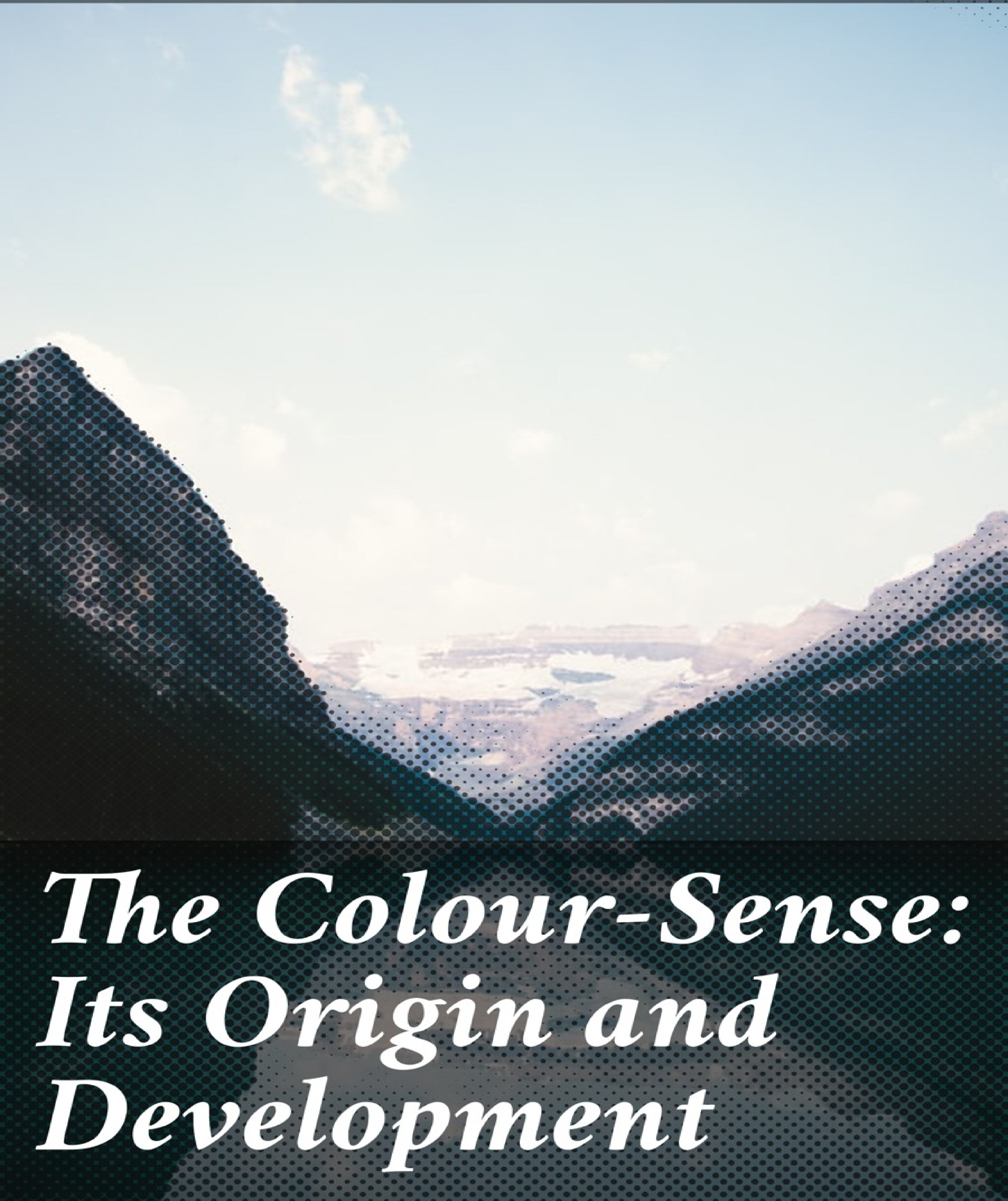
Grant Allen

The Colour-Sense: Its Origin and Development



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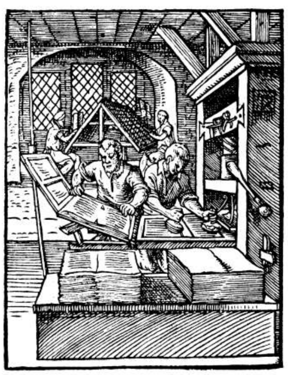

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PREFACE.

