Theory of Colours

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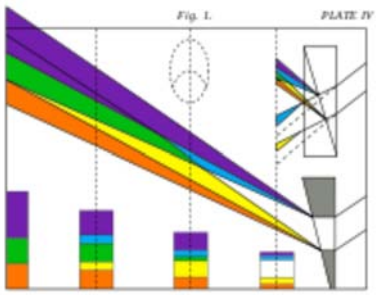
Theory of Colours (original German title ***Zur Farbenlehre***) is a work by Johann Wolfgang von Goethe about the poet's views on the nature of colours and how these are perceived by humans. Published in 1810, it contains some of the earliest published descriptions of phenomena such as coloured shadows, refraction, and chromatic aberration.[*citation needed*]

The work originated in Goethe's occupation with painting and mainly exerted an influence onto the arts (Philipp Otto Runge, J. M. W. Turner, the Pre-Raphaelites, Wassily Kandinsky).

Although Goethe's work was rejected by physicists, a number of philosophers and physicists have concerned themselves with it, including Thomas Johann Seebeck, Arthur Schopenhauer (see: *On Vision and Colors*), Hermann von Helmholtz, Rudolf Steiner, Ludwig Wittgenstein, Werner Heisenberg, Kurt Gödel, and Mitchell Feigenbaum.

Goethe's book provides a catalogue of how colour is perceived in a wide variety of circumstances, and considers Isaac Newton's observations to be special cases.[2] Unlike Newton, Goethe's concern was not so much with the analytic treatment of colour, as with the qualities of how phenomena are perceived. Philosophers have come to understand the distinction between the optical spectrum, as observed by Newton, and the phenomenon of human colour perception as presented by Goethe — a subject analyzed at length by Wittgenstein in his exegesis of Goethe in *Remarks on Colour*.

Theory of Colours



Light spectrum, from *Theory of Colours* – Goethe observed that colour arises at the edges, and the spectrum occurs where these coloured edges overlap.

Author(s)	Johann Wolfgang von Goethe
Original title	*Zur Farbenlehre*
Translator	Charles Eastlake[1]
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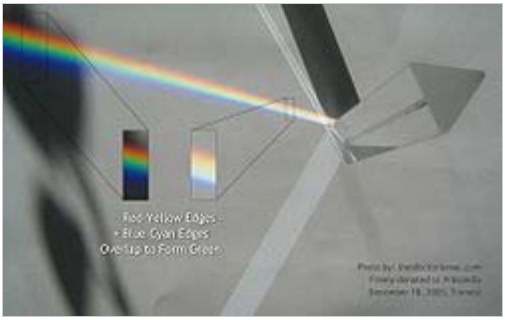
Historical background

At Goethe's time, it was generally acknowledged that, as Isaac Newton had shown in his *Opticks* in 1704, colourless (white) light is split up into its component colours when directed through a prism.[3]



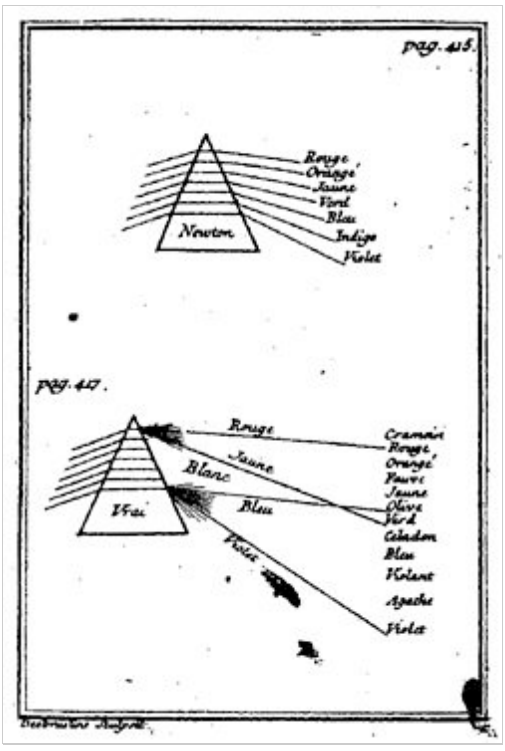
Reddish-yellow edges overlap blue-violet edges to form green.

> Along with the rest of the world I was convinced that all the colours are contained in the light; no one had ever told me anything different, and I had never found the least cause to doubt it, because I had no further interest in the subject.
>
> But how I was astonished, as I looked at a white wall through the prism, that it stayed white! That only where it came upon some darkened area, it showed some colour, then at last, around the window sill all the colours shone... It didn't take long before I knew here was something significant about colour to be brought forth, and I spoke as through an instinct out loud, that the Newtonian teachings were false.
>
> —Goethe[4]

Goethe's starting point was the supposed discovery of how Newton erred in the prismatic experiment,[5] and by 1793 Goethe had formulated his arguments against Newton in the essay "Über Newtons Hypothese der diversen Refrangibilität" (*"On Newton's hypothesis of diverse refrangibility"*).[6] By 1794, Goethe had begun to increasingly note the importance of the physiological aspect of colours.[7]

