative, we leave space.* We are then no longer in space.

Note now, this has an extremely important bearing. I have in the previous course, made a very definite differentiation between mere kinematics and what enters into our consideration as mechanical, such as mass, for instance. As long as I consider only kinematics, I need only think of things. I can write them down on a blackboard or a sheet of paper and complete the survey of motion and space so far as my thinking takes me. But in that case I must remain within what can be surveyed in terms of time and space. Why is this? This is so for a very definite reason. You must make the following clear to yourselves: All human beings, as they exist on earth, are as you yourselves, within time and space. They are

bounded by a definite space and are related as space objects to other space objects. Therefore, when you speak of space, you are not able, considering the matter in an unprejudiced way, to take seriously the Kantian ideas. For if space were inside of us, then we could not ourselves be within space. We only think space is inside of us. We can free ourselves of this fancy, of this notion, if we consider the fact that this being-within space has a very real meaning for us. If space were inside of us, it would have no meaning for a person whether he were born in Moscow or Vienna. But where we are born has a very real significance. As a terrestrial-empirical person, I am quite completely a product of space facts. That is, as a human being, I belong to relations that form themselves in space. Likewise, with time, you would all be different persons if you had been born 20 years earlier. That is to say, your life does not have time inside of it, but time has your life within it. Thus as experiencing persons, you stand within time and space. And when we talk of time and space, or when we make a picture of will impulses, as I have explained we do in geometry, this is because we ourselves live inside of spatial and temporal relations, and are therefore quite definitely conditioned by them, and so are able, a priori, to speak of them as we do in mathematics. When you go over to the concept of mass, this is not so. The matter must then be put otherwise. In respect to mass, you are dealing with something quite special. You cannot say that you cut out a portion of time or space, but rather that you live in the general space mass and make it into your own mass. This mass then, is within you. It cannot be gainsaid that this mass with all its activities, all of its potentialities, is active *inside* of you; at this moment it falls into a different category from time and space so far as its relations to you are concerned. It is precisely because you yourself take part, as it were, with your inner being in the properties of the mass, because you take it up into your being, that it does not allow itself to be brought into consciousness like time and space. In the realm where the world gives us our own substance, we thus enter an unknown region. This is related to the fact that our will is, for instance, closely connected with the phenomena of mass inside us. But we are unconscious of these phenomena; we are asleep to them. And we are related to the will activity and accompany mass phenomena within us in no other way than we are to the world in general between going to sleep and waking up. We are not conscious of either one. Both these things are hidden from human consciousness, and in this respect, there is no immediate distinction between them.

Thus we gradually bring these things nearer to the human being. It is this that the physicists shy away from, the bringing of such things near to man. But in no other way can we obtain real concepts except by developing relationship between the human being and the world, a relationship that does not exist at the start, as in the case of time and space. We speak of time and space, let us say, out of our rational faculties, whence comes the remoteness of the mathematical and kinematical sciences. Of the things experienced merely through the senses, in an external fashion, things related to mass, we can at first speak only in an empirical fashion. But we can analyze the relation between the activity of a portion of mass within us and outer mass activity. As soon as we do this we can begin to deal with mass in the same way that we deal with the obvious relation between ourselves and time or ourselves and space. That is, we must grow inwardly into such relation with the world in our physical concepts, as we have for the mathematical or kinematical concepts.

It is a peculiar thing that, as we loosen ourselves from our own bodies in which all those

things take place to which we are asleep, as we raise ourselves to imaginative concepts, we really take a step nearer the world. We approach always nearer to that which otherwise reigns in us unconsciously. There is no other way to enter into the objectivity of the facts than to push forward with our own developed inner soul forces. At the same time that we detach ourselves from our own materiality, we approach more and more closely to what is going on in the outside world.

However, it is not so easy to obtain even the most elementary experiences in this region, since a person must so transform himself that he pays attention to things that are not noticed at all under ordinary circumstances. But now, I will tell you something that will probably greatly astonish you. Let us suppose you have advanced further on the path of imaginative thinking. Suppose you have really begun to think imaginatively. You will then experience something that will astonish you. It will be much easier than it formerly was for you to recite in a merely mechanical way a poem that you have learned by heart. It will not be more difficult for you, but less so. If you examine your soul organism without prejudice and with care, you will at once find that you are more prone to recite a poem mechanically without thinking about it, if you have undergone an occult training than if you have not undergone such a training. You do not dislike this going over into the mechanical so strongly as you did before the occult development. It is such things as this that are not usually stated but are meant when it is said over and over again: The experiences you have in occult training are really opposed to the concepts that are ordinarily had before you enter occult training and thus it is, when the more advanced stage is reached, that one comes to look more lightly on the ideas of ordinary life. And therefore, anyone who advances in occultism is exposed to the danger of afterwards becoming a greater mechanist than before. An orderly occult training guards against this, but the tendency to become materialistic is quite marked in the very people who have undergone occult development. I will, by example, tell you why.

You see, in ordinary life, it is really, as the theorists say it is, the brain thinks. But ordinarily, a man does not actually experience this fact. It is quite possible in this ordinary life to carry out such a dialogue as I did in my childhood with a youthful friend who as a crass materialist and became more and more so. He would say, "When I think my brain does the thinking." I would say to that: " Yes, but when you are with me you always say, *I* will do this, *I* think. Why do you not say, my brain will do this, my brain thinks? You are always speaking an untruth." The reason is that for the theoretical materialist, quite naturally, there does not exist the possibility of observing the processes in the brain. He cannot observe these physical processes. Therefore, materialism remains for him merely a theory.

The moment a person advances somewhat from imaginative to inspirational ideas, he becomes able really to observe the parallel processes in the brain. Then what goes on in the material part of the brain becomes really visible. Aside from the fact that it is extremely seductive, the things a person can observe in his own activity appear to him more and more wonderful to a high degree. For this activity of the brain is observable as something more wonderful than all that the theoretical materialists can describe about it. Therefore, the temperature comes to grow materialistic for the very reason that the activity of the human

brain has become observable. Only one is, as has been said, protected from this.

But as I have explained to you these steps in occult development, I have at the same time showed you how this development creates the possibility of a deeper penetration into material processes. This is the extraordinary thing. He who functions in the spirit simply as an abstract thing, will be relatively powerless in the face of nature. He grows into contact with other natural phenomena as he has already grown into contact with time and space.

We must now set up on the one side, all the things we have just tried to place before our minds, and on the other side, those things that have met us from the realm of heat.

What has come to us from the realm of heat? Well, we followed the rise of temperature as we warmed a solid body to melting point. We showed how the temperature rise disappeared for a time, and then re-appeared until the body began to boil, to evaporate. When we extended our observations, another thing appeared. We could see that the gas produced passed over in all directions on its surroundings. (Fig. 1a), seeking to distribute itself in all directions, and could only be made to take on form if its own pressure were opposed by an equal and opposite pressure brought to bear from the outside. These things have been brought out by experiment and will be further cleared up by other experiments. The moment the temperature is lowered to the point where the body can solidify, it can give itself a form (Fig. 1b). When we experience temperature rise and fall, we experience what corresponds externally to form. We are experiencing the dissolution of form and the re-establishment of it. The gas shows us the dissolution, the solid pictures for us the establishment of form. We experience the transition between these two, also, and we experience it in an extremely interesting fashion. For, imagine to yourselves the solid and the gas and the liquid, the fluid body standing between. This liquid need not be enclosed by a vessel surrounding it completely, but only on the bottom and sides. On the upper side, the liquid forms its own surface perpendicular to the line between itself and the center of the earth. Thus we can say that we have here a transition form between the gas and the solid (Fig. 1c). In a gas we never have such a surface. In a liquid such as water, we have one surface formed. In the case of a solid, we have that all around the body which occurs in the liquid only on the upper surfaces.

Now this is an extremely interesting and significant relation. For it directs our attention to the fact that a solid body has over its entire surface something corresponding to the upper surface of a liquid, but that it determines the establishment of the surface on a body of water. It is at right angles to the line joining it to the center of the earth. The *whole earth* conditions the establishment of the surface. We can therefore say: In the case of water, each point within it has the same relation to the entire earth that the points in a solid have to something within the solid. The solid therefore includes something which in the case of water resides in the relation of the latter to the earth. The gas diffuses. The relation to the earth does not take part at all. It is out of the picture. Gases have no surface at all.

You will see from this that we are obliged to go back to an old conception. I called your attention in a previous lecture to the fact that the old Greek physicists called solid bodies *Earth*. They did this, not account of some superficial reason such as has been ascribed to

them by people today, but they did it because they were conscious of the fact that the solid, of itself, takes care of that which is the case of water is taken care of by the earth as a whole. The solid takes into itself the role of the earthly. It is entirely justified to put the matter in this way: The earthly resides within a solid. In water it does not reside within, but the whole earth takes up the role of forming a surface on the liquid.

Thus you see, when we proceed from solid bodies to water, we are obliged to extend our considerations not only to what actually lies before us but in order to get an intelligent idea of the nature of water, we must extend them to include the water of the whole earth and to think of this as a unity in relation with the central point of the earth. To observe a "fragment" of water as a physical entity is absurd, just as much so as to consider a cut-off garment of my little finger as an organism. It would die at once. It only has meaning as an organism if it is considered in its relation to the whole organism. The meaning that the solid has *in itself*, can only be attached to water if we consider it in relation to the whole earth. And so it is with all liquids on earth.

And again, when we pass on from the fluid to the gaseous, we come to understand that the gaseous removes itself from the influence of the earth. It does not form surfaces. It partakes of everything which is not terrestrial. In other words, we must not merely look on the earth for the activities of a gas, we must bring in the environment of the earth to help us out, we must go out into space and seek there the forces involved. When we wish to learn the laws of the gaseous state, we become involved in nothing less than astronomical considerations.

Thus you see how these things are related to the whole terrestrial scheme when we examine the phenomena that we have up to this time simply gathered together. And when we come to such a point as the melting or boiling point, then there enter in things that must now appear to us as very significant. For, if we consider the melting point we pass from the terrestrial condition of the solid body where it determines its own form and relations, to something which includes the whole earth. The earth takes the sold captive when the latter goes over into the fluid state. From its own kingdom, the solid body enters the terrestrial kingdom as a whole when we reach the melting point. It ceases to have individuality. And when we carry the fluid body over into the gaseous condition, then we come to the point where the connection with the earth as shown by the formation of a liquid surface is loosened. The instant we go from a liquid to a gas, the body loosens itself from the earth, as it were, and enters the realm of the extra-terrestrial. When we consider a gas, the forces active in it are to be thought of as having escaped from the earth. Therefore, when we study these phenomena we cannot avoid passing from the ordinary physical-terrestrial into the cosmic. For we no longer are in contact with reality if our attention is not turned to what is actually working in the things themselves.

But now another phenomena meets us. Consider such a thing as the one you know very well and to which I have called your attention, namely that water behaves so remarkably, in that ice floats on water, or, stated otherwise, is less dense than water. When it goes over into the fluid condition its temperature rises, and it contracts and becomes denser. Only by virtue of this fact can ice float on the surface of the water. Here we have between zero and four degrees, water showing an exception to the general rule that we find when temperature

increases, namely that bodies become less and less dense as they are warmed up. This range of four degrees, where water expands as the temperature is lowered, is very instructive. What do we learn from this range? We learn that the water sets up an opposition. As ice it is a solid body with a kind of individuality, but opposes the transition to an entirely different sphere. It is very necessary to consider such things. For then we begin to get an understanding as to why, under certain conditions, the temperature as determined by a thermometer disappears, say at the melting or boiling points. It disappears just as our bodily reality disappears when we rise to the realm of imagination. We will go into the matter a little more deeply, and it will not appear so paradoxical when we try to clear up further the following: What happens then, when a heat condition obliges us to raise the temperature to the third power, or in this case to go into the fourth dimension, thus passing out of space altogether? Let us at this time, put this proposition before our souls and tomorrow we ill speak further about it. Just as it is possible for our bodily activity to pass over into the spiritual when we enter the imaginative realm, so we can find a path leading from the external and visible in the realm of heat tot he phenomena that are pointed to by our thermometer when the temperature rise we are measuring with it disappears before our eyes. What process goes on behind this disappearance? That is the question which we are asking ourselves today. Tomorrow we will speak of it further.

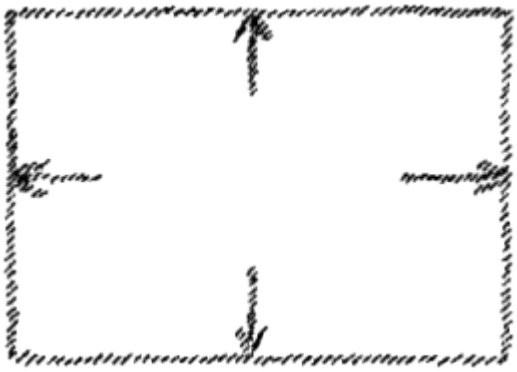


Figure 1a

Figure 1b

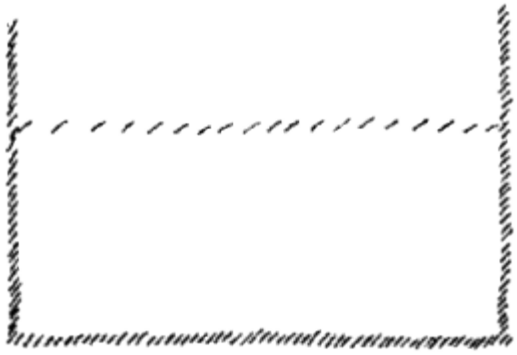


Figure 1c

Second Scientific Lecture-Course: Warmth Course

Lecture VI

Stuttgart, March 6th, 1920.

My dear friends,

We will today first examine a phenomenon that comes in the region where heat, pressure and the expansion of bodies are related. You will see that by a simultaneous examination of the things we experience in this field the way will open to an understanding of what heat really is. First we will turn our attention to what is revealed here in these three tubes. In the first one on the right, we have mercury in a barometer tube and on top of it is some water. Water placed in such a manner in this space evaporates. The water is in a vacuum, as we call it, in empty space, and it can be stated that the water evaporated. The small amount of water in the tube gives off vapor. We can determine that it evaporates by testing for the presence of water vapor in the space above the mercury. When you compare the height of the mercury column in this tube with the height here where the mercury is under the normal atmospheric pressure, and where there is no water vapor over the mercury, you will see that the level is lower in the tube containing water (Fig. 1a, 1b). Naturally, the mercury can lower only if there is a pressure on top of the column. For in the barometer tube, there is no pressure on the top of the column. There is only empty space and the mercury column balances the atmospheric pressure and is equal to if. Here it is forced down. When we measure we find the value of this difference in height. And the amount of the depression is brought about by the pressure of the water vapor, by the vapor tension as it is called. That is, the mercury volume is forced down here. We see therefore, that vapor always presses on the confining walls. Moreover, a definite pressure corresponds to a definite temperature. We can demonstrate this by warming the upper part of the tube. You can see that when the temperature is raised, the mercury column sinks, due to the increased pressure of the vapor. Thus we see that the vapor increases its pressure on the wall more and more the higher its temperature. You can observe the mercury fall and see how the vapor tension increases with the temperature. The volume

occupied by the vapor is correspondingly increased.

In the second tube we have alcohol over the column of mercury (Fig. 1c). Again you can see the liquid alcohol occupying definite volume. It evaporates and consequently the column is less in height than the barometric column on the left. If I measure, I find that it is shorter than the column which is under the pressure of the water vapor. We must wait until the water vapor returns to the same temperature as it was before being heated. Then we will find the vapor tension dependent on the substance we are using. The tension is greater in the case of alcohol than in the case of water. Here again, I can make the same experiment with heat. You will see that the pressure becomes considerably greater when we raise the temperature. When we cool the vapor to the same point at which it was at first, the mercury column rises, since with smaller vapor tension there is less pressure.

In the third tube we have ether under the same conditions as in the other tubes. It also evaporated (Fig. 1d). You observe the column here is very low. From this you can see that ether evaporating under the same conditions as water shows a widely different pressure. Not only is the pressure exerted by a vapor dependent on the temperature, but on the material as well. Here you see the effect of increased temperature, but on the material as well. Here you see the effect of increased temperature, shown by lowering of the column (tube warmed slightly) due to the rise in vapor pressure. We can again in this case, verify the phenomena and thus round out our survey and lead to the result we wish to attain.

Now there is an occurrence that I wish especially to call to your attention. You know from the foregoing observation and also from elementary physics that solids may be changed to liquids and liquids to solids if we raise the temperature above the melting point and lower it below the melting point. Now, when a fluid body is solidified by being brought under the melting point, it remains a solid body. The noteworthy fact, however, is that if we impose on this solid body a sufficiently great pressure, it will melt at a temperature below its melting point under ordinary pressure.

Thus it can become liquid at a lower temperature than the one at which it solidified. You know that water changed to ice at 0°C. and it must be a solid at all temperatures under 0°C. We will now carry out an experiment on this ice which will show you that we can make it a liquid without raising the temperature. Ordinarily, we would have to raise the temperature to do this. In this case we will not raise the temperature but simply exert a strong pressure on the ice. This we can do by hanging a weight over the ice by means of a thin wire. The ice melts under the wire, and the wire cuts its way through the ice. Now, you would expect this block of ice to fall apart into two pieces since it is being cut through the middle. It we could make it work faster you would see the results of this experiment. (Note: the cutting of the block proceeded so slowly that the result described in the following did not occur until several hours after the end of the lecture.) If you will now step up here and examine the block of ice, you will find there is no reason to fear that the two halves will crash down when the wire has cut its way through. For the solid ice grows together at once above the cut; so that the wire goes through the block, the weight falls off and the block remains whole. This shows that fluidity is brought about under the pressure of the wire, but as soon as the fluid is released from the spot where the pressure is exerted, it solidifies and the block of ice

becomes whole again.

At the temperature of ice, the state of fluidity only establishes itself under increased pressure. Thus a solid can be melted at a temperature under its melting point, but the pressure must be maintained if it is to stay melted. As soon as the pressure is released it reverts to the solid state. This is what you would see if you could wait here an hour or so.

A third thing I wish to present to you and which will furnish support for our observations is the following: To illustrate it we can take any bodies making an alloy, that is, mixing without forming a chemical compound; the principle holds for all of them. In this tube we have bismuth that melts at 269°C. and here we have tin, melting at 232°C. Thus we have three bodies all of which have melting points over 200°C. Now we will first melt these three, bringing them into the fluid condition in order to form an alloy. They will mix without combining chemically. (Note: the three metals were melted and poured together.)

Now, you would naturally reason as follows: Since each of these metals has a melting point above 200°C. it would remain solid in boiling water, for water has a melting point of 0°C. and a boiling point of 100°C. Therefore these three metals could not melt in boiling water. Let us however carry out the experiment of bringing the allow, the mixture of the three, into water, just at the boiling point of 100°C. In this way we can see how it acts. We hold the thermometer here in the fluid metallic mixture and read a temperature of 94°C. This shows that although no single metal was fluid at this temperature, the alloy is fluid. We can state the fact thus: when metals are mixed, the fact is brought out that the melting point of the mixture is lower than the melting point of any of its constituents. Thus you can see how bodies mutually influence each other. From this particular fact we can derive an important principle for our view of the nature of heat phenomena.

Here we have the still fluid alloy in boiling water that is at 100°C., and now we let the water cool, observing the temperature meanwhile. The alloy finally solidifies. By measuring the temperature of the water at this point, we have the melting point of the alloy and can show that this melting point is lower than the melting point of any of the single metals.

We have now added this phenomenon to the others to extend the foundations of our view. Let us continue by tying in the things we considered yesterday in regard to the distinction between the solid, the fluid and the gaseous or vapor states. You know that solid bodies such as most metals and other mineral bodies, occur not in an indefinite form, but in very definite shapes that we call crystals. We can say: Under ordinary circumstances as they exist on the earth, solids occur in very definite shapes or crystal forms. This naturally leads us to turn our attention to these forms, and to try to puzzle out how these crystals originate. What forces lie at the foundation of crystal formation? In order to gain some insight into these matters, it will be necessary for us to consider the forces on and around the earth in their entirety as they are related to solids.

You know that when we hold a solid in our hand and let go of it, it falls to the earth. In physics this is usually explained as follows: The earth attracts solid bodies, exerts a force on them; under the influence of this force — the gravitational force — the body falls to the

earth.

When we have a fluid and cool it so that it solidifies, if forms definite crystals.

The question is now, that is the relation between the force acting on all solids — gravitation — to these forces tending to produce crystal form which must be present and active to a certain extent? You might easily think that gravity as such, through whose agency a body falls to the earth (we may at this stage speak of the force of gravity) you might think that this gravitational force had nothing to do with the building of crystal form. For gravity affects all crystals. No matter what form an object may have, it is subject to gravity. We find when we have a number of solids in a row and take way the support, that they all fall to earth in parallel lines. This fall may be represented in somewhat the following way: (Fig. 3).

We can say, whatever form a solid may have, it falls along a line perpendicular to the surface of the earth. When now, we draw the perpendicular to these parallel lines of fall, we obtain a surface parallel to the earth's surface (line a-b, Fig. 3). By drawing all possible perpendiculars, to the lines of fall, we will obtain a complete surface parallel to the earth's surface. This is at first an imagined surface. We may now ask the question, where in reality is this surface? It is actually present in fluid bodies. A liquid which I place in a vessel shows as a real liquid surface that which I have assumed here as produced by drawing perpendiculars to the line of fall (see c, d, e, f, in Fig. 3).

What is really involved here and what does it mean? What we are speaking of is a thing of tremendous import. For, imagine to yourselves the following: Suppose someone were trying to explain the liquid surface and stated it this way. Every minute portion of the liquid has the tendency to fall to the earth. Since the other portions hinder this, the liquid surface is formed. The forces are really there, and the presence of the liquid causes the surface to form.

Picture to ourselves the real condition of the bodies you are going to let fall, and nature herself will show you what you have said in this explanation, (Fig. 4). You must include the liquid surface in your thinking. I have said formerly: the liquid surface is to be thought of in its relation to solids at right angles to their line of fall. When you think this through to the end, you come upon the noteworthy thing that what you have to bring into the solid as something thought out, this is represented in a material way before you by liquid bodies. These incorporate, as it were, what is materially present in the liquid. We may say: bodies of lower degrees of aggregation, solids in their relation to the earth, show a picture of that which is really present in the liquid, in a material way, and which in the case of water present in the liquid, in a material way, and which in the case of water prevents the surface particles from falling into the liquid. This is pictured, as it were, in considering the solid in its relation to the whole earth.

Think what this enables us to do When I draw the line of fall and the surface formed under the pressure of a system of falling bodies, then I have a picture of the gravitational activity. This is a direct representation of matter in the liquid state.

We can proceed further. When we leave water at any temperature sufficiently long it dries

up. Water is always evaporating. The conditions under which it forms a liquid surface are only relative. It must be confined all around except on the liquid surface. It evaporates continuously, more rapidly in a vacuum. If we draw lines showing the direction in which the water is tending, their direction must indicate the movement of the water particles when it actually evaporates. When I actually draw these lines, however, I get nothing more or less than a representation of a gas that is enclosed all around and is striving to escape in every direction (Fig. 5). On the surface of water there is a certain tendency which, when I picture it for explanatory purposes, represents a gas set free and distributing itself in all directions. So again, we can state the proposition: that which we observe in water as a force is actually represented in a material way in a gas.

There is a curious fact brought out here. If we look at fluids correctly from a certain point of view, we discover in them a picture of the gaseous state of aggregation. When we picture solids properly, we discover in them a representation of the fluid state of aggregation. *In every step as we go down there is a representation of the preceding step*. Let us illustrate by going from below up. We can say, *in the solids we have a representation of the fluid state, in the fluid a representation of the gaseous, in the gaseous a representation of heat.* It is this that we have especially to deal with tomorrow. I will say only this today, that we have sought to find the bridge for thought from gases to heat. It will become clearer tomorrow. Now when we have followed further this path of thinking:

In solids the picture of the fluid state;
In fluids the picture of the gaseous state;
In gases the picture of the heat state;

Then we will have, indeed, taken a great step ahead. We have advanced to the point where we have a picture in the gaseous state which is accessible to human observation, of heat manifestations and even of the real nature of heat itself. The possibility then exists for us that by rightly seeking the representations of heat in the gaseous state, we can explain its nature even though we are obliged to admit that it is an unknown entity to us at the outset. But we must do this in a *proper manner*. When the various phenomena that we have described so far are handled as physics usually handles them, we get nowhere. But when we hold correctly in our minds those things that are revealed to us by bodies under the influence of heat and pressure, then we will see how we, actually in fact, come to stand before that which the gases can reveal to us — the real being of heat.