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The materials which form the nucleus of the present volume were originally collected as part of the basis for a chapter on “the Genesis of Æsthetics” in my little work on “Physiological Æsthetics,” published some two years since. I found, however, when I came to arrange them, that the subject had grown under my hands, and that it would be impossible fully to develop my ideas except in the form of a separate treatise. The omission seemed all the more desirable, because my former work dealt only with Æsthetics as an element of human psychology: while the materials here collected refer rather to the wider science which studies the phenomena of mind throughout the whole animal world. Accordingly, I deferred their publication for the time, only mentioning my original intention in a footnote on p. 156 of “Physiological Æsthetics.” But most of the critics who kindly noticed that little work were so unanimous in calling attention to the hints which I had thrown out with reference to the Colour-Sense, and the love for colour which forms such a striking characteristic of mankind, that I determined on following up the subject on a wider basis, and elucidating my view by full inductive generalisations. The present volume is the result.

Meanwhile two works appeared, in Germany and in England, which necessitated considerable divergences from my original plan. The first was Dr. Hugo Magnus’s “Geschichtliche Entwickelung des Farbensinnes;” the second Mr. A. R. Wallace’s “Tropical Nature.” Put shortly, the gist of my theory was this: that the taste for bright colours has been derived by man from his frugivorous ancestors, who acquired it by exercise of their sense of vision upon bright-coloured food-stuffs; that the same taste was shared by all flower-feeding or fruit-eating animals; and that it was manifested in the sexual selection of brilliant mates, as well as in other secondary modes, such as the various human arts. The two volumes mentioned above came like utterly destructive criticisms of any such belief. Dr. Magnus endeavoured to prove that the Colour-Sense of mankind was a late historical acquisition of the race, whose beginnings hardly dated back as far as the Homeric and Vaidik periods. Mr. Wallace controverted, with all his well-known vigour and ingenuity, the theory of sexual selection, first announced by Mr. Darwin, upon which rested almost the whole argument for a love of pure colour among the lower animals. Thus these two books between them cut away the whole ground from under my feet. It became necessary to go back over my materials afresh, and to seek for evidence against both anticipatory assailants. I have tried, therefore, to show, in opposition to Dr. Magnus, that the Colour-Sense of mankind dates back to the earliest appearance of our race upon earth; and, in opposition to Mr. Wallace, that a modified form of the sexual selection theory may still survive his powerful attack. I am aware how ill prepared I am to encounter so thorough a biologist as the joint discoverer of Natural Selection on his own ground; but I have humbly offered such arguments as lay in my power, trusting to the generosity of my opponent to forgive any technical errors which may easily creep into a discussion of the sort.

I should like to add that I enter the lists as a comparative psychologist, not as a biological student. I do not pretend to discover facts of botany or zoology at first hand: I accept them as data from the lips of competent specialists. Yet I hope my work may prove valuable in its own peculiar sphere, which ought to be kept distinct from the objective biological sciences whose conclusions form its basis. Our great naturalists supply us with the facts upon which to build our comparative psychology: and I hope there is no presumption in employing them sometimes to test the logical correctness of a few among the naturalists' own conclusions.

One of the main necessities of science at the present day is the existence of that organising class whose want was pointed out by Comte, and has been further noted by Mr. Herbert Spencer. To this class I would aspire, in a humble capacity, to belong. But the organising student cannot also himself be a specialist in all the sciences whose results he endeavours to co-ordinate: and he must, therefore, depend for his data upon the original work of others. If specialists find technical errors in such co-ordinated results, they should point them out frankly for correction and improvement, but they should not regard them as fit subjects for carping criticism. I shall feel grateful to any biologists who can suggest alterations or modifications in any part of what I cannot but feel a very tentative and rudimentary work. But unless we make a beginning in psychology we shall never reach the end: and I send forth my speculations rather in the hope that they may arouse comment and lead to further researches, than because I consider them in any way final or complete.

With regard to the authorities used or quoted, I have followed the plan of making no references to original works when dealing with the accepted common-places of science; but wherever I have occasion to note a particular fact, of comparatively modern ascertainment or specialist knowledge, I give the authority in a footnote. For the general groundwork of my theory, my acknowledgments are mainly due to the works of Mr. Darwin and Mr. Herbert Spencer, which I seldom quote by name, because they now form part of the established body of scientific doctrine. After these, I owe most to Mr. A. R. Wallace, Mr. Bates, and Mr. Belt. For personal assistance, by letter or otherwise, I must thank Mr. Darwin, who supplied me with corrections on the colours of flowers; Mr. Wallace, who kindly wrote to me with regard to the colours of fruits; Mr. Galton, F.R.S., for an introduction to the library of the Royal Society; Mr. Gladstone, who called my attention to notes in German periodicals; the Rev. A. H. Sayce, for reference to Assyrian and Babylonian works of art; the Rev. T. K. Cheyne, for aid on the question of Hebrew colour-terms; Mr. H. N. Moseley, naturalist to the *Challenger* expedition, for references to papers on the colouration of deep-sea organisms; Sir John Lubbock and Mr. B. T. Lowne, for copies of their original researches on the eyes and optical perceptions of insects; and the Rev. S. J. Whitmee of Samoa, with a large number of other missionaries or civil servants, for information with regard to the Colour-Sense of savages.

