in dialogue

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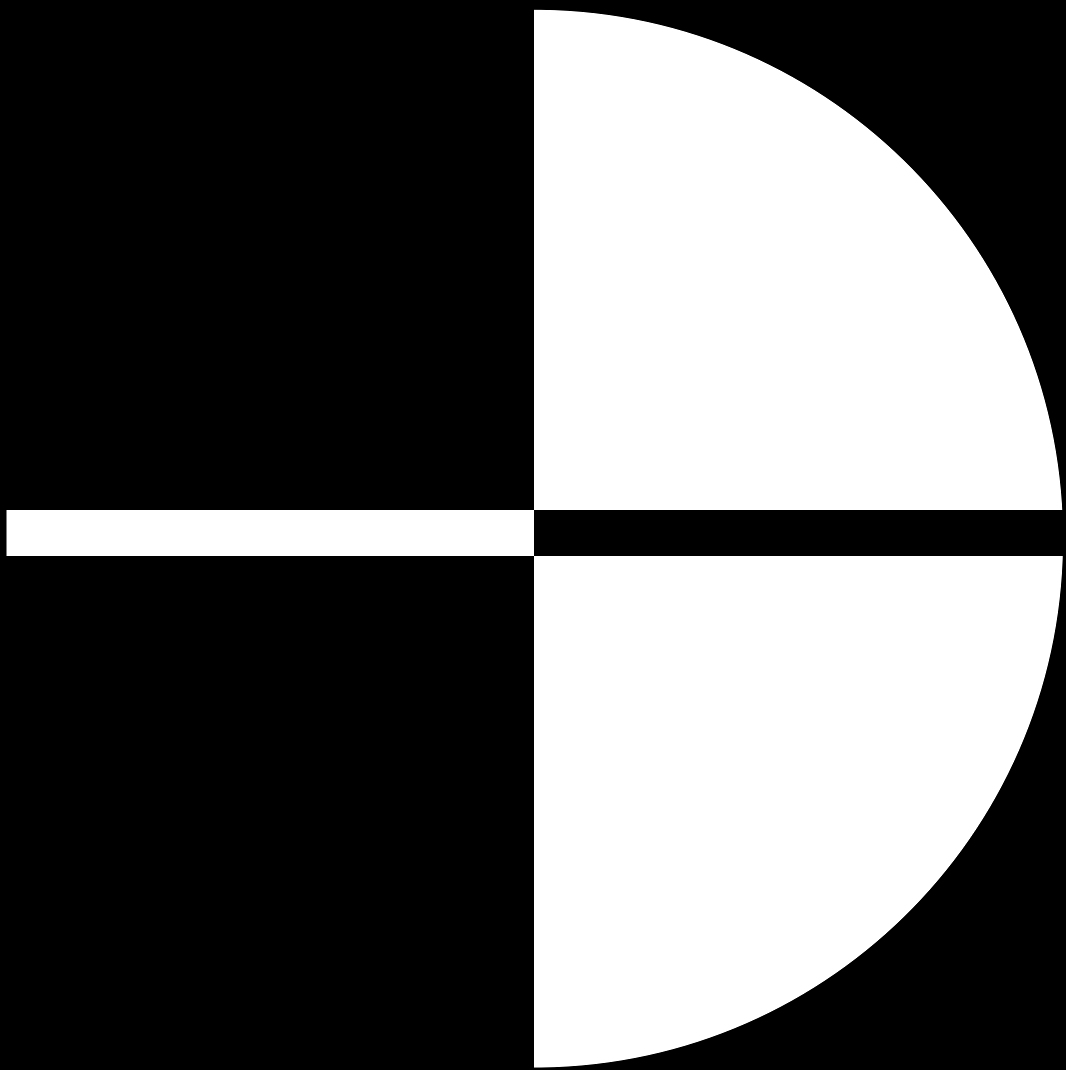

Few of us can remain insensitive to the alluring quality of colours spread all over the entire visible realm of nature.

- Goethe

[in]

preposition

- expressing inclusion or involvement
- as an integral part of (an activity)
- indicating the language or medium used

ORIGIN
Old English *in* (preposition), *inn, inne* (adverb), of Germanic origin; related to Dutch and German *in* (preposition), German *ein* (adverb), from an Indo-European root shared by Latin *in* and Greek *en.*

[dialogue]

noun

- discussion between two or more people or groups, especially one directed towards exploration of a particular subject or resolution of a problem

ORIGIN
Middle English: from Old French *dialoge,* via Latin from Greek *dialogos*, from *dialegesthai* 'converse with', from *dia* 'through' + *legein* 'speak'.

Welcome

/ Philip Franses and Troy Vine

For Johann Wolfgang von Goethe, the essence of colour expresses itself in dialogue: in the dialogue between light and dark, in the dialogue between experiments and, most importantly, in human dialogue. This joint issue of *Holistic Science Journal* and *The Field Centre Journal of Research and Practice* is an expression of this multifaceted dialogue on colour. This issue is also the expression of a particular dialogue that began between us when we first met at the Experience Colour exhibition in Stourbridge in 2018, where Troy had organized a conference bringing together experts in the field of Goethean science.

