Helmholtz's Treatise

on

PHYSIOLOGICAL OPTICS

Translated from the Third German Edition

Edited by

James P. C. Southall

Formerly Professor of Physics in Columbia University

complete in three volumes bound as two

Volume III

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Volume III

Handbuch

der

Physiologischen Optik

von

H. von Helmholtz.

Dritte Auflage

ergänzt und herausgegeben in Gemeinschaft mit

Prof. Dr. A. Gullstrand und **Prof. Dr. J. von Kries**
Upsala Freiburg

von

Professor Dr. W. Nagel
Rostock

Dritter Band

Mit 81 Abbildungen im Text, 6 Tafeln
und einem Porträt von H. von Helmholtz

Die Lehre von den Gesichtswahrnehmungen
herausgegeben von Prof. Dr. **J. von Kries**

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EDITOR'S NOTE

This last volume comprising the third division of the Treatise on Physiological Optics is much larger than either of the other two volumes, although except for two brief Notes by Professor v. KRIES, which have been inserted at the end of Chapters 30 and 32, the text of the English Translation contains no new additions. While the Bibliography of recent literature which has been appended at the end of the volume does not pretend to be complete by any means, at least it will afford some idea of the vast amount of contemporary research and speculation on the subject of light and vision in all its manifold aspects and practical bearings; and taken in conjunction with similar lists given in Volumes I and II and the occasional references to new literature in the added footnotes in all three volumes, it should be useful in enabling the student to obtain some clues to the particular developments of those questions in which he happens to be mainly interested. The Index to all three volumes which is included also at the end of this volume is another addition that will increase the usefulness of the treatise as a book of reference. For many of the corrections given in the list of "Corrigenda in Volume II" I am especially indebted to Professor FRANK ALLEN and Professor E. J. WALL.

When one considers the comparatively limited means by which the sense of sight enables us to form more or less accurate conclusions about the nature and configuration of the various objects that are exposed to view in the visual field, and the amount of information that is conveyed to us in this way, the clearness and precision of the so-called Perceptions of Vision, which is the subject treated in this third volume, is indeed little short of marvellous. Here we are concerned not so much with physiological as with psychological optics; and here also fundamental philosophical speculations are bound to arise, which have been, and perhaps always will be, the subject of much controversy. Owing to the metaphysical nature of many of the questions that come up here for discussion, and doubtless owing also to my own limitations, the translation of this volume has been far more difficult than that of either of the other two volumes. I have sometimes doubted whether I had succeeded in expressing the precise shade of meaning that the writer wished to convey, conscientiously as I have striven to do so. However, any faults of this kind certainly cannot be attributed to lack of competent editorial assistance, as the enumeration of the following list of collaborators will suffice to show:

Dean R. P. ANGIER, Yale University (Chapters 6, 7 and 8 of v. KRIES's Appendix I); Dr. H. S. GRADLE, Chicago, Ill., (§§27 and 28); Prof. WILLIAM

Kunerth, Iowa State College (§§26 and 29); Prof. Jakob Kunz (and also Prof. Elmer Culler), University of Illinois (§§32 and 33, together with v. Kries's Notes on §31, and Chapters 1, 2, 3, 4 and 5 of v. Kries's Appendix I);Adolph Lomb, Esq., and H. C. Lomb, Esq., New York City, (two new Notes by v. Kries at the end of §§30 and 32); Dr. G. W. Moffitt, Frankford Arsenal, (v. Kries's Appendix II); Prof. L. D. Weld, Coe College (§31); and Prof. W. Weniger, Oregon State Agricultural College (§30).

I am particularly grateful also to Professor E. J. Wall for helping me with the proof-reading and to Miss Ruth Townsend for transcribing the entire manuscript with the most painstaking fidelity. Professor Wall and Mr. C. A. Peerenboom have both assisted me in compiling the Index of Authors.

I wish I could pay an adequate tribute to Mr. Adolph Lomb for his unfailing support and encouragement throughout. His noble and single-minded devotion to the advancement of science for the welfare of mankind is so genuine and unstinted that I know he will consider himself amply rewarded if the usefulness of Helmholtz's work is continued and extended by this English edition of the Treatise on Physiological Optics.

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Department of Physics,
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New York City, N. Y.
May 1, 1925.

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PART THIRD

The Theory of the Perceptions of Vision

§26. Concerning the Perceptions in General

The sensations aroused by light in the nervous mechanism of vision enable us to form conceptions as to the existence, form and position of external objects. These ideas are called *visual perceptions*. In this third subdivision of Physiological Optics we must try to analyze the scientific results which we have obtained concerning the conditions which give rise to visual perceptions.

Perceptions of external objects being therefore of the nature of ideas, and ideas themselves being invariably activities of our psychic energy, perceptions also can only be the result of psychic energy. Accordingly, strictly speaking, the theory of perceptions belongs properly in the domain of psychology. This is particularly true with respect to the mode of the mental activities in the case of the perceptions and with respect to the determination of their laws. Yet even here there is a wide field of investigation in both physics and physiology, inasmuch as we have to determine, scientifically as far as possible, what special properties of the physical stimulus and of the physiological stimulation are responsible for the formation of this or that particular idea as to the nature of the external objects perceived. In this part of the subject, therefore, we shall have to investigate the special properties of the retinal images, muscular sensations, etc., that are concerned in the perception of a definite position of the observed object, not only as to its direction but as to its distance; how the perception of the form of a body of three dimensions depends on certain peculiarities of the images; and under what circumstances it will appear single or double as seen by both eyes, etc. Thus, our main purpose will be simply to investigate the material of sensation whereby we are enabled to form ideas, in those relations that are important for the perceptions obtained from them. This problem can be solved entirely by scientific methods. At the same time, we cannot avoid referring to psychic activities and the laws that govern them, as far as they are concerned with the perception of the senses. But the discovery and description of these psychic activities will not be regarded as an essential part of our present task, because then we might run the risk of losing our hold of established facts and of not adhering steadily to a method founded on clear, well-recognized principals. Thus, for the present at least, I[1] think the psychological domain of the physiology

[1] ¶In this volume (contrary to the usage adopted in the two previous volumes of the English translation), the editor has deemed it best to retain the more intimate language of the original text, and let the author speak throughout in the first person. (J.P.C.S.)

of the senses should be kept separate from pure psychology, whose province really is to establish as far as possible the laws and nature of the processes of the mind.

Still we cannot altogether avoid speaking of the mental processes that are active in the sense-perceptions, if we wish to see clearly the connection between the phenomena and to arrange the facts in their proper relation to one another. And hence, to prevent any misconception of the plan I have in mind, I intend to devote the latter part of this chapter to a discussion of the conclusions which I think can be inferred with respect to these mental processes. And yet we know by experience that people very seldom come to any agreement as to abstract questions of this nature. The keenest thinkers, philosophers like KANT for instance, have long ago analyzed these relations correctly and demonstrated them, and yet there is no permanent and general agreement about them among educated people. And, therefore, in the subsequent chapters devoted specially to the theory of the visual perceptions, I shall endeavour to avoid all reference to opinions as to mental activity, as involving questions that always have been, and perhaps always will be, subjects of debate between the various metaphysical schools; so as not to distract the reader's attention from those facts about which an agreement may possibly be reached, by wrangling over abstract propositions that are not necessarily involved in the problem before us.

Here I shall merely indicate at the outset certain general characteristics of the mental processes that are active in the sense-perceptions, because they will be constantly encountered in connection with the various subjects to be considered. Without some previous explanation of their general significance and wide range of activity, the reader might be apt in some special case to regard them as paradoxical and incredible.

The general rule determining the ideas of vision that are formed whenever an impression is made on the eye, with or without the aid of optical instruments, is that *such objects are always imagined as being present in the field of vision as would have to be there in order to produce the same impression on the nervous mechanism, the eyes being used under ordinary normal conditions.* To employ an illustration which has been mentioned before, suppose that the eyeball is mechanically stimulated at the outer corner of the eye. Then we imagine that we see an appearance of light in front of us somewhere in the direction of the bridge of the nose. Under ordinary conditions of vision, when our eyes are stimulated by light coming from outside, if the region of the retina in the outer corner of the eye is to be stimulated, the light actually has

to enter the eye from the direction of the bridge of the nose. Thus, in accordance with the above rule, in a case of this kind we substitute a luminous object at the place mentioned in the field of view, although as a matter of fact the mechanical stimulus does not act on the eye from in front of the field of view nor from the nasal side of the eye, but, on the contrary, is exerted on the outer surface of the eyeball and more from behind. The general validity of the above rule will be shown by many other instances that will appear in the following pages.

In the statement of this rule mention is made of the ordinary conditions of vision, when the visual organ is stimulated by light from outside; this outside light, coming from the opaque objects in its path that were the last to be encountered, and having reached the eye along rectilinear paths through an uninterrupted layer of air. This is what is meant here by the normal use of the organ of vision, and the justification for using this term is that this mode of stimulation occurs in such an enormous majority of cases that all other instances where the paths of the rays of light are altered by reflections or refractions, or in which the stimulations are not produced by external light, may be regarded as rare exceptions. This is because the retina in the fundus of the firm eyeball is almost completely protected from the actions of all other stimuli and is not easily accessible to anything but external light. When a person is in the habit of using an optical instrument and has become accustomed to it, for example, if he is used to wearing spectacles, to a certain extent he learns to interpret the visual images under these changed conditions.

Incidentally, the rule given above corresponds to a general characteristic of all sense-perceptions, and not simply to the sense of sight alone. For example, the stimulation of the tactile nerves in the enormous majority of cases is the result of influences that affect the terminal extensions of these nerves in the surface of the skin. It is only under exceptional circumstances that the nerve-stems can be stimulated by more powerful agencies. In accordance with the above rule, therefore, all stimulations of cutaneous nerves, even when they affect the stem or the nerve-centre itself, are perceived as occurring in the corresponding peripheral surface of the skin. The most remarkable and astonishing cases of illusions of this sort are those in which the peripheral area of this particular portion of the skin is actually no longer in existence, as, for example, in case of a person whose leg has been amputated. For a long time after the operation the patient frequently imagines he has vivid sensations in the foot that has been severed. He feels exactly the places that ache on one toe or the other. Of course, in a case of this sort the stimulation can affect only what is left of the stem of the nerve

whose fibres formerly terminated in the amputated toes. Usually, it is the end of the nerve in the scar that is stimulated by external pressure or by contraction of the scar tissue. Sometimes at night the sensations in the missing extremity get to be so vivid that the patient has to feel the place to be sure that his limb is actually gone.