As Goethe notes in the historical section, Louis Bertrand Castel had already published a criticism of Newton's spectral description of prismatic colour in 1740[8] in which he observed that the sequence of colours split by a prism depended on the distance from the prism — and that Newton was looking at a special case.[9]

"Whereas Newton observed the colour spectrum cast on a wall at a fixed distance away from the prism, Goethe observed the cast spectrum on a white card which was progressively moved away from the prism... As the card was moved away, the projected image elongated, gradually assuming an elliptical shape, and the coloured images became larger, finally merging at the centre to



Castel's 1740 comparison of Newton's

produce green. Moving the card farther led to the increase in the size of the image, until finally the spectrum described by Newton in the Opticks was produced... The image cast by the refracted beam was not fixed, but rather developed with increasing distance from the prism. Consequently, Goethe saw the particular distance chosen by Newton to prove the second proposition of the Opticks as capriciously imposed." (Alex Kentsis, Between Light and Eye)[10]

spectral colour description with his explanation in terms of the interaction of light and dark, which Goethe later developed into his *Theory of Colours*

> The theory we set up against this begins with colourless light, and avails itself of outward conditions, to produce coloured phenomena; but it concedes worth and dignity to these conditions. It does not arrogate to itself developing colours from the light, but rather seeks to prove by numberless cases that colour is produced by light as well as by what stands against it.
>
> —Goethe[11]

In the preface to the *Theory of Colours*, Goethe explained that he tried to apply the principle of *polarity*, in the work – a proposition that belonged to his earliest convictions and was constitutive of his entire study of nature.[12]

Goethe's theory

> Goethe's theory of the origin of the spectrum *isn't* a theory of its origin that has proved unsatisfactory; it is really not a theory at all. *Nothing* can be predicted by means of it. It is, rather, a vague schematic outline, of the sort we find in James's psychology. There is no *experimentum crucis* for Goethe's theory of colour.
>
> —Ludwig Wittgenstein, *Remarks on Colour*

It is hard to present Goethe's "theory", since he refrains from setting up any actual theory; he says, "its intention is to portray rather than explain" (*Scientific Studies*[13]). Instead of setting up models and explanations, Goethe collected specimens — he was responsible for the meteorological collections of Jena University.[14] By the time of his death, he had amassed over 17,800 minerals in his personal collection — the largest in all of Europe. He took the same approach to colour — instead of narrowing and isolating things to a single experimentum crucius, he sought to gain as much breadth for his understanding as possible by developing a wide range of experiments through which he wished to reveal the essential character of colour (the UR phenomena) — without having to resort to explanation and theories about the perceived phenomena such as 'wavelength' or 'particle'.

"The crux of his color theory is its experiential source: rather than impose theoretical statements, Goethe sought to allow light and color to be displayed in an ordered series of experiments that readers could experience for themselves." (Seamon, 1998[15]). According to Goethe, "Newton's error.. was trusting math over the sensations of his eye." (Jonah Lehrer, 2006).[16]

To stay true to the perception without resort to explanation was the essence of Goethe's method. What he provided was really not so much a theory, as a *rational description* of colour. For Goethe, "the highest is to understand that all fact is really theory. The blue of the sky reveals to us the basic law of color. Search nothing beyond the phenomena, they themselves are the theory."[17]

> [Goethe] delivered in full measure what was promised by the title of his excellent work: *Data for a Theory of Color.* They are important, complete, and significant data, rich material for a future theory of color. He has not, however, undertaken to furnish the theory itself; hence, as he himself remarks and admits on page xxxix of the introduction, he has not furnished us with a real explanation of the essential nature of color, but really postulates it as a phenomenon, and merely tells us how it originates, not what it is. The physiological colors ... he represents as a

> phenomenon, complete and existing by itself, without even attempting to show their relation to the physical colors, his principal theme. ... it is really a systematic presentation of facts, but it stops short at this.
>
> —Schopenhauer, *On Vision and Colors*, Introduction

Goethe outlines his method in the essay, *The experiment as mediator between subject and object* (1772).[18] It underscores his experiential standpoint. "The human being himself, to the extent that he makes sound use of his senses, is the most exact physical apparatus that can exist." (Goethe, *Scientific Studies*[13])

Light and darkness

Unlike his contemporaries, Goethe didn't see darkness as an absence of light, but rather as polar to and interacting with light; colour resulted from this interaction of light and shadow. For Goethe, light is *"the simplest most undivided most homogenous being that we know. Confronting it is the darkness"* (Letter to Jacobi).

> ...they maintained that *shade is a part of light*. It sounds absurd when I express it; but so it is: for they said that *colours*, which are shadow and the result of shade, *are light itself*.
>
> —Johann Eckermann, Conversations of Goethe, entry: January 4, 1824; trans. Wallace Wood

Based on his experiments with turbid media, Goethe characterized colour as arising from the dynamic interplay of darkness and light. Rudolf Steiner, the science editor for the Kurschner edition of Goethe's works, gave the following analogy:

> Modern natural science sees darkness as a complete nothingness. According to this view, the light which streams into a dark space has no resistance from the darkness to overcome. Goethe pictures to himself that light and darkness relate to each other like the north and south pole of a magnet. The darkness can weaken the light in its working power. Conversely, the light can limit the energy of the darkness. In both cases color arises.
>
> —Rudolf Steiner, 1897[19]

Goethe writes:[20]

> Yellow is a light which has been dampened by darkness Blue is a darkness weakened by light.