Troy is doing research on the historical and philosophical development of a holistic approach to colour at Humboldt University of Berlin and is an associate researcher at The Field Centre. The Field Centre, in Nailsworth, Gloucestershire, acts as a hub for collaborative research into Ruskin Mill Trust's educational method and its underpinning influences of Goethe and Rudolf Steiner. Philip is the founding editor of *Holistic Science Journal* and taught on the Holistic Science MSc at Schumacher College in Devon for the best part of the last decade alongside pioneers of holistic science, such as Margaret Colquhoun, Brian Goodwin and Henri Bortoft.

Given our interests and where we first met, it was natural that our discussions, and subsequently this issue, focused on the topic of colour. Colour is where we believe the holistic expression of nature is most visible; it wears its polarity on its sleeve. We have included colour experiments so that readers can see this for themselves. Moreover, we feel that the scientific, historical and philosophical context of an holistic approach to science is particularly perspicuous in the realm of colour. Thus, a consideration of the history of colour science facilitates a deeper understanding of holistic science and its purpose; for when we look at the history of colour science, as Goethe did in the third part of his monumental *Farbenlehre*, we see not only nature reflected back, but also ourselves — as we were, as we are, and as we can become.

Holistic Science Journal
the quest for perception in lived experience

thefieldcentre
JOURNAL OF RESEARCH AND PRACTICE

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/ Philip Franses

Ariadne's Thread

There is a great scene in Dostoevsky's *The Brothers Karamazov* in which the Grand Inquisitor gives the argument to the returning Christ, that people want certainty not revelation. The darkness in the argument is that the nature of existence is uncertainty, so reason has no way to answer back to the claim of certainty that the Grand Inquisitor is presenting. Yet the book does not end with the darkness of this argument but in the exploration of love, taking us into the hope and promise of a future generation.

Something similar is happening with Holistic Science. On the one hand it seems to have fallen into a very unfortunate need for certainty which is anathema to its very foundation. On the other hand there is major movement at its foundations which is poised to give it new life. I am delighted to be co-editing this long-awaited issue with Troy Vine of Humboldt University Berlin and the Field Centre.

Finding Holistic Science in need of renewal, I spent some time looking around for other languages, places, approaches where attention to the whole-part dynamic was being practised. This took me to Stourbridge for the "Experience Colour" Exhibition at Glasshouse College by Lora Nöbe and Matthias Rang with a conference organised by Troy in the summer of 2018. The exhibition showed me how the question one asks determines the form of how colour answers. Newton (or at least his followers) had wanted a story of certainty as to the relation of colour and light. But Goethe showed that one could invert Newton's experiment so that darkness and uncertainty were being interpreted by colour into light. Goethe's approach gave a fundamentally different primary spectrum than Newton's.

As Steiner writes in *Goethe's World View:* 'For Goethe darkness is not the completely powerless absence of light. It is something active. It confronts the light and enters with it into a mutual interaction. 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 colour arises.'

In the autumn of 2018, travelling to Colombia and teaching with Efecto Mariposa, this view of colour was mirrored in a visit to the Gold Museum in Bogota. For the indigenous people of Colombia, gold represented that essence out of which life e.g. deer, shaman or universe differentiated into spiritual identity and knowable form. Gold was the source through which the myth and detail of the world emerged and was told. The conquering Spanish, however, saw only the material wealth and divided it from this spiritual connotation, melting it down into a measureable quantity of gold bars of known value.

In August 2019 I travelled to Liverpool for the 50 year anniversary of the writing of *Laws of Form* by George Spencer Brown. This gathering was a think-tank of how fundamental mathematical and physical structure arises from the potential for nothing to change into something. This attempt to bring the whole-part story into the foundation of mathematics has been given new energy recently by the work of Lou Kauffman. Henri Bortoft in the 1960's had first seen the need for this work when doing his PhD with David Bohm at Birkbeck College, London.