In cooling, where we deal with the liquid and solid states, the being of heat penetrates further. We have then to recognize in these states the nature of this entity, although we can do it best in the gaseous condition where it is more evident. We must see whether in the fluid and solid states, heat suffers a special change, and thus work out the distinction between the manifestation in the gas where it shows itself in pictures form and its manifestation in fluids and solids.

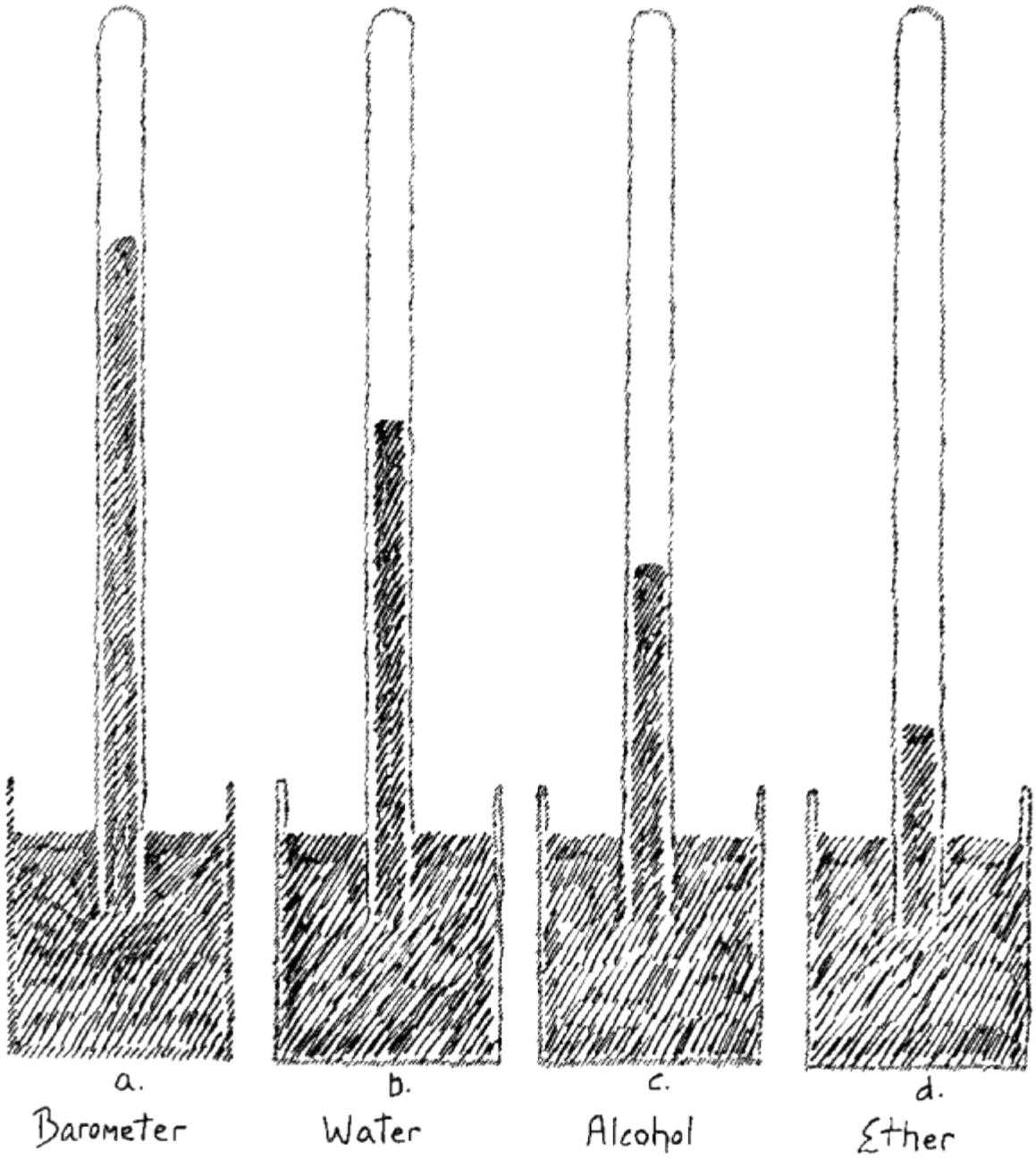


Figure 1

Melting Points

Bismuth ..... 269°C

Lead ..... 327°C

Tin ..... 232°C

Rose's Metal - melting point of 94°C is composed of:

Bismuth ..... 2 parts

Lead ..... 1 part

Tin ..... 1 part

Figure 2

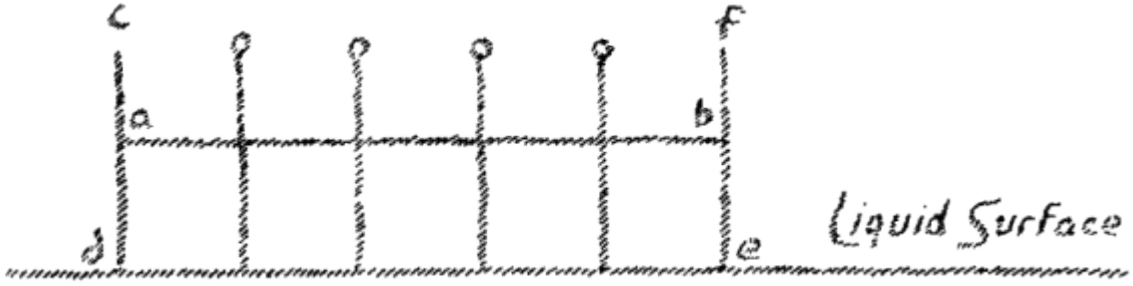


Figure 3

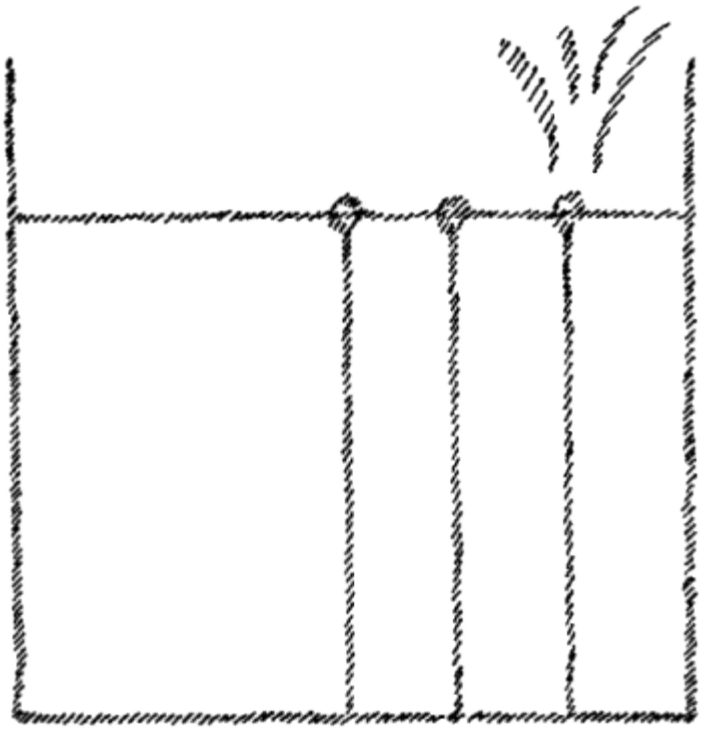


Figure 4

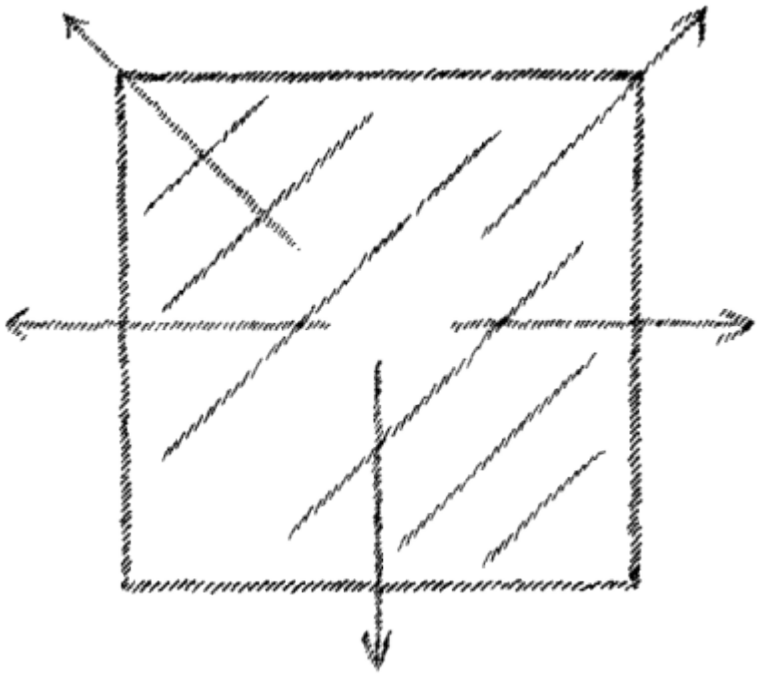


Figure 5

Second Scientific Lecture-Course: Warmth Course

Lecture VII

Stuttgart, March 7th, 1920.

My dear friends,

You will recall how yesterday we had here a block of ice which we would have expected to fall apart in two pieces when we cut it with a wire from which a weight was hanging. Although you only saw the beginning of the experiment, you were able to convince yourselves that such was not the case, because as soon as the pressure of the wire liquefied the ice below, it immediately froze together again above the wire. That is to say a liquefaction took place only in consequence of the pressure. Therefore, since we preserved the ice as ice, the heat entity acted in such a way that the block closed itself up at once. I am using the expression advisedly.

Now this surprised you considerably at first, did it not? But it surprised you only because you are not accustomed to the matter of fact observation necessary if you are really to follow physical phenomena In another case you are making the same experiment all the time and do not wonder at it at all. For when you take up your pencil and pass it through the air, you are continually cutting the air and it is immediately closing up behind. You are then doing nothing else than what we did yesterday with the block of ice, but you are doing it in another sphere, in another realm. We can learn quite a little from this observation, for we see that when we simply pass the pencil through the air (the conditions under which we do this will not be taken up) that the properties of the air itself bring about the closing up of the material behind the pencil. In the case of the ice we cannot avoid the thought that the heat entity enters into the process in such a way that it contributes the same thing as is contributed by the nature of the air itself when the pencil passes through. You have here only a further extension of what I said to you yesterday. When you picture the air to yourselves and imagine it cut and closing up at once, the matter composing the air is responsible for all that you can perceive. When you are dealing with a solid body, such as ice, then the heat is active in the same manner as the material air itself is in the other case. That is, you met here with a real picture of what goes on in heat. And again you have established that when we observe the gaseous or vapor condition — air is vaporous, gaseous in reality — we have represented in a material way in the phenomena of gases a picture of what takes place in the heat entity.

And if we observe heat phenomena in a solid body we have fundamentally nothing other than the solid existing alongside of something taking place in the realm of the heat being. We see, as it were, before our eyes, the phenomena within the realm of heat which we see also playing through gas. From this we can conclude or rather simply state, since it is only the obvious that we are presenting, we can state the following: If we wish to approach the being of heat in its reality we must seek as well as we can to force our way into the realm of

the gaseous, into the gaseous bodies. And in what goes on in gases we will see simply pictures of the phenomena within the heat realm. Thus nature conjures up before our eyes, as it were, pictures of processes in the heat being by a manifestation of certain phenomena in gases. Notice now, we are being led very far from the modern method of observation as practiced in natural science generally, not merely physics. Let us ask ourselves where the modern method really leads us ultimately. I have here a work by Eduard von Hartmann, in which he treats a special field from his point of view, namely the field of modern physics. Here is a man who has built up for himself entirely out of the spirit of the times a broad horizon, and who we may say, is therefore in a position to say something as a philosopher about physics. Now it is interesting to see how such a man, speaking entirely in the modern spirit, deals with physics. He begins the very first chapter as follows: "Physics is the study of transformations and movements of energy and of its separation into factors and their resummation." Having said this, he must naturally add a further statement. He says further: "Physics is the study of the movements and transformations of energy (force) and of its resolution into factors and its summations. The validity of this definition is not dependent on how we consider energy. It does not rest on our considering it as something final, ultimate, nor on our looking upon it as really a product of some more widely embracing factors. Nor is it dependent on whether we hold this or that view of the constitution of matter. It only states all observations and perceptions of energy to rest on the fact that it can change place and form and be analyzed within these categories." (*View of the World According to Modern Physics* by Edw. V. Hartmann, Leipzig, 1902, Hermann Haake, page 3)

Now what does it mean when one speaks in such a fashion? It means that an attempt is made so to define what is before one physically that there is no necessity to enter into its real nature. A certain concept of energy is formed and it is said: all that meets us from without, physically, is only a transformation of this energy concept. That is to say, everything essential is thrown out of one's concepts, and one is thought to be quite secure, because it is not realized that this is precisely the most insecure sort of a definition. But this sort of thing has found its way to a most unfortunate extent into our physical concepts. So completely has it entered in, my friends, that it is today almost impossible for us to make experiments that will reveal reality to us. All our laboratories, which we depend upon to do physical research, are completely given over to working out the theoretical views of modern physics. We cannot easily use what we have in the way of tools to reveal the essential physical nature of things. The cure for this situation is that first a certain number of people should become acquainted with the effect on methods of entering into the real physical nature of things. This group then will have to find the experimental method, the appropriate laboratory set-up to make possible a gradual entrance into reality. We need, in fact today, not merely to overhaul our view of the world in its conceptual aspect, but we need research institutes working to our manner of thinking. We cannot proceed as rapidly as we should in getting people to consider anthroposophy unless we are able to take them out of the rut in which modern thinking runs. Just as the physicists can point to factories to show plainly, very plainly, that what he says is true, so we must show people by experiments that what we say about things is correct. Naturally however, we must penetrate to real physical thinking before we can do this. And to think in real physical terms it is necessary that we bring

ourselves into the state of mind indicated in these lectures, especially yesterday's lecture.

Is it not true that the modern physicist observes what happens, and when he observes it, he at once bends every effort to strike out from the perceived phenomena all that he cannot reduce to calculation. Let us now make this experiment in order to place before our minds today something that we will build on in the course of subsequent lectures. We set up this paddle which can be turned in a liquid and arrange it so that the paddle rotated by means of this apparatus will transmit mechanical world. As a result of the fact that this mechanical work is transmitted to the water in which the paddle is immersed, we will have a marked rise in temperature. There is thus brought before us in the most elementary experimental way what is called the transformation of mechanical energy into warmth or thermal energy. We have now a temperature of 16° and after a short time we will note the temperature again. (Later the rise in temperature was determined.)

Let us now return for a moment to what has already been said. We have tried to grasp the destiny, so to speak, of physical corporeality, by carrying the corporeality through the melting and boiling points. That is, by making solid bodies fluid and fluid bodies gaseous. I will now speak of these things in the simplest terms possible.

We have seen that the fundamental property of solid bodies is the possession of form. The solids do not show form-building forces as these latter act in liquids before evaporation has had time to take place. Solids have a form of themselves. Liquids must be enclosed in a vessel, and in order to form a liquid surface, as they do everywhere, they require the forces of the entire earth. We have indeed, brought this before our souls. This requires us to make the following statement: When we consider the liquids of the whole earth in their totality, we are obliged to consider them as related to the body of the earth in its totality. Only the solids emancipate themselves from this relation to the earth, they take on an individuality, assume their own form. If now we bring to bear the method by which ordinary physics represents things on what is called gravity, on what causes the formation of the liquid surface, then we must do it in the following way. We must, if we are to stick to the observable, in some way introduce into individualized solid bodies the thing that is essential in this horizontal liquid surface. In some way or other, we must conceive of that which is active in the liquid surface, and which is thought of under the heading of gravity as within solids which, therefore, in a certain way individualize gravity. Thus we see that solids take gravity up within themselves. On the other hand we see that at the moment of evaporation the formation of liquid surface ceases. Gas does not form a surface. If we wish to give form to a gas, to limit the space occupied by it, we must do so by placing it in a vessel closed on all sides. In passing from the liquid to the gas we find that the surface formation ceases. We see dissipated this last remainder of the earth-induced tendency to surface formation as shown by the liquid. And we see also that all gases are grouped together in a unity, as illustrated by the fact that they all have the same co-efficient of expansion; gases as a whole represent material emancipated from the earth.

Now place these thoughts vividly before yourselves: you find yourselves on the earth as a carbonaceous organism, you are among the phenomena produced by the solids of the earth. The phenomena produced by the solids are ruled by gravity which, as stated, manifests itself

everywhere. As earth men you have solids around you that have in some way taken up gravity for their form-building. But consider the phenomena manifested by the solids in the case I spoke of yesterday where you added in thought a liquid surface to the system — in this phenomenon you have a kind of continuum, something you can think of as a sort of invisible fluid spread out everywhere. Thus solids of the earth, in so far as they are free to move, manifest as a whole what may be considered as a fluid state. They constitute something similar to what is manifested in a material fluid. We can therefore say: since we are placed on the earth we are aware of this, calling it gravity. Working on the liquid it forms a surface.

Imagine now, that we were as human beings able to live on a fluid cosmic body, being so organized that we could exist on such a body. We would then live in the surface of this liquid, and we would have the same relation to the gaseous, striving outward in all directions that we now have to the fluid. This means nothing more or less than that we should be unaware of gravity. To speak of gravity would cease to have a meaning. *Gravity rules only solid planetary bodies and is only known to those beings who live on such bodies*. Beings who could live on a fluid planet would know nothing of gravity. It would not be possible to speak of such a thing. And beings who lived on a gaseous planetary body would regard as normal something which would be the opposite of gravity, a striving in all directions away from the center. If I may express myself somewhat paradoxically I might say: Beings dwelling on a gaseous planet instead of seeing bodies falling toward the planet would see them always flying off. We must think in really physical terms and not merely in mathematical terms, which stand outside of reality if we are to find the path here. Then we can state the matter thus: Gravity begins when we find ourselves on a solid planet. In passing from the solid to the gaseous planet, we go through a kind of null-point, and come to an opposite condition to that on the solid planet, to a manifestation of forces in space which may be considered negative in respect to gravity. You see therefore that as we pass through the material states, we actually come to a null-point in spatiality, to a sphere where the spatiality is zero. For this reason we have to consider gravity as something quite relative. But when we conduct heat to a gas (the experiment has been shown to you) this heat which always raises the diffusing tendency in the gas shows you again the picture I am trying to bring before you. Does not that which is active in the gas really lie on the far side of this null-point on this side of which gravity is active? Is it not possible for us to think the matter through further, still remaining in close contact with the actual phenomena when we say that going from a solid to a gaseous planet we pass through a null-point? Below we have gravity; above, this gravity changing into its opposite, in a negative gravity. Indeed we find this, we do not have to imagine it. The being of heat does just what a negative gravity would do. Certainly, we have not completely attained our goal but we have reached a point where we can comprehend the being of heat in a relative fashion to such an extent that the matter may be stated so: *The being of heat manifests exactly like the negation of gravity, like negative gravity*. Therefore, when one deals with physical formulae involving gravity and sets a negative sign in front of the symbol representing gravity, it is necessary to think of the magnitude in question not as a gravity quantity nor as a line of action of gravity, but as a heat quantity, a line of action of heat. Do you not see that in this way we can suffuse mathematics with vitality? The formulae as they are given may be looked upon as representing a gravitational system, a mechanical system. If we set negative signs in front of

"g" then we are obliged to consider as heat what formerly represented gravity. And we realize from this that we must grasp these things concretely if we are to arrive at real results. We see that in passing from the solid to the fluid we go through a condition in which form is dissolved. The form loses itself. When I dissolve a crystal or melt it, it loses the form that it previously had. It goes over into that form which is imposed upon it by virtue of the fact that it comes under the general influence of the earth. The earth gives it a liquid surface and I must put this liquid into a vessel if I am to preserve it.

Now let us consider another general phenomenon which we will approach more concretely later. If a liquid is divided into sufficiently small particles there comes about the formation of drops, which take on the spherical shape. Fluids have the possibility, when they are finely enough subdivided, of emancipating themselves from the general gravitational field and of manifesting in this special case that which otherwise comes to light in solids as crystalline shape. Only, in the case of fluids, the peculiarity is that they all take on the form of the sphere.

If now, I consider this spherical form, I may regard it as the synthesis of all polyhedral shapes, of all crystal forms.

When I pass from the fluid to the gas, I have the diffusion, the dissolution of the spherical form, but in this case, outwardly directed. And now we come to a rather difficult idea. Imagine to yourselves that you are observing some simple form, say a tetrahedron, and you wished to turn it inside out as you might do a glove. You will then realize that in going through this process of turning inside out it is necessary to pass through the sphere. Moreover, all the form relations become negative and a negative body appears. As the tetrahedron is put through this transformation, you must imagine to yourselves that the entire space outside the tetrahedron is filled, within it is gaseous. With this outside space filled you must imagine in a tetrahedral hole. There it is empty. You must then make the quantities related to the tetrahedron negative. Then you have formed the negative, the opened-up tetrahedron, in place of the one filled with matter. But the intermediate condition between the positive and the negative tetrahedron is the sphere. The polyhydric body goes over into its negative only by passing through the spherical as a null-point.

Now let us follow this completely in the case of actual bodies. You have the solid body with definite form. It goes through the fluid form, that is the sphere, and becomes a gas. If we wish to look rightly on the gas we must look upon it as a form, but as a negative form. We reach a type of form here which we can comprehend only by passing through the zero point into the negative. That is to say, when we go over to the gaseous, the picture of the phenomena of heat, we do not enter into the region of the formless. We enter only into a region more difficult to comprehend than the one in which we live ordinarily where form is positive and not negative. But we see just here that any body in which the fluid state is in question is in an intermediate position. It is in the state between the formed and that which we call the "formless," or that of negative form.

Do we have any example where we can actually follow this? Aside from what is in our immediate environment, an example which we observe but do not really enter into vitality?

We can do it when we consider the phenomenon of the melting of a solid or the evaporation of a liquid. But can we in any way enter vitally into this? Yes, we can and as a matter of fact we do so continually. We experience this process by virtue of our status as earth men, and because the earth, or at least the part of it on which we live, is a solid upon which are other solids involving many phenomena which we observe. In addition there is embedded in the earthly and belonging to it, the fluid state. The gaseous also belongs to it. Now there comes about a great distinction between what I will call *WÃ¤rmenacht* and *WÃ¤rmetag*. (I use these terms in order to lead us nearer to an understanding of the problem.) What is *WÃ¤rmenach*? *WÃ¤rmenacht* and *WÃ¤rmetag* are simply what happens to our earth under the influence of the heat being of the cosmos. And what does happen? Let us take up these phenomena of the earth so that we can grasp what can be easily understood by our thinking. Under the influence of the *WÃ¤rmenach,* that is during the time when the earth is not exposed to the sun, while the earth is left to herself and is emancipated from the influence of the cosmic sun being, she strives for form as the droplet takes on form when it can withdraw itself from the general force of gravitation. We have therefore, when we consider the general striving of the earth for form, the characteristic of the *WÃ¤rmenach* as compared to ordinary night. It is quite justifiable for me to say in this connection that the earth strives toward the drop form. Many other tendencies are operative during the *WÃ¤rmenach,* such as a tendency toward crystallization. And what we experience every night is a continuous emergence of forces tending toward crystallization. During the day under the influence of the being of the sun, a continual dissolving of this tendency toward crystallization is present, a continual will to overcome form.

And we may speak of the "dawn" and "twilight" of this heat condition. By dawn we mean that after the earth has sought to crystallize during the *WÃ¤rmenach*, this crystallization process dissolves again and the earth goes through the sphere state in her atmosphere and seeks to scatter herself again. Following the *WÃ¤rmetag* comes a twilight condition where the earth again starts seeking to form a sphere and crystallize during the night. We have thus to think of the earth as caught up in a cosmic process consisting in a drawing together in the *WÃ¤rmenach* when the motion of the earth turns it away from the sun, a tendency to become a crystal. At the proper time this is checked when the earth is led through the dawn condition, through the sphere. Then the earth seeks to dissipate her forces through the cosmos until the twilight condition reestablishes the opposite forces. In the case of the earth we do not have to do with something fixed in the cosmos, but with something that vibrates between two conditions, *WÃ¤rmetag* and *WÃ¤rmenach.* You se*e it is with such things as this that our research institute should deal.* To our ordinary thermometer, hygrometers, etc., we should add other instruments *through which we could show that certain processes of the earth, especially of the fluid and gaseous portions, take place at night otherwise than during the day*. You can see further that we have here a rational leading to a physical view by which we can finally demonstrate with appropriate instruments the delicate differences in all the processes in liquids and gases during the day and during the night. In the future we must be able to make a given experiment during the day and at a corresponding hour of the night and have measuring instruments that will show us the difference in the way the process goes by day and by night. For by day those forces tending toward crystallization in the earth do not play through the process, but by night, they do. Forces arise that come from the cosmos in the night. And these cosmic forces that seek to crystallize the earth

necessarily have their effect on the process. Here is opened a way of experimentation which will show the relation of the earth to the cosmos. You can realize that the research institute that must in the future be established according to our anthroposophically oriented views of the world will have weighty problems. They must reckon with the things which today are taken into account only rarely. Naturally we do take them into account today, with light phenomena at least in certain cases when we have to darken the room artificially, etc. But in other phenomena that take place within a certain null sphere, we do not. Then, when we have made these facts obvious and have demonstrated them, we will replace by them all kinds of theoretical forces in atoms and molecules.