In a more strictly personal sense, I owe my acknowledgments to my friends, Mr. F. T. Richards of Trinity College, Oxford, Mr. G. J. Romanes, F.L.S., and Professor G. Croom Robertson, for constant assistance in calling my attention to passages in books or periodicals which bore on the subject under investigation.

Finally, I should mention that, although most of the matter contained in the present volume is entirely new, I have incorporated into Chapters IV. and VI. the substance of two papers on “The Origin of Flowers” and “The Origin of Fruits,” which appeared in the “Cornhill Magazine” for May and August 1878. Part of the materials for Chapter X. were also included in a note which I contributed to “Mind” for January of the same year.

G. A.

CHAPTER I.

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INTRODUCTORY.

There is no element of our sensuous nature which yields us greater or more varied pleasure than the perception of colour. Whether we look at the larger physical wholes, the azure heaven above us, the purple sea beneath us, and the green meadows by our side;—or at the smaller organic bodies, the brilliant flowers, the crimson foliage of autumn, the gaudily painted butterflies, the beetles clad in burnished gold, the peacock adorned with all the hues of the rainbow, and the humming-birds decked out in ruby, sapphire, and amethyst;—or again at the transient effects of light in the spectrum, the soap-bubble, the iridescent surface of the opal, the tints of eventide mirrored in the glassy lake;—in each and every case we feel a thrill of pure and unselfish enjoyment, which no other mere sensuous stimulation is capable of arousing in our breasts. The pleasure of colour is one which raises itself above the common level of monopolist gratification, and attains to the higher plane of æsthetic delight.

Nor is man the only creature who can appreciate and enjoy the lavish store of beauty which nature pours forth for his pleasure in the fields and the forest. We shall see reason to conclude, from the facts collected in this volume, that many of our dumb relations can fully enter into the love for exquisite colour, at least in its simplest and earliest forms. We shall find good ground for believing that the bird of paradise does not display its gorgeous plumage to the careless eyes of an unobservant mate; that the gaily painted butterfly is not insensible to the lovely tracery upon the wings of its fellow; and even that the tropical lizards or batrachians can duly admire the glistening coats, crimson crests, or golden pouches of their lissome helpmates. We shall further note certain habits which may lead us to suspect that birds and insects are pleasurably affected, not only by the colour of their own kind, but also by the delicate or brilliant tints of the fruits and flowers upon which they feed. In short, our object must be to trace back the pleasure which man experiences from the deft combination of red and green and violet, in painting or in decorative art, to a long line of ante-human ancestry, stretching back indefinitely through geological ages to the first progenitors of vertebrate life.

More than this we must attempt to show. If we would learn fully the whole history of the colour-sense, we must track it backward through the generations of the earlier earth, till we discover what were the circumstances by which it was first produced. We must find out how the various modes of æther-waves, which we now know as colours, came originally to be distinguished from one another by the nascent eyes of half-developed reptiles and insects. We must see by what steps the hues of flowers, and seeds, and fruits, and small animal prey caused the growth of a distinctive colour-perception in the creatures which fed upon them. And we shall probably conclude at the same time that the sense thus developed became in turn a source of new pleasure to its possessors, and a groundwork for more marvellous developments in future. The taste which was formed by the lilies and roses, the golden oranges and purple grapes, ended by producing the metallic lustre of the sun-birds and the daintily shaded ornamentation of the argus-pheasant.

We may hope to show, furthermore, that the existence of bright colouring in the world at large is almost entirely due to the influence of the colour-sense in the animal kingdom. I do not mean, of course, that animals have anything to do with the objective existence of those different æther-waves in the pencil of light which, when decomposed or separated, we perceive as colours; nor do I mean to include in this category the shades of earth, sea, sky, and other great inorganic masses. Obviously the human or animal eye could have no influence upon their origin or colouring. Even the green leaves of the trees and grasses seem quite independent of man or beast. But I still think that a vast mass of the coloured objects with which we are most familiar owe their hues to the perceptions of some insect, bird, or animal. If we look briefly at a few of the best-known cases, the reader will more clearly comprehend the line of argument which this book proposes to itself.