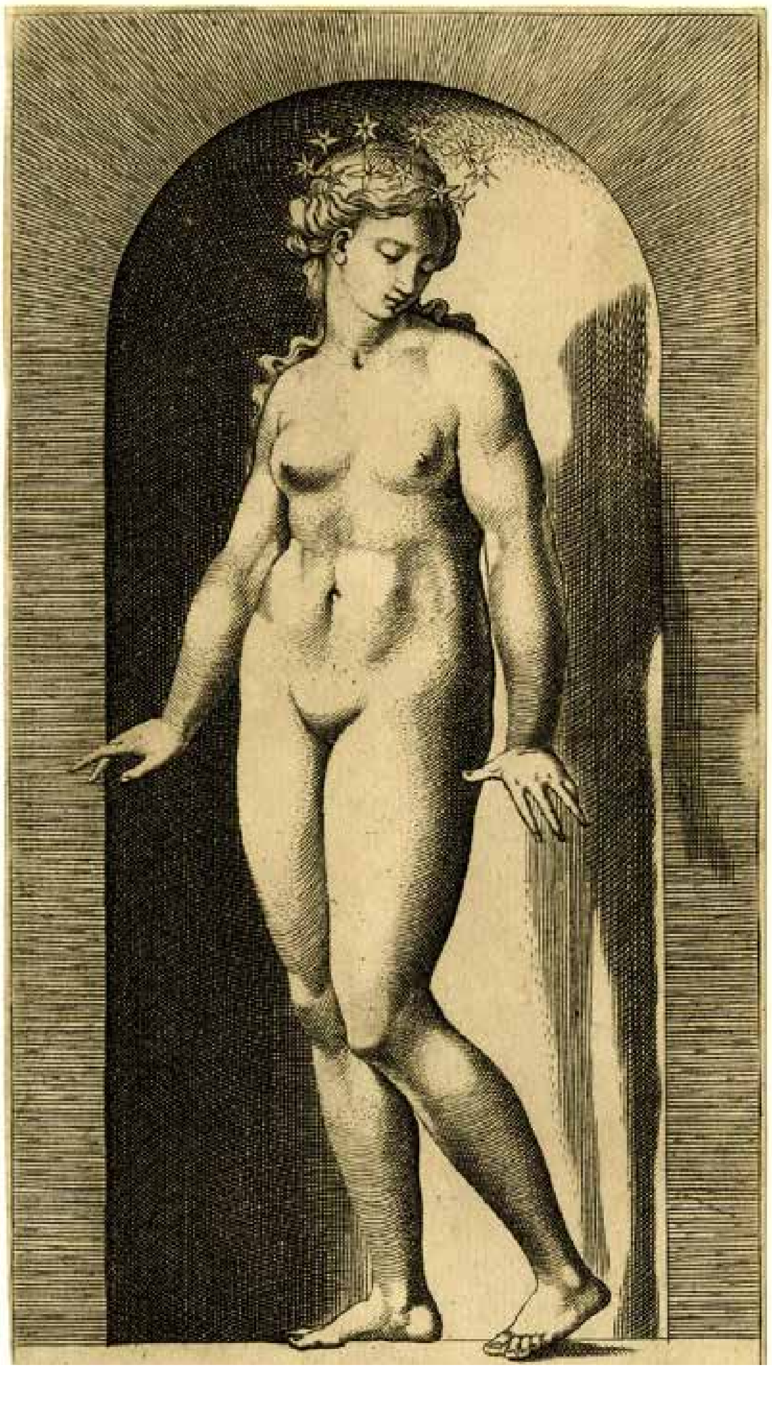
Holistic Science Journal began when I invited Henri Bortoft to a conference on *Paradox* in 2010 held in Italy. He replied that although he could not come, he had written *The Transformative Potential of Paradox* as a contribution we could read out. The article was so profound it needed a journal to hold it! But also a journal was needed to hold such spontaneous outpourings that were not yet exactly formed into something fixed. In the end, Henri did come to the conference at which then the journal was launched formally.

In many ways, the journal addressed a gap between Henri's early scientific work when working as a PhD student with David Bohm and Basil Hiley which never found its deserved platform; and Henri's later work into wholeness of experience through Goethe. In my years of teaching Holistic Science this exploration was taken further with the students that came each year to the course with some of their particular insights making their way to the pages of the journal. In 2013 a special tribute issue to Henri Bortoft (who had passed away in December 2012) was produced. In this issue we asked Basil Hiley to write a tribute, which he did and in which he drew out how he had used the work of Spencer Brown, whom Henri had introduced to the group, to arrive at the basic form of quantum logic.

So it feels fitting that in this issue, Lou Kauffman finds a novel way to lay out and resolve the difference of approach of Henri and his quantum colleagues. The foundation of self-recursion applies equally to Henri's concise way of describing what happens in quantum experiment, and to his colleagues search for mathematical formula to encapsulate the phenomena. Only when description is able to report on the phenomena is the other side of the mathematical form able to build the structure of what is seen.

Dissolving all apparent structure, a new vision returns from dissolution as a dynamic appearing. Just when one accepts that Holistic Science has reached its end-point, the potential in the foundation of Holistic Science finds a form more suited to the challenge of the time.

Life does not exist without death.
Something does not exist
without nothing.



Right:
Ariadne standing naked with her head turned lower right and a garland of stars, set within a niche; Jacopo Caraglio, from a series of 20 engravings depicting mythological gods and goddesses. 1526 engraving

Editorial

/ Troy Vine

Physics and Philosophy in Dialogue

Something is being criticized here: it is not science but some pervasive stories we tend to be told about science. […] I doubt very much whether science needs to be defended through perpetuating fables and myths cobbled together to pour value over it. To do so would truly be the final denial of the of the cultural legacy of the Scientific Revolution.

- Steven Shapin

With these words, the historian of science Steven Shapin brings to an end his classic book *The Scientific Revolution*. He is responding to the assumption that a critical historical or philosophical investigation of a particular episode in the history of science constitutes a criticism of science in general. I believe that this assumption has also contributed to Goethean science and holistic science being seen by friends and foes alike as an alternative science, or, in the more extreme version, an alternative to science. In discussion, Philip Franses and I kept returning to the question of how such misunderstandings arise, and it is therefore a reflection of our own dialogue that the articles in this special issue address this question, either directly or indirectly.