The whole matter as it is understood now rests on the belief that we can investigate everything during the day. *In this new sort of investigation, we will, for instance, first find in crystallization differences depending on whether we carry out the same experiment during the day or during the night*. This is the sort of thing our attention must be turned to especially. And on such a path will we first come to true physics. For today, physical facts really stand in a chaotic relation to each other. We speak for instance of mechanical energy, of acoustical energy. But it is not to be understood that when we think about these things in the correct way mechanical energy can only operate where there are solids. The fluid realm lies between the purely mechanical and the acoustical energies. Indeed, when we leave the region in which we observe most readily the acoustical energy, the gaseous region, then we come to the region of the next state of aggregation, as it is called, to heat. This lies above the gaseous, just as the fluid lies above the solid. We may tabulate these things as follows:

X

Heat

Gaseous-acoustical

Fluid

Solid mechanical

We find the mechanical as a characteristic of the solid state. In the gaseous we find acoustical energy as the characteristic. Just as we have left out the fluid here, so we must leave out the heat realm and above we find something that I will at this time indicate by X. Thus we have to look beyond the heat region for something. Between this X and our acoustic phenomena playing themselves out in the air would lie the being of heat, just as the fluid condition lies between the gaseous and the solid states. We are trying, you see, to grasp the nature of heat in all the ways we can, to approach it by all possible paths. And when you say to yourselves: the fluid condition lies between the gaseous and X, you must in a similar way seek to pass from the heat condition to the X condition. You must find something which lies on the far side of the heat region just as for instance the tone world as it is expressed in the air lies on this side of the heat region. By this means you see how to attempt to build such real concepts of the physical as will lead you out of the mere abstract. Geometry really comprehends space forms but can never comprehend the mechanical

except as motion. The concepts we are forming attempt really to include the physical. They immerse themselves in the nature of the physical and toward such concepts must we strive. Therefore I would think these are properly the sort of thing that should belong to what lies at the foundation of the "Free Waldorf School." The attempt should be made to extend the experimental in the manner indicated here today. What is very much neglected in our physical processes, time and the passage of time, will thus be drawn into physical experiments.

Second Scientific Lecture-Course: Warmth Course

Lecture VIII

Stuttgart, March 8th, 1920.

My dear friends,

Yesterday we carried out an experiment which brought to your attention the fact that mechanical work exerted by friction of a rotating paddle in a mass of water has changed into heat. You were shown that the water in which the paddle turned became warmer.

Today we will do just the opposite. We showed yesterday that we must in some ways seek an explanation for the coming of heat into existence upon the expenditure of work. Now let us follow the reverse process. We will first of all heat this air (see Figures at end of Chapter) using a flame, raise the pressure of the vapor, and thus bring about a mechanical effect by means of heat, in a way similar to that by which all steam engines are moved. Heat is turned into work through pressure change. By letting the pressure come through from one side we raise the bell up and by letting the vapor cool, the pressure is lessened, the bell goes down again and we have performed mechanical work, consistive in this up and down movement. We can see the condensation water which reappears when we cool, and runs into this flask. After we have let the entire process take place, after the heat that we have produced here has transformed itself into work, let us determine whether this heat has been entirely transformed into the up and down movement of the bell or whether some of it has been lost. The heat not changed into work must appear as such in the water. In case of a complete transformation the condensation water would not show any rise in temperature. If there is a rise in temperature which we can determine by noting whether the thermometer shows a temperature above the ordinary, then this temperature rise comes from the heat we have supplied. In this case, we could not say that the heat has been completely changed over into work; there would be portion remaining over. Thus we can ascertain whether the whole of the heat has gone over into work or whether some of it appears as heat in the condensate. The water is 20° and we can see whether the condensate is 20° or shows a higher temperature indicating a loss of heat to this condensate. Now we condense the vapor; the condensate water drops in the flask. A machine can be run in this way. If the experiment succeeds fully, you may determine for yourselves that the condensate shows a considerable increase in temperature. In this way we can demonstrate, when we carry out the reverse of yesterday's experiment, that it is not

possible to get back as mechanical work in the form of up and down movement of the bell all the heat left over. The heat used in producing work does not change completely, but a portion always remains.

We wish first to grasp this phenomenon. Now let us consider how ordinary physics and those who use ordinary physical principles handle these things.

We have at the beginning to deal with the fact that we in fact do change heat into work and work into heat just as it is said we do. As previously stated an extension of this idea has been made. It is supposed that every form of so-called energy — heat energy, mechanical energy, and the experiment may be made with other forms — that all such energies are mutually changeable the one into the other. We will for the moment neglect the quantitative aspect of the transformation and consider only the fact. Now, the modern physicist says: It is therefore impossible for energy to arise anywhere except from energy of another sort already present. If I have a closed system of energy, let us say of a certain form, and another energy appears, then this must be considered as transformation of the energy already present in the closed system. In a closed system, energy can never appear except as a transformation product. Eduard von Hartmann, who, as I have said, expressed current physical views in the form of philosophical concepts, states the so-called first law of the mechanical theory of heat as follows: "A perpetuum mobile of the first kind is impossible."

Now we come to the second series of phenomena illustrated for us by today's experiment. This is that in an energy system apparently closed, we have one form of energy changing over to another form. In this transformation however, it is apparent that a certain law underlies the process and this law is related to the quality of the energy. In this case of heat energy, the relation is such that it cannot go over completely to mechanical energy, but there is always a certain amount unchanged. Thus it is impossible in a closed system to transform completely all the heat energy into its mechanical equivalent. If this were possible the reverse transformation of mechanical energy completely into heat energy would also be possible. We would then have in a closed energy system one type of energy transformed into another. This law is stated, again by Eduard von Hartmann, as follows: A closed energy system in which for instance, the entire amount of heat could be changed into work, or where work could be completely changed into heat, when a cycle of complete transformation could exist, this would be a perpetuum mobile of the second type. But, says he, a perpetuum mobile of the second type is impossible. Fundamentally, these two are the principle laws of the mechanical theory of heat as this theory is understood by thinkers in the realm of physics in the 19th century and the early part of the 20th century.

"A perpetuum mobile of the first type is an impossibility." This concept is intimately connected with the history of physics in the 19th century. The first person to call attention to this change of heat into other forms of energy or vice-versa was Julius Robert Mayer. He had observed, as a physician, that the venous blood showed a different behavior in the tropics and in the colder regions, and from this concluded that there was a different sort of physiological work involved in the human organism in the two cases. Using principally these experiences, he later presented a somewhat confused theory which as he worked it out meant little more than this, that it was possible to transform one type of energy into another. The matter was

then taken up by various people, Helmholtz among others, and further developed. In the case of Helmholtz a characteristic form of physical-mechanical thinking was taken as the starting point for these things.

If we consider the most important treatise by which Helmholtz sought to support the mechanical theory of heat in the forties of the 19th century, we see that such ideas as expressed by Hartmann are really postulated as their foundation. A perpetuum mobile of the first type is impossible. Since it is impossible the various forms of energy must be transformations of each other. No form of energy can arise from nothing. The axiom from which we proceed — "a perpetuum mobile of the first type is impossible" — can be changed into another: the sum of the energy in the universe is constant. Energy never is created, never disappears, it is only transformed. The sum of the energy in the universe is constant.

These two principles fundamentally, then, mean precisely the same thing. "There is no perpetuum mobile of the first type." "The sum of all the energy in the cosmos is constant." Now applying the method of thinking that we have used before in all our observations, let us throw a little light on this whole point of view.

Note now, when we make an experiment with the object of transforming heat into what we call work, that some of the heat is lost so far as the transformation is concerned. Heat reappears as such and only a portion of it can be turned into the other energy form, the mechanical form. What we learn from this experiment we may apply to the cosmos. This is what the 19th century investigators did. They reasoned somewhat as follows: "In the world about us work is present and heat is present. Processes are continually going on by which heat is transformed into work. We see that heat must be present if we would produce work. Only recollect how great a part of our technical achievements rest on the fact that we produce work by the use of heat. But it always comes out that we cannot completely transform heat into work, a portion remains as heat. And since this is so, these remainders not capable of yielding work, accumulate. These non-transformable residues accumulate. And the universe approaches a condition in which all mechanical work will have been turned into heat."

It has even been said that the universe in which we live is approaching what has been learnedly called its "warmth-death." We will speak in coming lectures of the so-called entropy concept. For the present our interest lies in the fact that certain ideas have been drawn from experiment bearing on the fate of the universe in which we find ourselves.

Eduard von Hartmann has presented the matter very neatly. He says: physical observation shows that the world-process in the midst of which we live, exhibits two sorts of phenomena. In the end, however, all mechanical work can be produced, and the universe will have to come to an end. Thus says Eduard von Hartmann; physical phenomena shows that the world process is running down. This is the way he expresses himself about the conditions within which we live. We live in a universe whose processes preserve us, but which has a tendency to become more and more sluggish and finally to lapse into a state of complete inaction. I am merely repeating Eduard von Hartmann's own words.

Now we must make clear to ourselves the following point. Is there ever really the possibility

of calling forth a series of processes in a closed system? Note well what I am saying. If I consider the totality of my experimental implements, I certainly am not myself in a vacuum, in empty space. And even when I believe myself to be standing in empty space, I am still not entirely certain but that this empty space is empty only because I am unable to perceive what is really in it. *Do I therefore ever really carry out my experiments in a closed system?* Is it not so that what I carry out in the simplest experiment has to be thought of as dovetailed into the world process immediately around me? Can I conceive of the matter otherwise than in this fashion, that when I do all these things it is as though I took a small needle and pricked myself here? When I prick myself here I experience pain which prevents me from having an idea that I would otherwise have had. It is quite certain indeed, that I cannot consider merely the prick of the needle and the reaction of the skin and muscles as the whole of the process. In such a case I would not be placing the whole process before my eyes. The process is not entirely contained in these factors. Imagine for a moment that I am so clumsy as to pick up a needle, prick myself and experience the pain. I will pull the needle away. What appears thus as an effect is very definitely not comprehended when I hold in mind only what goes on in the skin. The drawing back of the needle is in reality nothing other than a continuation of what I apprehend when I hold before my mind the first part of the process. If I wish to describe the whole process, I must take into account that I have not stuck the needle into my clothes, but into my organism. This organism must be considered as a regulating whole, calling forth the consequences of the needle prick.

Is it legitimate for me to speak of an experiment such as we have before our eyes in the following way: "I have produced heat, and caused mechanical work. The heat not transformed remains over in the condensation water as heat." It is not in this way that I stand in relation to the whole thing. The production or retention of heat, the passage of it into the condensation water are related to the reaction of the whole great system as the reaction of my whole organism is to the small activity of being pricked with the needle. What must be taken into account especially is: *That it is never valid for me to consider an experimental procedure as a closed system*. I must keep in mind that this whole experimental procedure falls under the influence of energies that work out of this environment.

Consider along with this another fact. Suppose you have to begin with a vessel containing a liquid with its liquid surface which implies an action of forces at right angles to this surface. Suppose now that through cooling, this liquid goes over into a solid state. It is impossible for you to think of the matter otherwise than that the forces in the liquid are short through by another set of forces. For the liquid forces are such as to make it imperative that I hold this liquid, say water, in a vessel. The only form assumed by the water on its own account is the upper surface. When by solidification a definite form arises it is absolutely necessary to assume that forces are added to those formerly present. More observation convinces us of it. And it is quite absurd to think that the forces creating the form *are* present in some way or other in the water itself. For if they were there they would create the form in the water. They are thus added to the system, but must have come into it from the outside. If we simply take the phenomenon as it is presented to us we are obliged to say: when a form appears, it represents as a matter of fact a new creation. If we simply consider what we can determine from observation we have to think of the form as a new creation. It is simply a matter of observation that we bring about the solid state from the fluid. We see that the form arises as a

new creation. And this form disappears when we change the solid back into a liquid. One simply rests on that which is given as an observable fact. What follows now from this whole process when one makes it over into a concept? It follows that the solid seeks to make itself an independent unit, that it tends to build a closed system, that it enters into a struggle with its surroundings in order to become a closed system.

I might put the matter in this way, that here in the solidification of a liquid we can actually lay our hands on nature's attempt to attain a perpetuum mobile. But the perpetuum mobile does not arise because the system is not left to itself but is worked upon by its whole environment. The view may therefore be advanced: in space as given us, there is always present the tendency for a perpetuum mobile to arise. But a counter tendency appears at once. We can therefore say that wherever the tendency arises to form a perpetuum mobile, the opposite tendency arises in the environment to prevent this. If you will orient your thinking in this way you will see that you have altered the abstract method of modern 19th century physics through and through. The latter starts from the proposition: a perpetuum mobile is impossible, therefore etc. etc. If one stands by the facts the matter has to be stated thus: a perpetuum mobile is always striving to arise. Only the constitution of the cosmos prevents it.

And the form of the solid, what is it? It is the impress of the struggle. This structure that forms itself in the solid is the impress of the struggle between the substance as individuality which strives to form a perpetuum mobile and the hindrance to its formation by the great whole in which the perpetuum mobile seeks to arise. The form of a body is the result of opposition to this striving to form a perpetuum mobile. It might be better understood in some quarters if, instead of perpetuum mobile, I spoke of a self-contained unit, carrying its own forces within itself and its own form-creating power.

Thus we arrive at a point where we have to reverse completely the entire point of view, the manner of thinking of 19th century physics. Physics itself, insofar as it rests on experiment, which deals with facts, we do not have to modify. The physical way of thinking works with concepts that are not valid and it cannot realize that nature strives universally for that which it holds as impossible. For this manner of thinking it is quite easy to consider the perpetuum mobile as impossible, but it is not impossible because of the abstract reasons advanced by the physicists. It is impossible because the instant the perpetuum mobile strives to establish itself in any given body, at that instant the environment becomes jealous, if I may borrow an expression from the realm of morals, and does not let the perpetuum mobile arise. It is impossible because of facts and not because of logic. You can appreciate how twisted a theory is that departs from reality in its very foundation postulate. If the facts are adhered to, it is not possible to get around what I presented to you yesterday in a preliminary sketchy way. We will elaborate this sketchy presentation in the next few days.

I said to you: we have, to begin with, the realm of solids. Solids are the bodies which manifest in definite forms. We have, touching on the realm of the solids as it were, the realm of fluids. Form is dissolved, disappears, when solids become liquids. In the gaseous bodies we have a striving in all directions, a complete formlessness — negative form. Now how does this negative form manifest itself? If we look in an unbiased manner on gaseous or aeriform bodies we can see in these that which may be considered as corresponding to the

entity elsewhere manifested as form. Yesterday I called your attention to the realm of acoustics, the tone world. In the gas, as you know, the manifestation of tone arises through condensations and rarefactions. But when we change the temperature we also have to do with condensation and rarefaction in the body of the gas as a whole. Thus if we pass over the liquid state and seek to find in the gas what corresponds to form in the solid, we must look for it in condensation and rarefaction. In the solid we have a definite form; in the gas, condensation and rarefaction.

And now we pass to the realm next adjacent to the gaseous. Just as the fluid realm borders on the solid, and just as we know how the solid pictures the fluid, the fluid gives the foreshadowing of the gaseous, so the gas pictures the realm which we must conceive as lying next to the gaseous, i.e. the realm of heat. The realm lying next above heat, we will have to postulate for the time being and call it the X region.

X	Materiality-Spirituality
Heat	
Gas — Negative Form	Condensation-rarefaction
Fluid	
Solids — Form	

If now, I seek to advance further, at first merely through analogy, I must look in this X region for something corresponding to but beyond condensation and rarefaction (this will be verified in our subsequent considerations.) I must look for something else there in the X region, passing over heat, just as we passed over the fluid state below. If you begin with a definitely formed body, then imagine it to become gaseous and by this process to have simply changed its original form into another manifesting as rarefaction and condensation and if then you think of the condensation and rarefaction as heightened in degree, what is the result? As long as condensation and rarefaction are present, obvious matter is still there. But now, if you rarefy further and further you finally pass entirely out of the realm of the material. And this extension we have spoken of must, if we are to be consistent, be made thus: a material-becoming — a spiritual-becoming. When you pass over the heat realm into the X realm you enter a region where you are obliged to speak of the condition in a certain way. Holding in mind this passage from solid to fluid and the condensation and rarefaction in gases you pass to a region of materiality and non-materiality. You cannot do other than enter the region of materiality and non-materiality. Stated otherwise: when we pass through the heat realm we actually enter a realm which is in a sense a consistent extension of what we have observed in the realms beneath it. Solids oppose heat — it cannot come to complete expression in them. Fluids are more susceptible to its action. In gases there is a thorough-going manifestation of heat — it plays through them without hindrance. They are in their material behavior a complete picture of heat. I can state it thus: the gas is in its material behavior essentially similar to the heat entity. The degree of similarity between matter and heat becomes greater and greater as I pass from solids through fluids to gases. Or, liquefaction and evaporation of

matter means a becoming similar of this matter to heat. Passage through the heat realm, however, where matter becomes, so to speak, identical with heat leads to a condition where matter ceases to be. *Heat thus stands between two strongly contrasted regions, essentially different from each other, the spiritual world and the material world. Between these two stands the realm of heat*. This transition zone is really somewhat difficult for us. We have on the one hand to climb to a region where things appear more and more spiritualized, and on the other side to descend into what appears more and more material. Infinite extension upwards appears on the one hand and infinite extension downward on the other. (Indicated by arrows.)

But now we use another analogy that I am bringing before you today because through a general view of individual natural facts a sound science may be developed. It will perhaps be useful to array these facts before our souls. (See below.)

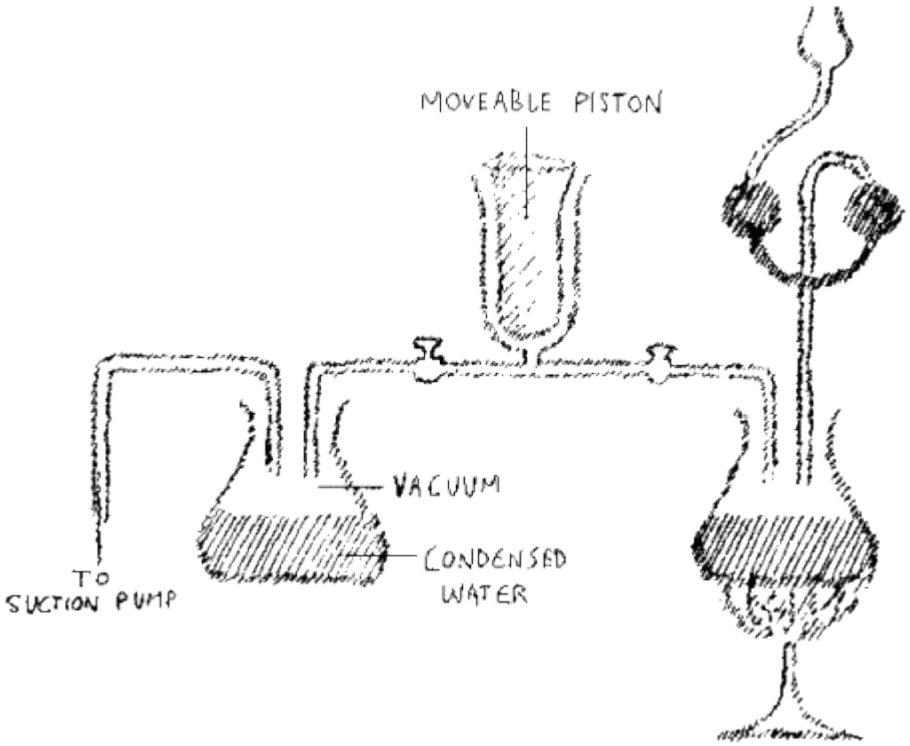
If you observe the usual spectrum you have red, orange, yellow, green, blue, indigo and violet.

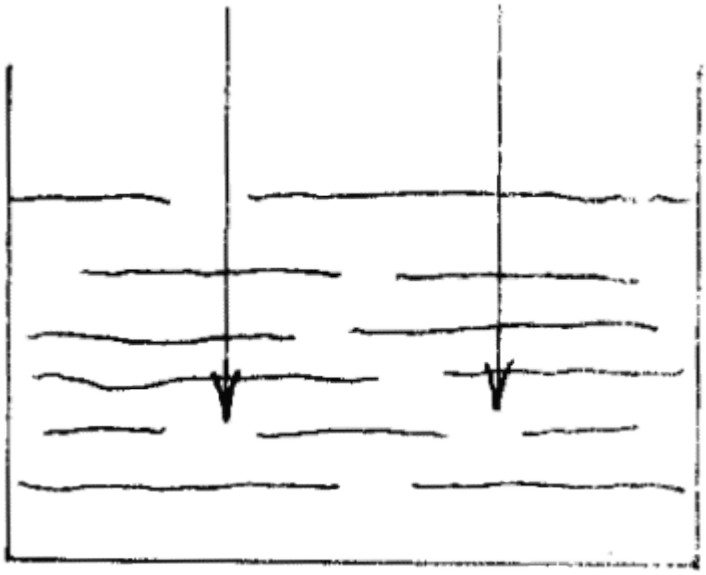
Infra red ——————————— r o y gr b i v ——————————— Ultra Violet

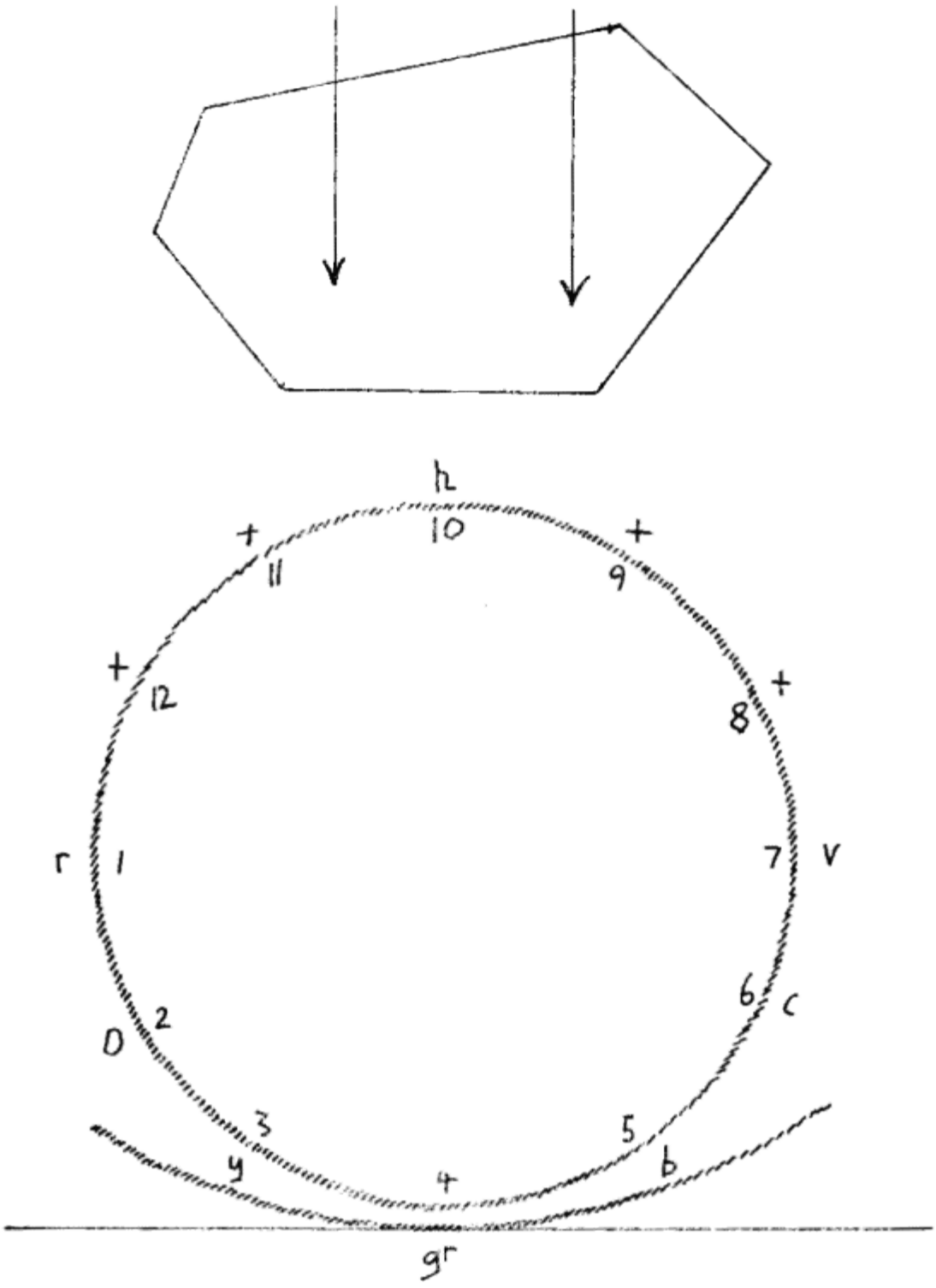
You have the colors following each other in a series of approximately seven nuances. But you know that the spectrum does not break off at either end. If we follow it further below the red we come to a region where there is more and more heat, and finally we arrive at a region where there is no light, but only heat, the infra red region. On the other side of the violet, also, we no longer have light. We come to the ultra violet where chemical action is manifested, or in other words effects that manifest themselves in matter. But you know also that according to the color theory of Goethe, this series of colors can be bent into a circle, and arranged in such a way that one sees not only the light from which the spectrum is formed, but also the darkness from which it is formed. In this case the color in the middle is not green but the peach-blossom color, and the other colors proceed from this. When I observe darkness I obtain the negative spectrum. And if I place the two spectra together, I have 12 colors that may be definitely arranged in a circle: red, orange, yellow, green, blue, indigo, and violet. On this side the violet becomes ever more and more similar to the peach blossom and there are two nuances between. On the other side there are two nuances between peach blossom and red. You have, if I may employ the expression, 12 color conditions in all. This shows that what is usually called the spectrum can be thought of as arising in this way: I can by any suitable means bring about this circle of color and can make it larger and larger, stretching out the upper five colors (peach blossom and the two shades on each side) until they finally disappear. The lower arc becomes practically a straight line, and I obtain the ordinary spectrum array of colors, having brought about the disappearance of the upper five colors.