In the drawing-room where we sit, every object has obtained its colour entirely with reference to the likes and fancies of humanity. Not only have the pictures and ornaments been painted so as to please our eyes, but the carpets, the wall-paper, the curtains, the table-covers, the embroidery, the damask on the chairs and sofas, the clothing of the women and children, have all been dyed on purpose to stimulate and gratify the sense of sight. Indeed, there is scarcely an article of human use and manufacture, from the vermilion-stained earthenware of the prehistoric savage and the woad adornment of the Cymric warrior, to the Lambeth and Vallauris pottery, or the cretonnes and crewel-work of modern æsthetic designers, which has not received some special manipulation to add pleasing colour by means of dyes or pigments. The universal effect of the colour-sense on human products is too obvious to need further illustration.

A step lower down, we reach the actual bodies of men and animals themselves. It would seem at first sight as though the colour-sense could have nothing to do with the production of these. Yet the theory of sexual selection, into which we shall enter more fully hereafter, shows us how the long-continued choice of beautiful mates may have had the effect of encouraging the growth of bright-hued individuals, and the obsolescence of their less favoured fellows. I shall try to point out, also, an adjunct to this theory, which seems to have escaped even the keen eyes of Mr. Darwin, Mr. Wallace, and their German allies. I shall endeavour to prove that only those animals display beautiful colours, due to sexual selection, in whom a taste for colour has already been aroused by the influence of flowers, fruits, or brilliant insects, their habitual food. As the liking cannot have grown up without some groundwork of advantage to be gained by it, we might gather, even *a priori*, that such would be the case; and I hope, in the sequel, to adduce a sufficiently large array of positive instances to justify an inductive conclusion to the same effect.

Taking still another step backward, we arrive at the brilliantly coloured fruits and flowers, upon which these tastes were formed. And here we shall have reason to believe that the agency of insects has been most powerful in developing the hues of blossoms; while the fruits, as we shall see, are rather due to the selective action of birds and mammals. Between them almost all the colours of vegetal life, except the uniform green of the foliage, are probably produced, being due to the colour-sense of one or other of the great seeing classes, the vertebrate and the articulate.

Many lesser cases may be alleged, where colours have been acquired for purposes of protection or deception, and of such an abundance will be forthcoming in their proper place. But enough has doubtless been said to show the immense importance of the colour-sense in man or animals, and the conspicuous part which (as I believe) it has played in the moulding of organic forms. If I put in two antithetical paragraphs the various great classes of coloured objects which we do or do not owe to its operation, the reader will be able to see at a glance just how much influence I claim for it.

We do not owe to the colour-sense the existence in nature of the rainbow, the sunset, or the other effects of iridescent light; the blue sky, the green or purple sea, the red rocks, or the other great inanimate masses; the foliage of trees and shrubs, the hues of autumn, and the tints of precious stones or minerals generally.

But we *do* owe to the colour-sense the beautiful flowers of the meadow and the garden,—roses, lilies, carnations, lilacs, laburnums, violets, primroses, cowslips, and daisies;

the exquisite pink of the apple, the peach, the mango, and the cherry, with all the diverse artistic wealth of oranges, strawberries, plums, melons, brambleberries, and pomegranates; the yellow, blue, and melting green of tropical butterflies; the magnificent plumage of the toucan, the macaw, the cardinal-bird, the lory, and the honeysucker; the red breast of our homely robin; the silver or ruddy fur of the ermine, the wolverine, the fox, the squirrel, and the chinchilla; the rosy cheeks and pink lips of English maidens; the whole catalogue of dyes, paints, and pigments; and, last of all, the colours of art in every age and nation, from the red cloth of the South Seas, the lively frescoes of the Egyptian, and the subdued tones of Hellenic painters, to the stained windows of Poitiers and the Madonna of the Sistine Chapel.

The origin and rise of this powerful sense, and the means by which it has effected all these marvellous reactions on the external world, form the text upon which we must string our discourse in the present volume. We shall begin with the nature of colour, viewed as an external and objective fact; we shall next look at the steps by which the various eyes of insects and animals became sensible to its diverse stimulations; we shall then proceed to ask what secondary effects the newly acquired sense produced upon the surrounding existences; and we shall finally examine its remote æsthetic results in the sphere of human activity. We shall thus have traced the perception of colour from its first faint beginnings in palæozoic seas or carboniferous forests down to its latest developments in the palaces or galleries of civilised man.

CHAPTER II.

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ÆTHER-WAVES AND THEIR VARIETIES.