In my area of research, the reception of Goethe's scientific investigation of colour provides a striking example of just how ingrained this habit of thought is. As Johannes Grebe-Ellis and Oliver Passon show in their article, the myth of Goethe offering an alternative (to) science arises by ignoring not only the contemporary scientific context of Goethe's

scientific work, but even the work itself; for it turns out that many of the influential commentaries on Goethe's *Farbenlehre* were by physicists who had not even read it, much less done the experiments Goethe describes.

This research also brings to the fore the more general problem that science is an evolving thing. Giving a satisfactory account of the evolutionary aspect of science has important implications for understanding Goethean and holistic science. The reason for this evolution is not just the discovery of new facts, but also the creation of new concepts to express the facts. The activity of scientists thus consists in scrutinizing not only the experimental evidence for a new theory, but also the concepts the new theory uses. Louis Kaufman's article on quantum mechanics is an excellent example of this conceptual activity; he does not question the empirical results of Young's famous double slit experiment, but rather the language that should be used to describe them. By doing so, he demonstrates the insights that can be gained by using the language developed by Henri Bortoft to describe phenomena holistically.

While it might seem strange to worry too much about language, debates on language are common in the history of science. Particularly during the seventeenth century, scientific debates were just as much about language as about experimental results. But as the acceptance of Newtonian mechanics grew, it was believed that a solid foundation had finally been found on which the exact sciences could be erected. The need for constant conceptual scrutiny of the foundations of science was thus no longer seen as important, and the first instance of what Thomas Kuhn calls a "scientific paradigm" was born. It was not long before natural philosophy split into science, on the one hand, and philosophy, on the other. Scientists no longer needed to worry about what counted as explanation, what counted as evidence, what counted as refutation, etc. Yet, the scientific idyll was relatively short-lived, and cracks began to appear in the Newtonian foundations which ultimately led to a scientific revolution and the establishment of a new paradigm: general relativity.

It is during such periods of paradigm change that science reengages with its philosophical heritage as the discussion invariably turns to philosophical issues. As Johannes Kühl and Mattthias Rang show in their contribution, it is here that we need to locate Goethe's scientific achievement—as a scientist trying to bring about a new paradigm in colour science. Goethe did not want to do away with science, or to inaugurate an alternative science, but to take science further; keep it evolving. He saw clearly that fixed positions and dogmatic claims can only hinder science. Goethe provides a philosophical criticism of those fixed positions and dogmatic claims. However, this criticism was mistaken for an attack on science. The myths about Goethean science are a testament to the extent to which science and philosophy have become estranged. It is only by science and philosophy coming into dialogue that a fuller picture can emerge of Goethean science and holistic science, on the one hand, and science in general, on the other.

This special edition began as a dialogue between Philip and myself, and I am very happy that it has developed into the dialogue between physics and philosophy presented in this issue.

Left: Johann Wolfgang von Goethe on 26 March 1832, four days after his death at the age of 82. Drawn true to life. By Friedrich Preller the Elder.

The Colour **of Equals**

/ Philip Franses and Manu Rees-Durham

1. Introduction

Mathematics uses = as the gateway to describing a material order. It allows mathematical equations to make fundamentally true statements of how the universe is ordered. Material objects obey external relationships that cause the universe to develop in predictable ways.

We explore a dynamic equality that does not count with what is visible but joins together the capacities of the unseen coming together into a just order. The colour equality “c=” we introduce is an inherent freedom of meaning that guides action into identity. Where = in a statement like 2+2=4 is a closed statement 2+2 “c=” 4 shows a partial aspect that has to be joined to other perspectives to illumine the depth of many-sided reality. We show the origin of c= in Maxwell’s equations, its development in Einstein’s equations and its fulfilment in the integration of meaning and structure.

2. Maxwell’s Equations

Maxwell made the mathematical step of writing down in four grand statements the equations of the relationship of electric and magnetic fields, integrated into electromagnetism. Electromagnetism radically transformed our understanding of the world. Moving charges transmitted electromagnetic waves that would propagate massless at the speed of light, undetectable until they were received by something physical resonating to the signal. Artificially produced waves introduced x-rays, radio-waves, light-speed telemetry signals that have transformed our world. There are however **two** solutions to Maxwell’s equations.

One solution describes an ordering relationship developing in time, known as a *retarded wave,* with which we are all familiar from our mobile phones etc. The wave in this solution has a velocity t-c, in other words it is *retarded* with a speed c, of light. This solution details the composition of light as electrical and magnetic fields. Colours represent different wavelengths of the phenomena of light. *Retarded waves* we can picture as like outgoing circles distributing over the surface at finite speed resulting from throwing a stone into a pond. The = sign of Maxwell’s equation established an *external relationship* that brought into connection many phenomena as electricity, magnetism, colour, light, telemetry signals into a defined lawfulness of behaviour.