Experiments with turbid media

> The action of turbid media was to Goethe the ultimate fact — the Urphänomen — of the world of colours.
>
> —John Tyndall, 1880[21]

Goethe's studies of colour began with experiments which examined the effects of turbid media, such as air, dust, and moisture on the perception of light and dark. The poet observed that light seen through a turbid medium appears yellow, and darkness seen through an illuminated medium appears blue.

> The highest degree of light, such as that of the sun... is for the most part colourless. This light, however, seen through a medium but very slightly thickened, appears to us yellow. If the density of such a medium be increased, or if its volume become greater, we shall see the light gradually assume a yellow-red hue, which at last deepens to a ruby colour. If on the other hand darkness is seen through a semi-transparent medium, which is itself illumined by a light striking on it, a blue colour appears: this becomes lighter and paler as the density of the medium is increased, but on the contrary appears darker and deeper the more transparent the medium becomes: in the least degree of dimness short of absolute transparence, always supposing a perfectly colourless

> medium, this deep blue approaches the most beautiful violet.
> —Goethe, *Theory of Colours*, pp. 150–151

He then proceeds with numerous experiments, systematically observing the effects of rarefied mediums such as dust, air, and moisture on the perception of colour.

Boundary conditions

When viewed through a prism, the orientation of a light-dark boundary with respect to the prism's axis is significant. With white above a dark boundary, we observe the light extending a blue-violet edge into the dark area; whereas dark above a light boundary results in a red-yellow edge extending into the light area.

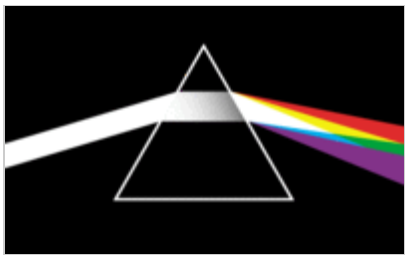
When looked at *through* a prism, the colours seen at a light-dark boundary depend upon the orientation of this light-dark boundary.

Goethe was intrigued by this difference. He felt that this arising of colour at light-dark boundaries was fundamental to the creation of the spectrum (which he considered to be a compound phenomenon).

Varying the experimental conditions by using different shades of grey shows that the intensity of coloured edges increases with boundary contrast.

Light and dark spectra

Since the colour phenomenon relies on the adjacency of light and dark, there are two ways to produce a spectrum: with a light beam in a dark room, and with a dark beam (i.e. a shadow) in a light room.



Light and dark spectra – when coloured edges overlap in a light spectrum, green results; when they overlap in a dark spectrum, magenta results. (Click for animation)

Goethe recorded the sequence of colours projected at various distances from a prism for both cases (see Plate IV, *Theory of Colours*). In both cases, he found that the yellow and blue edges remain closest to the side which is light, and red and violet edges remain closest to the side which is dark. At a certain distance, these edges overlap – and we obtain Newton's spectrum. When these edges overlap in a light spectrum, green results; when they overlap in a dark spectrum, magenta results.

With a light spectrum, coming out of the prism, one sees a shaft of light surrounded by dark. We find yellow-red colours along the top edge, and blue-violet colours along the bottom edge. The spectrum with green in the middle arises only where the blue-violet edges overlap the yellow-red edges.

With a dark spectrum (i.e. a shadow surrounded by light), we find violet-blue along the top edge, and red-yellow along the bottom edge – where these edges overlap, we find magenta.

Goethe's colour wheel

Main article: Color wheel

> When the eye sees a colour it is immediately excited and it is its nature, spontaneously and of necessity, at once to produce another, which with the original colour, comprehends the whole chromatic scale.
> — Goethe, Theory of Colours

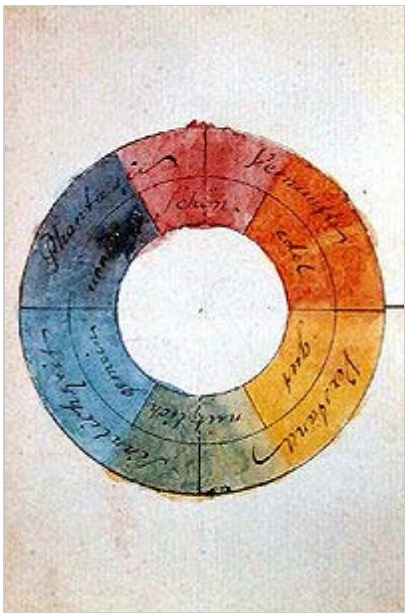
Goethe anticipated Ewald Hering's Opponent process theory[22] by proposing a symmetric colour wheel. He

writes, "The chromatic circle... [is] arranged in a general way according to the natural order... for the colours diametrically opposed to each other in this diagram are those which reciprocally evoke each other in the eye. Thus, yellow demands violet; orange, blue; red, green; and vice versa: thus... all intermediate gradations reciprocally evoke each other; the simpler colour demanding the compound, and vice versa. (Goethe, *Theory of Colours*[23]).