[1]

Before we can investigate any sensation in men or animals, we must find out what is the external agency to which it corresponds. Every feeling answers to some outer fact, and in the development of life the fact must necessarily have preceded the feeling. Unless there had been matter there could never have been mind. Without resistance we could not experience touch; without air we could not possess hearing; without æther we could not have developed the wonderful faculty of sight. Organic substances, acted upon by peculiar agencies in the inorganic world, give rise to the phenomena of sensation; but we cannot understand the existence of sensation unless we previously grant the existence of an influence capable of developing it. Idealism, which looks fallaciously plausible when applied to the fully evolved intelligence, becomes meaningless and self-contradictory when applied to the problem of its evolution.

We must begin, then, by allowing that, previous to all perception of colour by men or animals, colour itself existed as an agency in the external universe. The development of the colour-sense is equivalent to the growth of a mechanism by which this agency became capable of affecting organic matter. In the present chapter we will consider the nature of the objective agency, while in the next we shall have to look at the first and rudest form of the percipient mechanism.

Throughout the whole vast ocean of space in which suns, stars, and planets float like inconspicuous islets of light, modern science has taught us that an all-pervading element, known as æther, fills every available interstice. From constellation to constellation of sidereal bodies the æther spreads in wide expanses, which stretch uninterrupted over countless millions of miles. Between atom and atom of terrestrial substances the æther penetrates into tiny intervals whose minuteness the boldest mathematicians have only lately ventured to measure. Where-ever matter is not, æther is. Every sun and every molecule floats in a circumambient matrix of this unknown agent. If we could view the most solid body with a microscopic eye, magnifying some thousands of millions of diameters, we should see that it was composed of innumerable little masses, none of them in actual contact with its neighbours, but all bound to one another, as the earth is to the sun, by their mutual attractions extending over an intervening space. This space would be filled, in the one case as in the other, by the ubiquitous æther. And though we can never succeed in knowing its existence directly, yet we are every moment experiencing its effects in the most obvious and unmistakable manner. Just as we believe in air, which we never see, because we can feel it, so we believe in æther, which we can never handle, because we perpetually see by it and through it.

Æther, though infinitely light and elastic, is naturally a solid, or something very like one. But it shares the common property of other solids in its ability to transmit undulations from a centre of disturbance. We all know that if we set any body in motion, it imparts a portion of its motion to all other bodies with which it comes in contact. So, too, if we set up vibratory movements in a bell, we know that its particles knock up against the air-particles in their neighbourhood, and thereby send off into surrounding space a series of concentric air-waves, which, when they strike the appropriate human organ, are known to us in consciousness as sounds or tones. And inexactly the same way, when disturbances of a peculiar kind affect material particles of any sort, they set up a like series of concentric waves in the circumambient æther, which, falling in turn on *their* appropriate organs, are recognised in consciousness as heat, light, or colour. What is the exact nature of these waves and their differences we have next to inquire.

Apparently every movement of a material body or particle sets up more or less motion in the surrounding æther. We know now that every sound, every moving energy, every activity of any sort, as it dies away, is transferred by minute friction to the ætherial medium which bathes us on every side. But the stronger class of æther-waves, with which we have now to deal, is originated only in a single way. They all arise from the vibrations of a material body in that state of rapid molecular or atomic motion which we commonly know as red or white heat. The waves thus set up may be reflected, refracted, twisted about, and returned in varying proportions by other surrounding objects, but they all owe their original existence to a heated material mass, whether that mass be the sun, the dog-star, the drawing-room fire, or the flame of a candle. So we must look for a moment at the source of such æther-waves before we can comprehend the nature of the waves themselves.

Directly or indirectly, in every case, the vibration of the original heated body is due to the rushing together of masses, molecules, or atoms which were previously in a state of separation. In the heavenly bodies, the sun and the fixed stars, the attraction of gravitation (which affects masses) is drawing together their skirts; and under its influence the outlying matter of their systems is clashing with the central sphere and producing a terrific degree of heat; just as the continued clashing of hammers on an anvil will heat a piece of iron red-hot here on our little earth. In the grate and the candle, again, the attraction of chemical affinity (which affects atoms) is drawing together tiny particles of carbon and oxygen; and as the atoms clash against one another in the embers or the flame, they are put into a similar state of rapid vibration or heat. In physical language, the potential energy of their previous separation has become kinetic in the act of union, and is now being radiated off to surrounding objects. As the quickly vibrating little bodies, either in the sun or the flame, fly from side to side, they impart each second a portion of their moving energy to the æther about them; and each ætherial molecule continues to impart the communicated impulse to adjacent molecules, so that a series of spherical waves is set up in every direction from the central disturbance. If nothing intervenes to prevent them, these waves go on widening and weakening through all space *ad infinitum*, at least as far as human science or conjecture can follow them.