There is another solution to Maxwell's equation, which Einstein, Feynman and Wheeler recognised and explored (Franses, 82-93), where the velocity of the wave , c+t, is *advanced* ahead of time. An *advanced wave* solution connects many expressions of possibility which work together towards a particular act of illumination. The wave now travels in *advance* of time to the moment that light translates an order of illumination as foundation to time. The identity of light establishes an *internal relationship* to all the preparatory freedoms. *Advanced waves* are as the incoming concentric circles anticipating in uniform rhythm the source of a stone lifting out of a pond at their centre.

The = of the equation for the *advanced solution* does not denote an absolute order that is identified. The = refers to an *internal relationship*, where different expressions are found to belong to the illumination of a single particular action that unites all the component aspects. The = is an act of illumination that bridges a culminating order to the anticipatory behaviours of time. In this solution the colours are partial rhythms = = = = = = that hold together freedoms in anticipatory statements between darkness and light. We denote by "c=" the set of partial equivalences that sum together into an act of illumination. "c=" or *can equals* or *colour equals* depicts an *internal relationship* uniting the phenomena within a particular act. In *internal relationship* we are talking about a *local order* of connection true with respect to a single unifying action of illumination.

3. Einstein's Equations

To determine the relation of c= (the partial equalities of colour) to =, we can follow the lead of twentieth century physics. Einstein in *special relativity* asks us to consider the case where space and time are only locally true, dependent on the relation to light. One person travelling at the speed of light from the sun, will experience no time or space separation, while another watching stationary from the earth can record the eight minutes the journey takes, also through the aging process of his organic clock. We thus in Einstein's relativity distinguish a local freedom (c=) at the level of individual observation for the = of the constituted universal world-order.

In *general relativity* Einstein asks what is the universal translation, the =, that brings together the c= of space and time, as locally defined expressions in relation to light. He finds the equation of gravity exactly translates one view of space and time with another, by uniquely bending the space and time of the universe to synchronise across local space-time perspectives. There is an *internal relationship* between space, time and matter, which results in each expression of space and time being endowed with a characteristic falling towards other bodies that accommodates each local version of space-time order. A child on a garden swing experiences gravity not as an external force, but a natural inclination of his/her space-time reality to pull down his/her motion towards the earth. Gravity = the behaviour of space-time integrating into a universal fabric a c= freedom, acting out on local perspectives.

There is a challenge in relativity where all the reality of space-time collapses in on its own weight into a singularity, named a black hole. From this singularity a white hole emerges. But there is no way of navigating this darkness, for = is looking to depict material static reality. The advantage of c= in this case is the partiality of its sign allows us to follow a process in time, where the colour gradient of possibility develops the darkness into a form of light. c= partially identifies space time threads that pull together the disintegration of the black hole into the united fabric of the white hole.

c= poses partial statements of equivalence prior to weaving together the universe in an illumination of space-time. These partial threads of structure through c= statements contribute gravitational attraction prior to visibility, consistent with dark matter.

We also note that quantum theory at the level of small particles is incompatible as theory with relativity, even though both claim they are describing fundamental orders of the universe. Schrodinger's wave equation derives electromagnetism, the weak and the strong force of the nucleus, as compensating for local freedoms of individual acts of participation in the collective harmony of the composite state. The forces argued in this way do not coalesce with gravity as argued through relativity. A bridge between these theories is built by letting c= infer partial statements joining together into an illumination of the composite ground on which each theory is built. 6 as the most potent number of variations in physics corresponds to the number of dimensions of c= statements that are needed to fully hold the interaction between darkness and illumination.

4. Universal Undefined Force

Every attempt to balance a local freedom with a universal picture leads to a force. The force in the balance of "c="in "=" we call the UUF or "Universal Undefined Force". The UUF guides the universe without applying any certainty. Instead of seeing = as depicting *external relationships* between entities, c = applies to an *internal relations* of meaning that specifically joins together as unifying illumination different intimations of balance experienced locally. Experience guides realities as freedoms to come into coherence. The aim of any dialogue is to touch the centre of a meaning that brings light to many different paths of introductory inquiry.

The UUF is a translation of one view of balance in the world with another perspective such that our experience together guides the engagement to the illumination of = as a bridge of coherence in meaning and structure. The UUF ensures that the fundamental constants are balanced just right to allow the world its expression (Davies). The c= is exactly facilitating the connection of local potentials so they disclose together an instance of = as quality unifying structure and meaning. Every partial result of science is thus exhibiting = not as imposition of order, but as a **striking of balance**.

5. Colour Equations

The colours of light relate not as *external relations* to a world understood as explanation, but more in the vision of Goethe as internal pointers to an illumination in which freedom is guided to an encounter with meaning. The three colours of the lightening of dark and the three of the darkening of the light arrange themselves in a 6 dimensional wheel. Each colour can be experienced following careful attention to bend in natural accommodation and resistance to the other colours. The c= invests the freedom of local expression with a universal clarity. The colour equals are different pathways that can bring together different freedoms of expression into collective illumination.