Goethe expressed his understanding of the light and dark spectra in including magenta in his colour wheel. Whereas for Newton magenta was an 'extraspectral' colour, for Goethe magenta was a natural result of violet and red being mixed in a dark spectrum (top of wheel), just as green resulted from the mixing of blue and yellow in the light spectrum (bottom of wheel).[24]

"For Newton, only spectral colors could count as fundamental. By contrast, Goethe's more empirical approach led him to recognize the essential role of (nonspectral) magenta in a complete color circle, a role that it still has in all modern color systems."[25]

Goethe also investigated the effects of colour on the physiology of individuals in an art of *colour psychology*. Because of this, he included aesthetic qualities in his colour wheel — associating Red with the beautiful, orange with the noble, yellow to the good, green to the useful, blue to the mean, and violet to the unnecessary.[26]



Goethe's symmetric colour wheel with 'reciprocally evoked colours' — includes magenta (top) as the mixture of red and violet, just as green results from yellow and blue (bottom)

Newton and Goethe

Due to their different approaches to a common subject, many misunderstandings have arisen between Newton's mathematical understanding of optics, and Goethe's experiential approach.[27]

Because Newton understands white light to be composed of individual colours, and Goethe sees colour arising from the interaction of light and dark, they come to different conclusions on the question: is the optical spectrum a primary or a compound phenomenon?

For Newton, the prism is immaterial to the existence of colour, as all the colours already exist in white light, and the prism merely fans them out according to their refrangibility. Goethe sought to show that, as a turbid medium, the prism was an integral factor in the arising of colour.

Whereas Newton narrowed the beam of light in order to isolate the phenomenon, Goethe observed that with a wider aperture, there was no spectrum. He saw only reddish-yellow edges and blue-cyan edges with white between them, and the spectrum arose only where these edges came close enough to overlap. For him, the spectrum could be explained by the simpler phenomena of colour arising from the interaction of light and dark edges.

Newton explains the appearance of white with colored edges by saying that due to the differing overall amount of refraction, the rays mix together to create a full white towards the centre, whereas the edges do not benefit from this full mixture and appear with greater red or blue components. For Newton's account of his experiments, see his *Opticks* (1704).[28]

Table of differences

Qualities of Light	Newton (1704)	Goethe (1810)
Homogeneity	White light is composed of coloured elements (heterogeneous).	Light is the simplest most undivided most homogenous thing (homogenous).
Darkness	Darkness is the absence of light.	Darkness is polar to, and interacts with light.
Spectrum	Colours are fanned out of light according to their refrangibility (primary phenomenon).	Coloured edges which arise at light-dark borders overlap to form a spectrum (compound phenomenon).
Prism	The prism is immaterial to the existence of colour.	As a turbid medium, the prism plays a role in the arising of colour.
Role of Refraction	Light becomes decomposed through refraction, inflection, and reflection.	Refraction, inflection, and reflection can exist without the appearance of colour.
Analysis	White light decomposes into seven pure colours.	There are only two pure colours – blue and yellow; the rest are degrees of these.
Synthesis	Just as white light can be decomposed, it can be put back together.	Colours recombine to shades of grey.
Particle or Wave?	Particle	Neither, since they are inferences and not observed with the senses.
Colour Wheel	Asymmetric, 7 colours	Symmetric, 6 colours

Goethe's reification of darkness is rejected by modern physics. Both Newton and Huygens defined darkness as an absence of light. Young and Fresnel combined Newton's particle theory with Huygen's wave theory to show that colour is the visible manifestation of light's wavelength. Physicists today attribute both a corpuscular and undulatory character to light — the Wave–particle duality.

History and influence

The first edition of the *Farbenlehre* was printed at the Cotta'schen Verlagsbuchhandlung on May 16, 1810, with 250 copies on grey paper and 500 copies on white paper. It contained three sections: i) a didactic section in which Goethe presents his own observations, ii) a polemic section in which he makes his case against Newton, and iii) a historical section.

From its publication, the book was controversial for its stance against Newton. So much so, that when Charles Eastlake translated the text into English in 1840, he omitted the content of Goethe's polemic against Newton.

> Significantly (and regrettably), only the 'Didactic' colour observations appear in Eastlake's translation. In his preface, Eastlake explains that he deleted the historical and entoptic parts of the book because they 'lacked scientific interest', and censored Goethe's polemic because the 'violence of his objections' against Newton would prevent readers from fairly judging Goethe's color observations.
>
> —Bruce MacEvoy, Handprint.com, 2008[29]

Influence on the arts

Goethe was initially induced to occupy himself with the study of colour by the questions of hue in painting. "During his first journey to Italy (1786-88), he noticed that artists were able to enunciate rules for virtually all the elements of painting and drawing except color and coloring. In the years 1786—88, Goethe began

investigating whether one could ascertain rules to govern the artistic use of color."[30]

Turner's *The fighting Temeraire*, 1839

This aim came to some fulfillment when several pictorial artists, above all Philipp Otto Runge, took an interest in his colour studies.[31] After being translated into English by Charles Eastlake in 1840, the theory became widely adopted by the art world – especially among the Pre-Raphaelites. J. M. W. Turner studied it comprehensively and referenced it in the titles of several paintings.[32] Wassily Kandinsky considered it "one of the most important works."[33]

Influence on Latin American flags

During a party in Weimar in the winter of 1785, Goethe had a late-night conversation on his theory of primary colours with the South American revolutionary Francisco de Miranda. This conversation inspired Miranda, as he later recounted, in his designing the yellow, blue and red flag of Gran Colombia, from which the present national flags of Colombia, Venezuela and Ecuador are derived. (See Flag of Colombia#History).