Thus it happens, that when the modes of stimulation of the organs of sense are unusual, incorrect ideas of objects are apt to be formed; which used to be described, therefore, as *illusions of the senses*. Obviously, in these cases there is nothing wrong with the activity of the organ of sense and its corresponding nervous mechanism which produces the illusion. Both of them have to act according to the laws that govern their activity once for all. It is rather simply an illusion in the judgment of the material presented to the senses, resulting in a false idea of it.

The psychic activities that lead us to infer that there in front of us at a certain place there is a certain object of a certain character, are generally not conscious activities, but unconscious ones. In their result they are equivalent to a *conclusion*, to the extent that the observed action on our senses enables us to form an idea as to the possible cause of this action; although, as a matter of fact, it is invariably simply the nervous stimulations that are perceived directly, that is, the actions, but never the external objects themselves. But what seems to differentiate them from a conclusion, in the ordinary sense of that word, is that a conclusion is an act of conscious thought. An astronomer, for example, comes to real conscious conclusions of this sort, when he computes the positions of the stars in space, their distances, etc., from the perspective images he has had of them at various times and as they are seen from different parts of the orbit of the earth. His conclusions are based on a conscious knowledge of the laws of optics. In the ordinary acts of vision this knowledge of optics is lacking. Still it may be permissible to speak of the psychic acts of ordinary perception as *unconscious conclusions*, thereby making a distinction of some sort between them and the common so-called conscious conclusions. And while it is true that there has been, and probably always will be, a measure of doubt as to the similarity of the psychic activity in the two cases, there can be no doubt as to the similarity between the results of such unconscious conclusions and those of conscious conclusions.

These unconscious conclusions derived from sensation are equivalent in their consequences to the so-called *conclusions from analogy*. Inasmuch as in an overwhelming majority of cases, whenever the parts of the retina in the outer corner of the eye are stimulated, it has been

found to be due to external light coming into the eye from the direction of the bridge of the nose, the inference we make is that it is so in every new case whenever this part of the retina is stimulated; just as we assert that every single individual now living will die, because all previous experience has shown that all men who were formerly alive have died.

But, moreover, just because they are not free acts of conscious thought, these unconscious conclusions from analogy are irresistible, and the effect of them cannot be overcome by a better understanding of the real relations. It may be ever so clear how we get an idea of a luminous phenomenon in the field of vision when pressure is exerted on the eye; and yet we cannot get rid of the conviction that this appearance of light is actually there at the given place in the visual field; and we cannot seem to comprehend that there is a luminous phenomenon at the place where the retina is stimulated. It is the same way in case of all the images that we see in optical instruments.

On the other hand, there are numerous illustrations of fixed and inevitable associations of ideas due to frequent repetition, even when they have no natural connection, but are dependent merely on some conventional arrangement, as, for example, the connection between the written letters of a word and its sound and meaning. Still to many physiologists and psychologists the connection between the sensation and the conception of the object usually appears to be so rigid and obligatory that they are not much disposed to admit that, to a considerable extent at least, it depends on acquired experience, that is, on psychic activity. On the contrary, they have endeavoured to find some mechanical mode of origin for this connection through the agency of imaginary organic structures. With regard to this question, all those experiences are of much significance which show how the judgment of the senses may be modified by experience and by training derived under various circumstances, and may be adapted to the new conditions. Thus, persons may learn in some measure to utilize details of the sensation which otherwise would escape notice and not contribute to obtaining any idea of the object. On the other hand, too, this new habit may acquire such a hold that when the individual in question is back again in the old original normal state, he may be liable to illusions of the senses.

Facts like these show the widespread influence that experience, training and habit have on our perceptions. But how far their influence really does extend, it would perhaps be impossible to say precisely at present. Little enough is definitely known about infants and very young animals, and the interpretation of such observations as have been made on them is extremely doubtful. Besides, no one can say that

infants are entirely without experience and practice in tactile sensations and bodily movements. Accordingly, the rule given above has been stated in a form which does not anticipate the decision of this question. It merely expresses what the result is. And so it can be accepted even by those who have entirely different opinions as to the way ideas originate concerning objects in the external world.

Another general characteristic property of our sense-perceptions is, that *we are not in the habit of observing our sensations accurately, except as they are useful in enabling us to recognize external objects. On the contrary, we are wont to disregard all those parts of the sensations that are of no importance so far as external objects are concerned.* Thus in most cases some special assistance and training are needed in order to observe these latter subjective sensations. It might seem that nothing could be easier than to be conscious of one's own sensations: and yet experience shows that for the discovery of subjective sensations some special talent is needed, such as PURKINJE manifested in the highest degree; or else it is the result of accident or of theoretical speculation. For instance, the phenomena of the blind spot were discovered by MARIOTTE from theoretical considerations. Similarly, in the domain of hearing, I discovered the existence of those combination tones which I have called summation tones. In the great majority of cases, doubtless it was accident that revealed this or that subjective phenomenon to observers who happened to be particularly interested in such matters. It is only when subjective phenomena are so prominent as to interfere with the perception of things, that they attract everybody's attention. Once the phenomena have been discovered, it is generally easier for others to perceive them also, provided the proper precautions are taken for observing them, and the attention is concentrated on them. In many cases, however—for example, in the phenomena of the blind spot, or in the separation of the overtones and combination tones from the fundamental tones of musical sounds, etc.—such an intense concentration of attention is required that, even with the help of convenient external appliances, many persons are unable to perform the experiments. Even the after-images of bright objects are not perceived by most persons at first except under particularly favourable external conditions. It takes much more practice to see the fainter kinds of after-images. A common experience, illustrative of this sort of thing, is for a person who has some ocular trouble that impairs his vision to become suddenly aware of the so-called *mouches volantes* in his visual field, although the causes of this phenomenon have been there in the vitreous humor all his life. Yet now he will be firmly persuaded that these corpuscles have developed as the result of his

ocular ailment, although the truth simply is that, owing to his ailment, the patient has been paying more attention to visual phenomena. No doubt, also, there are cases where one eye has gradually become blind, and yet the patient has continued to go about for an indefinite time without noticing it, until he happened one day to close the good eye without closing the other, and so noticed the blindness of that eye.[1]

When a person's attention is directed for the first time to the double images in binocular vision, he is usually greatly astonished to think that he had never noticed them before, especially when he reflects that the only objects he has ever seen single were those few that happened at the moment to be about as far from his eyes as the point of fixation. The great majority of objects, comprising all those that were farther or nearer than this point, were all seen double.

Accordingly, the first thing we have to learn is to pay heed to our individual sensations. Ordinarily we do so merely in case of those sensations that enable us to find out about the world around us. In the ordinary affairs of life the sensations have no other importance for us. Subjective sensations are of interest chiefly for scientific investigations only. If they happen to be noticed in the ordinary activity of the senses, they merely distract the attention. Thus while we may attain an extraordinary degree of delicacy and precision in objective observation, we not only fail to do so in subjective observations, but indeed we acquire the faculty in large measure of overlooking them and of forming our opinions of objects independently of them, even when they are so pronounced that they might easily be noticed.

The most universal sign by which subjective visual phenomena can be identified appears to be by the way they accompany the movement of the eye over the field of view. Thus, the after-images, the *mouches volantes*, the blind spot, and the "luminous dust" of the dark field all participate in the motions of the eye, and coincide successively with the various stationary objects in the visual field. On the other hand, if the same phenomena recur again invariably at the same places in the visual field, they may be regarded as being objective and as being connected with external bodies. This is the case with contrast phenomena produced by after-images.

The same difficulty that we have in observing subjective sensations, that is, sensations aroused by internal causes, occurs also in trying to analyze the compound sensations, invariably excited in the same connection by any simple object, and to resolve them into their separate

[1] ¶Nearly everybody has a dominant eye, which governs the other eye; and in which the vision is superior to that in the other eye. But not many persons are aware of the fact. (J.P.C.S.)

components. In such cases experience shows us how to recognize a compound aggregate of sensations as being the sign of a simple object. Accustomed to consider the sensation-complex as a connected whole, generally we are not able to perceive the separate parts of it without external help and support. Many illustrations of this kind will be seen in the following pages. For instance the perception of the apparent direction of an object from the eye depends on the combination of those sensations by which we estimate the adjustment of the eye, and on being able to distinguish those parts of the retina where light falls from those parts where it does not fall. The perception of the solid form of an object of three dimensions is the result of the combination of two different perspective views in the two eyes. The gloss of a surface, which is apparently a simple effect, is due to differences of colouring or brightness in the images of it in the two eyes. These facts were ascertained by theory and may be verified by suitable experiments. But usually it is very difficult, if not impossible, to discover them by direct observation and analysis of the sensations alone. Even with sensations that are much more involved and always associated with frequently recurring complex objects, the oftener the same combination recurs, and the more used we have become to regarding the sensation as the normal sign of the real nature of the object, the more difficult it will be to analyze the sensation by observation alone. By way of illustration, it is a familiar experience that the colours of a landscape come out much more brilliantly and definitely by looking at them with the head on one side or upside down than they do when the head is in the ordinary upright position. In the usual mode of observation all we try to do is to judge correctly the objects as such. We know that at a certain distance green surfaces appear a little different in hue. We get in the habit of overlooking this difference, and learn to identify the altered green of distant meadows and trees with the corresponding colour of nearer objects. In the case of very distant objects like distant ranges of mountains, little of the colour of the body is left to be seen, because it is mainly shrouded in the colour of the illuminated air. This vague blue-grey colour, bordered above by the clear blue of the sky or the red-yellow of the sunset glow, and below by the vivid green of meadows and forests, is very subject to variations by contrast. To us it is the vague and variable colour of distance. The difference in it may, perhaps, be more noticeable sometimes and with some illuminations than at other times. But we do not determine its true nature, because it is not ascribed to any definite object. We are simply aware of its variable nature. But the instant we take an unusual position, and look at the landscape with the head under one arm, let us say, or

between the legs, it all appears like a flat picture; partly on account of the strange position of the image in the eye, and partly because, as we shall see presently, the binocular judgment of distance becomes less accurate. It may even happen that with the head upside down the clouds have the correct perspective, whereas the objects on the earth appear like a painting on a vertical surface, as the clouds in the sky usually do. At the same time the colours lose their associations also with near or far objects, and confront us now purely in their own peculiar differences.[1] Then we have no difficulty in recognizing that the vague blue-grey of the far distance may indeed be a fairly saturated violet, and that the green of the vegetation blends imperceptibly through blue-green and blue into this violet, etc. This whole difference seems to me to be due to the fact that the colours have ceased to be distinctive signs of objects for us, and are considered merely as being different sensations. Consequently, we take in better their peculiar distinctions without being distracted by other considerations.