In Goethe's study *The Metamorphosis of Plants* (Goethe, 76–97) the organs, as leaf, sepal, petal, carpel, stamen, pistil are shown as the different variants by which the universal of meaning takes on material expression (Goethe). The different forms of space-time combine into the unity of organic function of the whole plant development. These mediating organs are as partial results of space-time under = = = = = =, which over the whole realise a new illumination.

Local impulses are guided to relate together internally to meet an = as meaning at universal level. The balance of local freedom is in the articulation of the universe as meaning. The use of c= unites relativity and quantum theory, gravity, electromagnetism, weak and strong force as an *internal relation* that guides different elements to illumination of meaning. The universe is a freedom that shapes and guides experience at all levels of scale from atom, to cell to organism, to discover their potential for meaning together.

This act of translation of colour into light fulfils its illumination into darkness at the centre of the nucleus. In an instant, darkness explored through the contour lines of colour breaks upon the illumination of insight. The translation of = to c= contours the field of local perspectives in a language of interpretation ordered in its receptivity to hear defining meaning. c= marks the rhythm, descending into and ascending from a singularity, giving 6-fold beat to time.

6. Conclusion

We have introduced an exciting symmetry between the universal of knowing, c=, and the particular of material physics. As the symmetry of material events are described by the fundamental forces, so the Universal Undefined Force navigates the in-between realm before the distinction into subject and object. Possibility opens up a dimension anticipating the ground of what can be known.

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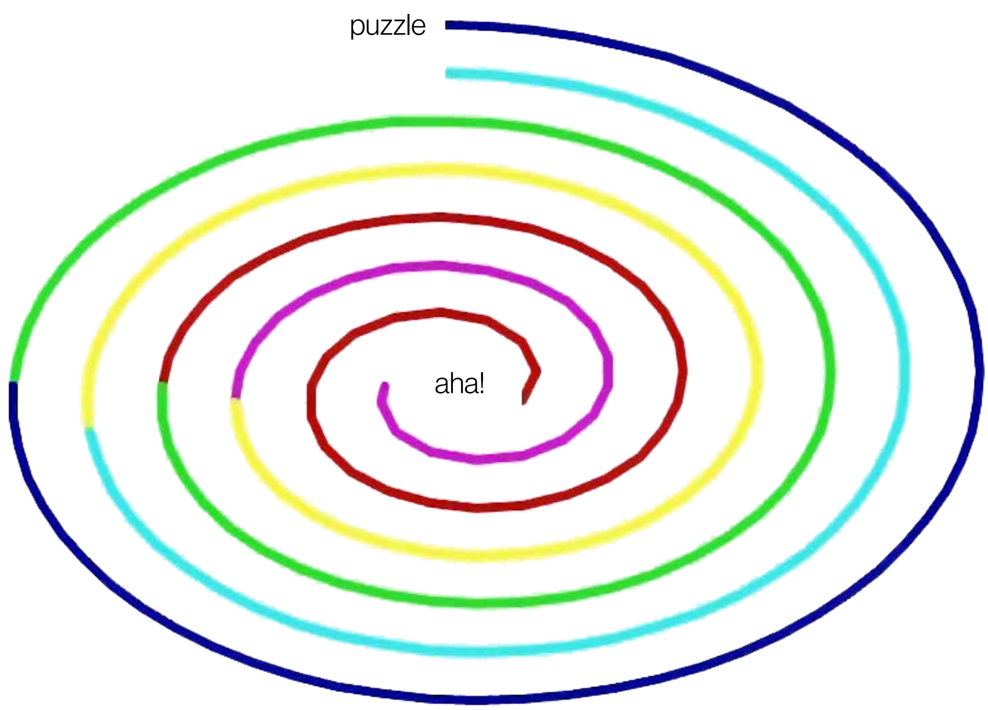

the**depth** of**colour**

/ Paul Carter

1. Introduction

The purpose of this study is to contrast two methods with colour as a focal point. The first is what I call the *standard method* of investigation, where we begin with 'what is known about a phenomenon' and end with a 'finished conceptual understanding of a phenomenon', the directionality of which is linear and the defining quality of which is one of abstract inertia. By outlining the standard method, its delineation will serve as a springboard into what I call the *dynamic method* of investigation, which begins with 'the phenomenon' and ends with 'the phenomenon', the directionality of which is one of dynamic reciprocity, the defining quality one of living depth.

Both methods are valuable, yet the directionality particular to each is of significance. This is because when we commit to a particular path, any problems we encounter therein are entirely endemic to that path. Thus, if we stop committing to that path, its problems will cease.

The standard method reflects our tendency to focus attention on what we already know. This is so in that phenomena in our field of perception appear as *known* because we have already successfully grasped them *conceptually*. Without the necessary concept to grasp something in this manner, that thing fails to have meaning for us, and consequently we cannot say that we know it. It could be said then, that a basic function of conceptual formulation is that it is a container for the meaning of things.

2. Goethe

Goethe is often considered as being one of the great Romantics, which is an interesting association: while he was of this era, there is nothing to suggest that he embraced Romanticism. Goethe's practical capacity as a functional member of his society provided the foundation for his prolific creative output of plays and poetry. Practical aptitude rails against Romanticism. It is ironic then that Goethe's artistic persona and the connections thereof have occluded this crucial aspect of his life, as well as its significance in terms of his desire and ability to influence society. Indeed, Goethe was the 'antidote to the sting of Romanticism'[1]. His competent, purposeful engagement with society shows no sign of a man self-obsessed with suffering the burdens of unrealisable ideals.