But all the æther-waves are not of exactly the same size, nor do they follow one another with exactly the same rapidity. When a material body vibrates with a comparatively slight motion (or, as we say in other words, is only slightly heated), the waves to which it gives rise are comparatively slow and voluminous: as the rate of vibration increases, more rapid waves succeed in the surrounding æther; and when the rapidity of vibration becomes very great, the resulting waves follow one another with an almost incredible speed. Three principal varieties of slower or quicker æther-waves are commonly distinguished, according to the effects which they produce upon the human organs.

The slowest undulations are known as heat-waves; those of intermediate rapidity as light-waves; and the quickest of all as chemical waves.

All three classes of waves are produced together by a body in a state of high molecular energy, such as the sun. Fortunately, we are able to separate the various kinds from one another, and to demonstrate their several properties, by means of a simple piece of triangular glass, known as a prism.

If we make a small slit in the shutter of a darkened room, and allow a few of the æther-waves, generated by the sun, to enter through this aperture, we can interpose the prism across their path, and project them sideways on to a screen. When we do so we find that the various waves are all bent upward, but not all equally. They occupy a broad space on the screen, the slowest waves striking the lowest portion, and the quickest falling at the top, while those of intermediate speed hit the middle space.[2] If we put a thermometer of very delicate construction (known as a thermopile) at the lowest point where the waves surge against the screen, we shall find that, in this portion of the wave-bundle, the undulations possess great heating power. If we put a piece of specially prepared paper at the highest point where the weaves alight, we shall similarly find that the undulations of that region possess high chemical power. And if we look at the intermediate space, we shall see for ourselves that the waves of that part produce the greatest amount of light and colour. So here we learn that in every bundle of solar æther-waves these three classes of undulations are closely combined; but by the interposition of a proper medium they can be sifted and separated each into a place of its own.

Fundamentally, then, light and radiant heat are identical. And not only so, but a third order of rays—the chemical—is always bound up with them in the waves which come to us from the sun. Yet though in their objective nature these various agencies are so similar—differing not at all in kind, but only in degree—there is a very strange diversity in our subjective perception of their effects. The slowest æther-waves we perceive with every portion of our bodies, and know as heat; the intermediate æther-waves we perceive through a pair of small and special organs—the eyes—and know as light; while the fastest æther-waves we do not perceive at all, except by very roundabout and indirect means.

The reasons for this difference must surely be very striking ones. It seems curious that such similar agencies should be so diversely cognised, or should escape our cognisance altogether. And it is for the purpose of bringing into clear relief so strange a fact that I have chosen what doubtless seemed at first sight an awkward and unfamiliar mode of envisaging a well-known subject. The question why we have two distinct methods for perceiving two closely allied forms of æther-waves, and no method at all for perceiving the third, is a question which evolutionism is bound to answer before it proceeds to the minor discrimination of those lesser differences known as colours.

For when we look at the matter objectively, we see at once that each colour differs from its neighbour in just the same manner as heat differs from light, though only to a less degree. Accordingly, we must ask first, Why are the senses of animals so differently affected by the extremes and the mean of the solar undulations? And when we have answered that question we may go on to the next, How did the various minor undulations of mean rapidity come to have differential sensations attached to them in consciousness?

Fortunately, the answer is not a very difficult one. The slower and more massive undulations, which we know as heat-waves, produce very marked results even upon inorganic bodies, while their effects upon organic matter are obvious and enormously important. To the animal, cold is death and warmth is life. Hence it is not astonishing that animals should very early have developed a sense which informed them of the changes of temperature taking place in their vicinity; and that this sense should have been equally diffused over the whole organism. Æther-waves of slow vibration are capable of setting up motion in the molecules of all bodies upon which they impinge, as we know familiarly when we touch a stone on the summer beach, or grasp a poker which has lain long in front of the fire; and the motion so absorbed we call warmth: while, on the other hand, molecules in rapid motion give up their energy to the surrounding æther, as we also know when a red-hot poker cools, or when we expose our faces to the chilly wind of winter; and the loss of motion so induced we call cold. In either case, the immediate effects are so highly important to animal life, that we may well imagine the accompanying sensations to be amongst the earliest which evolution could have produced. As soon as moving creatures began to feel at all, they probably began to feel heat and cold.