The connection between the sensations and external objects may interfere very much with the perception of their simplest relations. A good illustration of this is the difficulty about perceiving the double images of binocular vision when they can be regarded as being images of one and the same external object.

In the same way we may have similar experiences with other kinds of sensations. The sensation of the *timbre* of a sound, as I have shown elsewhere,[2] consists of a series of sensations of its partial tones (fundamental and harmonics); but it is exceedingly difficult to analyze the compound sensation of the sound into these elementary components. The tactile sensation of wetness is composed of that of coldness and that of smoothness of surface. Consequently, on inadvertently touching a cold piece of smooth metal, we often get the impression of having touched something wet. Many other illustrations of this sort might be adduced. They all indicate that we are exceedingly well trained in finding out by our sensations the objective nature of the objects around us, but that we are completely unskilled in observing the sensations *per se*; and that the practice of associating them with things outside of us actually prevents us from being distinctly conscious of the pure sensations.

This is true also not merely with respect to qualitative differences

[1] This explanation is given also by O. N. Rood, Silliman's *Journ.*, (2) xxxii. 1861. pp. 184, 185.

[2] Helmholtz, *Die Lehre von den Tonempfindungen.* Braunschweig 1862. (¶See English translation by A. J. Ellis, entitled *On the sensations of tone as a physiological basis for the theory of music.* 3rd ed. London and New York, 1895.—J.P.C.S.)

of sensation, but it is likewise true with respect to the perception of space-relations. For example, the spectacle of a person in the act of walking is a familiar sight. We think of this motion as a connected whole, possibly taking note of some of its most conspicuous singularities. But it requires minute attention and a special choice of the point of view to distinguish the upward and lateral movements of the body in a person's gait. We have to pick out points or lines of reference in the background with which we can compare the position of his head. But look through an astronomical telescope at a crowd of people in motion far away. Their images are upside down, but what a curious jerking and swaying of the body is produced by those who are walking about! Then there is no trouble whatever in noticing the peculiar motions of the body and many other singularities of gait; and especially differences between individuals and the reasons for them, simply because this is not the everyday sight to which we are accustomed. On the other hand, when the image is inverted in this way, it is not so easy to tell whether the gait is light or awkward, dignified or graceful, as it was when the image was erect.

Consequently, it may often be rather hard to say how much of our apperceptions (*Anschauungen*) as derived by the sense of sight is due directly to sensation, and how much of them, on the other hand, is due to experience and training. The main point of controversy between various investigators in this territory is connected also with this difficulty. Some are disposed to concede to the influence of experience as much scope as possible, and to derive from it especially all notion of space. This view may be called the *empirical theory* (*empiristische Theorie*). Others, of course, are obliged to admit the influence of experience in the case of certain classes of perceptions; still with respect to certain elementary apperceptions that occur uniformly in the case of all observers, they believe it is necessary to assume a system of innate apperceptions that are not based on experience, especially with respect to space-relations. In contradistinction to the former view, this may perhaps be called the *intuition theory* (*nativistische Theorie*) of the sense-perceptions.

In my opinion the following fundamental principles should be kept in mind in this discussion.

Let us restrict the word *idea* (*Vorstellung*) to mean the image of visual objects as retained in the memory, without being accompanied by any present sense-impressions; and use the term *apperception* (*Anschauung*) to mean a perception (*Wahrnehmung*) when it is accompanied by the sense-impressions in question. The term *immediate perception* (*Perzeption*) may then be employed to denote an apperce-

tion of this nature in which there is no element whatever that is not the result of direct sensations, that is, an apperception such as might be derived without any recollection of previous experience. Obviously, therefore, one and the same apperception may be accompanied by the corresponding sensations in very different measure. Thus idea and immediate perception may be combined in the apperception in the most different proportions.[1]

A person in a familiar room which is brightly lighted by the sun gets an apperception that is abundantly accompanied by very vivid sensations. In the same room in the evening twilight he will not be able to recognize any objects except the brighter ones, especially the windows. But whatever he does actually recognize will be so intermingled with his recollections of the furniture that he can still move about in the room with safety and locate articles he is trying to find, even when they are only dimly visible. These images would be utterly insufficient to enable him to recognize the objects without some previous acquaintance with them. Finally, he may be in the same room in complete darkness, and still be able to find his way about in it without making mistakes, by virtue of the visual impressions formerly obtained. Thus, by continually reducing the material that appeals to the senses, the perceptual-image (*Anschauungsbild*) can ultimately be traced back to the pure memory-image (*Vorstellungsbild*) and may gradually pass into it. In proportion as there is less and less material appeal to the senses, a person's movements will, of course, become more and more uncertain, and his apperception less and less accurate. Still there will be no peculiar abrupt transition, but sensation and memory will continually supplement each other, only in varying degrees.

But even when we look around a room of this sort flooded with sunshine, a little reflection shows us that under these conditions too a large part of our perceptual-image may be due to factors of memory and experience. The fact that we are accustomed to the perspective distortions of pictures of parallelopipeds and to the form of the shadows they cast has much to do with the estimation of the shape and dimensions of the room, as will be seen hereafter. Looking at the room with one eye shut, we think we see it just as distinctly and definitely as with both eyes. And yet we should get exactly the same view in case every

[1] ¶It is very difficult to find the precise English equivalents for these metaphysical terms, which will prove satisfactory to everybody. And it may not be quite possible to restrict the English word "idea," for example, to the definition here given. It is doubtful whether the author himself is scrupulously careful throughout the remainder of this work to distinguish these shades of meaning always exactly. (J.P.C.S.)

point in the room were shifted arbitrarily to a different distance from the eye, provided they all remained on the same lines of sight.

Thus in a case like this we are really considering an extremely multiplex phenomenon of sense; but still we ascribe a perfectly definite explanation to it, and it is by no means easy to realize that the monocular image of such a familiar object necessarily means a much more meagre perception than would be obtained with both eyes. Thus too it is often hard to tell whether or not untrained observers inspecting stereoscopic views really notice the peculiar illusion produced by the instrument.

We see, therefore, how in a case of this kind reminiscences of previous experiences act in conjunction with present sensations to produce a perceptual image (*Anschauungsbild*) which imposes itself on our faculty of perception with overwhelming power, without our being conscious of how much of it is due to memory and how much to present perception.

Still more remarkable is the influence of the comprehension of the sensations in certain cases, especially with dim illumination, in which a visual impression may be misunderstood at first, by not knowing how to attribute the correct depth-dimensions; as when a distant light, for example, is taken for a near one, or *vice versa*. Suddenly it dawns on us what it is, and immediately, under the influence of the correct comprehension, the correct perceptual image also is developed in its full intensity. Then we are unable to revert to the previous imperfect apperception.

This is very common especially with complicated stereoscopic drawings of forms of crystals and other objects which come out in perfect clearness of perception the moment we once succeed in getting the correct impression.

Similar experiences have happened to everybody, proving that the elements in the sense-perceptions that are derived from experience are just as powerful as those that are derived from present sensations. All observers who have thoroughly investigated the theory of the sense-perceptions, even those who were disposed to allow experience as little scope as possible, have always admitted this.

Hence, at all events it must be conceded that, even in what appears to the adult as being direct apperception of the senses, possibly a number of single factors may be involved which are really the product of experience; although at the time it is difficult to draw the line between them.

Now in my opinion we are justified by our previous experiences in stating that no indubitable present sensation can be abolished and

overcome by an act of the intellect; and no matter how clearly we recognize that it has been produced in some anomalous way, still the illusion does not disappear by comprehending the process. The attention may be diverted from sensations, particularly if they are feeble and habitual; but in noting those relations in the external world, that are associated with these sensations, we are obliged to observe the sensations themselves. Thus we may be unmindful of the temperature-sensation of our skin when it is not very keen, or of the contact-sensations produced by our clothing, as long as we are occupied with entirely different matters. But just as soon as we stop to think whether it is warm or cold, we are not in the position to convert the feeling of warmth into that of coldness; maybe because we know that it is due to strenuous exertion and not to the temperature of the surrounding air. In the same way the apparition of light when pressure is exerted on the eyeball cannot be made to vanish simply by comprehending better the nature of the process, supposing the attention is directed to the field of vision and not, say, to the ear or the skin.

On the other hand, it may also be that we are not in the position to isolate an impression of sensation, because it involves the composite sense-symbol of an external object. However, in this case the correct comprehension of the object shows that the sensation in question has been percieved and used by the consciousness.

My conclusion is, that *nothing in our sense-perceptions can be recognized as sensation which can be overcome in the perceptual image and converted into its opposite by factors that are demonstrably due to experience.*

Whatever, therefore, can be overcome by factors of experience, we must consider as being itself the product of experience and training. By observing this rule, we shall find that it is merely the qualities of the sensation that are to be considered as real, pure sensation; the great majority of space-apperceptions, however, being the product of experience and training.

Still it does not follow that apperceptions, which persist in spite of our better conscious insight and continue as illusions, might not be due to experience and training. Our knowledge of the changes of colour produced in distant objects by the haziness of the atmosphere, of perspective distortions, and of shadow is undoubtedly a matter of experience. And yet in a good landscape picture we shall get the perfect visual impression of the distance and the solid form of the buildings in it, in spite of knowing that it is all depicted on canvas.

Similarly, our knowledge of the composite sound of the vowels is certainly obtained from experience; and yet we get the auditory-

impression of the vowel sound by combining the individual tones of tuning forks (as I have demonstrated) and grasp the sound in its entirety, although in this instance we know that it is really compound.