I finally bring these colors to the vanishing point. May it not be that the going off into infinity is somewhat similar to this thing that I have done to the spectrum? Suppose I ask what happens if that which apparently goes off into infinity is made into a circle and returns on itself. May I not be dealing here with another kind of spectrum that comprehends for me on the one hand the condition extending from heat to matter, but that I can close up into a

circle as I did the color spectrum with the peach blossom color? We will consider this train of thought further tomorrow.







Figures for Chapter 8

Second Scientific Lecture-Course: Warmth Course

Lecture IX

Stuttgart, March 9th, 1920.

My dear friends,

The fact that we have spoken of the transformation of energy and force assumed by modern physics makes it necessary for us to turn our attention to the problem of indicating what really lies behind these transformations. To aid in this, I wish to perform another experiment to be ranged alongside of yesterday's. In this experiment we will perform work through the use of another type of energy than the one that is immediately evident in the work performed. We will, as it were, bring about in another sphere the same sort of thing that we did yesterday when we turned a wheel, put it in motion and thus performed work. For the turning of the wheel can be applied in any machine, and the motion utilized. We will bring about the turning of a wheel simply by pouring water on these paddle, and this water by virtue of its weight will bring the paddle wheel into motion. The force that somehow or other exists in the running water is transformed into the rotational energy of the wheel. We will let the water flow into this trough in order to permit it to form a liquid surface as it did in previous experiments. What we show is really this, that by forming a liquid surface below we make the motion of the wheel slower than it was before. Now, it will slow down in proportion to the degree to which the lower level approaches the upper level. Thus we can say: if we indicate the total height of the water from the point "**a**" here where it flows onto the wheel by "**h**," and the perpendicular distance to the liquid surface by "$\mathbf{h^1}$" then we can state the difference as $h - h^1$. We can further state that the work available for the wheel is connected in some way with the difference between the two levels. (The sense in which this is so we will seek in our further considerations.) Yesterday in our experiment we also had a kind of difference in levels, $t - t^1$. For you will recollect we denoted the heat of the surroundings at the beginning of our experiments by t^1 and the heat we produced in order to do work to raise and lower a bell, this we denoted by t. Therefore you can say: the energy available for work depends on the difference between t and t^1. Here too, we have something that can be denoted as a difference in level.

I must ask you to note especially how both these experiments show that wherever we deal with what is called energy transformation, we have to take account of difference in level. The part played by this, what is really behind the phenomenon of energy transformation, this we will find only where we pursue further the train of thought of yesterday. As we do this we will illuminate so to speak, the phenomena of heat and take into account that which Eduard von Hartmann set aside before he attempted a definition of physical phenomena. In this connection we must emphasize again and again a beautiful utterance of Goethe's regarding physical phenomena. He gave utterance to this in various ways, somewhat as follows: what is all that goes on in outer physical apparatus as compared to the ear of the musician, as compared to the revelation of nature that is given us in the musician's ear itself. What Goethe wishes to emphasize by this is that we will never understand physical things if we observe them separately from man himself. According to his view, the only way to attain the goal is to consider physical phenomena in connection with the human being, the phenomena of

sound in connection with the sense of hearing. But we have seen that great difficulties arise when we try in this way to bring the phenomena of heat in connection with the human being — really seek to connect heat with the being of man. Even the facts that have led to the discover of the so-called modern mechanical theory of heat support this view. Indeed, that which appears in this modern mechanical theory of heat took its origin from an observation made on the human organism by Julius Robert Mayer. Julius Robert Mayer, who was a physician, had noticed from blood-letting he was obliged to do in the tropical country of Java, that the venous blood of tropical people was redder than that of people in northern climes. He concluded correctly from this that the process involved in the coloration of blood varies, depending on whether man lives in a warmer or cooler climate, and is thus under the necessity of giving off less or more heat to his surroundings. This in turn involves a smaller or greater oxidation. Essentially he discovered that this process is less intense when the human being is not obliged to work so intensely on his environment. Thus, the human being of the tropics, since he loses less heat to his environment, is not obliged to set up so active a relation with the outer oxygen as when he gives off more heat. Consequently man, in order to maintain his life processes and exist at all on the earth in the cooler regions, is obliged to tie himself in more closely with his environment. He must take in more oxygen from the air in the colder regions where he works more intensely in connection with his environment than in the warmer zones where he labors more intensely in his inner nature.

Right here you get an insight into the inner workings of the whole human organization. You see that it has only to become warmer and the human being then works more in his inner individuality than he does when his environment is colder and he is thereby obliged to link his activities more intimately with his outer environment.

From this process in which we have represented a relation of man to his environment, there proceeded the observations that resulted in the theory of heat. These observations led Julius Robert Mayer to submit his small paper on the subject to the *Poggnedorfschen Annalen*. From this paper arose the entire movement in physics that we know about. This is strange enough since the paper that Mayer handed the *Poggnedorfschen Annalen* was returned as entirely lacking in merit. Thus we have the odd circumstance that physicists today say: we have turned physics into entirely new channels, we think entirely otherwise about physical things than they did before the year 1842. But attention has to be called to the fact that the physicists of that time, and they were the best physicists of the period, had considered Mayer's paper as entirely without merit and would not publish it in the *Poggnedorfschen Annalen.* Now you can see that it might be said: this paper in a certain sense brings to a conclusion the kind of view of the physical that was, as it were, incompletely expressed in Goethe's statement. After the publication of this paper, a physics arises which sees science advancing when physical facts are considered apart from man. This is indeed the principle characteristic of modern views on the subject. Many publications bring this idea forward as necessary for the advance of physics, stating that nothing must enter in which comes from man himself, which has to do with his own organic processes. But in this way we shall arrive at nothing. We will however continue our train of thought of yesterday, a train of thought drawn from the world of facts and one which will lead us to bring physical phenomena nearer to man.

I wish once more to lay before you the essential thing. We start from the realm of *solids* and find a common property at first manifesting as *form*. We then pass through the intermediate state of the *fluid* showing form only to the extent of making for itself a liquid surface. Then we reach the *gaseous bodies*, where the property corresponding to form manifests itself as *condensation and rarefaction*.

We then come to the region bordering on the gaseous, the heat region, which again, like the fluid, is an intermediate region, and then we come to our "X". Yesterday we saw that pursuing our thought further we have in X to postulate *materialization and dematerialization*. It is not difficult then to see that we can go beyond X to Y and Z just as, for instance, we go in the light spectrum from green to blue, from blue to violet and to ultra violet.

Z	
Y	
X	materialization dematerialization
Heat Realm	
Gaseous Bodies	} condensation rarefaction
Fluids	
Solids — Form	
U	

And now it is a question of studying the mutual relations between these different regions. In each one we see appearing what I might call definitely characteristic phenomena. In the concrete realm we see a circumscribed for; in gas a changing form, so to speak, in condensations and rarefactions. This accompanies, and I am now speaking precisely, this accompanies the tone entity, under certain conditions. When we pass through the warmth realm into X realm, we see materialization and dematerialization. The question now arising is this: how does one realm work into another?

Now I have already called your attention to the fact that when we speak of gas, the phenomena there enacted present a kind of picture of what goes on in the realm of heat. We can say therefore, in the gas we find a picture of what goes on in the heat realm. This comes about in no other manner than that we have to consider gas and heat as mutually interpenetrating each other, as so related that gaseous phenomena are seized upon in their spatial relationship by the heat entity. What is really taking place in the realm of heat expresses itself in the gas through the interpenetration of the two realms. Furthermore we can

say, fluids show us a relationship of forces similar to that obtaining between gases and heat. Solids show the same sort of relationship to fluids do to gases and as gases do to heat.

What then, comes about in the realm of solids? In this realm forms appear, definite forms. Forms circumscribed within themselves. These circumscribed forms are in a relative sense pictures of what is really active in fluids. Now we can pass here to a realm U, below the solid, whose existence we at the start will merely postulate; and let us try to create concepts in the realm of the observable. By extending our thinking which you can feel is rooted in reality, we can create concepts and these concepts springing from the real bring into us a bit of the real world.

What must take place if there is to be such a reality as the U realm? In this realm there must be pictured that which in solids is a manifested fact. In a manner corresponding to the other realms the U realm must give us a picture of the solids. In the world of solids we have bodies everywhere, everywhere forms. These forms are conditioned from within their own being, or at least conditioned according to their relation to the world. We will consider this further in the next few days. Forms come into being, mutually inter-related.

Let us go back for a moment to the fluid state. There we have, as it were, the fluid throwing out a surface and thus showing its relation to the entire earth. In gravity therefore, we have to recognize a force related to the creation of form in solids. In the U realm we must find something that happens in a similar manner to the form-building in the world of solids, if we are to pursue our thinking in accordance with reality. And this must parallel the picturing of the fluid world by solids. In other words: in the U world we must be able to see an action which foreshadows the solid world. We must in some way be able to see this activity. We must see how, under the influence of forms related to each other something else arises. There must come into existence as a reality what further manifests as varying forms in the solid world. We really have today only the beginning of such an insight. For, suppose you take a suitable substance, such as tourmaline, which carries in itself the principle of form. You then bring this tourmaline into such a relation that form can act on form. I refer to the inner formative tendency. You can do this by allowing light to shine through a pair of tourmaline crystals. At one time you can see through them and then the field of vision darkens. This you can bring about simply by turning one crystal. You have brought their form-creating force into a different relation. This phenomena, apparently related to the passage of light through systems of differing constitution, shows us the polarization figures. Polarization phenomena always appear when one form influences another. There we have the noteworthy fact before our eyes that we look through the solid realm into another realm related to the solid as the solid is to the liquid. Let us ask ourselves now, how come it is that under the influence of the form-building force there arises in the U realm that which we observe in the polarization figures as they are called, and which really lies in the realm beneath the solid realm? For we do, as a matter of fact, look into a realm here that underlies the world of the solids. But we see something else also.

We might look long into such a solid system, and the most varied forces might be acting there upon each other, but we would see nothing. It is necessary to have something playing through these systems, just as the U realm plays through the world of solids in order to bring

out the phenomenon. And the light does this and makes the mutual inter-working of the form-building forces visible for us.

What I have here expressed, my friends, is treated by the physics of the 19th century in such a way that the light itself is supposed to give rise to the phenomenon while in reality the light only makes the phenomenon visible. Looking on these polarization figures, one must seek for their origin in an entirely different source from the light itself. What is taking place has nothing whatever to do with the light as such. The light simply penetrates the U realm and makes visible what is going on there, what is taking place there as a foreshadowing of the solid form. Thus we can say we have to do with an interpenetration of different realms which we have simply unfolded before our eyes. In reality we are dealing with an interpenetration of different realms.

And now the facts lead us to the same point which we reached, for instance, in the realm of the gaseous by means of the forces of form. Our concepts of what has been said will be better if we consider condensation and rarefaction in connection with the relation of tone to the organ of hearing. We must not feel it necessary to identify these condensations and rarefactions in a gaseous body entirely with what we are conscious of as tone. We must seek for something in the gas that uses the condensations and rarefactions as an agency when these are present in a suitable fashion. What really happens we must express as follows: that which we call tone exists in a non-manifested condition. But when we bring about in a gas certain orderly condensations and rarefactions, then there occurs what we perceive consciously as tone. Is not this way of stating the matter entirely as though I should say the following: we can imagine in the cosmos heat conditions where the temperature is very high — about 100°C. We can also imagine heat conditions where very low temperatures prevail. Between the two is a range in which human beings can maintain themselves. It is possible to say that wherever in the cosmos there is a passage from the condition of high temperature to a condition of low temperature, there obtains at some intermediate point a heat condition in which human beings *may* exist. The opportunity for the existence of man is there, if other necessary factors for human existence are present. But we would on no account say: man *is* the temperature

Variation from high to low and the reverse variation. (For here the conditions would be right again for his existence.) We would certainly not say that. In physics, however, we are always saying, tone is nothing but the condensation and rarefaction of the air; tone is a wave-motion that expresses itself as condensation and rarefaction in the air. Thus we accustom ourselves to a way of thinking that prevents us from seeing the condensations and rarefactions simply as bearers of the tone, and not constituting the tone itself. And we should conceive for the gaseous something that simply penetrates it, but belongs to another realm, finding in the realm of the gaseous the opportunity so to manifest as to form a connection between itself and our higher organs. Concepts formed in this way about physical phenomena are really valid. If however, one forms a concept in which tone is merely identified with the air vibrations, then one is naturally led to consider light merely as ether vibrations. A person thus passes from what is not accurately conceived to the creation of a world of thought-out fantasies resulting simply from loose thinking. Following the usual ideas of physics, we bury

ourselves in physical concepts that are nothing more than the creation of inaccurate thinking.

But now we have to consider the fact that when we pass through the heat realm to the X, Y and Z realms, we have to pass out into infinity and here from the U region we have also to step into the infinite.

Recollect now what I told you yesterday. In the case of the spectrum also, when we try to get an idea of it as it exists ordinarily, we have to go from the green through the blue to the violet and then of to the infinite, or at least to the undetermined. So likewise at the red end of the spectrum. But we can imagine the spectrum in its completeness as a series of 12 independent colors in a circle, with green below and peach-blossom above, and ranged between these the other colors. When we can imagine the circle to become larger and larger, the peach blossom disappears above and the spectrum extends on the one hand beyond the red and on the other beyond the violet. In the ordinary spectrum therefore, we really have only a part of what would be there if the entire color series could appear. Only a portion is present.

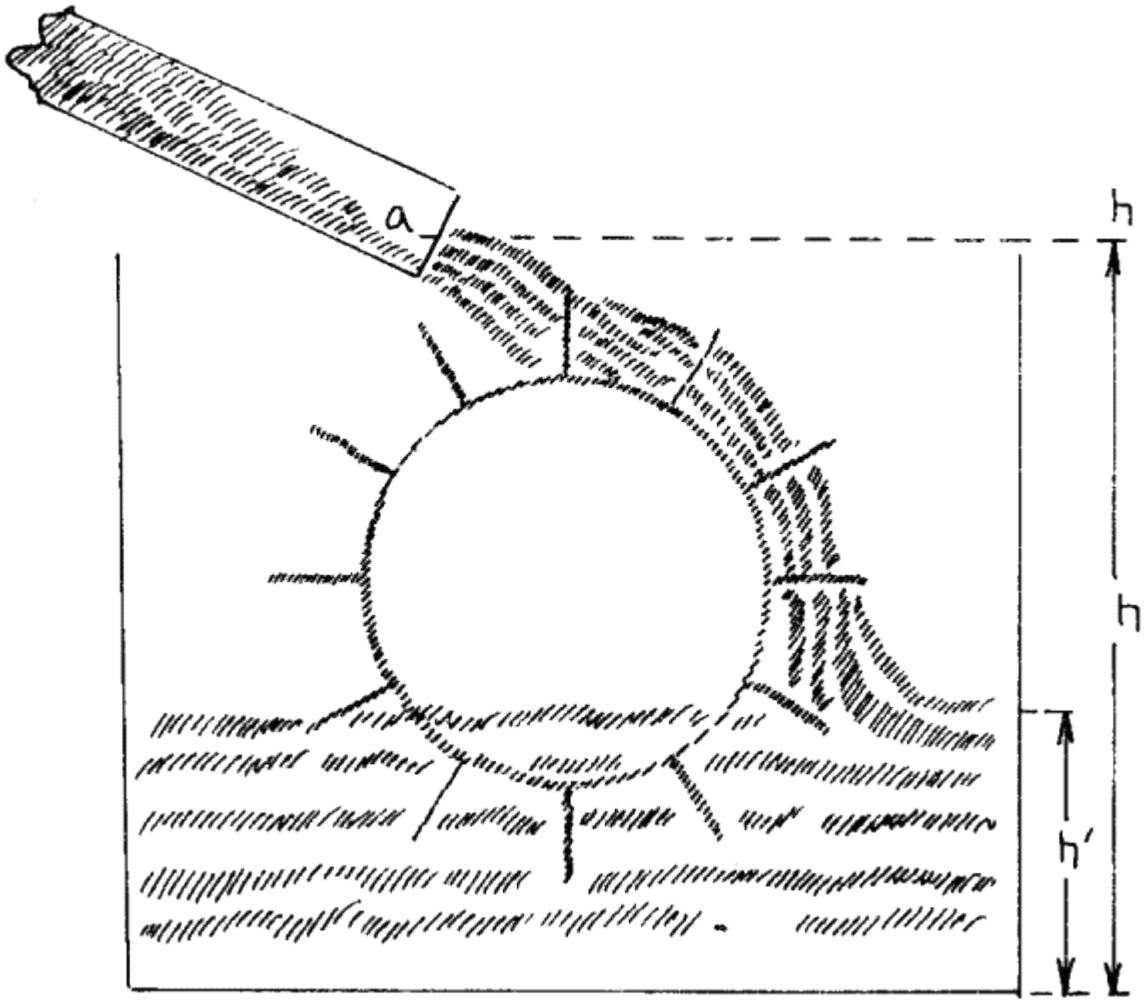
Now there is a very remarkable thing. I think, my friends, if you take as a basis the ordinary presentation of optics in the physic books and read what is there given as explanation of a special spectral phenomenon, namely the rainbow, you will be rather uneasy if you are a person who likes clear concepts. For the explanation of the rainbow is really given in such a manner that one has no foundation on which to stand. One is obliged to follow all sorts of things going on in the raindrop from the running together of extremely small reflections that are dependent on where one stands in relation to the rainbow. These reflections are said really to come from the raindrops. In brief you have in this explanation an atomistic view of something that occurs in our environment as unity. But even more perplexing is the fact that his rainbow or spectrum conjured up before us by nature herself, never occurs singly. A second rainbow is always present, although sometimes very completely hidden. Things that belong together cannot be separated. The two rainbows, of which one is clearer than the other, belong of necessity together, and if one is to explain this phenomenon, it is not possible to do so simply by explaining one strip of color. If we are to comprehend the total phenomenon we must make it clear to ourselves that something of a unique nature is in the center and that it shows two bands of color. The one band is the clearer rainbow, and the other band is the more obscure bow. We are dealing with a representation in the greatness of nature herself, which is an integral portion of the “All” and must be comprehended as a unity. Now, when we observe carefully we will see that the second rainbow, the accessory bow, shows colors in the reverse order from the first. It reflects, so to speak, the first and clearer rainbow. As soon as we go from the partial phenomenon as it appears in our environment, to a relatively more complete one, when we conceive of the whole earth in its relation to the cosmic system, we see in the rainbows a different aspect. I wish only to mention this here — we will go into it more completely in the course of our lecture. But I wish to say here that the appearance of the second bow converts the phenomenon into a closed system, so to speak. The system is only an open one so long as I limit my consideration to the special spectrum arising in the “U” portion of my environment. The phenomenon of the rainbow really leads me to think of the matter thus, that when I produce a spectrum experimentally, I grasp nature only at one pole, the opposite pole escapes me. Something has slipped into the unknown, and

I really have to add to the seven-colored spectrum the accessory spectrum.

Now hold in mind this phenomenon and the ideas that arise from it and recollect the previous ideas that we have brought out here. We are trying to close up the band of color that stretches out indefinitely on both sides, and bring the two together. If now, we do a similar things in this other realm, what happens? (See sketch at end of Chapter) Then we will pass from solids to the U region and beyond, but as we do this we also come back from the other end of the series and the system becomes a closed one. But now, when the downward path and the upward one come together to make a closed system, what does that form for us? What happens then?

I will try as follows to lead you to an understanding of this: suppose you really go in one direction in the sense indicated in our diagrams. Let us say we go out from the sphere where, as we have explained in these lectures, gravity becomes negative. We have, let us say, arrived in one of the realms. From this realm, suppose we go downward, and imagine that we pass through first the fluid and then the solid realms. Now when we go further, we must really come back from the other side — it is difficult to show this diagrammatically. Since we come back from the other side, that which belongs to this other side has to insert itself into the realm from which we have just passed. That is to say, while I pass from the solid to the U region, if I want to represent the whole cycle I must bend what is at the other end of the series around and thrust it in here. I can picture it in this way. From the null sphere I go through the fluid into the solid and then into the U region. Returning then, I come to the same point from the other side. Or, I might say: I observe the gas, it extends to here where I have colored with blue (referring to the drawing at end of Chapter). But from the other side comes that which inserts itself, interpenetrates it from the cosmic cycle, but appearing there only as a picture. It impregnates the gas, so to speak, and manifests as a picture. The fluid in its essence interpenetrates the sphere of the solid, and attains a form. Similarly, form appears in the gas as tone and this we have indicated in our diagram. Turn over in your minds this returning and interpenetration in these world-processes. You will of necessity have to think not of a world-cycle only, but of a certain sort of world-cycle. You will have to think of a world cycle that moves from one realm to another, but in which any realm shows reflection of other realms. In this way we get a basis for thinking about these things that has a root in reality. This way of thinking will help you, for instance, to see how light arises in matter, light which belongs to an entirely different realm; but you will see that the matter is simply "overrun" by the light, as it were. And you will then, if you treat these things mathematically, have to extend your formulae somewhat.