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1. Henri Bortoft used this analogy in a lecture at Schumacher College 2011.

Scientific investigation appealed to Goethe because of its grounding in close and persistent observation of phenomena. This offered a way to counter one of the prevailing sicknesses of the time – Romanticism, the spirit of which was one of '*Go inwards, my friend; and discover your true nature*!' Hence, Romantics made suspect scientists simply because their focus was not really the phenomenal world, but instead was groping in the dubious depths of their inner most recesses. Any ability to observe things accurately was lost behind the veil of this pseudo higher pursuit. Because of its introspective orientation, the Romantic attitude produced an unstable psychology, and this is the very thing Goethe warns of in *The Sorrows of Young Werther:* self-obsession leads to instability, which leads to suicide.

3. Theory of Colours

Goethe's practical study of colours spanned over two decades. His activity was driven by a desire to find and understand a natural relationship of colours, or indeed whether or not such a thing could be discovered. This project arose from the practice of mixing colour pigments for painting. Goethe wished to *deliberately* – not haphazardly – produce specific colours in a definite way, so as to help improve the quality of his paintings. Such an understanding, he thought, could facilitate the comprehension and communication of phenomenal reality through art.

With this aim, Goethe familiarised himself with the existing body of scientific research devoted to colour. It was in this way that he found Newton's work, available in textbooks at the time. Goethe was well informed of historical developments in natural philosophy, and readily apprehended the widespread prioritisation of quantitative properties over the direct experience of qualities. This was a view he not only thought to be a serious limitation – he considered it to be a complete degradation of the senses. Thus, Goethe's scientific work strove to re-establish the senses as central to scientific investigation.

The goal of *logical certainty* necessitates the simplification of phenomena in that the terms employed in this search discern 'sameness' and 'difference' by an *external relationship.* According to this approach, phenomena are categorised by distinguishing features which are present or in absentia. If we translate these terms and conditions into the logic of the part and the whole, there are two organising directions which are possible. Either the part is identified as exclusively essential (atomism/reductionism), or the whole is identified as exclusively essential (Neo-Platonism/holism). In either approach, one aspect dominates the other. Any logic that does not entertain paradox would seem to have this basic pattern built into its syntax.

Standard logic functions in terms of statements in tune with certainty, where certainty is usually conceived of as being *singular* in nature. This is a Judaeo-Christian idea of certainty, as epitomised in *statements of truth*. Thus in Judaeo-Christian cultures we predominately posit things as either wrong or right, black or white, for or against, this not that – which is entirely useful, up to a point.

We are not however, taught to entertain paradoxes, i.e. that things could be *both,* or *pluralistic* in terms of existence. We are conditioned to accept one thing, or the other, or we may attempt to make a diluted compromise between two extremes. But compromise also has a singular nature. This predominate pattern of thinking emphases one-sidedness, and makes it difficult to appreciate the *intrinsic relationship* between two or more elements. It is this relationship that I believe is vital. In simple terms, this is because when one element of a given polarity is eliminated, the counterpart thereof would also cease to exist. In other words, without *difference* to provide definition and contrast there can only be a singular, self-same state – a state of total oblivion in which no thing can exist in terms of relationship.

History is full of examples illustrating how concepts are not very good candidates for holding multiplicity together. This is so because when concepts are applied in standard logical fashion, they initially serve to separate things. By separating things, we seem to be left with multiplicity that requires relating or unifying. So, in turn, a unifying concept is sought to organise these disparate fragments. However, concepts conceived to unify multiplicity actively exclude difference, functioning as they do by *eliminating diversity* in search of unity. Conceptual unity therefore tips unavoidably towards a state of self-same, one-dimensional unity, and that is what many recognise as counterfeit unity. While this approach may initially lead us in interesting directions, its failure is inescapable because any conceptual unity is limited in it appropriateness – things change.

4. Paradox

A way out of this pattern is to entertain paradox – which is the principal characteristic of the dynamic method. This method is holistic in the sense that the two poles of a dichotomy can be apprehended as *intrinsically co-dependent, co-defining, and co-creating*; and as such the cul-de-sac of self-sameness is avoided. This is why Goethe is our contemporary. I believe that for Goethe science was what we could call a precise intuitive activity, one in which phenomena are brought clearly and completely into one's perceptual discernment, not by theoretical explanation, but by experiencing things accurately in their multifarious dynamic manifestations. This goes in the opposite direction to which we are accustomed. Here we are not interested in reducing phenomena to an arrangement of externally related parts. On the contrary, we set out to observe how a phenomenon *manifests in different forms under different circumstances and yet remains the same*. This practice could be called *finding the intrinsic unity of diversity*.