Here we still have to explain how experience counteracts experience, and how illusion can be produced by factors derived from experience, when it might seem as if experience could not teach anything except what was true. In this matter we must remember, as was intimated above, that the sensations are interpreted just as they arise when they are stimulated in the normal way, and when the organ of sense is used normally.

We are not simply passive to the impressions that are urged on us, but we *observe*, that is, we adjust our organs in those conditions that enable them to distinguish the impressions most accurately. Thus, in considering an involved object, we accommodate both eyes as well as we can, and turn them so as to focus steadily the precise point on which our attention is fixed, that is, so as to get an image of it in the fovea of each eye; and then we let our eyes traverse all the noteworthy points of the object one after another. If we are interested in the general shape of the object and are trying to get as good an idea as we can of its relative dimensions, we assume a position such that, without having to turn the head, we can survey the whole surface, enabling us at the same time to view as symmetrically as possible those dimensions we wish to compare. Thus, in looking at an object, as, for example, a building with prominent horizontal and vertical lines, we like to stand opposite to it with the centres of rotation of the two eyes in a horizontal line. This position of the eyes can be controlled at any moment by separating the double images; which in the case mentioned here are in the same horizontal plane.

Unquestionably, our reason for choosing this definite mode of seeing is because in this way we can observe and compare most accurately; and, consequently, in this so-called *normal* use of the eyes we learn best how to compare our sensations with the reality. And so we obtain also the most correct and most accurate perceptions by this method.

But if, from necessity or on purpose, we employ a different mode of looking at objects, that is, if we view them merely indirectly or without focusing both eyes on them, or without surveying them all over, or if we hold the head in some unusual position, then we shall not be able to have as accurate apperceptions as when the eyes are used in the normal fashion. Nor are we so well trained in interpreting what we see under such circumstances as in the other case. Hence there is more scope for interpretation, although, as a rule, we are not clearly aware

of this uncertainty in the explanation of our sense-perceptions. When we see an object in front of us, we are obliged to assign it to some definite place in space. We cannot think of it as having some dubious intermediate position between two different places in space. Without any recollections coming to our aid, we are wont to interpret the phenomenon as it would have to be interpreted if we had received the same impression in the normal and most accurate mode of observation. Thus certain illusions enter into the perception, unless we concentrate our eyes on the objects under observation, or when the objects are in the peripheral part of the visual field, or if the head is held to one side, or if we do not focus the object with both eyes at once. Moreover, the agreement between the images on the two retinas is most constant and regular in looking at distant objects. The fact that the horizontal floor usually happens to be in the lower part of the visual field, apparently influences the comparison of the fields of the two eyes in a peculiar manner. Thus, our judgment as to the position of near objects is not entirely correct when we observe them with the look tilted decidedly up or down. The retinal images presented in this way are interpreted just as if they had been obtained by looking straight ahead. We run across many illustrations of this sort. Our training in interpreting immediate perceptions is not equally good in all directions of the eyes, but simply for those directions which enable us to have the most accurate and most consistent perceptions. We transfer the latter to all cases, as in the instances just cited.

Now it is quite possible that the similarity between a visual impression of this kind and one of the possible impressions obtained by normal observation may not be so overwhelming and striking as to preclude many other comparisons and corresponding interpretations of that impression. In such cases the explanation of the impression varies. Without any change of the retinal images, the same observer may see in front of him various perceptual images in succession, in which case the variation is easy to recognize. Or else one observer may incline more toward one comparison and interpretation, and another toward another. This has been a source of much controversy in physiological optics, because each observer has been disposed to consider the apperception which he obtained by the most careful observation he could make as being the only valid one. But supposing that we have such confidence in the observers as to assume that their observations were careful and unprejudiced, and that they knew how to make them, it would not be proper in such cases to adopt one of the conflicting interpretations of the visual phenomenon as being the only correct one. And yet that is what they are disposed to do who try to derive the

origin of perceptual images mainly from innate factors. The truth rather is, that in a case of this sort various perceptual images may be developed; and we should seek rather to discover what circumstances are responsible for the decision one way or the other.

It is true we meet with a difficulty here that does not exist in the other parts of the natural sciences. In many instances we have simply the assertions of individual observers, without being in the position to verify them by our own observation. Many idiosyncrasies are manifested in this region, some of which are doubtless due to the structure of the eyes, others to the habitual way of using the eyes, and others still perhaps to previous impressions and apperceptions. Of course, nobody save the person who has peculiarities of this nature can observe their effects, and nobody else can give an opinion about them. On the other hand, observation in this region is by no means so easy as might be supposed at first. Steady fixation of a point for a long time while observations are being made in indirect vision; controlling the attention; taking the mind away from the ordinary objective interpretation of sense-impression; estimation of difference of colour and of difference of space in the visual field—all these things take much practice. And hence a number of facts in this region cannot be observed at all without having had previous long training in making observations in physiological optics. It cannot be done even by persons who are skilled in making other kinds of observations. Thus, with respect to many matters we have to depend on the observations of a very limited number of individuals, and hence when the results found by somebody else are different, it is much harder in this subject than anywhere else to judge rightly whether secondary influences have not contributed in an observation of this sort. Accordingly, I must apprise the reader in advance that much of the material that is perhaps new in the following chapters may possibly be due to individual peculiarities of my own eyes. Under such circumstances, there was no alternative for me except to observe as carefully as possible the facts as they appeared to my own eyes, and to try to ascertain their connection. Discrepancies that have been found by other observers have been noted. But how widespread this or the other mode of vision may be, is something that has to be left to the future to determine.

Incidentally, the more the visual impressions are unlike the normal ones, the greater will be the variety of interpretation as a rule. This is a natural consequence of the view which I hold, and is an essential characteristic of the activity of psychic influences.

Heretofore practically nothing has been ascertained as to the nature of psychic processes. We have simply an array of facts. Therefore, it is

not strange that no real explanation can be given of the origin of sense-perceptions. The *empirical theory* attempts to prove that at least no other forces are necessary for their origin beyond the known faculties of the mind, although these forces themselves may remain entirely unexplained. Now generally it is a useful rule in scientific investigation not to make any new hypothesis so long as known facts seem adequate for the explanation, and the necessity of new assumptions has not been demonstrated. That is why I have thought it incumbent to prefer the empirical view essentially. Still less does the *intuition theory* attempt to give any explanation of the origin of our perceptual images; for it simply plunges right into the midst of the matter by assuming that certain perceptual images of space would be produced directly by an innate mechanism, provided certain nerve fibres were stimulated. The earlier forms of this theory implied some sort of self-observation of the retina; inasmuch as we were supposed to know by intuition about the form of this membrane and the positions of the separate nerve terminals in it. In its more recent development, especially as formulated by E. HERING, there is an hypothetical subjective visual space, wherein the sensations of the separate nerve fibres are supposed to be registered according to certain intuitive laws. Thus in this theory not only is KANT's assertion adopted, that the general apperception of space is an original form of our imagination, but certain special apperceptions of space are assumed to be intuitive.

The naturalistic view has been called also a special *theory of identity*, because in it the perfect fusion of the impressions on the corresponding places of the two retinas has to be postulated. On the other hand, the *empirical* theory is spoken of as a *theory of projection*,[1] because according to it the perceptual images of objects are projected in space by means of psychic processes. I should like to avoid this term, because both supporters and opponents of this view have often attached undue importance to the idea that this projection must take place parallel to the lines of direction; which was certainly not the correct description of the psychic process. And, even if this construction were admitted as being valid simply with respect to the physiological description of the process, the idea would be incorrect in very many instances.

I am aware that in the present state of knowledge it is impossible to refute the intuition theory. The reasons why I prefer the opposite view are because in my opinion:

1. The intuition theory is an unnecessary hypothesis.

[1] See remarks in Appendix I as to misunderstandings connected with the term "projection theory."—K.

2. Its consequences thus far invariably apply to perceptual images of space which only in the fewest cases are in accordance with reality and with the correct visual images that are undoubtedly present; as will be shown in detail later. The adherents of this theory are, therefore, obliged to make the very questionable assumption, that the *space sensations*, which according to them are present originally, are continually being improved and overruled by knowledge which we have accumulated by experience. By analogy with all other experiences, however, we should have to expect that the sensations which have been overruled continued to be present in the apperception as a conscious illusion, if nothing else. But this is not the case.

3. It is not clear how the assumption of these original "*space sensations*" can help the explanation of our visual perceptions, when the adherents of this theory ultimately have to assume in by far the great majority of cases that these sensations must be overruled by the better understanding which we get by experience. In that case it would seem to me much easier and simpler to grasp, that all apperceptions of space were obtained simply by experience, instead of supposing that the latter have to contend against intuitive perceptual images that are generally false.

This is by way of justifying my point of view. A choice had to be made simply for the sake of getting at least some sort of superficial order amid the chaos of phenomena; and so I believed I had to adopt the view I have chosen. However, I trust it has not affected the correct observation and description of the facts.

To prevent misunderstandings as to my meaning, and to make it clearer to the natural intelligence of those readers who have never thought much about their sense-perceptions, the following explanations will be added.

Thus far the sensations have been described as being simply *symbols* for the relations in the external world. They have been denied every kind of similarity or equivalence to the things they denote. Here we touch on the much disputed point as to how far our ideas agree in the main with their objects; that is, whether they are true or false, as one might say. Some have asserted that there is such an agreement, and others have denied it. In favour of it, a *pre-established harmony* between nature and mind was assumed. Or it was maintained that there was an *identity* of nature and mind, by regarding nature as the product of the activity of a general mind; the human mind being supposed to be an emanation from it. The *intuition theory* of space-apperceptions is connected with these views to the extent that, by some innate mechanism and a certain pre-established harmony, it

admits of the origin of perceptual images that are supposed to correspond with reality, although in a rather imperfect fashion.

Or else the agreement between ideas and their objects was denied, the ideas being explained therefore as illusions. Consequently, it was necessary to deny also the possibility of all knowledge of any objects whatsoever. This was the attitude of certain so-called "sensational" philosophers in England in the eighteenth century. However, it is not my purpose here to undertake an analysis of the opinions of the various philosophical schools on this question. That would be much too extensive a task in this place. I shall confine myself therefore merely to inquiring what I think should be the attitude of an investigator toward these controversies.