You may, if you will, consider these things under the symbol of ancient wisdom, the snake that swallows its own tail. The ancient wisdom represented these things symbolically and we have to draw nearer to the reality. This drawing nearer is the problem we must solve.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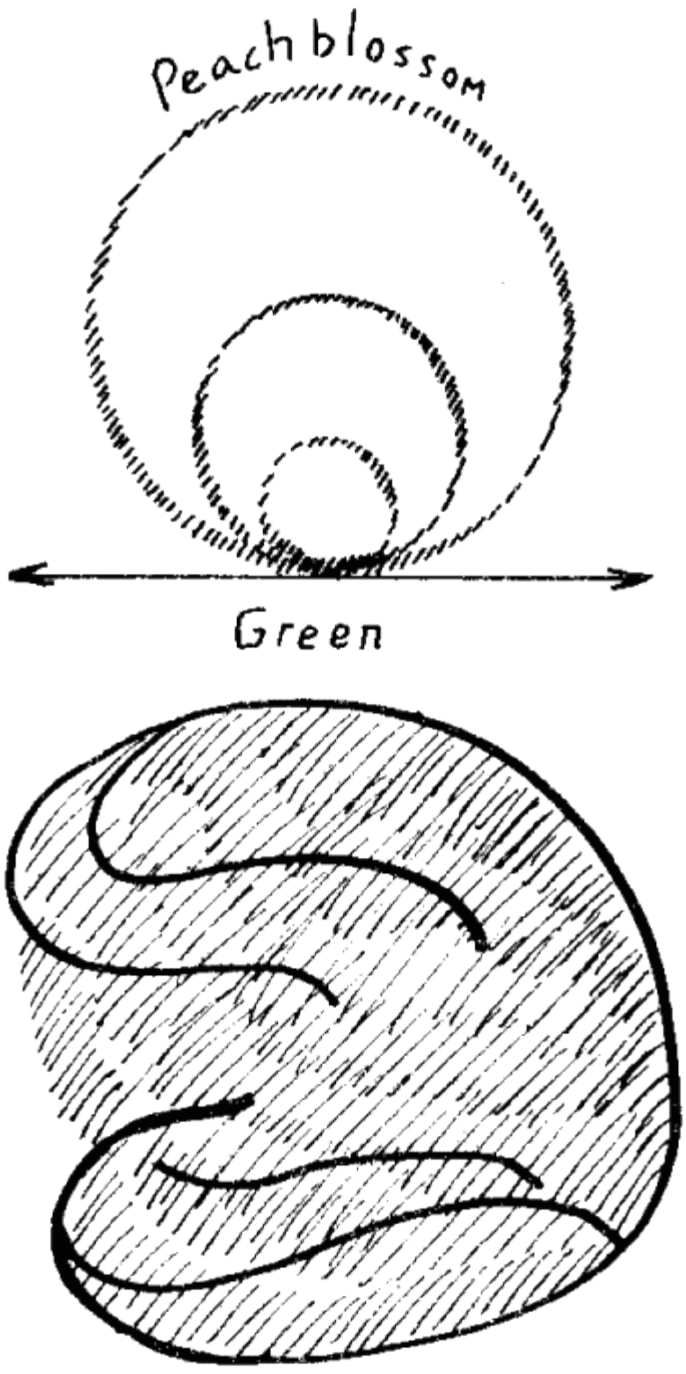

Figure for Chapter 9

Second Scientific Lecture-Course: Warmth Course

Lecture X

Stuttgart, March 10th, 1920.

My dear friends,

Before we continue the observations of yesterday which we have nearly brought to a conclusion, let us carry out a few experiments to give support to what we are going to say. First we will make a cylinder of light by allowing a beam to pass through this opening, and into this cylinder we will bring a sphere which is so prepared that the light passes into it, but cannot pass through. What happens we will indicate by this thermometer (see drawing Fig. 1). You will note that this cylinder of energy, let us say, passing into the sphere reveals its effect by causing the mercury column to sink. Thus we are dealing with what we have formerly brought about by expansion. And indeed, in this case we have to assume also that heat passes into the sphere, causes an expansion and this expansion makes itself evident by a depression of the column of mercury. If we placed a prism in the path of the light we would get a spectrum. We do not form a spectrum in this experiment, but we catch the light — gather it up and obtain as a result of this gathering up of what is in the bundle of light, a very market expansion. You can see the definite depression of the mercury. Now we will place in the path of the energy cylinder, an alum solution, and see what happens under the influence of this solution. You will see after a while that the mercury will come to exactly the same level in the right and left hand tubes. This shows that originally heat passed through, but under the influence of the alum solution the heat is shut off, not more goes through. The apparatus then comes only under the influence of the heat generally present in the space around it and the mercury readjusts itself to equilibrium in the two tubes. The heat is stopped as soon as I put the alum solution in the path of the energy cylinder. That is to say, from this cylinder which yields for me both light and heat, I separate out the heat and permit the light to pass through. Let us keep this firmly in mind. Something still rays through. But we see that we can so treat the light-heat mercury that the light passes on and the heat is separated by means of the alum solution.

This is one thing we must keep in mind simply as a phenomenon. There is another phenomenon to be brought to our attention before we proceed with our considerations. When we study the nature of heat we can do so by warming a body at one particular spot. We then notice that the body gets warm not only at the spot where we are applying the heat, but that one portion shares its heat with the next portion, then this with the next, etc. and that finally the heat is spread over the entire body (Fig. 2). And this is not all.

If we simply bring another body in contact with the warm body, the second body will become warmer than it formerly was. In modern physics this is ordinarily stated by saying that heat is spread by conduction. We speak of the conduction of heat. The heat is conducted from one portion of a body to another portion, and it is also conducted from one body to another in contact with the first. A very superficial observation will show you that the conduction of heat varies with different materials. If you grasp a metallic rod in your fingers by one end and hold the other end in a flame, you will soon have to drop it, since the heat travels rapidly from one end of rod to the other. Metals, it is said, are good conductors of heat. On the other hand, if you hold a wooden stick in the flame in the same way, you will not have to drop it quickly on account of the conduction of heat. Wood is a poor conductor of

heat. Thus we may speak of good and poor conductors of heat. Now this can be cleared up by another experiment. And this experiment we are unfortunately unable to make today. It has again been impossible to get ice in the form we need it. At a more favorable time the experiment can be made with a lens made of ice as we would make a lens of glass. Then from a source of heat, a flame, this ice lens can be used to concentrate the heat rays just as light rays can be concentrated (to use the ordinary terminology.) A thermometer can then be used to demonstrate the concentration by the ice lens of the heat passing through it. (See Fig. 4).

Now you can see from this experiment that it is a question here of something very different from conduction even though there is a transmission of the heat, otherwise the ice lens could not remain an ice lens. What we have to consider is that the heat spreads in two ways. In one form, the bodies through which it spreads are profoundly influenced, and in the other form it is a matter of indifference what stands in the path. In this latter case we are dealing with the propagation of the real being of heat, with the spreading of heat itself. If we wish to speak accurately we must ask what is spreading, then we apply heat and see a body getting warmer gradually piece by piece, we must ask the question: is it not perhaps a very confused statement of the matter when we say that the heat itself spreads from particle to particle through the body, since we are able to determine nothing about the process except the gradual heating of the body?

You see, I must emphasize to you that we have to make for ourselves very accurate ideas and concepts. Suppose, instead of simply perceiving the heat in the metal rod, you had a large rod, heated it here, and placed on it a row of urchins. As it became warm the urchins would cry out, the first one, then the second, then the third, etc. One after another they would cry out. But it would never occur to you to say that what you heard from the first urchin was conducted to the second, the third, the fourth, etc. When the physicist applies heat at one spot, however, and then perceives it further down the rod, he says: the heat is simply conducted. He is really observing how the body reacts, one part after another, to give him the sensation of warmth, just as the urchins give a yell when they experience the heat. You cannot, however, say that the yells are transmitted.

Now we will perform also an experiment to show how the different metals we have here in the form of rods behave in respect to what we call the conduction, and about which we are striving to get valid ideas. We have hot water in this vessel (Fig. 3). By placing the ends of the rods in the water, they are warmed. Now we will see how this experiment comes out. One rod after another will get warm, and we will have a kind of graduated scale before us. We will be able to see the gradual spreading of the effect of the heat in the different substances. (The rods consisted of copper, nickel, lead, tin, zinc, iron.) The iodide of mercury on the rods (used to indicate rise in temperature) becomes red in the following order: copper, nickel, zinc, tin, iron and lead. The lead is, therefore, among these metals, the poorest conductor of heat, as it is said.

This experiment is shown to you in order to help form the general view of the subject that I have so often spoken to you about. Gradually we will rise to an understanding of what the

heat entity is in its reality.

Now, from our remarks of yesterday we have seen that when we turn our attention to he realm of corporeality, we can in a certain way, set limits to the realm of the solids by following what it is essentially that takes on form. We have the fluids as an intermediate stage and then we go over to the gaseous realm. In the gaseous we have a kind of intermediate state, exactly as we would expect, namely the heat condition. We have seen why we can place it as we do in the series. Then we come, as I have said, into an X region in which we have to assume materialization and dematerialization, pass then to a Y and a Z. This is all similar to the manner in which we find in the light spectrum the transition from green through blue to violet and then apparently on to infinity. Yesterday we convinced ourselves that we have to continue below the solid realm into a U region. Thus we think of the world of corporeality as arranged in an order analogous to the arrangement in the spectrum. This is exactly what we do when we pursue our thinking in contact with reality.

Now let us further extend the ideas of yesterday. In the case of the spectrum we conceive of what disappears at the violet end and at the red end in the straight line spectrum as bent into a circle. In exactly the same way we can, in this different realm of states of aggregation, imagine that the two ends of the series do not disappear into infinity. Instead, what apparently goes off into the indefinite on the one side and what goes off into indefiniteness on the other may be considered as bending back (Fig. 1) and then we have before us a circle, or at least a line whose two ends meet.

The question now arises, what is to be found at the point of juncture? When we observe the usual spectrum, we can in that case find something at this point. In Goethe's sense you know that the spectrum considered as a whole with all its colors included shows as its middle color on one side green, when we make a bright spectrum. On the other side peach blossom which is also a middle color when we make a dark spectrum. Thus we have green, blue, violet extending to peach blossom. By closing the circle we note that at the point where it closes, there is the peach blossom color.

If we then construct a similar circle in our thinking about the realm states of aggregation, what do we find at the point of juncture? This brings us to an enormously important consideration. What must we place in the spectrum of states of aggregation which will correspond to the peach blossom of the color spectrum? The idea that arises naturally from the facts here may perhaps be easier for you to grasp if I lead you to it as follows: What do we have in reality which disappears as it were in two opposite directions — just as in the color spectrum the tones shade off on the one side into the region beyond the violet and on the other side into the region beyond the red? Ask yourselves what it is. It is nothing more or less than the whole of nature. The whole of nature is included in it. For you cannot in the whole of nature find anything not included in the form categories we have mentioned. Nature disappears from us on the one hand when we go through corporeality into heat and beyond. She disappears from us on the other when we follow form through the solid realm into the sub-solid where we saw the polarization figures as the effect of form on form. The tourmaline crystals show us now a bright field, now a dark one. By the mutual effect of one

form on another there appear alternately dark and light fields.

It is essential for us to determine what we should place here when we follow nature in one direction until we meet what streams from the other side. What stands there? Man as such stands there. The human being is inserted at that point. Man, taking up what comes from both sides is placed at that point. And how does he take up what comes from the two sides? (Fig. 2) He has form. He is also formed within. When we examine his form among other formed bodies we are obliged to give him this attribute. Thus, the forces that give from elsewhere are within man. And now we must ask ourselves, are these forces to be found in the sphere of consciousness? No, they are not in the human consciousness. Think of the matter a moment. You cannot get a real understanding of the human form from what you can see in either yourselves or other men. You cannot experience it immediately in consciousness. We have a corporeality, but this form is not given in our immediate consciousness. What do we have in our immediate consciousness in the place of form?

Now, my friends, that can be experienced only when one gradually and in an unbiased manner learns to observe the physical development of man. When the human being first enters physical existence, he must be related very plastically to his formative forces. That is, he must do a great deal of body building. The nearer we approach the condition of childhood, the greater the body building, and as we take on years there is a withdrawal of the body building forces. In proportion as the body building forces withdraw, conscious reasoning comes into play. The more the formative forces withdraw the more reasoning advances. We can create ideas in regard to form in proportion as we lose the ability to create form in ourselves. This considered in a matter of fact way, is simply an obvious truth. But now you see, we can say that we experience formative forces — forces that create form outside the body can be experienced. And how do we experience them? In this way, that they become ideas within us. Now we are at the point where we can bring the formative forces to the human being. These forces are not something that can be dreamed about. Answers to the questions that nature puts to us cannot be drawn from speculation or philosophizing, but must be got from reality. And in reality we see that the formative forces show themselves where, as it were, form dissolves into ideas, where it becomes ideas. In our ideas we experience what escapes us as a force while our bodies are building.

When we place human nature before us in thought, we can state the matter as follows: man experiences as ideas the forces welling up from below. What does he experience coming down from above? What comes into consciousness from the realms of gas and heat? Here again when you look at human nature in an unprejudiced way, you have to ask yourselves: how does the will relate itself to the phenomena of heat?

You need only consider the matter physiologically to see that we go through a certain interaction with the heat being of outer nature in order to function in our will nature. Indeed heat must appear if willing is to become a reality. We have to consider will related to heat. Just as the formative forces of outer objects are related to ideas, so we have to consider what is spread abroad as heat as related to that which we find active in our wills. Heat may be thus looked upon as will, or we may say that we experience the being of heat in our will.

How can we define form what it approaches us from within-out? We see it, in this form, in any given solid body. We know that if conditions are such that this form can be seized upon by our life processes, ideas will arise. These ideas are not within the outer object. It is somewhat as if I observed the spirit separated from the body in death. When I see form in outer nature, what brings about the form is not there in the object. It is in truth not there. Just as the spirit is not within the corpse but has been in it, so is that which determines form not within the object. If I therefore turn my eyes in an unprejudiced way towards outer nature I have to say: Something works in the process of form building in objects, but in the corpse this something "has been active," while in the object its activity is *becoming*. We will see that what is there active lives in our ideas.

If I experience heat in nature, then I experience what works in a certain way as my will. In the thinking and willing man we have what meets us in outer nature as form and heat respectively.

But now there are all possible intermediate stages between will and thought. A mere intellectual self-examination will soon show you that you never think without exercising the will. Exercise of the will is difficult for modern man especially. The human being is more prone to will unconsciously the course of his thoughts, he does not like to send will impulses into the realm of thought.

Entirely will-free thought content is really never present just as will not oriented by thought is likewise not present. Thus when we speak of thought and will, of ideas and will, we are dealing with extreme conditions, with what from one side builds itself as thought and from the other side builds itself as will. We can therefore say that in experiencing will permeated by thinking and thinking permeated by will, we experience truly and essentially the outer forms of nature and the outer heat being of nature. There is only one possibility for us here and that is to seek in man for essential being of what meets us in outer nature.

And now pursue these thoughts further. When you follow further the condition of corporeality on the one hand you can say that you proceed along a line into the indeterminate. The opposite must be the case here. And how can we state this? How must it be within man? We must indeed, find again here what goes off into infinity. Instead of it going off into infinity, so that we can no longer follow it, we must picture to ourselves that it moves out of space. What wells up in man from the states of aggregation we must think of as going out of space. That is, the forces that are in heat must so manifest themselves in man that they move out of space. Likewise, the forces that produce form, pass out of space when they enter man.

In other words, in man we have a point where that which appears spatially in the outer world as form and heat, leaves space. Where the impossibility arises, that that which becomes non-spatial can still be held mathematically.

I think we can see here in a very enlightening way how an observation of nature in accordance with facts obliges us to leave space when we approach man, provided we properly place him in the being of nature. We have to go to infinity above and below (the

scale of that states of aggregation.) When we enter the being of man, we leave the realm of space. We cannot find a symbol which expresses spatially how the facts of nature meet us in the being of man. Nature properly conceived, shows us that when we think of her in relation to man, we must leave her. Unless we do, when we consider the content of nature in relation to man, we simply do not come to the human being.

But what does this mean mathematically? Suppose you set down the lineal series among which you are following states of aggregation to infinity. The words one after another may be considered as positive. Then what works into the nature of man must be set down as negative. If you consider this series as positive, the effects in the human being have to be made negative. What is meant by positive and negative will be cleared up I think by a lecture to be given by one of our members during the next few days. We have to conceive, however, of what comes before our eyes plainly here in this way that the essential nature of heat, insofar as this belongs to the outer world, must be made negative when we follow it into the human being, and likewise the essentiality of form becomes negative when we follow it into man. Actually then, what lives in man as ideas is related to outside form as negative numbers are to positive numbers and vice versa. Let us say, as credits and debits. What are debits on the one hand are credits on the other and vice versa. What is form in the outside world lives in man in a negative sense. If we say "there in the outside world is some sort of a body of a material nature," we have to add: "if I think about its form the matter must be negative, in a sense, in my thinking." How is matter characterized by me as a human being? It is characterized by its pressure effects. *If I go from the pressure manifestation of matter to my ideas about form, then the negative of pressure, or suction, must come into the picture*. That is, we cannot conceive of man's ideas as material in their nature if we consider materiality as symbolized by pressure. We must think of them as the opposite. We must think of something active in man which is related to matter as the negative is to the positive. We must consider this as symbolized by suction if we think of matter as symbolized by pressure. If we go beyond matter we come to nothing, to empty space. But if we go further still, we come to less-than-nothing, to that which sucks up matter. We go from pressure to suction. Then we have that which manifests in us as thinking.

And when on the other hand you observe the effects of heat, again you go over to the negative when it manifests in us. It moves out of space. It is, if I may extend the picture, sucked up by us. In us it appears as negative. This is how it manifests. Debits remain debits, although they are credits elsewhere. Even though our making external heat negative when it works within us results in reducing it to nothing, that does not alter the matter. Let me ask you again to note: we are obliged by force of the facts to conceive of man not entirely as a material entity, but we must think of something in man which not only is not matter, but is so related to matter as suction is to pressure. Human nature properly conceived must be thought of as containing that which continually sucks up and destroys matter.

Modern physics, you see, has not developed at all this idea of negative matter, related to external matter as a suction is to a pressure. That is unfortunate for modern physics. What we must learn is that the instant we approach an effect manifest in man himself all our formulae must be given another character. Will phenomena have to be given negative values in contrast to heat phenomena; and thought phenomena have to be given negative values as

contrasted to the forces concerned in giving form.

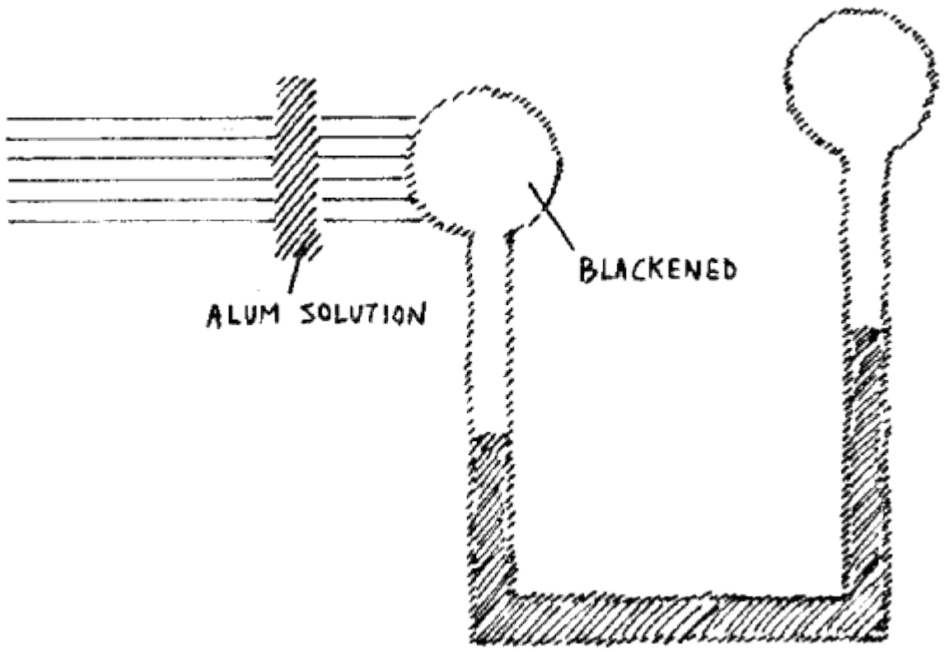

Figure 1

Figure 2

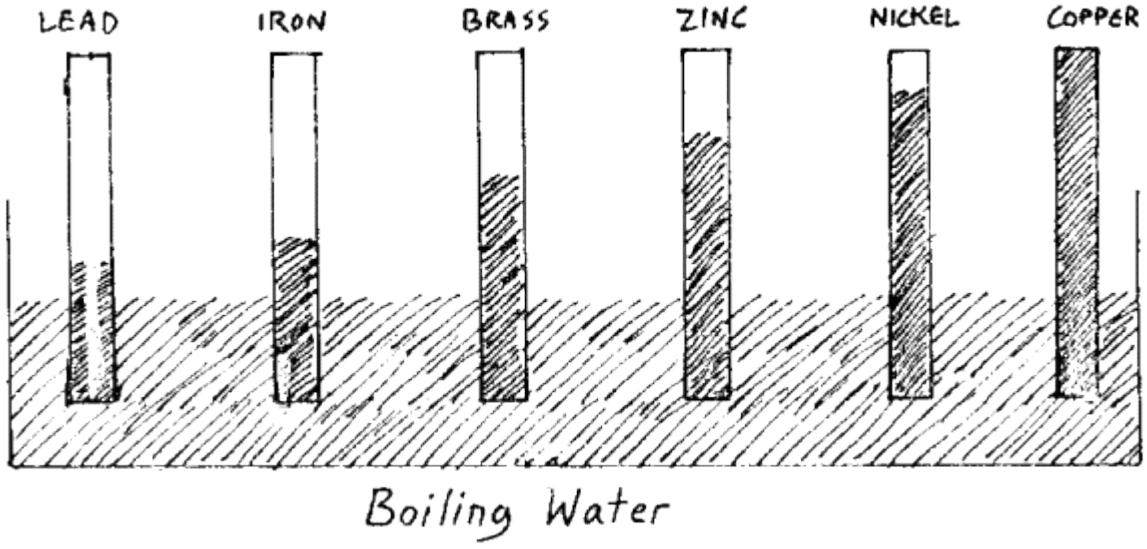

Figure 3

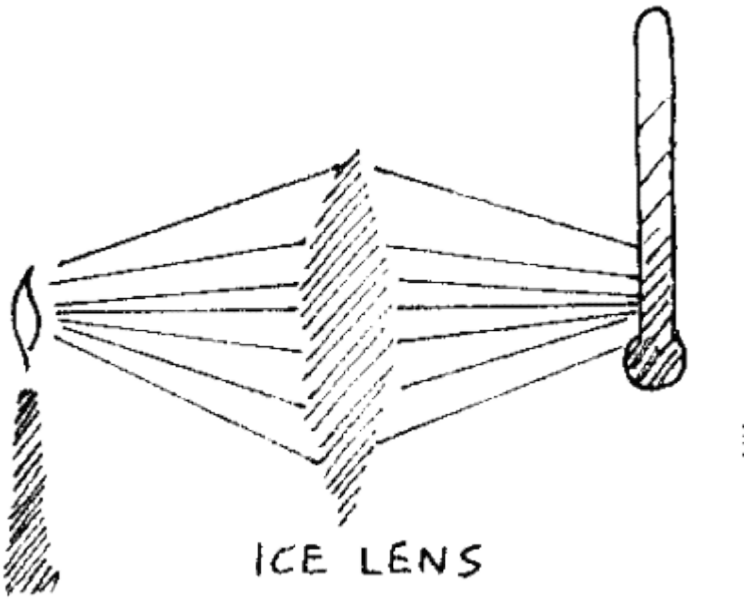

Figure 4

Second Scientific Lecture-Course: Warmth Course

Lecture XI

Stuttgart, March 11th, 1920.

My dear friends,

At this point I would like to build a bridge, as it were, between the discussions in this course and the discussion in the previous course. We will study today the light spectrum, as it is called, and its relation to the heat and chemical effects that come to us with the light. The simplest way for us to bring before our minds what we are to deal with is first to make a spectrum and learn what we can from the behavior of its various components. We will, therefore, make a spectrum by throwing light through this opening — you can see it here. (The room was darkened and the spectrum shown.) It is to be seen on this screen. Now you can see that we have something hanging here in the red portion of the spectrum. Something is to be observed on this instrument hanging here. First we wish to show you especially how heat effects arise in the red portion of the spectrum. Something is to be observed on this instrument hanging here. These effects are to be observed by this expanding action of the energy cylinder on the air contained in the instrument, which expanding action in turn pushes the alcohol column down on this side and up on this one. This depression of the alcohol column shows us that there is a considerable heat effect in this part of the spectrum.

It would be interesting also to show that when the spectrum is moved so as to bring the instrument into the blue-violet portion, the heat effect is not noticeable. It is essentially characteristic of the red portion. And now, having shown the occurrence of heat effects in the red portion of the spectrum by means of the alcohol column, let us show the chemical activity of the blue-violet end. We do this by allowing the blue portion to fall on a substance which you can see is brought into a state of phosphorescence. From the previous course you know that this is a form of chemical activity. Thus you see an essential difference between the portion of the spectrum that disappears on the unknown on this side and the portion that disappears on this other side; you see how the substance glows under the influence of the chemical rays, as they are called. Moreover, we can so arrange matters that the middle portion of the spectrum, the real light portion, is cut out. We cannot do this with absolute precision, but approximately we can make the middle portion dark by simply placing the path of the light a solution of iodine in carbon disulphate. This solution has the property of stopping the light. It is possible to demonstrate the chemical effect on one side and the heat effect on the other side of this dark band. Unfortunately we cannot carry out this experiment completely, but only mention it in passing. If I place an alum solution in the path of the light the heat effect disappears and you will see that the alcohol column is no longer displaced because the alum, or the solution of alum, to speak precisely, hinders its passage. Soon you will see the column equalize, now that we have placed alum in the path, because the heat is not present. We have here a cold spectrum.