The æther-waves of middle frequency, however, do not produce such plain and universal results. If we interpose a slab of rock-salt in the course of a solar beam, we can sift out of it all the slower undulations (or heat-waves), which are selected and absorbed by the salt itself. On placing our hands in the path of the remaining wavelets, we do not experience any feeling of heat whatsoever. And if we put a piece of inorganic matter—say a pebble—in the course of the sifted ray, we shall find that it is similarly unaffected in temperature or structure. The thermopile conclusively shows us that little or no immediate mechanical power is left in the wavelets which pass through the rock-salt. If we examine the results which these middle undulations produce upon the world at large, we shall arrive at similar conclusions. While to the heat-waves are due the conspicuous differences of summer and winter, ice, snow, and rain, the poles and the tropics, besides the great phenomena of ocean-currents, winds, evaporation, clouds, rainfall, and atmospheric disturbances generally; their companions, the light-waves, scarcely produce any noticeable effects at all. Falling upon the mass of the earth’s surface, they are not, like the slower undulations, absorbed and communicated through the substance on which they impinge, but are reflected and twisted back upon space in every possible direction. Even if they are partially taken in by the matter on which they fall, yet the greater portion of them are returned without effecting any change in its arrangement; and if, as in the case of what we call a black surface, a large number or the whole of them are absorbed and retained, they are yet degraded by the process into the form of heat-waves, from which they cannot be consciously discriminated except by indirect means. These middle waves could not, therefore, prove of any great importance to animal life in its earliest days; and we need not wonder that no sense for their perception was at first developed.

There is one conspicuous exception, however, to this comparative inertness of the light-waves—I mean the case of plants. In their leaves, the middle and quickest ætherial undulations become the agents for effecting great chemical and physical changes, upon which the whole course of mundane life entirely depends. But these facts, all-important in themselves, do not directly affect our present question. Light is essential to animal life, because it is essential to the plants upon which, mediately or immediately, animal life subsists. But a perception or discrimination of light is not at all necessary, except in a very roundabout and derivative way. Why it has arisen at all we may next briefly inquire.

The light-waves falling upon a body do not largely affect it, as a rule, in any way. They may occasionally be employed in bringing about slight changes of its superficial molecules, but they do not penetrate deeply or work conspicuous rearrangements of its whole substance. Nevertheless, the power of discriminating them may indirectly benefit an animal organism. If a jelly-fish, swimming at the water's top, has eyelets upon which the incident light-waves produce distinct effects, it may be warned of the approaching enemy, or informed of passing prey, by having the path of the æther-waves cut off from above. Still more valuable will the nascent sense become, if, instead of being restricted to the full force of directly incident undulations, it is capable of being impressed by reflected waves. In this case, not only will the creature be conscious of objects passing between it and the source of light, but it will be able to receive varying stimulations from all surrounding objects upon which the light falls. The more highly developed its sight becomes (for we may now use the language of ordinary life without fear of ambiguity), the more clearly will it be affected by the beams which are twisted about and returned upon space from every neighbouring body. Until at last that very fact in the light-waves which made them originally so unimportant—the fact that they glance off every object they hit like a ball rebounding from a wall—gives them, in our eyes, the greatest value, by enabling us to discriminate from a distance the shape and texture of all we see, without the trouble of actual examination by the hands and fingers.

But this specialised sense is hardly likely to spread itself over the whole body, like the sense of heat and cold. Not only should we derive no advantage from being all eye, but we should be positively incommoded rather than benefited by such an arrangement. It will only be in certain special spots or *ocelli* that the perception of light will probably begin; and as the sense strengthens, we shall find these spots becoming fewer and fewer, until in the approximately perfect organisms they are reduced to the two conspicuous orbs which we commonly call eyes. All such questions, however, must be left over for a while, until we come to examine the development of the rudimentary vision. At present we must hurry on to reach our proper subject—the objective nature of colour.

As for the third class of ætherial undulations, the quickest or chemical waves, their effects are so slight and inconspicuous that we have never had occasion to develop any sense whatsoever for their perception. It is only quite recently, and by quite indirect methods (chiefly through the investigations of the earliest photographers), that we have come to recognise their existence at all. Neither upon inorganic substances nor upon animal bodies do they produce any striking result; so that we need not wonder at our inability to perceive them, either with our whole organism or with any specialised organ. Whatever has no influence upon our welfare as a species can never have any effect upon the modification of our senses.

We can dimly understand, then, why these three kinds of æther-waves, differing from one another only in their relative size and frequency, should be commonly thought of as such utterly unlike agencies. The slowest waves affect all material substances alike, and are consequently cognised by our whole bodies as heat. The middle waves are cast off in varying proportions by almost every substance upon which they fall, but possess little power of modifying their arrangement, and are consequently cognised by a very special organ—the eye; while the quickest waves are almost inert, so far as our present purpose is concerned, and are consequently not cognised by us at all, except mediately and intellectually.

And now that we have seen the objective nature of light in general, let us ask what is the objective nature of colours in particular.