Our apperceptions and ideas are *effects* wrought on our nervous system and our consciousness by the objects that are thus apprehended and conceived. Each effect, as to its nature, quite necessarily depends both on the nature of what causes the effect and on that of the person on whom the effect is produced. To expect to obtain an idea which would reproduce the nature of the thing conceived, that is, which would be true in an absolute sense, would mean to expect an effect which would be perfectly independent of the nature of the thing on which the effect was produced; which would be an obvious absurdity. Our human ideas, therefore, and all ideas of any conceivable intelligent creature, must be images of objects whose mode is essentially co-dependent on the nature of the consciousness which has the idea, and is conditioned also by its idiosyncrasies.

In my opinion, therefore, there can be no possible sense in speaking of any other truth of our ideas except of a *practical* truth. Our ideas of things *cannot* be anything but symbols, natural signs for things which we learn how to use in order to regulate our movements and actions. Having learned correctly how to read those symbols, we are enabled by their help to adjust our actions so as to bring about the desired result; that is, so that the expected new sensations will arise. Not only is there *in reality* no other comparison at all between ideas and things—all the schools are agreed about this—but any other mode of comparison is entirely *unthinkable* and has no sense whatever. This latter consideration is the conclusive thing, and must be grasped in order to escape from the labyrinth of conflicting opinions. To ask whether the idea I have of a table, its form, strength, colour, weight, etc., is true *per se*, apart from any practical use I can make of this idea, and whether it corresponds with the real thing, or is false and due to an illusion, has just as much sense as to ask whether a certain musical note is red, yellow, or blue. Idea and the thing conceived evidently

belong to two entirely different worlds, which no more admit of being compared with each other than colours and musical tones or than the letters of a book and the sound of the word they denote.

Were there any sort of similarity of correspondence between the idea in the head of a person *A* and the thing to which the idea belongs, another intelligent person *B*, conceiving both the thing itself and *A*'s idea of it, according to the same laws, might be able to find some similarity between them or at least to suppose so; because the same sort of thing represented (conceived) in the same way would have to give the same kinds of images (ideas). Now I ask, what similarity can be imagined between the process in the brain that is concomitant with the idea of a table and the table itself? Is the form of the table to be supposed to be outlined by electric currents? And when the person with the idea has the idea that he is walking around the table, must the person then be outlined by electric currents? Perspective projections of the external world in the hemispheres of the brain (as they are supposed to be) are evidently not sufficient for representing the idea of a bodily object. And granted that a keen imagination is not frightened away by these and similar hypotheses, such an electrical reproduction of the table in the brain would be simply another bodily object to be perceived, but no idea of the table. However, it is not simply persons with materialistic opinions who try to refute the proposed statement, but also persons with idealistic views. And for the latter I should think the argument would be still more forcible. What possible similarity can there be between the idea, some modification of the incorporeal mind that has no extension in space, and the body of the table that occupies space? As far as I am aware, the idealistic philosophers have never once investigated even a single hypothesis or imagination in order to show this connection. And by the very nature of this view it is something that cannot be investigated at all.

In the next place as to the *properties* of objects in the external world, a little reflection reveals that all properties attributable to them may be said to be simply *effects* exerted by them either on our senses or on other natural objects. Colour, sound, taste, smell, temperature, smoothness, and firmness are properties of the first sort, and denote effects on our organs of sense. Smoothness and firmness denote the degree of resistance either to the gliding contact or pressure of the hand. But other natural bodies may be employed instead of the hand. And the same thing is true in testing other mechanical properties such as elasticity and weight. Chemical properties are described by certain reactions, that is, by effects exerted by one natural body

on others. It is the same way with any other physical property of a body, optical, electrical, or magnetic. In every case we have to do with the mutual relations between various bodies and with the effects depending on the forces that different bodies exert on each other. For all natural forces are such as are exerted by one body on others. When we try to think of mere matter without force, it is void of properties likewise, except as to its different distribution in space and as to its motion. All properties of bodies in nature are manifested therefore simply by being so situated as to interact with other bodies of nature or with our organs of sense. But as such interaction may occur at any time, particularly too as it may be produced by us voluntarily at any moment, and as then we see invariably the peculiar sort of interaction occurring, we attribute to the objects a permanent capacity for such effects which is always ready to become effective. This permanent capacity is a so-called characteristic *property*.

The result is that in point of fact the characteristic *properties* of natural objects, in spite of this name, do not denote something that is peculiar to the individual object by itself, but invariably imply some relation to a second object (including our organs of sense). The kind of effect must, of course, depend always on the peculiarities both of the body producing it and of the body on which it is produced. As to this there is never any doubt even for an instant, provided we have in mind those properties of bodies that are manifested when two bodies belonging to the external world react on each other, as in the case of chemical reactions. But in the case of properties depending on the mutual relations between things and our organs of sense, people have always been disposed to forget that here too we are concerned with the reaction toward a special reagent, namely, our own nervous system; and that colour, smell, and taste, and feeling of warmth or cold are also effects quite essentially depending on the nature of the organ that is affected. Doubtless, the reactions of natural objects to our senses are those that are most frequently and most generally perceived. For both our welfare and convenience they are of the most powerful importance. The reagent by which we have to test them is something we are endowed with by nature, but that does not make any difference in the connection.

Hence there is no sense in asking whether vermilion as we see it, is really red, or whether this is simply an illusion of the senses. The sensation of red is the normal reaction of normally formed eyes to light reflected from vermilion. A person who is red-blind will see vermilion as black or as a dark grey-yellow. This too is the correct reaction for an eye formed in the special way his is. All he has to know is that his eye is

simply formed differently from that of other persons. In itself the one sensation is not more correct and not more false than the other, although those who call this substance red are in the large majority. In general, the red colour of vermilion exists merely in so far as there are eyes which are constructed like those of most people. Persons who are red-blind have just as much right to consider that a characteristic property of vermilion is that of being black. As a matter of fact, we should not speak of the light reflected from vermilion as being red, because it is not red except for certain types of eyes. When we speak of the properties of bodies with reference to other bodies in the external world, we do not neglect to name also the body with respect to which the property exists. Thus we say that lead is soluble in nitric acid, but not in sulphuric acid. Were we to say simply that lead is soluble, we should notice at once that the statement is incomplete, and the question would have to be asked immediately, Soluble in what? But when we say that vermilion is red, it is implicitly understood that it is red for our eyes and for other people's eyes supposed to be made like ours. We think this does not need to be mentioned, and so we neglect to do so, and can be misled into thinking that red is a property belonging to vermilion or to the light reflected from it, entirely independently of our organs of sense. The statement that the waves of light reflected from vermilion have a certain length is something different. That is true entirely without reference to the special nature of our eye. Then we are thinking simply of relations that exist between the substance and the various systems of waves in the aether.

The only respect in which there can be a real agreement between our perceptions and the reality is the time-sequence of the events with their various peculiarities. Simultaneity, sequence, the regular recurrence of simultaneity or sequence, may occur likewise in the sensations as well as in the events. The external events, like their perceptions, proceed in time; and so the temporal relations of the latter may be the faithful reproduction of the temporal relations of the former. The sensation of thunder in the ear succeeds the sensation of lightning in the eye, just in the same way as the sound vibrations in the air due to the electrical discharge reach the place where the observer is later than the vibrations of the luminiferous aether. Yet here it certainly should be noted that the time-sequence of the sensations is not quite a faithful reproduction of the time-sequence of the external events, inasmuch as the transmission from the organs of sense to the brain takes time, and in fact a different time for different organs. Moreover, in case of the eye and the ear, the time has to be added that it takes light and sound to reach the organ. Thus at present we see the fixed stars as they were various long periods of years ago.

As to the representation of space-relations, there certainly is something of this sort in the peripheral nerve terminals in the eye and to a certain extent in the tactile skin, but still only in a limited way; for the eye gives only perspective surface-images, and the hand reproduces the objective area on the surface of a body by shaping itself to it as congruently as possible. A direct image of a portion of space of three dimensions is not afforded either by the eye or by the hand. It is only by comparing the images in the two eyes, or by moving the body with respect to the hand, that the idea of solid bodies is obtained. Now since the brain itself has three dimensions, of course, there is still another conceivable possibility, and that is to fancy by what mechanism in the brain itself images of three dimensions can arise from external objects in space. But I cannot see any necessity for such an assumption nor even any probability for it. The idea of a body in space, of a table, for instance, involves a quantity of separate observations. It comprises the whole series of images which this table would present to me in looking at it from different sides and at different distances; besides the whole series of tactile impressions that would be obtained by touching the surface at various places in succession. Such an idea of a single individual body is, therefore, in fact a *conception* (*Begriff*) which grasps and includes an infinite number of single, successive apperceptions, that can all be deduced from it; just as the species "table" includes all individual tables and expresses their common peculiarities. The idea of a single individual table which I carry in my mind is correct and exact, provided I can deduce from it correctly the precise sensations I shall have when my eye and my hand are brought into this or that definite relation with respect to the table. Any other sort of similarity between such an idea and the body about which the idea exists, I do not know how to conceive. One is the mental symbol of the other. The kind of symbol was not chosen by me arbitrarily, but was forced on me by the nature of my organ of sense and of my mind. This is what distinguishes this sign-language of our ideas from the arbitrary phonetic signs and alphabetical characters that we use in speaking and writing. A writing is correct when he who knows how to read it forms correct ideas by it. And so the idea of a thing is correct for him who knows how to determine correctly from it in advance what sense-impressions he will get from the thing when he places himself in definite external relations to it. Incidentally, it does not matter at all what sort of mental symbols we employ, provided they constitute a sufficiently varied and ordered system. Nor does it matter either how the words of a language sound, provided there are enough of them, with sufficient means of denoting their grammatical relations to one another.