Flag of Colombia

Influence on philosophers

In the nineteenth century Goethe's Theory was taken up by Schopenhauer in On Vision and Colors, who developed it into a kind of arithmetical physiology of the action of the retina, much in keeping with his own representative realism. In the twentieth century the theory was transmitted to philosophy via Wittgenstein, who devoted a series of remarks to the subject at the end of his life. These remarks are collected as _Remarks on Colour_, (Wittgenstein, 1977). Wittgenstein was interested in the fact that some propositions about colour are apparently neither empirical nor exactly a priori, but something in between: phenomenology, according to Goethe. However, he took the line that 'There is no such thing as phenomenology, though there _are_ phenomenological problems.' He was content to regard Goethe's observations as a kind of logic or geometry. Wittgenstein took his examples from the Runge letter included in the "Farbenlehre", e.g. "White is the lightest colour", "There cannot be a transparent white", "There cannot be a reddish green", and so on. The logical status of these propositions in Wittgenstein's investigation, including their relation to physics, was discussed in Jonathan Westphal's _Colour: a Philosophical Introduction_ (Westphal, 1991).

Reception by scientists

As early as 1853, in Hermann von Helmholtz's lecture on Goethe's scientific works—he says of Goethe's work that he depicts the perceived phenomena — "circumstantially, rigorously true to nature, and vividly, puts them in an order that is pleasant to survey, and proves himself here, as everywhere in the realm of the factual, to be the great master of exposition" (Helmholtz 1892). Helmholtz ultimately rejects Goethe's theory as the work of a poet, but expresses his perplexity at how they can be in such agreement about the facts of the matter, but in violent contradiction about their meaning — 'And I for one do not know how anyone, regardless of what his views about colours are, can deny that the theory in itself is fully consequent, that its assumptions, once granted, explain the facts treated completely and indeed simply'. (Helmholtz 1892)[34]

Although the accuracy of Goethe's observations does not admit a great deal of criticism, his theory's failure to demonstrate significant predictive validity eventually rendered it scientifically irrelevant. Thomas Johann Seebeck was the only prominent scientist among Goethe's contemporaries who acknowledged the theory, but later also saw it critically.[35]

> Goethe's colour theory has in many ways borne fruit in art, physiology and aesthetics. But victory, and hence influence on the research of the following century, has been Newton's.
> — Werner Heisenberg, 1952

Much controversy stems from two different ways of investigating light and colour. Goethe was not interested in Newton's analytic treatment of colour – but he presented an excellent *rational description* of the phenomenon of human colour perception. It is as such a collection of colour observations that we must view this book.

> Most of Goethe's explanations of color have been thoroughly demolished, but no criticism has been leveled at his reports of the facts to be observed; nor should any be. This book can lead the reader through a demonstration course not only in subjectively produced colors (after images, light and dark adaptation, irradiation, colored shadows, and pressure phosphenes), but also in physical phenomena detectable qualitatively by observation of color (absorption, scattering, refraction, diffraction, polarization, and interference). A reader who attempts to follow the logic of Goethe's explanations and who attempts to compare them with the currently accepted views might, even with the advantage of 1970 sophistication, become convinced that Goethe's theory, or at least a part of it, has been dismissed too quickly.
> —Judd, 1970[36]

Mitchell Feigenbaum came to believe that "Goethe had been right about colour!"[25]

> As Feigenbaum understood them, Goethe's ideas had true science in them. They were hard and empirical. Over and over again, Goethe emphasized the repeatability of his experiments. It was the perception of colour, to Goethe, that was universal and objective. What scientific evidence was there for a definable real-world quality of redness independent of our perception?
> — James Gleick, *Chaos*[37]

Current status

> Goethe started out by accepting Newton's physical theory. He soon abandoned it... finding modification to be more in keeping with his own insights. One beneficial consequence of this was that he developed an awareness of the importance of the physiological aspect of colour perception, and was therefore able to demonstrate that Newton's theory of light and colours is too simplistic; that there is more to colour than variable refrangibility.
> —Michael Duck, 1988[38]

As a catalogue of observations, Goethe's experiments are useful for understanding the complexities of human colour perception. Whereas Newton sought to develop a mathematical model for the behaviour of light, Goethe focused on exploring how colour is perceived in a wide array of conditions. Developments in understanding how the brain interprets colours, such as colour constancy and Edwin H. Land's retinex theory bear striking similarities to Goethe's theory (Ribe & Steinle, 2002).

A modern treatment of the book is given by Dennis L. Sepper in the book, *Goethe contra Newton: Polemics and the Project for a New Science of Color* (Cambridge University Press, 2003).[30]

Quotations

> As to what I have done as a poet... I take no pride in it... but that in my century I am the only person who knows the truth in the difficult science

On the catalytic moment

> Aber wie verwundert war ich, als die

of colours – of that, I say, I am not a little proud, and here I have a consciousness of a superiority to many.