Now let us place in the light path the solution of iodine in carbon disulphate, and the middle portion of the spectrum disappears. It is very interesting that a solution of esculin will cut out the chemical effect. Unfortunately we could not get this substance. In this case, the heat effect and the light remain, but the chemical effect ceases. With the carbon disulphide you see clearly the red portion — it would not be there if the experiment were an entire success — and the violet portion, but the middle portion is dark. We have succeeded partly in our attempt to eliminate the bright portion of the spectrum. By carrying out the experiment in a suitable way as certain experimenters have done (for instance, Dreher, 50 years ago) the two bright portions you see here can be done away with. Then the temperature effect may be demonstrated on the red side, and on the other side phosphorescence shows the presence of the chemically active rays. This has not yet been fully demonstrated and it is of very great importance. It shows us how that which we think of as active in the spectrum can be conceived in its general cosmic relations.

In the course that I gave here previously I showed how a powerful magnet works on the spectral relations. The force emanating from the magnet alters certain lines, changes the picture of the spectrum itself. It is only necessary for a person to extend the thought prompted by this in order to enter the physical processes in his thinking. You know from what we have already said that there is really a complete spectrum, a collection of all possible twelve colors; that we have a circular spectrum instead of the spectrum spread out in one dimension of space. We have (in the circular spectrum) here green, peach blossom here, here violet and here red with the other shades between. Twelve shades, clearly distinguishable from one another.

Now the fact is that under the conditions obtaining on the earth such a spectrum can only

exist as a mental image. When we are dealing with this spectrum we can only do so by means of a mental picture. The spectrum we actually get is the well-known linear one extending as a straight line from red through the green to the blue and violet — thus we obtain a spectrum formed from the circular one, as I have often said, by making the circle larger and larger, so that the peach blossom disappears, violet shades off into infinity on one side and red shades off on the other, with green in the middle.

We may ask the question: how does this partial spectrum, this fragmentary color band arise from the complete series of color, the twelve color series which must be possible? Imagine to yourselves that you have the circular spectrum, and suppose forces to act on it to make the circle larger and larger and finally to break at this point (see drawing). Then, when it has opened, the action of these forces would make a straight line of the circle, a line extending apparently into infinity in each direction. (Fig. 1).

Now when we come upon this straight line spectrum here under our terrestrial conditions we feel obliged to ask the question: how can it arise? It can arise only in this way, that the seven known colors are separated out. They are, as it were, cut out of the complete spectrum by the forces that work into it. But we have already come upon these forces in the earth realm. We found them when we turned our attention to the forces of form. This too is a formative activity. The circular form is made over into the straight-line form. It is a form that we meet with here. And considering the fact that the structure of the spectrum is altered by magnetic forces, it becomes quite evident that forces making our spectrum possible are everywhere active. This being the case, we have to assume that our spectrum, which we consider a primary thing, has working within it certain forces. *Not only must we consider light variation in our ordinary spectrum, but we have to think of this ordinary spectrum as including forces which render it necessary to represent the spectrum by a straight line*. This idea we must link up with another, which comes to us when we go through the series, as we have frequently done before (Fig. 2), from solids, through fluids, to condensation and rarefaction, i.e. gases, to heat and then to that state we have called X, where we have materialization and dematerialization. Here we meet a higher stage of condensation and rarefaction, beyond the heat condition, just as condensation and rarefaction proper constitute a kind of fluidity of form.

When form itself becomes fluid, when we have a changing form in a gaseous body, that is a development from form as a definite thing. And what occurs here? A development of the condensation-rarefaction condition Keep this definitely in mind, that we enter a realm where we have a development of the condensation-rarefaction state.

What do we mean by a “development of rarefaction”? Well, matter itself informs us what happens to it when it becomes more and more rarefied. When I make matter more and more dense, it comes about that a light placed behind the matter does not shine through. When the matter becomes more and more rarefied, the light does pass through. When I rarefy enough, I finally come to a point where I obtain brightness as such. Therefore, what I bring into my understanding here in the material realm is empirically found to be the genesis of brightness or luminosity as a heightening of the condition of rarefaction; and darkening has to be thought of as a condensation, not yet intense enough to produce matter, but of such an

intensity as to be just on the verge of becoming material.

Now you see how I place the realm of light above the heat realm and how the heat is related to the light in an entirely natural fashion. But when you recollect how a given realm always gives a sort of picture of the realm immediately above it, then you must look in the being of heat for something that foreshadows, as it were, the conditions of luminosity and darkening. Keep in mind that we do not always find only the upper condition in the lower, but also always the lower condition in the upper. When I have a solid, it foreshadows for me the fluid. What gives it solidity may extend over into the non-solid realm. I must make it clear to myself, if I wish to keep my concepts real, that there is a mutual interpenetration of actual qualities. For the realm of heat this principle takes on a certain form; namely this, that dematerialization works down into heat from above (see arrow). From the lower side, the tendency to materialization works up into the heat realm.

Thus you see that I draw near to the heat nature when I see in it a striving for dematerialization, on the one hand, and on the other a striving for materialization. (If I wish to grasp its nature I can do it only by conceiving a life, a living weaving, manifesting itself as a tendency to materialization penetrated by a tendency to dematerialization.) Note, now, what an essential distinction exists between this conception of heat based on reality and the nature of heat as outlined by the so-called mechanical theory of heat of Clausius. In the Clausius theory we have in a closed space atoms or molecules, little spheres moving in all directions, colliding with each other and with the walls of the vessel, carrying on an outer movement. (Fig. 3) And it is positively stated: heat consists in reality in this chaotic movement, in this chance collision of particles with each other and with the walls of the vessel. A great controversy arose as to whether the particles were elastic or non-elastic. This is of importance only as the phenomena can be better explained on the assumption of elasticity or on the assumption that the particles are hard, non-elastic bodies. This has given form to the conviction that heat is purely motion in space. Heat is motion. We must now say "heat is motion," but in an entirely different sense. It is motion, but *intensified motion*. Wherever heat is manifest in space, there is a motion which creates the material state striving with a motion which destroys the material state. It is no wonder, my friends, that we need heat for an organism. We need heat in our organism simply to change continuously the spatially-extended into the spatially non-extended. When I simply walk through space, my will carries out a movement in space. When I think about it, something other than the spatial is present. What makes it possible for me as a human organism to be inserted into the form relationships of the earth? When I move over the earth, I change the entire terrestrial form. I change her form continually. What makes it possible that I am in relation to the other things of the earth, and that I can form ideas, outside of space, within myself as observer, of what is manifested in space? This is what makes it possible, my being exists in the heat medium and is thus continually enabled to transform material effects, spatial effects, into non-spatial ones that no longer partake of the space nature. In myself I experience in fact what heat really is, intensified motion. Motion that continually alternates between the sphere of pressure and the sphere of suction.

Assume that you have here (Fig. 4) the border between pressure and suction forces. The forces of pressure run their course in space, but the suction forces do not, as such, act in

space — they operate outside of space. For my thoughts, resting on the forces of suction, are outside of space. Here on one side of this line (see figure) I have the non-spatial. And now when I conceive of that which takes place neither in the pressure nor in the suction realms, but on the border line between the two, then I am dealing with the things that take place in the realm of heat. I have a continually maintained equilibrium tendency between pressure effects of a material sort and suction effects of a spiritual sort. It is very significant that certain physicists have had these things right under their noses but refuse to consider them. Planck, the Berlin physicist, has made the following striking statement: if we wish to get a concept of what is called ether nowadays, the first requisite is to follow the only path open to us, in view of the knowledge of modern physics, and consider the ether non-material. This from the Berlin physicist, Planck. The ether, therefore, is not to be considered as a material substance. But now, what we are finding beyond the heat region, the realm wherein the effects of light take place, that we consider so little allied to the material that we are assuming the pressure effects — characteristic of matter — to be completely absent, and only suction effects active there. Stated otherwise, we may say: we leave the realm of ponderable matter and enter a realm which is naturally everywhere active, but which manifests itself in a manner diametrically opposite to the realm of the material. Its forces we must conceive of as suction forces while material things obviously manifest through pressure forces. Thus, indeed, we come to an immediate concept of the being of heat as intensified motion, as an alternation between pressure and suction effects, but in such a way that we do not have, on the one hand, suction spatially manifested and, on the other hand, pressure spatially manifested. Instead of this, we have to think of the being of heat as a region where we entirely leave the material world and with it three-dimensional space. If the physicist expresses by formulae certain processes, and he has in these formulae forces, in the case where these forces are given the negative sign — when pressure forces are made negative — they become suction forces. Attention must be paid to the fact that in such a case one leaves space entirely. This sort of consideration of such formulae leads us into the realm of heat and light. Heat is only half included, for in this realm we have both pressure and suction forces.

These facts, my dear friends, can be given, so to speak, only theoretically today in this presentation in an auditorium. It must not be forgotten that a large part of our technical achievement has arisen under the materialistic concepts of the second half of the 19th century. It has not had such ideas as we are presenting and therefore such ideas cannot arise in it. If you think over the fruitfulness of the one-sided concepts for technology, you can picture to yourselves how many technical consequences might flow from adding to the modern technology, knowing only pressures — the possibility of also making fruitful these suction forces. (I mean not only spatially active suction which is a manifestation of pressure, but suction forces *qualitatively* opposite to pressure.)

Of course, much now incorporated in the body of knowledge known as physics will have to be discarded to make room for these ideas. For instance, the usual concepts of energy must be thrown out. This concept rests on the following very crude notions: when I have heat I can change it into work, as we saw from the up and down movement of the flask in the experiment resulting from the transformation of heat. But we saw at the same time that the heat was only partly changed and that a portion remained over of the total amount at hand.

This was the principle that led Eduard von Hartmann to enunciate the second important law of the modern physics of heat — a perpetuum mobile of the second type is impossible.

Another physicist, Mach, well known in connection with modern developments in this field, has done quite fundamental thinking on the subject. He has thought along lines that show him to be a shrewd investigator, but one who can only bring his thinking into action in a purely materialistic way. Behind his concepts stands the materialistic point of view. He seeks cleverly to push forward the concepts and ideas available to him. His peculiarity is that when he comes to the limit of the usual physical concepts where doubts begin to arise, he writes the doubts down at once. This leads soon to a despairing condition, because he comes quickly to the limit where doubts appear, but his way of expressing the matter is extremely interesting. Consider how things stand when a man who has the whole of physics at his command is obliged to state his views as mach states them. He says (Ernst Mach, *Die Prinzipien der Warme Lehre*, p. 345): "There is no meaning in expressing as work a heat quantity which cannot be transformed into work." (We have seen that there is such a residue.) "Thus it appears that the energy principle like other concepts of substance has validity for only a limited realm of facts. The existence of these limits is a matter about which we, by habit, gladly deceive ourselves."

Consider a physicist who, upon thinking over the phenomena lying before him, is obliged to say the following: "Heat exists, in fact, that I cannot turn into work, but there is no meaning in simply thinking of this heat as potential energy, as work not visible. However, I can perhaps speak of the changing of heat into work within a certain region — beyond this it is not valid." And in general it is said that every energy is transformable into another, but only by virtue of a certain habit of thinking about those limits about which we gladly deceive ourselves.

It is extremely interesting to pin physics down at the very point where doubts are expressed which must arise from a straightforward consideration of the facts.

Does this not clearly reveal the manner in which physics is overcome when physicists have been obliged to make such statements? For, fundamentally, this is nothing other than the following: one can no longer hold to the energy principle put forth as gospel by Helmoltz and his colleagues. *There are realms in which this energy principle does hold.*

Now let us consider the following: How can one make the attempt symbolically (for fundamentally it is symbolic when we try to set the outlines of something), how can we make the attempt to symbolize what occurs in the realm of heat? When you bring together all these ideas I have developed, and through which in a real sense I have tried to attain to the being of heat, then you can get a concept of this being in the following manner.

Picture this to yourselves (Fig. 5). Here is space (blue) filled with certain effects, pressure effects. Here is the non-spatial (red) filled with suction effects. Imagine that we have projected out into space what we considered as alternately spatial and non-spatial. The red portion must be thought of as non-spatial. Using this intermediate region as an image of what is alternately spatial and non-spatial, you have in it a region where something is

appearing and disappearing. Think of something represented as extended and disappearing. As substance appears, there enters in something from the other side that annihilates it, and then we have a physical-spiritual vortex continually manifesting in such a manner that what is appearing as substance is annihilated by what appears at the same time as spirit. We have a continual sucking up of what is in space by the entity which is outside of space.

What I am outlining to you here, my dear friends, you must think of as similar to a vortex. But in this vortex you should see simply in extension that which is "intensive" in its nature. In this way we approach, I might say figuratively, the being of heat. We have yet to show how this being of heat works so as to bring about such phenomena as conduction, the lowering of the melting point of an alloy below the melting point of its constituents, and what it really means that we should have heat effects at one end of the spectrum and chemical effects at the other.

We must seek the *deeds of heat* as Goethe sought out the *deeds of light*. Then we must see how knowledge of the being of heat is related to the application of mathematics and how it affects the imponderable of physics. In other words, how are real formulae to be built, applicable to heat and optics.

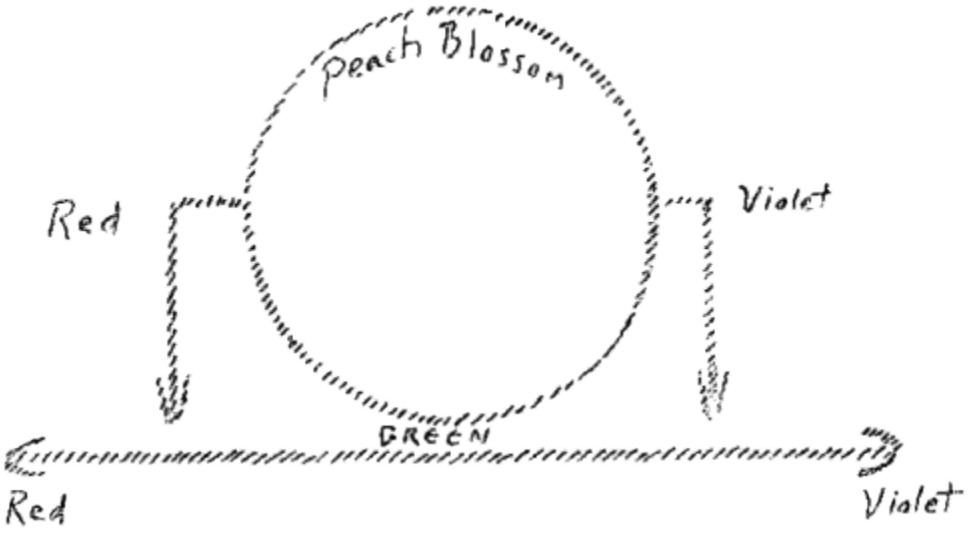

Figure 1

Materialize · Dematerialize	Dark · Light
Warmth	
Rarefaction, Condense	
Fluid	
Solid Form	

Figure 2

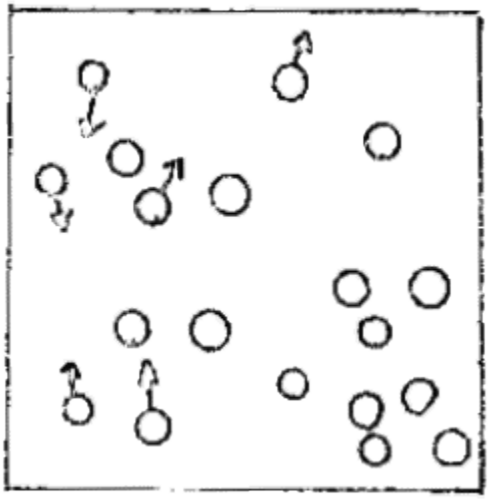

Figure 3

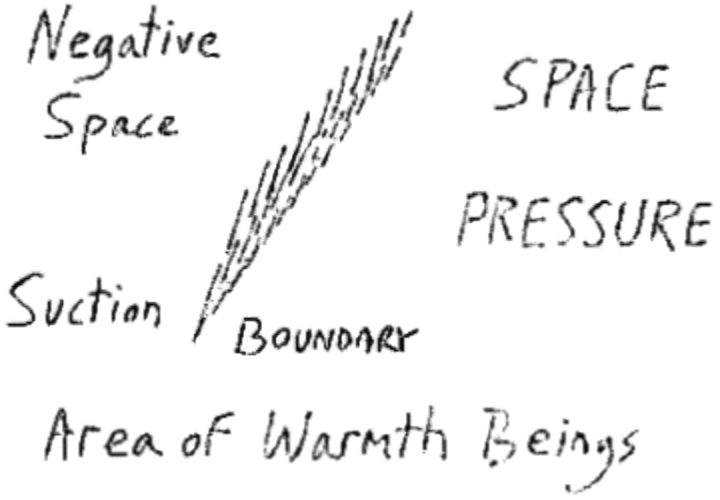

Figure 4

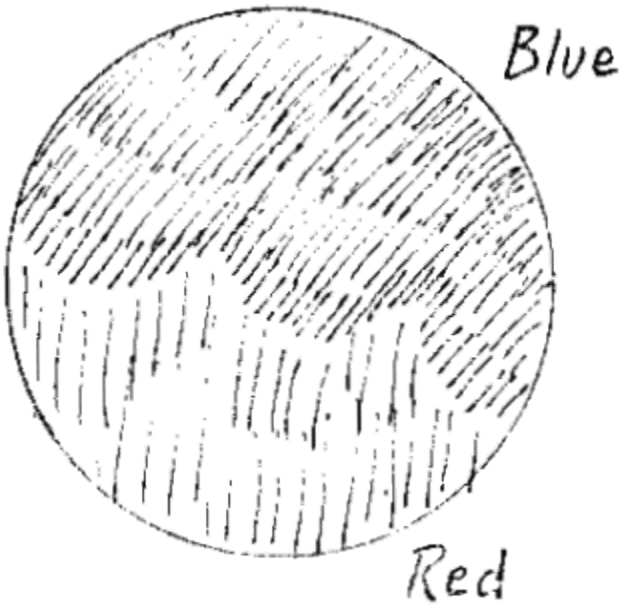

Figure 5

Second Scientific Lecture-Course: Warmth Course

Lecture XII

Stuttgart, March 12th, 1920.

My dear friends,

The experiments we had anticipated carrying out today we will unfortunately have to postpone until tomorrow. At that time they will be arranged so as to show you what is necessary if I am to prove to you all that I wish to prove. Today, therefore, we will consider some things which, together with the experiments of tomorrow, will enable us to bring our observations to a conclusion the following day.

As a help toward the understanding of the being of heat, I wish to call your attention to a certain fact. This fact is one which we must take into account in developing our ideas on this subject, and it is that there is a certain difficulty in understanding what is really involved in a transparent body. I am not now speaking of transparency in connection with heat. You will see, however, when we have finished that we can get helpful ideas for understanding heat from the realm of light.

I said there was a certain difficulty in understanding what a relatively transparent body is

and what an opaque body is as these reveal themselves under the influence of light. I have to express myself in a different way from that ordinarily used. The ordinary method of expression in physics would be as follows: an opaque body is one that by some peculiar property of its surface reflects the rays of light that fall on it and thus become a visible body. I cannot use this form of expression because it is not a reflection of the facts, it is a statement of a preconceived theory and is not by any means to be taken as self-evident.

For to speak of rays, of light rays, is theoretical. I have dealt with that in my former course. What we meet in reality is not light rays, but an image and it is this we must hold firmly in mind. As a matter of fact, we cannot simply say: a transparent body is one that by virtue of its inner molecular properties passes light through, and an opaque body is one that throws the light back. For how can such a theory be substantiated? Recollect what I have said to you about the relations of the various realms of reality. We have solids, fluids, gaseous bodies, heat, X, Y, Z and below the solid and bordering on it the U region, and you can see that the light realm must have a relation to heat and so also must the realm of chemical activity. On the other side that which we meet, so to speak, as the fluid nature in heat or in gases must have a relation to the essence of tone. For tone appears alone with the occurrence of condensation and rarefaction in gases or aeriform bodies. We may therefore suspect that where we have assumed X, Y, Z, we will find the essence of light. Now the question is whether we have to look for the explanation of transparency of certain bodies is not to be immediately derived from the nature of light, nor from the relation of light to these bodies.

We have the U region and this U region must have a relation to the solids on the surface of the earth. We must first ask the question and seek to apply the answer to this question to our consideration of these things. What influence has the U region on solids and can we from the nature of this influence derive anything that will show use the difference between transparent bodies and the ordinary non-transparent metals? This question must be considered and the answer to it will appear when we extend further our ideas of yesterday in regard to heat by the addition of certain other conceptions.

Note now, the warmth phenomena naturally are considered as belonging to the realm of physics. Such things as conduction have been included, thought of in the way I have described to you. This spreading of heat through conduction or flow of the heat condition either through a body or from one body to another one touching it has been observed. The flow has been conceived of as though a kind of fluid were involved, and the picture is of a liquid flow. It may be compared to something readily observable in the objective world, namely the water in a brook which is at one point now, and a moment later is at a distant point. Thus is pictured the flow of heat from one spot to another when the so-called conduction of heat takes place. The phenomenon are to be found in Fourrier (other investigators might also be cited.) Let us consider these a little from our own point of view and see if we can establish their validity.

Imagine that we have a body bounded by a definite wall, say of metal (Fig. 1). Assume the wall to extend indefinitely above and below, and suppose it to consist of some sort of metal. Let us place boiling water in contact with the wall on one side holding it at a temperature U_1

which in this case is 100°C. On the other side we place melting ice to hold the wall at a temperature U_2 which in this special case will be 0°C.

Considering the entire phenomenon you will see that we have to do with a difference, here U_1, here U_2; and U_1 and U_2 gives us the temperature difference. Upon this difference depends the fact that we have a conduction of heat. Obviously, this transfer of heat will proceed otherwise when the difference is small, a small quantity of heat is transferred to attain equilibrium, and when the difference is great a larger quantity is transferred. Thus I may say that the quantity of heat needed to attain a certain condition depends on this temperature difference, $U_1 - U_2$. Furthermore, it will depend not only on the difference $U_1 - U_2$, but on the thickness of the wall which I may denote by L, becoming greater when this is large and less when it is small. That is, the amount of heat transferred is inversely proportional to L. I may calculate for a given area that I will call Q, how much heat I will need to get a certain degree of conduction. The greater Q is, the greater will be the amount. Thus the amount of heat is directly proportional to Q and I must multiply by this factor.

Finally, the whole process is dependent upon time. A greater effect is produced by permitting a given amount of heat to act for a longer time, a smaller effect in a less time. Therefore I have to multiply by the time. Obviously then, I must multiply through by a constant representing the heat itself, by something involving heat, since none of the quantities so far mentioned include the heat and thus cannot by themselves give the quantity of heat, W, which I wish to secure. This quantity of heat, W, is directly proportional to L. Now if you equate all the other factors with U_1 and U_2, you are expressing what really flows and this not a heat quantity, essentially, nor dependent directly on a heat quantity, but is a temperature fall, a difference in level. Please keep this in mind. Just as when we pour water through a sluice and turn a paddle wheel, and the motion is due to the energy arising from a different in level, so there we have to do with a drop from one level to another, and it is this we must keep our attention on.

Now we have to take up another consideration of Fourrier's to draw nearer to the being of heat. We will work over the ordinary concepts as it were so as to move nearer to reality than the physicists of the 20th century. So far I have taken into consideration only what pertains to the conducting of heat from one spot to another, but I can assume that something goes on in the body itself. Let me now ask a question. Suppose we assume that the progress of heat instead of being uniform from left to right was non-uniform, then the formula would have to apply to the inner lack of uniformity. If the irregularity in the partition of heat is present I must bring it into my considerations in some way. I must bring in the differences that reveal themselves within, that is, what takes place in the body as the temperature effects equalize themselves. As you can easily see, my formula is applicable to the process. I can say

$$W = \frac{U_1 - U_2}{L} t, c, q.$$

That represents what takes place here. I will not consider the whole thickness of the wall, but deal with small portions of it, and will consider what happens in these small portions, as

over the entire distance it is expressed by the factor

$$\frac{U_1 - U_2}{L}$$

It is thus a question of dealing with minute distances within the body. To do this, I employ the differential ratio du

$$\frac{du}{dx}$$

where dx represents an infinitesimal movement of heat. If this is considered for an instant of time, I must multiply by dt, this being left out of account if I do not consider the time. Thus we have W as an expression of the quantity of heat transferred through small distance in order to equalize the temperature within the body. The following formula expresses the effects of temperature fall within the body:

$$W = \frac{du}{dx} dt, c, q.$$

In relation to this, I will ask you please to consider what we took up yesterday in a sketchy way, which will be clearer tomorrow when we have carried out the necessary experiments. Today, I will simply mention it, since we must keep it in mind. I refer to the relation between heat, light and chemical effect in the spectrum. Yesterday, your attention was called to the following fact: when we have an ordinary terrestrial spectrum, in the middle is the light effect proper, towards one end (Fig. 2, arrow) heat effects, toward the other end the chemical effects Now we have to consider the following.