On this view of the matter, we must be on our guard against saying that all our ideas of things are consequently *false*, because they are not *equal* to the things themselves, and that hence we are not able to know anything as to the *true nature* of things. That they cannot be equal to things, is in the nature of knowledge. Ideas are merely pictures of things. Every image is the image of a thing merely for him who knows how to read it, and who is enabled by the aid of the image to form an idea of the thing. Every image is similar to its object in one respect, and dissimilar in all others, whether it be a painting, a statue, the musical or dramatic representation of a mental mood, etc. Thus the ideas of the external world are images of the regular sequence of natural events, and if they are formed correctly according to the laws of our thinking, and we are able by our actions to translate them back into reality again, the ideas we have are also the *only true* ones for our mental capacity. All others would be false.

In my opinion, it is a mistake, therefore, to try to find pre-established harmony between the laws of thought and those of nature, an identity between nature and mind, or whatever we may call it. A system of signs may be more or less perfect and convenient. Accordingly, it will be more or less easy to employ, more exact in denoting or more inexact, just as is the case with different languages. But otherwise each system can be adapted to the case more or less well. If there were not a number of similar natural objects in the world, our faculty of forming shades of conception would indeed not be of any use to us. Were there no solid bodies, our geometrical faculties would necessarily remain undeveloped and unused, just as the physical eye would not be of any service to us in a world where there was no light. If in this sense anybody wishes to speak of an adaptation of our laws of mind to the laws of nature, there is no objection to it. Evidently, however, such adaptation does not have to be either perfect or exact. The eye is an extremely useful organ practically, although it cannot see distinctly at all distances, or perceive all sorts of aether vibrations, or concentrate exactly in one point all the rays that issue from a point. Our intellectual faculties are connected with the activities of a material organ, namely the brain, just as the faculty of vision is connected with the eye. Human intelligence is wonderfully effective in the world, and brings it under a strict law of causation. Whether it necessarily must be able to control whatever is in the world or can happen—I can see no guarantee for that.

We must speak now of the manner in which our ideas and perceptions are formed by inductive conclusions. The best analysis of the nature of our conclusions I find in J. S. Mill's Logic. As long as the

premise of the conclusion is not an injunction imposed by outside authority for our conduct and belief, but a statement related to reality, which can therefore be only the result of experience, the conclusion, as a matter of fact, does not tell us anything new or something that we did not know already before we made the statement. Thus, for example:

Major: All men are mortal.
Minor: Caius is a man.
Conclusion: Caius is mortal.

The major premise, that all men are mortal, which is a statement of experience, we should scarcely venture to assert without knowing beforehand whether the conclusion is correct, namely, that Caius, who is a man, either is dead or will die. Thus we must be sure of the conclusion before we can state the major premise by which we intend to prove it. That seems to be proceeding in a circle. The real relation evidently is, that, in common with other folks, we have observed heretofore without exception that no person has ever survived beyond a certain age. Observers have learned by experience that Lucius, Flavius and other individuals of their acquaintance, no matter what their names are, have all died; and they have embraced this experience in the general statement, that *all* men die. Inasmuch as this final result occurred regularly in all the instances they observed, they have felt justified in explaining this general law as being valid also for all those cases which might come up for observation hereafter. Thus we preserve in our memory the store of experiences heretofore accumulated on this subject by ourselves and others in the form of the general statement which constitutes the major premise of the above conclusion.

However, the conviction that Caius would die might obviously have been reached directly also without formulating the general statement in our consciousness, by having compared his case with all those which we knew previously. Indeed, this is the more usual and original method of reasoning by induction. Conclusions of this sort are reached without conscious reflection, because in our memory the same sort of thing in cases previously observed unites and reinforces them; as is shown especially in those cases of inductive reasoning where we cannot succeed in deducing from previous experiences a rule with precisely defined limits to its validity and without any exceptions. This is the case in all complicated processes. For instance, from analogy with previous similar cases, we can sometimes predict with tolerable certainty what one of our acquaintances will do, if under certain circumstances he decides to go into business; because we know his character and that he is, let us say, ambitious or timid. We may not be

able to say exactly how we have estimated the extent of his ambition or timidity, or why this ambition or timidity of his will be enough to decide that his business will turn out as we expect.

In the case of conclusions properly so-called, which are reached consciously, supposing they are not based on injunctions but on facts of experience, what we do, therefore, is really nothing more than deliberately and carefully to retrace those steps in the inductive generalizations of our experiences which were previously traversed more rapidly and without conscious reflection, either by ourselves or by other observers in whom we have confidence. But although nothing essentially new is added to our previous knowledge by formulating a general principle from our previous experiences, still it is useful in many respects. A definitely stated general principle is much easier to preserve in the memory and to be imparted to others than to have to do this same thing with every individual case as it arises. In formulating it we are led to test accurately every new case that occurs, with reference to the correctness of the generalization. In this way every exception will be impressed on us twice as forcibly. The limits of its validity will be recalled much sooner when we have the principle before us in its general form, instead of having to go over each separate case. By this sort of conscious formulation of inductive reasoning, there is much gain in the convenience and certainty of the process; but nothing essentially new is added that did not exist already in the conclusions which were reached by analogy without reflection. It is by means of these latter that we judge the character of a person from his countenance and movements, or predict what he will do in a given situation from a knowledge of his character.

Now we have exactly the same case in our sense-perceptions. When those nervous mechanisms whose terminals lie on the right-hand portions of the retinas of the two eyes have been stimulated, our usual experience, repeated a million times all through life, has been that a luminous object was over there in front of us on our left. We had to lift the hand toward the left to hide the light or to grasp the luminous object; or we had to move toward the left to get closer to it. Thus while in these cases no particular conscious conclusion may be present, yet the essential and original office of such a conclusion has been performed, and the result of it has been attained; simply, of course, by the unconscious processes of association of ideas going on in the dark background of our memory. Thus too its results are urged on our consciousness, so to speak, as if an external power had constrained us, over which our will has no control.

These inductive conclusions leading to the formation of our sense-

perceptions certainly do lack the purifying and scrutinizing work of conscious thinking. Nevertheless, in my opinion, by their peculiar nature they may be classed as *conclusions*, inductive conclusions unconsciously formed.

There is one circumstance quite characteristic of these conclusions which operates against their being admitted in the realm of conscious thinking and against their being formulated in the normal form of logical conclusions. This is that we are not able to specify more closely what has taken place in us when we have experienced a sensation in a definite nerve fibre, and how it differs from corresponding sensations in other nerve fibres. Thus, suppose we have had a sensation of light in certain fibres of the nervous mechanism of vision. All we know is that we have had a sensation of a peculiar sort which is different from all other sensations, and also from all other visual sensations, and that whenever it occurred, we invariably noticed a luminous object on the left. Naturally, without ever having studied physiology, this is all we can say about the sensation, and even for our own imagination we cannot localize or grasp the sensation except by specifying it in terms of the conditions of its occurrence. I have to say, "I see something bright there on my left." That is the only way I can describe the sensation. After we have pursued scientific studies, we begin to learn that we have nerves, that these nerves have been stimulated, and that their terminals in fact lie on the right-hand side of the retina. Then for the first time we are in a position to define this mode of sensation independently of the mode in which it is ordinarily produced.

It is the same way with most sensations. The sensations of taste and smell usually cannot be described even as to their quality except in terms of the bodies responsible for them; although we do have a few rather vague and more general expressions like "sweet," "sour," "bitter" and "sharp."

These judgments, in which our sensations in our ordinary state of consciousness are connected with the existence of an external cause, can never once be elevated to the plane of conscious judgments. The inference that there is a luminous object on my left, because the nerve terminals on the right-hand side of my retina are in a state of stimulation, can only be expressed by one who knows nothing about the inner structure of the eye by saying, "There is something bright over there on my left, because I see it there." And accordingly from the standpoint of everyday experience, the only way of expressing the experience I have when the nerve terminals on the right-hand side of my eyeball are stimulated by exerting pressure there, is by saying, "When I press my eye on the right-hand side, I see a bright glow on the left."

There is no other way of describing the sensation and of identifying it with other previous sensations except by designating the place where the corresponding external object appears to be. Hence, therefore, these cases of experience have the peculiarity that the connection between the sensation and an external object can never be expressed without anticipating it already in the designation of the sensation, and without presupposing the very thing we are trying to describe.

Even when we have learned to understand the physiological origin and connection of the illusions of the senses, it is impossible to get rid of the illusion in spite of our better knowledge. This is because inductive reasoning is the result of an unconscious and involuntary activity of the memory; and for this very reason it strikes our consciousness as a foreign and overpowering force of nature. Incidentally, manifold analogies for it are to be found in all other possible modes of *apparition*. We might say that all apparition originates in premature, unmeditated inductions, where from previous cases conclusions are deduced as to new ones, and where the tendency to abide by the false conclusions persists in spite of the better insight into the matter based on conscious deliberation. Every evening apparently before our eyes the sun goes down behind the stationary horizon, although we are well aware that the sun is fixed and the horizon moves. An actor who cleverly portrays an old man is for us an old man there on the stage, so long as we let the immediate impression sway us, and do not forcibly recall that the programme states that the person moving about there is the young actor with whom we are acquainted. We consider him as being angry or in pain according as he shows us one or the other mode of countenance and demeanour. He arouses fright or sympathy in us, we tremble for the moment, which we see approaching, when he will perform or suffer something dreadful; and the deep-seated conviction that all this is only show and play does not hinder our emotions at all, provided the actor does not cease to play his part. On the contrary, a fictitious tale of this sort, which we seem to enter into ourselves, grips and tortures us more than a similar true story would do when we read it in a dry documentary report.

The experiences we have that certain aspects, demeanours and modes of speech are indicative of fierce anger, are generally experiences concerning the external signs of certain emotions and peculiarities of character which the actor can portray for us. But they are not nearly so numerous and regular in recurrence as those experiences by which we have ascertained that certain sensations correspond with certain external objects. And so we need not be surprised if the idea of an object which is ordinarily associated with a sensation does not vanish,

even when we know that in this particular instance there is no such object.