> — Goethe, as recalled by Johann Eckermann, *Conversations of Goethe*, (tr. John Oxenford), London, 1930, p.302

[Goethe] delivered in full measure what was promised by the title of his excellent work: data toward a theory of colour. They are important, complete, and significant data, rich material for a future theory of colour. He has not, however, undertaken to furnish the theory itself; hence, as he himself remarks and admits on page xxxix of the introduction, he has not furnished us with a real explanation of the essential nature of colour, but really postulates it as a phenomenon, and merely tells us how it originates, not what it is.

> —Schopenhauer, *On Vision and Colors*

Goethe's theory of the origin of the spectrum *isn't* a theory of its origin that has proved unsatisfactory; it is really not a theory at all. *Nothing* can be predicted by means of it. It is, rather, a vague schematic outline, of the sort we find in James's psychology. There is no *experimentum crucis* for Goethe's theory of colour.

> —Wittgenstein, *Remarks on Colour*

Can you lend me the *Theory of Colours* for a few weeks? It is an important work. His last things are insipid.

> —Ludwig van Beethoven, *Conversation-book*, 1820

Should your glance on mornings lovely
Lift to drink the heaven's blue
Or when sun, veiled by sirocco,
Royal red sinks out of view –
Give to Nature praise and honor.
Blithe of heart and sound of eye,
Knowing for the world of colour

durch's Prisma angeschaute weiße Wand nach wie vor weiß blieb, daß nur da, wo ein Dunkles dran stieß, sich eine mehr oder weniger entschiedene Farbe zeigte, daß zuletzt die Fensterstäbe am allerlebhaftesten farbig erschienen, indessen am lichtgrauen Himmel draußen keine Spur von Färbung zu sehen war. Es bedurfte keiner langen Überlegung, so erkannte ich, daß eine Gränze nothwendig sey, um Farben hervorzubringen, und ich sprach wie durch einen Instinct sogleich vor mich laut aus, daß die Newtonische Lehre falsch sey.

But I was astonished, as I looked at a white wall through the prism, how it stayed white! That only there where it came upon some darkened area, it showed more or less some colour, then at last, around the window sill all the colours shone, in the light grey sky outside there was no colour to be seen. It didn't take long before I knew that a border was required for colour to be brought forth, and I spoke as through an instinct out loud, that the Newtonian teachings were false.

> —Goethe, *Goethes Werke*, Weimar: Hermann Böhlau, 1887–1919, II. Abtheilung: Naturwissenschaftlichte Schriften, Bd. 4, pp 295–296

Where its broad foundations lie.
— Goethe

See also

- Theory of painting
- Checker shadow illusion (Same color illusion)

Notes and references

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3. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 528. "das zentrale Axiom von Newtons Farbentheorie, daß in dem weißen, farblosen Licht alle Farben enthalten seien" (*"the central axiom of Newton's colour theory that there were all colours in the white, colourless light"*)
4. ^ Goethe, Goethes Werke, Weimar: Hermann Böhlau, 1887–1919, II. Abtheilung: Naturwissenschaftlichte Schriften, Bd. 4, pp 295–296
5. ^ Matthaei, Rupprecht. Über die Anfänge von Goethes Farbenlehre (*On the beginnings of Goethe's Theory of Colours*). In: Jahrbuch der Goethe-Gesellschaft (*Yearbook of the Goethe Society*) 11, 1949, p. 259, cited in Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 553. "Goethes Ausgangspunkt, die Entdeckung des Newtonschen Irrtums, wie er es nannte, im prismatischen Versuch, schwand ihm aus dem Blickfeld in dem Maße, als er die Bedeutung der Physiologischen Farben zu ahnen begann." (*"Goethe's starting point, the discovery of the Newton error, as he called it, in the prismatic experiment, dwindled from his horizon according to how he began to sense the meaning of the Physiological Colours."*)
6. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 528. "Bereits 1793 hat Goethe seine Einwände gegen Newton formuliert in dem Aufsatz *Über Newtons Hypothese der diversen Refrangibilität* (...)." (*"Already in 1793, Goethe formulated his arguments against Newton in the essay* Über Newtons Hypothese der diversen Refrangibilität *[...]."*)
7. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 553. "Diese Wendung ist bereits angedeutet in Goethes Briefentwurf an Sömmerring vom Januar/Februar 1794, der Antwort auf Sömmerrings Brief an Goethe vom 18. Januar 1794 (...): *Es ist weit mehr Physiologisches bei den Farbenerscheinungen, als man denkt, nur ist hier die Schwierigkeit noch größer als in andern Fällen, das Objektive vom Subjektiven zu unterscheiden*." (Italics mark citations that may only slightly have been adapted to the descriptive sentence regarding the grammar.) Translation: *"This change is already indicated in Goethe's draft for a letter to Sömmerring from January/February 1794, the answer to Sömmerring's letter from January 18, 1794 (...): There is much more physiological with the phenomena of colours than one would think, just that it is even more difficult, here, to distinguish between the objective and the subjective."* The letter is cited by Mandelkow after: Goethe, Die Schriften zur Naturwissenschaft. Herausgegeben im Auftrage der Deutschen Akademie der Naturforscher (Leopoldina) zu Halle von R. Matthaei, W. Troll und L. Wolf. Weimar 1949 ff (*Goethe, The writings on sciences. Edited on behalf of the German Academy of Sciences Leopoldina at Halle by R. Matthaei, W. Troll and L. Wolf. Weimar 1949 et seq.*) See: Samuel Thomas von Sömmerring
8. ^ Louis-Bertrand Castel (1740). *L'Optique des couleurs*. Paris.
9. ^ Thomas L. Hankins and Robert J. Silverman (1995). *Instruments and the Imagination* (http://books.google.com/?id=O9e_7E22caAC&pg=PA250&lpg=PA250&dq=castel+goethe+colour#PPA83,M1) . Princeton University Press. ISBN 0-691-00549-4. http://books.google.com/?id=O9e_7E22caAC&pg=PA250&lpg=PA250&dq=castel+goethe+colour#PPA83,M1.
10. ^ http://arxiv.org/pdf/physics/0511130 | Alex Kentsis, Between Light and Eye
11. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 528. "Die Lehre dagegen, die wir mit Überzeugung aufstellen, beginnt zwar auch mit dem farblosen Lichte, sie bedient sich äußerer