We have seen that when we construct a picture of this spectrum, we must not think of light, heat and chemical effects as stretched out in a straight line. We go toward the left to approach the warm end of the spectrum and toward the right to approach the chemically active end. (Fig. 2) thus, it is not possible to remain in the lane of the pure light effects if we wish to symbolize the heat effects; nor can we remain in this place if we wish to symbolize the chemical effects. We have to move out of this plane.

Now to visualize the whole matter, let us make clear to ourselves how we must really represent a heat quantity working within a body by means of our formula. How must we represent qualitatively the relation between it and the chemical effect? We will not do this properly until we take into account the fact that we go one way to reach the heat and the opposite way to reach the chemical effects. This fact must be kept in mind if we would orient ourselves. So when we consider W as a *positive quantity* here (or we might consider

it negative) then we have to consider the corresponding chemical effect as:

$$W = - \frac{du}{dx} dt, c, q. \quad (1)$$

The foregoing equation corresponds to the chemical effect, and this one:

$$W = + \frac{du}{dx} dt, c, q. \quad (2)$$

corresponds to the heat effect.

As a matter of fact, these things demonstrate for us an important point. This point is that when we use formulae we cannot handle the mathematical quantities merely as such if we at the same time expect the formulae to express the relations within a field of actual effects, an observed realm, where heat and chemical action are manifesting themselves. In ordinary combustion, for instance, where we wish to bring heat and chemical effects into relation, we must, if we use formulae, *set down as positive what represents heat and as negative what represents chemical effect.*

Now if you carry your considerations further, you may make the following statement: When we think of heat as extending in one direction, so to speak, and chemical action as extending in the opposite, then we have what is essential in light left in a plane at right angles to the imagined chemical action-heat lines and between them. But if you have reserved positivity for heat and negativity for chemical action, you cannot use either of these for light effects. At this point you have to apply to the light effects a set of facts which today are only vaguely felt and not by any means explained, namely the relation between positive and negative numbers and imaginary numbers. When you are dealing with light phenomena you have to say:

$$W = \sqrt{\frac{du}{dx}} dt. c. q. \quad (3)$$

That is to say, if you wish to deal with the relation of heat, chemical action and light working in the same phenomenological field at the same time, you have to use imaginary numbers — your calculation has to involve the mathematical relations expressed in imaginary numbers. But now we have already made the following statement. The spectral band that we can produce experimentally under terrestrial conditions is to be thought of actually as a circle that has been opened out. Furthermore, the complete spectrum has the peach blossom color above. If, by the employment of a sufficiently great force, you were able to bend the spectrum into a circle, you would bring together what apparently extends off into infinity in either direction. Now you can realize that this closing up cannot simply

be thought of as being carried out in a circle in one plane. For as you go out into the heat region you also go off to one side (i.e. into something qualitatively different) and, proceeding into the chemical effect region, you go off to the other side. You are then in a situation where you must go first into the infinite on one side and then into the infinite on the other side and then into the infinite on the other side. You have first the awkward problem of going into infinity in a plane in one direction and then coming back from infinity and entering the plane on the other side. This implies that you reach the same infinite point no matter what direction you take. Moreover, you are confused unless you assume that you reach the same point as you go out in one direction and then in the other and you then have to come back from two different points at infinity. The way to discovery of the peach blossom color is thus a doubly complicated one. Not only must you bend the spectrum in one plane, but at right angles with, say an electromagnet, you will have to turn the magnet. That, however, lead to another point. If the magnet would have to be turned, then none of the mathematical expressions so far given would apply entirely. We then have to call in what was put before you yesterday in the discussion following the lecture by Messrs. Blumel and Strakesch, namely the *super-imaginary number*. You will doubtless recollect that we have to take into account that there is controversy about these super-imaginary numbers. They are readily handled mathematically and have, so to speak, more than one meaning. Some mathematicians even question whether there is any justification for them at all. Physics does not give us a definite formulation of the super-imaginary numbers. Nevertheless we put them into the series because we are led to see that they are necessary if we wish to formulate in an orderly manner what happens in the realm of chemical activity, light, heat, and what takes place in addition when we pass out in one direction through this series and come back into it from the other direction.

One who has the organ to perceive these things finds something very peculiar. He finds something which, I believe, furnishes a real foundation for illuminating the basic facts of physical phenomena. What I mean my friends, is this. The same sort of difficulty that meets one in the consideration of super-imaginary numbers also meets one when the attempt is made to apply the science of the inorganic to the phenomena of *life*. It cannot be done with these concepts of the inorganic. They simply do not apply. What has been the result of this? On the one hand there are thinkers who say: "The organic things of the earth have arisen by a transformation out of the inorganic." But with this view alone one can never enter the reality of the living. Other thinkers like Prayer, regard the organic as the source of the inorganic and come nearer the truth. They think of the earth as originally a living body and what is today inorganic they consider as something thrown off or as that which has died out of the organic. But these people do not make us an entirely satisfactory picture.

The same difficulty that meets us in the phenomena of nature considered by and for themselves is met also when we attempt a comprehensive formulation of what is present in the realms of heat, light, and chemical activity and what is come upon when we attempt to close the color band in a natural manner. We must assume, of course, that this color band can be closed somewhere although it is obvious that it cannot be done under terrestrial conditions.

It is necessary for us to recognize how the purely mathematical leads up to the problem of

living. With the faculties at hand today you can handle the phenomena of light, heat and chemical action, let us say, but you cannot handle what is evidently connected with these, namely the opening up of the spectrum. This cannot be formulated in a manner corresponding to the others.

It will be helpful to us at this stage if we set up a terminology. We can base this terminology on rather definite concepts. We say: Something real is at the basis of the formula for W. Let us speak of this as *heat ether*. Likewise something real is involved when we change the positive signs of the heat formula to negative ones, and here we speak of the *chemical ether*. Where our formulae involve imaginary numbers, we speak of the *light ether*. You see here an interesting parallelism between thinking in mathematics and thinking within science itself. The parallelism shows how we are really dealing not so much with an objective difficulty but rather with a subjective one. For the purely mathematical difficulty arises of itself, and independently of the science of external things. No one would think that a beautifully built lecture could be delivered on the limits of mathematical thinking, similar to the one du Bois-Reymond delivered on the limits of knowledge of nature. At least the conclusions would be different. Within mathematics, unless the matter slips us because it is too complicated, in this realm of the purely mathematical it must be possible to set up a completely formulated expression. The fact that one cannot do this hangs together with our own relative lack of maturity. It is unthinkable that we have here an absolute shortcoming or limit to human knowledge. It is extremely important that you hold this before your minds as a fundamental. For this shows us how we cannot apply mathematics if we wish to enter reality unless we keep in mind certain relations. We cannot simply say with the energeticists, for instance, "a given quantity of heat changes into a certain quantity of chemical energy and vice versa." That we cannot do, but we must bring in certain other values when a process of this kind takes place. For the necessity of the case constrains us to see as essential not the quantitative mechanical change from one energy to another but rather the qualitative aspect of the transformation. This is indeed to be found along with the quantitative.

If people turned their attention to these qualitative changes which are expressed by the numerical formulations, such ideas as the following would not be advanced: "Apparently heat is just heat because we experience it as such, mechanical energy is as we experience it, chemical energy is what we see as chemical processes; but within, these processes are all alike. Mechanical energy is manifesting everywhere and heat is nothing but a form of this energy."

This idea of a bombardment, of collisions between molecules and atoms or between these and the wall of the vessel — this struggle for an abstract unity of all energy which makes it into a mechanical motion and nothing more — such things as these would not have arisen if it had been seen that even when we calculate we must take into account the qualitative differences between various forms of energy. It is very interesting in this connection to see how Eduard von Hartmann was obliged to find definitions for physics that excluded the qualitative. Naturally, one cannot find this in the one-sided mathematics of physics, and aside from the cases where negative quantities arise from purely mathematical relations, physicists do not like to reckon with numerical quality differences. They use positive and

negative signs, but only because of purely mathematical relationships. In the ordinary theory of energy, justification would never be found for making one energy positive and another negative on the basis of qualitative differences.

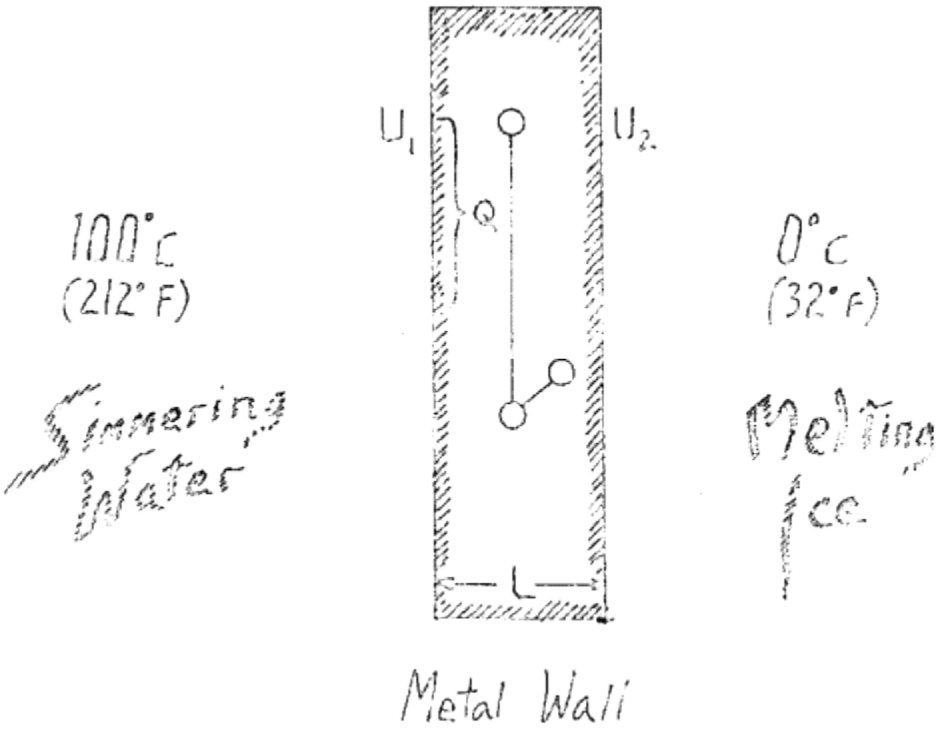

Figure 1

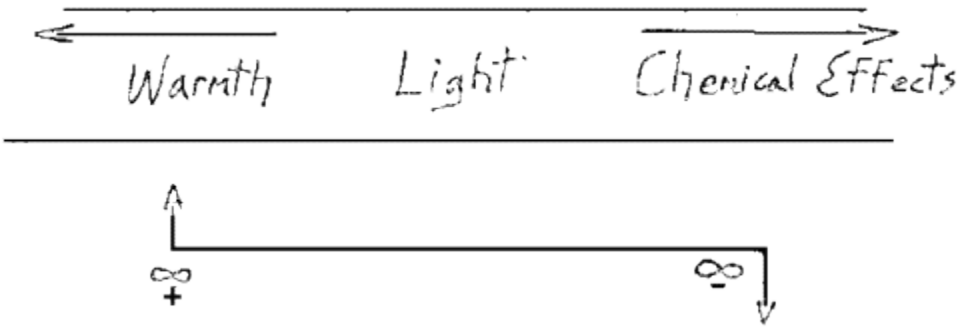

Figure 2

Second Scientific Lecture-Course: Warmth Course

Lecture XIII

Stuttgart, March 13th, 1920.

My dear friends,

We will today first carry out what I had in mind yesterday because it will lead us to a more prompt conclusion of our series. Tomorrow, I will try to conclude the lecture series being given during my present visit with you. We will now demonstrate to ourselves in a completely adequate fashion that within what we call the sun's spectrum or a light spectrum, there are wrapped up heat effects, light effects and chemical effects. Yesterday, also, we saw that the forces involved in the phenomena of life as well were hidden away here; only we are not able to bring these life-effects into the field of our investigations in the same manner as we can the chemical, light and heat effects. For, there is not a simple experimental method by which the reality of the twelve-fold spectrum can be shown in its objectivity. Just this thing will be the task of a Research Institute, working entirely within our movement. Such investigations will not only be undertaken but they must be followed out in detail.

Now I would like to call your attention to something. When we consider the hypothetical inclusion of life effects or the fact that our series , as we think of it at least, has hidden away in it life, heat, light and chemical effects, an important realm escapes us. This realm is physically more definitely manifested than the ones we have named. The realm that escapes us in the acoustical realm. The realm of acoustics is manifested strikingly in the movements of the air, that is, in the movement of the gaseous or aeriform body. And now comes up an important fundamental question.

How do we come in the one direction through the heat, light and chemical spectra to the *life forces* and on the other side to the *acoustic forces*?

This is the question that presents itself when we look over the whole field of phenomena and about which we can teach according to Goethe's views of the physical world, as we have done heretofore rather than simply theorizing about it.

Now let us show our first experiment. When we place a solution of alum in the path of a light cylinder made into a spectrum by passage through a prism we remove the heat effects. Let us permit the thermometer to rise in consequence of the action of the spectrum. When we place the solution of alum in the path of the spectrum, we have to look for a fall in the column of the thermometer. (the thermometer that had been going up rapidly, rose more slowly and then stopped.) The effect is shown by the fact that the thermometer rises more slowly. Therefore, the alum solution removes heat from the spectrum. We may consider this as proven — it has been done times without number and is a well-known fact.

The second experiment we will make is to insert into the light cylinder a solution of iodine in carbon disulphide. You will see, the central portion of the spectrum is thereby entirely blotted out and the other portions considerably weakened. From the previous course you will remember that we have to consider this central portion as the light-portion proper. Thus, the light-portion of this spectrum is stopped by the solution of iodine in carbon

disulphide just as the heat portion is stopped by the solution of alum. The thermometer now rises rapidly because the heat effect is present again. The third thing we will do is to place a solution of esculin in the path of light. This has the peculiarity of stopping the chemical effect leaving the heat and light effects unchanged.

We can, thus, so handle the spectrum that we can remove the heat effect by means of an alum solution, the light portion by a solution of iodine in carbon disulphide, and the chemical part by an esculin solution. We will establish the facts in regard to the chemical effect by showing that when the chemical portion is there, the phosphorescent body glows. You can see that this body has been in the light cylinder, because when I shut off the light momentarily, with my hand, it slows. Now we will place it again in the spectrum, but this time with the light cylinder passing through the esculin solution. The action is excellent. There is no phosphorescence visible. Now, place before yourselves the fact that we have first the realm of heat, then the realms of light and chemical action. From our considerations taken in their entirety, you can conclude with a fair degree of certainty, at least, that a relation must exist here similar to the ones I have in the past few days pointed out as the X and Y realms. It is in this way that we are approaching definitely the place where we can begin to identify these two realms:

Z
Y chemical effect
X light
heat
gaseous
fluid
solid
U

Let us observe particularly the following: The heat realm, the X, Y, and Z realms, the gaseous, fluid, solid and the U realms are to be arranged as we have outlines. Recollect that there is a matter of fact a certain very loose relationship to be observed between heat effects and the phenomena manifested in a gaseous mass. We are able to observe that the gaseous body manifests in its material configuration, what is manifested otherwise in the case of heat. The nature of heat is set before us materially in the gas. Now if we will cultivate a vivid insight into what occurs in this interplay between gaseous matter and heat, we will be able to get a concept also of the difference between the realm of gases and the x-realm. We need only consider what we have many times seen in our lives. This is that light relates itself quite otherwise to gases than does heat. The gas does not follow changes in light by corresponding changes in its material configuration. When the light spreads, the gas does

not do likewise, it does not show difference in pressure, etc.

Therefore when light is playing through a gas, the relationship is different from the one existing between the gas and heat playing through it. Thus, when light is active through the gas, there is a different relation involved than when heat is active through the gas. Now, in the observations made previously, we said: fluids stand between gas and solids, heat between gases and the X realm. Also the solid realm foreshadows the gaseous, and the gaseous gives a picture of heat. So likewise we can say that heat gives a picture of the X realm while heat is itself pictured in the gaseous. We have, as it were, in the gaseous, pictures of pictures of the X realm. Imagine now, these pictured pictures are really present with light passes through the air. Considering how the air relates itself in various phenomena to light, one must say that we are not dealing with a picturing of the one realm by the other, but rather that the light has an independent status in the gas. The matter may be figuratively expressed as follows: Suppose we paint a landscape and hang the picture on the wall of this room and then photograph the room. By thus changing something in the room, I alter its whole appearance and this alteration shows on the photograph. If I were accustomed always to sit on this chair when giving a lecture, and some ill-disposed person removed it while I lectured without my noticing what he was doing, I would do what many have done under similar circumstances, namely, sit on the floor. The relation of things in the room suffers real changes when I alter something in it. But whether I hand the picture in one place or another the relationship between the various figures painted upon it do not change. What exists in the picture itself in the way of relationships is not changed by alterations that go on in the room. In the same way, my experiments with light are not affected by the air in the space in which they are carried out. Experiments with heat are, on the contrary, related to the space in which they are carried out as you can convince yourselves, and indeed, you are made aware of this by the whole room becoming warm. But my light experiments have an independent being. I can think of them by themselves. Now, when I build up a concept of the action of X in a gas-filled space by analogy, I find the same relationships as if I am experimenting with light. I can identify X with light. A further extension of this train of thought leads to the identification of Y with chemical effects, and of Z with vital effects. However, as you see, there is a certain autonomy of light acting in the gaseous realm. The same sort of relationships are found when we extend a train of thought. You can do it for yourselves, it would lead us too far to do it here today. For instance, we would expect to find chemical effects in fluids, and this is in fact the case. In order to have chemical action solutions are necessary. In these solutions chemical action is related to the fluid as light is to the gas. We then have to expect to find a Z associated with the solid. This may be stated so — if I indicate the three realms by Z, Y and X, with heat as the intermediate realm and put X′ for the gas, Y′ for the fluid and Z′ for the solid, I can represent the order:

Z, Y, X, heat, X′, Y′, Z′.

X in X′ represents light in gas, Y in Y′ represents chemical effect in fluids, Z in Z′ represents the Z effect in solid bodies.

Formerly we knew these realms only as various types of manifested form. Now we meet interminglings as it were. These are representations of things that are very real in our lives.

X in X′ is light-filled gas, Y in Y′ is fluid in which chemical processes are going on, Z in Z′, life acting in solids. After yesterday's talk, you can scarcely doubt that just as we proceed beyond heat to find chemical effects. This was spoken of yesterday in a preliminary way. Therefore Z in Z′ represents vital effects in solid bodies. But there is no such thing as vital effects in solid bodies. We know that under terrestrial conditions a certain degree of fluidity is necessary for life. Under terrestrial conditions life does not manifest in the purely solid state. But, these same conditions force us to set it up as a hypothesis that such a condition is not beyond the realms of possibility. For the order in which we have been able to think of these things necessarily leads to this.

We find solid bodies, we find fluid bodies, we find gas. The solids we find without vitality. Vital effects in the terrestrial sphere we discover by unfolding themselves adjacent to solid bodies, in relation with them, etc. But we do not find an immediate coupling up of what we call solids with the living. We are led to this last member of the series, Z in Z′, the living in the solid realm by analogy from Y in Y′ and X in X′. Fluid bodies have the same relation to chemical activity although not so strong as do solid bodies to life. Gases, in the realm of the terrestrial, stand in the same relation to light that solids do to the living. Now, this leads us to recognize that solids, fluids and gases in their supplementary relations to light, chemical action and vital phenomena represent, as it were, something that has died out.

These things cannot be made as obvious as people like to make most presentations of empirical facts. If you wish to make these facts really mean something to you, you must work them over within yourselves and then you will find that *there is a relation between*:

The solid and the living
The fluid and the chemical
The gaseous and light

That stands as it were set off by itself. These relations are not, however, under terrestrial conditions immediately active. The relations that actually exist point to something that was once there but is there no longer. Certain inner relationships of the things force us to ring time concepts into the picture. When you look at a corpse you are forced into time concepts. The corpse is there. Everything that makes possible the presence of the corpse, that gives it the appearance it has, all this you must consider as soul and spirit since the corpse has in itself no possibilities of self-determination. A human form would never arise except for the presence of soul and spirit. What the corpse presents to you, forces you to say the following: The corpse as it exists there has been abandoned by the living, the terrestrial fluid by the emanations of chemical effects and the terrestrial gaseous by the emanations of light effects. And just as we glance back from the corpse to the living, to the time when matter that is now the corpse was bound together with the soul and spirit, so we glance from the solid bodies of the earth back to a former physical condition, when the solid was bound up with the living and only occurred bound to the living; fluid existed only bound to chemical effect and gases only bound to the light. In other words, all gas had an inner glittering, or inner illumination, an illumination that showed a wave-like phosphorescence and darkening as the gas was rarefied or condensed. Fluids were not as they are today but were permeated by a continuous living chemical activity. And at the foundation of all was life, active in

solidification (as it solidifies now in the horn formation in cattle, for instance) passing back again into fluid or gas, etc. In brief, we are forced by physics itself to admit a previous period of time when realms now torn apart existed together. The realms of the gaseous, the fluid and the solid are now found on the one hand, and on the other realms of light, chemical effects and vital activity. At that time they were within each other, not merely side by side, but actually within each other. Heat had an intermediate position. It did not appear to share this association of the more material and the more etheric natures. But since it occupied an intermediate position, it possessed an independence that was attributable to its not taking part in the two. If now we call the upper realm the etheric and the lower realm the region of ponderable matter, we obviously have to consider the heat realm as the equilibrium condition between them. *Thus in heat we have found that which is the equilibrium condition between the etheric body and the ponderable material*. It is ether and matter at the same time and indicates by its dual nature what we actually find in it, namely, a difference in level of transition. (Unless we understand this, we cannot understand or do anything in the realm of heat phenomena). If you take up this line of thinking, you will come to something much more fundamental and weighty than the so-called second law of thermodynamics: a perpetuum mobile of the second type is possible. For this second law really tears a certain realm of phenomena out of its proper connection. This realm is bound up with certain other phenomena and essentially and profoundly modified by them.

If you make it clear to yourselves that the gaseous realm and light were once united, that the fluid realm and chemical activity were once one, etc. then you will also be led to think of the two polarically opposed portions of the heat realm, namely ether and ponderable matter, as originally united. That is to say, you must conceive of heat in former ages as quite different from the heat you know now. Then you will come to say to yourselves, the things we define as physical phenomena today, the things that bear the impress of physical entities, these considerations of ours are limited in their meaning by time. *Physics is not eternal. In the case of certain types of reality physics has absolutely no validity*. For the reality that gas was once illumined within is an entirely different reality from the condition where gas and light are together in a relatively independent condition.

Thus, we come to see that there was a time when another type of physics was valid; and, looking forward, there will be a time when a still different type will be valid. Our modern physics must conform with the phenomena of the present time, with what is in our immediate environment. In order to avoid paradoxes, and not only these but absurdities, physics must be freed of the tendency to study terrestrial phenomena, build hypotheses based on them, and then apply these hypotheses to the whole universe. We do this, and forget that *what we know as physical is time-limited on the earth. That it is space-limited, we have already seen*. For the moment we move out to the sphere where gravity ceases and everything streams outward, at that moment our entire physical scheme ceases to apply.

We have to say that our earth is spatially limited as a physical body and what is more, spatially limited in its physical qualities. It is nonsensical to suppose that beyond the null-sphere the terrestrial physical laws apply. *Just as nonsensical is it to apply the present laws to former ages and infer the nature of earth evolution from what is going on at a particular*

time.

The madness of the Kant-Laplace theory consists in the belief that it is possible to abstract something from contemporary physical phenomena and extend it without more ado backwards in time. Modern astrophysics also shows the same madness to the belief that what can be abstracted from terrestrial physical conditions can be applied to the constitution of the sun and that we can look upon the sun as governed by the laws of the earth.

But a tremendously important thing unfolds for us when we take a general view over the phenomena we have considered and bring certain series of phenomena together.