Finally, the tests we employ by voluntary movements of the body are of the greatest importance in strengthening our conviction of the correctness of the perceptions of our senses. And thus, as contrasted with purely passive observations, the same sort of firmer conviction arises as is derived by the process of experiment in scientific investigations. The peculiar ultimate basis, which gives convincing power to all our conscious inductions, is the law of causation. If two natural phenomena have frequently been observed to occur together, such as thunder and lightning, they seem to be regularly connected together, and we infer that there must be a common basis for both of them. And if this causal connection has invariably acted heretofore, so that thunder and lightning accompany each other, then in the future too like causes must produce like effects, and the result must be the same in the future. However, so long as we are limited to mere observations of such phenomena as occur by themselves without our help, and without our being able to make experiments so as to vary the complexity of causes, it is difficult to be sure that we have really ascertained all the factors that may have some influence on the result. There must be an enormous variety of cases where the law is obeyed, and the law must define the result with great precision, if we are to be satisfied with a case of mere observation. This is the case with the motions of the planetary system. Of course, we cannot experiment with the planets, but the theory of universal gravitation as propounded by NEWTON gives such a complete and exact explanation of the comparatively complicated apparent motions of the heavenly bodies, that we no longer hesitate about considering it as being sufficiently proved. And yet there are REICH's experiments on the gravitational attraction of lead balls, FOUCAULT's experiment on the deviation of the plane of vibration of a pendulum in consequence of the earth's rotation, and the experimental determinations of the velocity of light in traversing terrestrial distances as made by FOUCAULT and FIZEAU, that are of the utmost value in strengthening our conviction experimentally also.

Probably there is no event of pure observation that has been found to be so unexceptionally correct as the general statement previously used by way of illustration, namely, that all human beings die before they have passed a certain age. In many millions of human beings not a single exception has been found. If one had occurred, we might assume that we should have heard of it. Among those who have died there are individuals who have lived in the most varied climates and on the most various kinds of nourishment, besides having been engaged

in the most diverse occupations. Nevertheless, the statement that all men are bound to die, cannot be said to have the same degree of certainty as any law of physics whose consequences have been precisely compared experimentally with experience in manifold modifications. I do not know the causal connection for the death of human beings. I cannot state the causes that inevitably entail old age, in case life has not been terminated sooner by some rougher external injury. I have not been able to verify by experiments that when I allow those causes to operate, old age inevitably occurs, and that it does not occur when I remove those causes of its occurrence. Anyone who tells me that the life of man can be indefinitely prolonged by employing certain means may be treated, of course, with the utmost incredulity, but he cannot be positively contradicted without knowing certainly that individuals have actually lived in the circumstances he describes, and yet have ultimately perished. On the other hand, when I assert that all liquid mercury will expand when it is heated, if it is free to do so, I know that whenever I have observed the two together, not only higher temperature and expansion of mercury were due to the action of an unknown common third cause, as I might have supposed from pure observation alone, but I know by experiment that the heat by itself was enough to cause the expansion of the mercury. At various times I have often heated mercury. I have deliberately selected the moment when I wished the experiment to begin. If therefore the mercury expanded under these circumstances, the expansion must have been dependent on those conditions that I produced in the experiment. Consequently, I know that the heating by itself was a sufficient cause for the expansion, and that no other latent influences were needed to bring about this result. By comparatively few carefully executed experiments we are enabled to establish the causal conditions of an event with more certainty than can be done by a million observations where we have not been able to vary the conditions as we please. For instance, if I had merely seen mercury expand in a thermometer which was inaccessible to me, and in a place where the air was saturated with moisture at all temperatures, I should have to inquire whether mercury expands on account of heat or on account of the moisture. The only way to determine this would be by experiment, and by finding out whether the volume of mercury changes with change of humidity, when the temperature is kept constant, or with change of temperature, when the humidity is kept constant.

The same great importance which experiment has for the certainty of our scientific convictions, it has also for the unconscious inductions of the perceptions of our senses. It is only by voluntarily bringing our

organs of sense in various relations to the objects that we learn to be sure as to our judgments of the causes of our sensations. This kind of experimentation begins in earliest youth and continues all through life without interruption.

If the objects had simply been passed in review before our eyes by some foreign force without our being able to do anything about them, probably we should never have found our way about amid such an optical phantasmagoria; any more than mankind could interpret the apparent motions of the planets in the firmament before the laws of perspective vision could be applied to them. But when we notice that we can get various images of a table in front of us simply by changing our position; and that we can sometimes have one view and sometimes another, just as we like at any time, by a suitable change of position; and that the table may vanish from sight, and then be there again at any moment we like, simply by turning the eyes toward it; we get the conviction based on experiment, that our movements are responsible for the different views of the table, and that whether we see it just at this moment or do not see it, still we can see it whenever we like. Thus by our movements we find out that it is the stationary form of the table in space which is the cause of the changing image in our eyes. We explain the table as having existence independent of our observation, because at *any moment we like*, simply by assuming the proper position with respect to it, we can observe it.

The essential thing in this process is just this principle of experimentation. Spontaneously and by our own power, we vary some of the conditions under which the object has been perceived. We know that the changes thus produced in the way that objects look depend solely on the movements we have executed. Thus we obtain a different series of apperceptions of the same object, by which we can be convinced with experimental certainty that they are simply apperceptions, and that it is the common cause of them all. In fact we see children also experimenting with objects in this way. They turn them constantly round and round, and touch them with the hands and the mouth, doing the same things over and over again day after day with the same objects, until their forms are impressed on them; in other words, until they get the various visual and tactile impressions made by observing and feeling the same object on various sides.

In this sort of experimentation with objects some of the changes in the sense-impressions are found to be due to our own will; whereas others, that is, all that depend on the nature of the object directly before us, are urged upon us by a necessity which we cannot alter as we like, and which we feel most when it arouses disagreeable sensations

or pain. Thus we come to recognize something independent of our will and imagination, that is, an external cause of our sensations. This is shown by its persisting independently of our instantaneous perception; because at any moment we like, by suitable manipulations and movements, we can cause to recur each one of the series of sensations that can be produced in us by this external cause. Thus this latter is recognized as an object existing independently of our perception.

The idea and the cause here combine, and it is a question whether we have a right to assume this cause in the original perception of the senses. Here again the difficulty is that we are not able to describe the processes except in the language of metaphysics, whereas the reflection of the consciousness in itself is not yet distinctly contained in the original form of the conscious perception.

Natural consciousness, which is entirely absorbed in the interest of observing the external world, and has little inducement to direct its attention to the Ego that appears always the same amid the multi-coloured variations of outside objects, is not in the habit of noticing that the *properties* of the objects that are seen and touched are their effects, partly on other natural bodies, but mainly on our senses. Now as our nervous system and our sensation-faculty, as being the constant reagent on which the effect is exerted, is thus left out of account entirely, and as the difference of the effect is regarded as being simply a difference in the object from which it proceeds, the effect can no longer be recognized as an effect (for every effect must be the effect on something else), and so comes to be considered objectively as being a property of the body and merely as belonging to it. And then as soon as we recall that we perceive these properties, our impression, consequently, seems to us to be a pure image of the external state of affairs reflecting only that external condition and depending solely on it.

But if we ponder over the basis of this process, it is obvious that we can never emerge from the world of our sensations to the apperception of an external world, except by inferring from the changing sensation that external objects are the causes of this change. Once the idea of external objects has been formed, we may not be concerned any more as to how we got this idea, especially because the inference appears to be so self-evident that we are not conscious of its being a new result.

Accordingly, the law of causation, by virtue of which we infer the cause from the effect, has to be considered also as being a law of our thinking which is prior to all experience. Generally, we can get no experience from natural objects unless the law of causation is already active in us. Therefore, it cannot be deduced first from experiences which we have had with natural objects.

This statement has been made in many ways. The law of causation was supposed to be a law of nature arrived at by induction. Recently it has been again interpreted in that way by J. S. Mill. He has even suggested the possibility of its not being valid in other parts of the universe. As opposed to that view, I shall merely say, for what it is worth, that there is good reason to think that the empirical proof of the law is extremely doubtful. For the number of cases in which we think we can trace perfectly the causal connection between natural processes is small as compared with the number of those in which we are absolutely unable to do so at present. The former cases belong almost exclusively to inorganic nature. The cases that are not understood include the larger part of the phenomena of organic nature. In fact, by the evidence of our own consciousness, we positively assume both in beasts and in man a principle of free will, for which we claim most decidedly complete independence of the force of the law of causation. And in spite of all theoretical speculations as to possible mistakes about this conviction, I am of the opinion that our natural consciousness will hardly ever be free from it. Thus the case of conduct itself, which we know best and most accurately, we consider as being an exception to that law. Were therefore the law of causation a law of experience, its inductive proof would seem to be in a very bad shape. The best we could say is that it was not any more valid than rules of meteorology like the law of rotation of the wind, etc. Perhaps, we could not positively controvert the vitalistic physiologists who maintain that the law of causation is valid in inorganic nature; although in the organic world they relegate it to a lower sphere of action.

Finally, the law of causation bears on its face the character of a purely logical law, chiefly because the conclusions derived from it do not concern actual experience, but its interpretation. Hence it cannot be refuted by any possible experience.[1] For if we founder anywhere in applying the law of causation, we do not conclude that it is false, but simply that we do not yet completely understand the complex of causes mutually interacting in the given phenomenon. And when at length we have succeeded in explaining certain natural processes by the law of causation, the conclusions we derive from it are that certain masses of matter exist and move in space and act on each other with certain motive forces. But the conception of both matter and force are entirely abstract in nature, as is shown by their attributes. Matter

[1] Helmholtz, *Über das Sehen des Menschen, ein populär wissenschaftlicher Vortrag.* Leipzig 1855.

without force[1] is assumed to exist only in space, but not to act or to have any properties. Thus it would be of no importance whatever for all other affairs in the world or for our perceptions. It would be practically non-existent. Force without matter is indeed said to act; but it cannot exist independently, for whatever exists is matter. Thus the two conceptions are inseparable; they are merely abstract modes of regarding the same objects of nature in various aspects. For that very reason neither matter nor force can be direct objects of observation, but are always merely the revealed causes of the facts of experience. Hence, if we conclude by proposing certain abstractions, which can never be objects of experience, as the final and sufficient bases of natural phenomena, how can we say that experience proves that the phenomena have sufficient bases?

The law of sufficient basis amounts simply to the requirement of wishing to understand everything. The process of our comprehension with respect to natural phenomena is that we try to find *generic notions* and *laws of nature*. Laws of nature are merely generic notions for the changes in nature. But since we have to assume the laws of nature as being valid and as acting independently of our observation and thinking, whereas as generic notions they would concern at first only the method of our thinking, we call them *causes* and *forces*. Hence, when we cannot trace natural phenomena to a law, and therefore cannot make the law objectively responsible as being the cause of the phenomena, the very possibility of comprehending such phenomena ceases.