Bedingungen, um farbige Erscheinungen hervorzubringen; sie gesteht aber diesen Bedingungen Wert und Würde zu. Sie maßt sich nicht an, Farben aus dem Licht zu entwickeln, sie sucht vielmehr durch unzählige Fälle darzutun, dass die Farbe zugleich von dem Lichte und von dem, was sich ihm entgegenstellt, hervorgebracht werde."

12. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 2: Briefe der Jahre 1786-1805 (*Letters of the years 1786-1805*). *Christian Wegner* publishers, Hamburg 1968, p. 530. "Das für Goethes gesamte Naturbetrachtung konstitutive Prinzip der Polarität gehört zu *seinen frühesten Überzeugungen..., an denen er niemals irre geworden sei* (Brief an Schweigger, 25. April 1814). Im Vorwort zur *Farbenlehre* wird es als *Hauptabsicht des gegenwärtigen Werkes* bezeichnet, dieses universelle Prinzip auch *auf die Farbenlehre anzuwenden*." (Italics mark citations that may only slightly have been adapted to the descriptive sentence regarding the grammar.) Translation: *"The principle of polarity, that is constitutive for all of Goethe's study of nature, belongs to* the earliest of his convictions*...,* that he had never lost faith in *(letter to Schweigger, April 25, 1814). In the preface to the* Theory of Colours*, it is called* the main intention of the work at hand to apply *this universal principle also* to the theory of colours*."* See Johann Schweigger
13. ^ ***a b*** Goethe, Johann (October 1995). Miller, Douglas. ed. *Scientific Studies (Goethe: The Collected Works, Vol. 12), p.57*. Princeton University Press.
14. ^ E. P. Hamm, *Unpacking Goethes Collections: The Public and the Private in Natural-Historical Collecting* The British Journal for the History of Science, Vol. 34, No. 3 (Sep., 2001), pp. 275-300, Cambridge University Press, [1] (http://www.jstor.org/stable/4028099)
15. ^ Seamon, David (1998). Seamon, David; Zajonc, Arthur. eds. *Goethe's Way of Science: A Phenomenology of Nature*. Albany, NY.
16. ^ Jonah Lehrer|*Goethe and Color* (http://scienceblogs.com/cortex/2006/12/post_7.php) , December 7, 2006
17. ^ Quoted in translation in: Hughes, Peter (1992). "Performing Theory: Wittgenstein and the Trouble with Shakespeare". *Comparative Criticism* **14**: 85.
18. ^ [2] (http://pages.slc.edu/~eraymond/bestfoot.html)
19. ^ Steiner, Rudolf (1897). *Goethe's World View, Chapter III The Phenomena of the World of Colors*.(published in German as *Goethe's Weltanshauung*)[3] (http://www.rsarchive.org/Books/GA006/)
20. ^ Goethe, Johann (1810). *Theory of Colours, paragraph #502*.
21. ^ Tyndall, John (1880). *Popular Science Monthly, Volume 17, June 1880, Goethe's Farbenlehre*.
22. ^ Goethe's Color Theory (http://webexhibits.org/colorart/ch.html) . *Webexhibits.org*, retrieved July 3, 2011
23. ^ Goethe, Johann (1810). *Theory of Colours, paragraph #50*.
24. ^ http://www.handprint.com/HP/WCL/color2.html
25. ^ ***a b*** Ribe & Steinle, 2002
26. ^ Goethe: Farbenkreis zur Symbolisierung des "menschlichen Geistes- und Seelenlebens". 1809 (http://www.kisc.meiji.ac.jp/~mmandel/recherche/goethe_farbenkreis.html) . *Kisc.meiji.ac.jp*, retrieved July 7, 2011 (German). "Jeder Farbe wird eine menschliche Eigenschaft zugeordnet (...). Im inneren Ring: rot – 'schön', gelbrot – 'edel', gelb – 'gut', grün – 'nützlich', blau – 'gemein', blaurot – 'unnöthig'." (*"Each colour, a human quality is attributed to [...]. In the inner ring: red – 'beautiful', orange – 'noble', yellow – 'good', green – 'useful', blue – 'mean', violet – 'unnecessary'."*)
27. ^ R. H. Stephenson, *Goethe's Conception of Knowledge and Science* (Edinburgh: Edinburgh University Press, 1995)
28. ^ *Opticks Or, A treatise of the Reflections, Refractions, Inflexions and Colours of Light, Also Two treatises of the Species and Magnitude of Curvilinear Figures* (London, 1704) [4] (http://www.newtonproject.sussex.ac.uk /prism.php?id=43)
29. ^ http://www.handprint.com/HP/WCL/goethe.html | Bruce MacEvoy | Handprint.com | 2008
30. ^ ***a b*** Sepper, Dennis L. | *Goethe contra Newton: Polemics and the Project for a New Science of Color* | Cambridge University Press | 2007 | ISBN 0-521-53132-2
31. ^ Karl Robert Mandelkow: Goethes Briefe (*Goethe's Letters*). 2. edition. Vol. 4: Briefe der Jahre 1821-1832 (*Letters of the years 1821-1832*). *C. H. Beck* publishers, München 1976, p. 622. "Wie die Anfänge von Goethes Beschäftigung mit der Farbenlehre veranlaßt waren durch die Frage nach dem Kolorit in der Malerei (...), so war die Anteilnahme bildender Künstler an seinen Farbenstudien für Goethe eine hochwillkommene Bestätigung des von ihm Gewollten, wie er sie vor allem von Philipp Otto Runge erfahren hat." (*"As the beginnings of Goethe's occupation with the theory of colours were induced by the question of hue in painting [...], the interest of pictorial artists in his colour studyings was a highly welcome acknowledgement of what he wanted, for him, which he above all received from Philipp Otto Runge."*)
32. ^ Bockemuhl, M. (1991). *Turner*. Taschen, Köln. ISBN 3-8228-6325-4.
33. ^ Rowley, Alison (September–December 2002). "Kandinskii's theory of colour and Olesha's Envy" (http://findarticles.com/p/articles/mi_qa3763/is_200209/ai_n9096866) . LookSmart FindArticles. http://findarticles.com/p/articles/mi_qa3763/is_200209/ai_n9096866. Retrieved 2007-07-14.