Your attention has been called to the fact that the physicists have come to a certain view so neatly expressed by Eduard von Hartmann. The second law of thermodynamics states that whenever heat is changed into mechanical work some heat remains unchanged, and thus, finally, all energy must change into heat and the earth come to a heat death. This view has been expressed by Eduard von Hartmann as follows: "The world process has the tendency to run down."

Now suppose we assume such a running down of the world-process does take place in the direction indicated. What happens then?

When we make experiments to illustrate the second law of the mechanical theory of heat, heat appears. We see mechanical work used up and heat appearing. What we see appearing is susceptible to further change. For we can show likewise when we produce lights from heat that not all of the heat reappears as light, since heat simply reverses the mechanical process as it is understood in the sense of the second thermodynamic law of mechanical phenomena. This has, however, led us to say that we have to imagine the *whole cosmic spectrum as closed into a circle*. Thus if it were really true, as examination of a certain series of phenomena indicates, that the entropy of the cosmos is striving to the maximum, and that the world process is running down, provision is made for re-energizing it. It runs out here, but it runs in again here (indicating figure) on the other side, for we have to think of it as a circle. Thus even if the heat-death enters on one side, on the other side, there comes in that which re-establishes the equilibrium *and which opposes the heat-death by a cosmic creating process*.

Physics can orientate itself according to this fact if it will no longer observe the world process as we usually look at the spectrum, going off into infinity in the past we go from the red and again into infinity in the future as we go from the blue. *Instead the world process must be symbolized as a circle*. It is only thus that we can draw near to this process.

When now we have symbolized the world process as a circle then we can include in it what lies in the various realms. But we have had no opportunity in these realms to insert the acoustic phenomena. These, as it were, do not lie in the plane. In them we have something new and we will speak further of this tomorrow.

Second Scientific Lecture-Course: Warmth Course

Lecture XIV

Stuttgart, March 14th, 1920.

My dear friends,

Today it is my object by giving you a few indications to bring these observations to a close for the time being.

It is indeed obvious that what we have sought for in the former course and in this one can only come out fully when we are in a position to extend our treatment of the subject further. Today I will have a few remarks to make on this phase of the matter, at the conclusion of the lecture.

Let me first give a general summary of what we have taken under consideration in connection with heat and the matter related to it. Out of the array of concepts you have got, I will draw your attention to certain ones. They are the following. When we bring before our eyes the realms of reality that we are able to distinguish in physics, we may list them as follows:

The *solid* realm, which was have called Z′
The *fluid* realm, which we have called Y′
The *gaseous* or aeriform world, denoted by X′
The realm of chemical effects, which we call Y

And lastly, by Z we have denoted the life activity realm (see Table at end.) Moreover, we considered yesterday very definite conditions obtaining in regard to the heat state when we pass from X to X′ and from Y to Y′. We tried for example to bring before you the facts which showed how chemical effects could make themselves felt in the fluid element. One who strives to comprehend chemical processes finds the following: Wherever chemical processes are taking place, wherever chemical combinations and chemical dissociations occur, all that has a certain relation to the fluid element must enter in its own particular way into the solid or gaseous realms in order for the chemical effects to manifest themselves there. Thus when we consider our terrestrial chemistry we must keep before our yes an interpenetration, and with this interpenetration, a kind of mutual binding of chemical effects and the fluid realm. Our terrestrial chemistry presents to us, as it were, the fluid element animated by chemical effects.

But now, you will readily see that when we consider these various realms of reality it is impossible for us to think that this working of one realm in another is limited to the activity of heat in the gaseous realm. The other realms also work within each other. These call forth their appropriate effects in this or that field of action. We can indeed say the following: although chemical effects work primarily in the fluid medium since they have an inner relationship to is, we have also to visualize the working of the chemical on X′, that is to say a direct working on the chemical or gaseous or aeriform bodies. When I say “chemical effect” you must not think of that which comes to clear manifestation and is penetrated with an inner spirituality in the blue-violet portion of the spectrum. Here was have the chemical effect

standing, as it were, by itself in a certain independence over against the material realm. When, however, we speak of chemical processes, we are really dealing with this effect as it interpenetrates physical bodies. We must conceive of something here in this chemical realm that, at the outset, has nothing to do with ponderable matter, but interpenetrates it, and in particular does it *interpenetrate the fluid element* owing to an inner relationship that I showed you yesterday. But let us now ask ourselves the question: What happens when the chemical effect picks out (figuratively speaking) the next realm, the gaseous, or its activities? Then it must happen, considering the matter simply from the external point of view, that something takes its rise in the gaseous which shows an inner relationship to the manifestation of this effect in fluids, which can be compared to this manifestation. In the fluid, the chemical effect seizes upon the material, as it were, and brings this material into such a condition that a mutual interaction sets in. When we put the fluid element before us in thought, we must conceive of it as in mutual reaction with the chemical effect. Let us assume, however, that the action does not go so far as to admit of this seizing of the chemical effect on the matter itself, but let us assume that it works on the matter from the outside only, that it is a stage removed from it as compared to its action on the fluid. Then we have as in the gaseous, a process in which the chemical effect accompanies the material, in one stage removed as compared to its action in fluids. Then there comes about a certain wide independence of the imponderable as compared to the material carrier. In chemical processes proper, the imponderable seizes definitely on the material. Here, however, we come upon a realm where there is not this definite linkage where the imponderable does not definitely insert itself into matter. This is the case in the acoustical realm, in the effect of tone; while *in chemical processes in matter we have a complete submergence of the imponderable in matter, in tone we have a persistence of the imponderable as such*, a preservation of it in gaseous or aeriform matter. This leads us to something further. It leads us to the point when we have to say: There must be some reason why in fluids the imponderable seizes directly on the material, while in tone effects in the gaseous realm, the imponderable is less able to do this. If we observe chemical activity and have a feeling for what is to be seen within the physically visible, then we will as a matter of course, understand that it belongs to the nature of matter that chemical phenomena go as they do. That is to say: the imponderable is there as something which is a characteristic of matter. It is not possible otherwise than in this way, that when we are dealing with terrestrial matter the seizing upon the imponderable matter takes place through the earth. By means of the forces of the earth, the chemical effect is, so to speak, seized upon and works within the fluids. You see the forces of form stretched out over the whole terrestrial realm and active by virtue of the fact that these forces of form get hold of the interpenetrating chemical effect. When we really understand correctly that we have here the forces of the earth, then we have understood something further, if we will grasp the meaning of tone in the air, namely that an opposite kind of force is involved in tone. That is, we have to think as active in tone a force passing into the earth in all directions from the cosmos, a tendency overcoming the earth forces, and thus striving to separate the imponderable from the earth. This is the peculiarity of the tone world. It is this which gives a certain characteristic to the physics of tone, of acoustics. For in this realm we can on the one hand study the material processes and on the other hand we can live in the world of tone by means of our sensations without paying the slightest attention to the acoustical side. What does acoustics matter to us perceiving men, when we live in tone with our sensations? Acoustics is a beautiful science; it reveals for us striking inner laws and an inner order, but that which lies before us as a

subjective experience of tone is far, far removed from the physics of the tone as it is expressed in the material world.

And this is really due to the fact that tone manifestation preserves a certain individuality. It takes its origin from the periphery of the cosmos, while such a process as we observe in the chemical forces active in fluids, for instance, proceeds from the earth as a center.

Now there is one relation brought out also yesterday in Dr. Kolisko's lecture which shows itself only when we rise, as it were, to a universal point of view. This is that we can conceive of the periodic arrangement of the elements as octaves. In this we have an analogy between the inner laws of tone and the whole nature of matter as it demonstrates itself in chemical processes.

Thus is established the fact that we may conceive of all the combinations and breaking down of material compounds as an outer reflection of an inner world music. This inner world music reveals itself to us outwardly as such in only one particular form, namely in our terrestrial music. Music should never be so conceived that we merely say, what is tone within us, subjectively, is only vibrating air outside of us. This must be looked upon as nonsense.

It is to be considered just as nonsensical as if we were to say the following: What you are outwardly as a physical body that you are inwardly as a soul; such a statement leaves out the subject. Likewise we leave out the subject when we consider tone in its inner nature as identical with the condensations and rarefactions of the air that constitute, in the aerial medium, the carrier of tone. Now if you get a correct conception of this matter, you will see that we have in chemical processes to do with a certain relationship between Y and Y′, and in tone we have to do with a certain relationship between Y and X′ (See Table.)

I have already indicated to you that when we stand within this or that realm, what we become aware of in the outer world always pertains to difference in level or potential differences. Please endeavor now, to trace what is similar to potential difference in this realm we are dealing with. Let us try to trace what is similar to the potential difference which becomes active in the case where gravity is used to furnish a driving force for a wheel through the falling water. Let us make clear to ourselves that we have differences in level involved in temperature, heat, tone and in the equalization of electric strains. Everywhere are potential differences, we meet them wherever we study forces. But what do we have, then? We have an inner relationship between what we perceive in the spectrum and liquid matter; and that which presents itself to us as chemical process is nothing but the result of the difference between chemical effects and the forces that are in the fluid. It is a Y - Y′ potential difference. And in tone, a lower Y - X′ potential difference is manifesting.

Thus we can say: In relating a chemical process to the world of reality we are dealing with a potential difference between chemical effects and fluid forces. In the manifestation of tone and sound in the air, we are dealing with a potential difference between what is working formatively into chemical effects, what starts from the periphery into the world and the material of the gas, the aeriform body. Furthermore, what shows itself in this realm of reality manifests through potential differences. The matter rests on these differences in potential

even though we remain in one element, in warmth, or even in gas or in water. But especially when we perceive distinctions between realms, do we deal with potential differences in the effects of these realms.

Taking all of this together you come to the following: from a consideration of fluids and their boundary surfaces we are obliged to attribute the form of solids to earth forces. The extent to which gravity and the energies of configuration, to borrow a term from modern physics, are related, has been brought before you in past lectures. If we proceed from the forces that manifest in gravity, to those which result in liquid surfaces, apparently plane surfaces on account of the great size of the earth, we find we are really dealing with a sphere. Obviously the liquid levels of all the terrestrial bodies of water taken together constitute a sphere. Now you see, when we pass outwards from the center of the earth toward the surface of the sphere we meet successively certain sets of conditions. For terrestrial relations, within the solid realm we have forces which tend to close in, to delimit. Fluid forces, however, may perhaps be represented in their configuration by a line or plane tangential to the surface of the sphere. If we go further and observe the sphere from without we must put the matter in this way: beneath the sphere of liquid we have to deal with the formative forces of solids. In these formative forces which delimit solids we are dealing with a single body if we consider the earth as a whole.

The many single bodies together form a single form like the fluid element of the earth. How must we then conceive of these various conditions? For we have passed beyond the formed, beyond what is shaped from within as the solid bodies are. How must we picture this to ourselves? Well, we must conceive of it as the opposite condition. Within the sphere we have solids filled with matter, and without we must think of space filled with negative matter. Within we have filled space (see figure). *We must become accustomed to thinking of an emptying of space*. The earth is indeed not influenced only by what happens on it, but by the other effects from all sides. If this were not so, the terrestrial phenomena themselves would be different. This can only be mentioned today; later we will go into it more thoroughly. For instance, it would not be possible for us to have a separations of continents from bodies of water, or a north and a south pole, if in the environment of the earth there were not empty spaces. These “matterless” spaces must work in from various directions. If we search for them we find them in what the older cosmic systems designated as the planets, to which we must add also the sun.

Thus we are forced from the realm of the earth into the realm of the cosmos, and we are obliged to find the transition from the one condition of space to the opposite condition. We must learn to pass from a space filled positively with matter to one filled negatively with matter and this condition of negativity filled space so far as it acts on our earth we must think of as localized in the planets around the earth. Thus there is active at the point where terrestrial phenomena are going on a mutual interaction of the terrestrial proper and the cosmic, and this is due to the fact that from the negatively filled spaces, a suction-like action is going on while the formative forces are expressing themselves as pressures. This mutual interaction meets us in that particular force-configuration ordinarily sought for in molecular forces and attractions. We should conceive of these things as they were thought of by the intuitive knowledge of former times. Manifestations in matter, which are always

accompanied by the imponderable, were then thought of as influenced by the whole cosmos instead of being misinterpreted fantastically as due to certain theoretical inner configurations. What the stars, like giants, do in the cosmos is reflected in the terrestrial dwarfs, the atoms and molecules.

This indeed, is what we have to do; we must know that when we represent a terrestrial process or perform calculations on it, we are dealing with a picture of extra-terrestrial effects, with a mutual action of the terrestrial and the cosmic.

Now you see here we have the force that fills space with matter (see drawing.) Also, *here* we *still* have this force that fills space with matter, but this force is attenuated. Ultimately we come to the condition where there is negative matter. There must be a region between where, so to speak, space is torn apart.

We can put the matter in this way. Our space as it surrounds us constitutes a kind of vessel for physical manifestations, and has an inner relationship to these forces. Something in it corresponds to them. But when we go from the ponderable to the imponderable, space is torn apart. And in this tearing apart, something enters that was not there before it happened.

Let us assume that we tear apart the three dimensional space. What is it that enters through the rift? When I cut my finger, blood comes out — it is a manifestation in three dimensional space. But when I tear apart space itself that which comes through is something that is otherwise non-spatial.

Note how modern physical thinking is lost in the woods. Is it not true that when we make electrical experiments in the school room, our apparatus must be painstakingly dried, we must make it a good insulator, or our experiments will fail. If it is moist, the experiment will fail. But I have often called attention to the fact that the inner friction of clouds which are certainly moist is supposed to give rise to electricity which in turn produced lightning and thunder. This is one of the most impossible ideas that can be conceived.

Now on the other hand, if we bring together these things we have considered as necessary for a real understanding, then we can see that space is torn apart the moment the flash appears. At that moment, what fills space as non-dimensional entity, intensively, comes forth like the blood when I cut my hand. This is indeed always the case when light appears accompanied by heat. Space is torn apart. Space reveals to us what dwells within, while it shows us only its exterior in the usual three dimensions that we have before us. Space then shows us its inner content.

We may thus say: when we proceed from the ponderable to the imponderable and have to pass through the realm of heat as we go, we find heat welling out wherever we make the transition from the pressure effects of ponderable matter to the suction effects of the imponderable. At all such points of transition heat wells out.

Now you will see that when we are constructing ideas about the processes which we spoke of several days ago as processes of conduction of heat, you have to relate to them the concept

that the heat is bound to the ponderable matter. This is quite the opposite condition to that which we have considered as existing in radiating heat itself. This heat we find as the entity welling out when matter is torn apart. How will it affect matter? It will work from the intensive condition to the extensive. It will, so to speak, work from the inner portion of space into its outer portions. When heat and a material body mutually react on one another we see a certain thing occurring. What occurs is that the characteristic tendency of the heat is transformed. The suction effect is transformed into a pressure effect so that the cosmic tendency of the heat opposes the individualizing tendency of the material which, in solids, is the force that gives form.

We thus have in heat, in phenomena of warmth, insofar as these manifest a conductivity, to seek, not for rays, but for a tendency to spread in all directions. We must look for a mirroring of the imponderable matter, or for the presence of the imponderable in the ponderable. Bodies that conduct heat bring it into manifestation by an intensive reflection of the impinging imponderable heat on their material portion This is in contracts to the extensive reflection characteristic of light.

Now I wish to ask you to work over in your minds such concepts as we are accustomed to entertain and to work them over in the way we do here so that they become saturated with reality, as it were. Let me give you a picture in closing to recapitulate and show you how much reality-saturated concepts can lead us into a vital grasp of the being of the cosmos.

I have already called your attention to the basis upon which rests the perception, the subjective experiences of temperature. We really experience the difference between our own temperature and the temperature of the environment, which, indeed, is what the thermometer does — I have drawn this to your attention. But perception depends precisely on this that we have within us a certain condition and that which lies outside this condition constitutes our perception. *We cannot be a thing and perceive it at the same time*. But we must always be other than the conditions we are experiencing. Suppose we consider tone. Insofar as we are tone, we cannot experience tone. If we would answer without prejudice the question: what are we as experiencers of tone, we come to the conclusion that we simply experience one potential difference while we are the other potential difference. We experience the Y - X′ difference; we do not experience the Y - Y′ difference because that is part of our being in time. It accompanies our perception of tone. It is an orderly inner chemical process in our fluid nature and is a part of our being. What causes chemical effects within us produces certain orderly effects in the world itself. It is by no means without interest to picture the following to yourselves. You know well that the human body consists only of a small degree of solid constituents. More than 90 percent of it is water, what plays through us as a delicate chemical process while we listen to a symphony is an inner continually phosphorescent marvel in this fluid nature. We are in our inner nature what these chemical processes reflect from tone. And we become aware of the tone world through the fact that we are chemically the tone world in the sense I have presented to you.

Our understanding of man himself is really much broadened, you see, if we bring an understanding of physical problems to bear on the human body. But the thing we must strive for is not to form abstract concepts of which physics is so fond today Rather, we must force

our way through the concepts really woven into the world, the objective world. Fundamentally everything that spiritual science is striving to bring into the conceptual world and especially what it is striving to do to promote a certain way of thinking, has for its object to bring back into human development thought permeated with reality. And it is indeed necessary for this to happen. For this reason we must prosecute vigorously such studies as have been presented here during the last few days.

You can see, my friends, how everywhere around you something old is dying out. Is it not possible from examination of physical concepts, to see that something old is really dying out, for little is to be done with them? The very fact that we can build up a new physical concept even when we attempt it in such a limited way — for we can only give indications now — this fact shows that we stand today at a turning point in human development.,

We must, my friends, give thought to certain things. We must push forward the varied lines of endeavor which Dr. Baravalle, Dr. Blumel, Mr. Strakesch, and Dr. Kolisko have presented to you in order to give a new impulse to the development hitherto consummated by the human race. Thus we will lay foundations for progress.

You must see that people the world over are asking for an extension of these things. We must found schools. What is happening in the world outside? People are encouraging schools, the Danish school movement is an example. What is characteristic of the old schools is being carried into the new ones. But nothing new will come of this. The whole people will simply have fastened on them the thing that up to now has been fastened on the learned.

There is nothing sadder than to contemplate a future where the manner of thinking which has devastated the heads of the learned men in the fashion we have seen will be transmitted to the people of the whole earth through the school system. If we would found schools for the people, we must be sure that there will be something available to teach in them, something whose inner configuration represents an advance. We need first the science that can be given in these schools. People wish always to remain superficial, considering only what is obvious. Consequently, in a spiritual movement, they do not wish to do anything radical toward renewing their manner of thinking, but simply to bring to people the old, the disappearing. It is just in regard to physical facts that this tendency is most noticeable.

You will certainly find many things in these lectures that are unsatisfactory, for they can only be suggestive at best. One thing however, is shown, and that is the necessity to build anew our whole physical, chemical, physiological and biological thought world. It must be rebuilt from the fundamental up. We will naturally accomplish this when we have reconstructed not only the schools, but also the science itself. And until we have succeeded in so arranging things that the academic side has been renewed along the lines started in these last few days, only then will we reach that which will and must be reached if European civilization is not to perish in a spiritual sense.

Only consider the shocking trend in the modern academic world. We have long controversial papers read, completely divorced from real life. People sit in fine lecture halls and each reads his paper, but the others do not listen. For it is a noteworthy fact that one man is a specialist

in one line, another man is a specialist in a different line. The mathematician reads but the medical man does not listen. And when the medical man reads the thoughts of the mathematician are busy elsewhere. This is indeed a well known sign. Something new must be injected. And this something must have its center in a spiritual striving. We must see this point. Therefore, one can say: if we can but bring together this striving towards a new kind of reality with a building up of the way of thinking in our schools, then we will attain what must be attained.

You can see there is much to be done. We really learn how such is to be done only when we begin to go into details.

For this reason it is so pathetic that people today who cling to the old way of thinking, for it has become old, it has had its day — coin phrases and accumulate great amounts of money to perpetuate their academic system in the world. It is especially difficult because we must become fundamentally convinced that a genuine new world is necessary. We must not deceive ourselves and simply say, "build schools." We must live in reality and say, "first it is necessary to have something to teach in these schools for the people." And I would like to say that while fruitful technological results have flowed from science, a still more fruitful technology will flow from a popularizing of science of such a nature as we have tried to indicate here in the realm of physics.

We have in every case tried to emerge from the old theoretical point of view and enter into a point of view that is real, so that our concepts will be saturated with reality. This will yield technical results quite different from those attained up to the present. Practice and theory hang together inwardly. And when we see in any one case what reform is needed as in the case of physics, for instance, we can understand what must happen. Since the time has come when we must separate, I wish to emphasize that I have only indicated to you in these lectures what you are to see, to stimulate you to develop these things further. You will be able to develop them. Our mathematical physicists, whom we have among our number will be able to give new life to the old formulae. And they will find, when they apply to these old formulae the ideas I have indicated to you, that certain transformations can be made that are real metamorphoses. From these will grow much that will be of enormous importance technically for the further development of mankind. This is, of course, something which cannot be gone into in detail, but only can be indicated at this time.

But these observations must now be brought to a close and their further progress will depend on your own work. It is this that I wish you to take especially to heart, for the things are now extremely pressing that have to be accomplished in the three paths of human endeavor. These things have become urgent in our era and there is no time to lose because chaos stands before the door. A second thing to remember is this: The end can only be attained satisfactorily through an orderly human working together. Thus we must try to work out further within ourselves the things that have been stimulated, and you will also find something arising in the work of the Waldorf School. The moment you really try to utilize in pedagogy the definite and valid ideas we have set forth here, they will be taken up at once, and you will also discover that they will go well if you find it necessary to apply them in the conduct of lie. We could wish that one did not always have to speak about science to a public which while it

takes in much, is always exposed to the opinions of "rigorous scientific thinkers," to "authorities." These authorities have no inkling that all we observe is very definitely shot through with the play of something else. We can see this even from language.

Note that in language we have everything mutually related. We speak of an impact. Now it is only because we have *ourselves* brought about an impact and given a name to the phenomenon that we speak of an impact in a space free of human activity, and vice versa we speak of things that happen within us in words drawn from the outer world. But we do not realize that we should look into the outer world, that is the planetary world, if we will understand the terrestrial bodies, and because we not know this we cannot learn what is happening in the embryos of plants and animals or in any tiny cell upon which we turn our microscopes. We discover all sorts of interesting things, but the source of all this, the thing we long to know, we will only be able to see when we understand macroscopically these processes microscopically observed. We must see that the fertilization and the fruiting of outer nature takes place in a mutual interaction with the outer cosmos. We must study how to *conceive of the planets as points of departure for the working of the imponderable in the physical world, as if we are to grasp the relation of the cosmos to plant and animal germ cells*.

If we can learn to see all these things on a grand scale without, these things that today we look for under the microscope where they are not really present, if we try to see these things in that which surrounds us (in the cosmos) then we will make progress.

The way is now clear before us. Human prejudice makes for us a very, very serious barricade. This prejudice is hard to overcome. It is for us to do all that we can to overcome it.

Let us hope that we can at some future time continue again these discussions.

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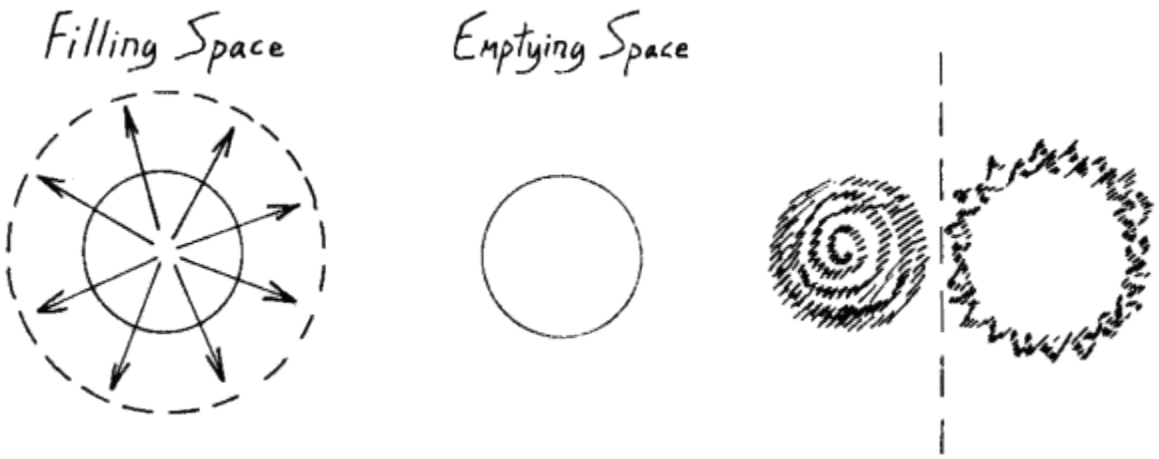

Figure 1