As I said above, each colour bears objectively the same relation to light as light itself, heat, and chemical rays bear to the whole set of ætherial undulations.

If, once more, we have recourse to the prism and the darkened room, we can throw a bundle of æther-waves as before upon a white screen. Neglecting now the two extremes, the heat-rays and the chemical rays, which are of course invisible, we need only concern ourselves with the middle or light-rays, which form a bright band of colours, ranging from red to violet. The lowest part of this band or spectrum, next to the place where the thermopile showed us the existence of the heat-rays, is occupied by red. After it, in ascending order, come orange, yellow, green, and blue; while the highest place, next to the point where the sensitised paper showed us the existence of the chemical rays, is filled by a belt of violet. Each of these colours answers to a set of æther-waves, whose frequency is intermediate between that of heat-rays and chemical rays in the order just given. Slowest of all visible rays are the red, next come the green and blue, while the violet are the quickest waves capable of producing any direct effect upon the eye.

In the case of such a solar spectrum, we have sifted out the various orders of æther-waves by means of their varying *refrangibility*, that is to say, the extent to which each is capable of being bent aside from its direct course by means of the prism. But there are other ways in which the same effect may be produced. For example, we may intercept the whole bundle of compound undulations with a piece of specially prepared glass, (red glass, as we call it), which sifts out all the quicker waves, leaving only the red, just as the rock-salt sifted out all the heat-waves. Similarly, we may take a piece of green, blue, or violet glass, which will cut off all but the proper kind of waves which it is intended to let through. Neither of these ways, however, is a common one in external nature. The rainbow shows us the solar spectrum, and the green light which has passed through a stratum of water gives us an instance of selective absorption; but the way in which ordinary colour is produced is a slightly different one.

We saw above that every æther-wave has its origin in an incandescent body, celestial or mundane. But most of the objects which we see every day are not themselves incandescent; the light by which we perceive them is reflected from the sun. Now when the light-waves from the sun strike upon any terrestrial object, they may be reflected in a great many different manners. If the surface upon which they fall is perfectly smooth and quite opaque (or incapable of transmitting the undulations through its substance), the waves will be returned in their entirety,[3] as when we see an image of the sun in a mirror. Here the waves are sent back as they came, exactly in the same way as when a ball rebounds from the wall. If, however, the surface is not quite smooth, but yet has no special selective power for any one set of waves rather than another, the light is then returned, not directly as it came, but dispersedly in every direction. Such an object is said to be white, and its mode of treating the light may be compared to the case of a stone thrown against a wall, and shivered in every direction into a thousand pieces. Again, if the surface has such a molecular disposition that it absorbs or neutralises one or more sets of waves, and only returns one or more other sets, then it is said to be coloured. If it absorbs all the green, blue, and violet rays, returning only the red, then it is said to be a red object, because the red rays alone strike our eyes when we look at it. Similarly, if it absorbs all the red, orange, and violet rays, returning only the green, it is said to be a green object. And so on throughout. Lastly, if it absorbs all the æther-waves, degrading their light into the form of heat, and returning none, it is said to be black.[4]

Almost every object upon which the sunlight falls possesses a power of selecting and returning various æther-waves in varying proportions. Were it not so, the sense of sight could never have been developed. If all objects alike absorbed all the rays which fell upon them, then the whole earth would be one unbroken sheet of black, and the only visible things would be the sun and the fixed stars. If all objects alike reflected all the rays which fell upon them, then the whole earth would be one mass of dazzling white, without distinction of shape or colour. But as each object reflects and disperses the light in different ways from every point of its surface, the discrimination of form, of light and shade, and of colour becomes possible. The existence of the two first-named faculties we must take for granted in this work, though we shall have somewhat further to say about them in the succeeding chapter. But the discrimination of colour, the proper subject of our treatise, demands a little more detailed treatment even at this preliminary stage.

By colour-perception, then, we shall understand in the present work *the power of discriminating between light-waves having different rates of frequency*. If any creature shows by its actions that it is endowed with such a power, we shall say that it possesses a colour-sense. Anything more than this it is impossible to prove. Whether the sensation or mental idea *blue*, as perceived or thought by a butterfly or a humming-bird, is the same in consciousness with the sensation or mental idea *blue* as perceived or thought by you and me, we can never know. For, observe, we can never even know, gifted with language as you and I are, whether my perception of blue is the same as yours; far less then can we know this same thing in the case of animals whose minds are so widely diverse as man's and the butterfly's, and between whom intercommunication is impossible. But we *can* know by means of language that certain objective differences which differentially affect me also differentially affect you. And so too we *can* know, by the testimony of