However, we must try to comprehend them. There is no other method of bringing them under the control of the intellect. And so in investigating them we must proceed on the supposition that they are comprehensible. Accordingly, the law of sufficient reason is really nothing more than the *urge* of our intellect to bring all our perceptions under its own control. It is not a law of nature. Our intellect is the faculty of forming general conceptions. It has nothing to do with our sense-perceptions and experiences, unless it is able to form general conceptions or laws. These laws are then objectified and designated as causes. But if it is found that the natural phenomena are to be subsumed under a definite causal connection, this is certainly an objectively valid fact, and corresponds to special objective relations between natural phenomena, which we express in our thinking as being their causal connection, simply because we do not know how else to express it.

[1] ¶The word *force* (*Kraft*) appears to be used here in the sense of *energy*; and in the same sense as it was used in the author's famous paper *Über die Erhaltung der Kraft*, read before the Physical Society of Berlin in 1847. (J.P.C.S.)

Just as it is the characteristic function of the eye to have light-sensations, so that we can *see* the world only as a *luminous phenomenon*, so likewise it is the characteristic function of the intellect to form general conceptions, that is, to search for causes; and hence it can *conceive* (*begreifen*) of the world only as being *causal* connection. We have other organs besides the eye for comprehending the external world, and thus we can feel or smell many things that we cannot see. Besides our intellect there is no other equally systematized faculty, at any rate for comprehending the external world. Thus if we are unable to *conceive* a thing, we cannot imagine it as existing.

The earlier history of the theory of the sense-perceptions is practically the same as the history of philosophy, as given at the end of §17. The investigations of the physiologists of the seventeenth and eighteenth centuries generally did not go beyond the image on the retina, for they supposed that when it was formed, everything was settled. Hence they were little troubled by the questions as to why we see objects erect and why we see them single, in spite of two inverted retinal images.

Among philosophers DESCARTES was the first to take any deep interest in visual perceptions as related to the knowledge of his time. He considered the qualities of sensation as being essentially subjective, but he regarded the ideas of the quantitative relations of size, form, motion, position, duration, number of objects, etc., as something that could be correctly perceived objectively. However, in order to explain the correctness of these ideas, he assumes, as the idealistic philosophers did who came after him, a system of *innate ideas* which are in harmony with the things. This theory was subsequently developed in its most logical and purest form by LEIBNITZ.

BERKELEY made a profound study of the influence of memory on the visual perceptions and their concomitant inductive conclusions. He says concerning them that they take place so quickly that we are not aware of them unless we are deliberately on the watch for them. It is true, this empirical basis led him to assert that not only the qualities of sensation but the perceptions also were mainly merely internal processes having no correspondence with anything outside. What led him into making this false conclusion was the error contained in the proposition that the cause (the object perceived) must be of the same kind as its effect (the idea), that is, must be a mental entity also, and not a real object.

In his theory of the human understanding, LOCKE denied the existence of innate ideas and attempted to establish an empirical basis for all understanding; but this attempt ended in HUME's denying all possibility of objective knowledge.

The most essential step for putting the problem in its true light was taken by KANT in his *Critique of Pure Reason*, in which he derived all real content of knowledge from experience. But he made a distinction between this and whatever in the form of our apperceptions and ideas was conditioned by the peculiar ability of our mind. Pure thinking *a priori* can yield only formally correct propositions, which, while they may certainly appear to be absolutely binding as necessary laws of thought and imagination, are, however, of no real significance for actuality; and hence they can never enable us to form any conclusion about facts of possible experience.

According to this view perception is recognized as an effect produced on our sensitive faculty by the object perceived; this effect, in its minuter deter-

minations, being just as dependent on what causes the effect as on the nature of that on which the effect is produced. This point of view was applied to the empirical relations especially by JOH. MÜLLER in his theory of the Specific Energy of the Senses.[1]

The subsequent idealistic systems of philosophy associated with the names of J. G. FICHTE, SCHELLING and HEGEL all emphasized the theory that idea is essentially dependent on the nature of the mind; thus neglecting the influence which the thing causing the effect has on the effect. Consequently, their views have had slight influence on the theory of the sense-perceptions.

KANT had briefly represented space and time as given forms of all apperception, without going farther and investigating how much might be derived from experience in the more minute formation of individual apperceptions of space and time. This investigation was outside of his special work. Thus, for example, he regarded the geometrical axioms as being propositions in space-apperception which were given to start with;—a view which is not at all settled yet.[2] His lead was followed by JOH. MÜLLER and the group of physiologists who tried to develop the *intuition theory* of space-apperception. JOH. MÜLLER himself assumed that the retina might "sense" itself in its space-extension by virtue of an innate ability for it, and that the sensations of the two retinas are fused together in this case. The one who has recently tried to carry out this view in its most logical form and to adapt it to newer discoveries is E. HERING.

Prior to MÜLLER, STEINBUCH had tried to explain individual apperceptions of space by means of the movements of the eye and of the body. Among the philosophers, HERBART, LOTZE, WAITZ and CORNELIUS attacked the same problem. From the empirical side, it was WHEATSTONE especially who, by inventing the stereoscope, gave a powerful incentive to the investigation of the influence of experience on our visual apperceptions. In addition to minor contributions which I myself have made to the solution of this problem in various works, attempts to give an *empirical* view may be found in the writings of NAGEL, WUNDT and CLASSEN. In the succeeding chapters, more will be said with reference to these investigations and the points of controversy.

1637. CARTESIUS, *Dioptrice.* See Tome V. of V. COUSIN's edition of his Works.
1644. CARTESIUS, *Principia Philosophiae,* T. III.
1703. LEIBNITZ, *Nouveaux essais sur l'entendement humain.* See Vol. I, p. 194 of his *Opera philos.* edited by ERDMANN.
1709. BERKELEY, *Theory of vision.* London.
1720. LOCKE, *Essay on the Human Understanding.*
HUME, *Untersuchungen über den menschlichen Verstand.*
1787. J. KANT, *Kritik der reinen Vernunft.* 2. Aufl. Riga 1787.
1811. STEINBUCH, *Beiträge zur Physiologie der Sinne.* Nürnberg.
1816. J. F. HERBART, *Lehrbuch zur Psychologie.* See Vol. V of his Works published by HARTENSTEIN, Leipzig 1850.
1825. HERBART, Psychologie als Wissenschaft. *Sämtliche Werke.* Bd. VI.
1826. JOH. MÜLLER, *Zur vergleichenden Physiologie des Gesichtssinns.* Leipzig.
1849. TH. WAITZ, *Lehrbuch der Psychologie als Naturwissenschaft.* Braunschweig.
1852. H. LOTZE, *Medizinische Psychologie.* Leipzig.

[1] ¶See E. MINKOWSKI, Zur MÜLLERschen Lehre von spezifischen Sinnesenergien. *Zft. f. Sinnesphysiol.*, 45 (1911), 129-152. (J. P. C. S.)

[2] As is well known, HELMHOLTZ subsequently defended the empirical value of the axioms of geometry with very much greater determination and in opposition to KANT. In another place we shall discuss more in detail the relation between apriority, as KANT intended, and HELMHOLTZ's empiricism.—K.

1856. H. Lotze, *Mikrokosmus.* Leipzig.
1861. Cornelius, *Die Theorie des Sehens und räumlichen Vorstellens.* Halle.
M. J. Schleiden, *Zur Theorie des Erkennens durch den Gesichtssinn.* Leipzig.
A. Nagel, *Das Sehen mit zwei Augen und die Lehre von den identischen Netzhautstellen.* Leipzig u. Heidelberg.
1861-64. E. Hering, *Beiträge zur Physiologie.* Leipzig.
1862. W. Wundt, *Beiträge zur Theorie der Sinneswahrnehmung.* Leipzig u. Heidelberg. Reprinted from the *Zeitschrift für rationelle Medizin* 1858-1862.
1863. A. Classen, *Das Schlussverfahren des Sehaktes.* Rostock.
E. Hering über Dr. A. Classens Beitrag zur physiologischen Optik. *Archiv für pathol. Anatomie und Physiologie.* VIII. 2. p. 179.
1864. C. S. Cornelius, *Zur Theorie des Sehens.* Halle.
J. Dastich, *Über die neueren physiologisch-psychologischen Forschungen im Gebiete der menschlichen Sinne.* Prag.
1866. H. Ulrici, *Gott und der Mensch. I. Leib und Seele, Grundzüge einer Psychologie des Menschen.* Leipzig.

§27. Movements of the Eyes

The movements of the eyes have much to do with the formation of apperceptions of space by the sense of sight; and so it will be necessary now to learn more about them.[1]

The eyeball, indeed, has no regular firm socket made of bone like the joints in the limbs of the body. The socket of the eye as a whole is rather as shown in Fig. 22, Volume I, that is, a recess shaped like a tetrahedral pyramid with its apex toward the rear, which is not conformable in any way to the almost spherically moulded eyeball. The intervals contained between the latter and the bony walls of the orbit are filled up with very fatty, loose connective tissue, where the muscles, nerves, vessels of the eye and tear glands are found. There is only quite a small space left, especially above on the outside and inside, between the eyeball and bone; as may be easily felt by trying to shove the tip of the finger in between. It cannot be done without producing pressure images at the same time. Downwards on the outside toward the cheek-bone the space is somewhat bigger. The consequence is that the soft mass of fat, muscles, nerves, vessels and glands lying behind the eyeball are all comprised in a cavity, which is almost completely surrounded by solid walls, and where only a few small wedges of more yielding substance are to be found. On the sides and behind, this cavity is formed by the bony walls of the eye-socket, while it is completed above by the eyeball itself. The conglomeration of fat, muscles, nerves, etc., mentioned above being almost entirely incompressible, like the water that constitutes the bulk of its weight,

[1] ¶A valuable book to be consulted in connection with this chapter is Dr. Ernest E. Maddox's *Tests and studies of the ocular muscles* (Third edition, specially revised and enlarged by the author and published in Philadelphia, U.S.A. 1907). (J.P.C.S.)