34. ^ Helmholtz, Hermann von. 1892. Goethes Vorahnungen kommender naturwissenschaftlicher Ideen. Berlin: Pastel. 1971. Philosophische Vortrdge und Aufsdtze. Ed. H. Horz and S. Wollgast. Berlin: Akademie-Verlag.
35. ^ Bodo Morawe: Goethes Briefe (*Goethe's Letters*). 1. edition. Vol. 3: Briefe der Jahre 1805-1821 (*Letters of the years 1805-1821*). *Christian Wegner* publishers, Hamburg 1965, p. 623. "[Seebeck] ist unter den Zeitgenossen der einzige profilierte Naturwissenschaftler, der Goethes *Farbenlehre* anerkannte, wenn er sie auch in den letzten Jahren dann kritisch sah." (*"[Seebeck] is the only prominent scientist among the contemporaries who acknowledged Goethe's* Theory of Colours*, even though he then saw it critically, in the last years."*)
36. ^ Judd, Deane B. (1970). *Introduction by Deane B. Judd, Goethe's Theory of Colours* (http://members.shaw.ca/competitivenessofnations/Anno%20Goethe.htm) . Cambridge: MIT Press. http://members.shaw.ca/competitivenessofnations/Anno%20Goethe.htm. Retrieved 2007-09-14.
37. ^ Gleick, James (1988). *Chaos, pp. 165-7*. London: William Heinemann Publishers.
38. ^ Duck, Michael (September 1988). "Newton and Goethe on colour: Physical and physiological considerations" (http://www.ingentaconnect.com/content/tandf/tasc/1988/00000045/00000005/art00004?crawler=true) . Annals of Science, Volume 45, Number 5, pp. 507-519. http://www.ingentaconnect.com/content/tandf/tasc/1988/00000045/00000005/art00004?crawler=true. Retrieved 2011-03-29.

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- Complete book content in German language (http://www.farben-welten.de/farben-welten/goethes-farbenlehre.html)
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- Goethe's Prismatic Experiments; Fotos by Sakae Tajima (http://www.scielo.br/img/revistas/ea/v7n19/encarte19.pdf)
- Light, Darkness and Colour, a film by Henrik Boëtius (1998) (http://magichourfilms.webhotel.net/index.php?specLan=eng&specPage=filmbasen_showMAX&specMovie=ok&id=36)
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- Critical review of Goethe's Theory of Colours (http://www.handprint.com/HP/WCL/book3.html#goethe)
- A list of links relating to Goethe's investigation of colour (http://alpha.lasalle.edu/~didio/courses/hon462/goethe_chaos.htm)
- Essay discussing color psychology and Goethe's theory (http://midwest-facilitators.net/downloads/mfn_19991025_frank_vodvarka.pdf)
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