In the dynamic approach, diversity does not need relating together as if one thing were separate from another. Instead, diversity can be experienced as intrinsically unified *by difference*. In other words, the transformation and/or contradistinction of one element in complete relation to another is inherently related by their difference. Perceiving this dynamic within multifaceted relationships is the aim of the dynamic method, the experiential basis of which permits what is observed to be brought into ever-deepening comprehension.

If this doesn't sound like science, it is because the dynamic method doesn't entertain conceptual abstractions as a primary source of certainty. Instead of looking for an underlying mechanism which can be posited as reality, this method remains focused on whatever arises and dissolves in the sense fields. Because of its openness and unfamiliarity, this method is susceptible to misinterpretation. For instance, when looking for a 'primary expression' of a phenomenon, there is the tendency to construct this in terms of an 'archetypal form', as evidenced in many interpretations of Goethe's work on plant morphology. This however, would be a Neo-Platonist interpretation of the dynamic method, and I believe that such interpretations have little in common with Goethe's intended direction.

Goethe's theory of colours is based on a thorough exploration of how colours manifest from the interplay of darkness and lightness. Understanding colour phenomena precisely in qualitative terms can be honed by engaging with a systematic series of prism experiments. This stage of the theory is, however, as Goethe acknowledged, artificial – we are looking through a purpose-made wedge of glass (which we don't really know the workings of) at purpose-made templates. After gaining a basic insight into colours with these instruments – namely that colours arise at the boundary of light and dark – we can set about looking for instances of this in the phenomenal world, from which we can comprehend the intricate workings of this interlay in an entirely accurate way.

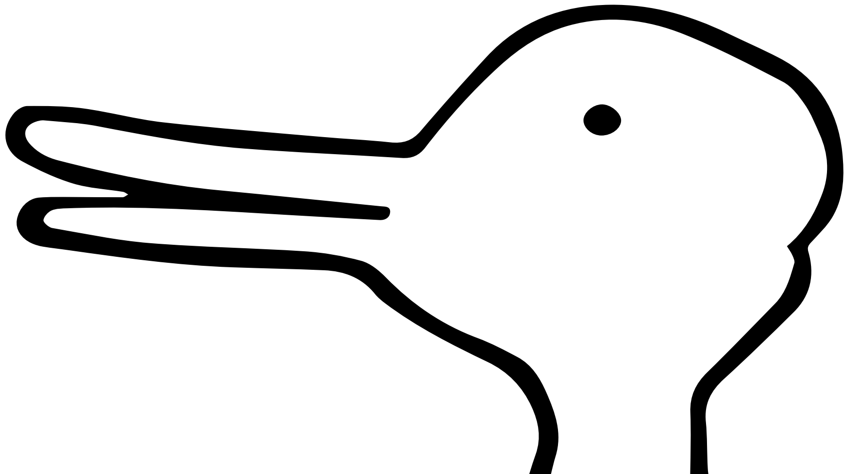
The interplay of light from the sun with the darkness of space is a primary expression of colour. However, this interplay is entirely dynamic and paradoxical: the two elements, light and dark, co-mingle, co-define, and co-create one another in a subtle and complex manner, the likes of which I believe can only be comprehensively approached *perceptually,* as opposed to conceptually. To concretise this dynamic in intellectual terms, while a potentially useful exercise, would be considerably limited. This is because linearity cannot succinctly contain simultaneously arsing and dissolving multiplicity. Standard logic is limited because it can only contain things separately, singularly. This is precisely why Goethe used imagination as a tool for accurately visulising a phenomenon, as opposed to emphasising conceptual analysis thereof. Unlike logic, imagination can accommodate the intricate, complex flux of multiplicity as a dynamic whole.

Of course, we can describe the interplay of colours conceptually, but our language begins to take on a different hue contra to that of conventional logic. For instance, we can say that the darkening of the light of the sun by space gives rise to yellow; and that the lightening of the darkness of space by the sun gives rise to blue. For mainstream physics, however, this does not qualify as an explanation of the workings of colour. It is understood to be merely descriptive. And yet this conclusion completely misses the focus of the dynamic method, because the dynamic method concerns the *direct observation of colour* and the relationships therein. For this reason, no explanatory mechanisms are sought in the dynamic method. This opens the possibility that colour phenomena are experienced as having a *natural logic,* and therefore explanatory theories are somewhat superfluous. Any account of our findings can be no more than a stepping-stone to further, precise apprehension of the dynamic of colours.

5. Seeing

It may be useful to introduce a template for thinking that can help us traverse between the standard method and the dynamic method. The duck/rabbit turns conventional logic inside out. We cannot say that the image is either a duck or a rabbit, because that would require two elements that are *separate* from one another, and clearly, they are not. Paradoxically, this image is both singular element/two distinct elements. If we drew another duck/rabbit next to it and said 'there's the duck and there's the rabbit,' we would still not have a duck *and* a rabbit at all. They are two and yet one; yet they are not two subsumed under one.

I believe that this conveys the principle at the heart of Goethe's theory of colours. Moreover, this is a principle which can be readily observed in the luminous display of the sky, wherein colours arise and dissolve from the interplay of the two indivisible, co-determining, co-creating elements of light and dark. To study colour in this way – to begin to observe the dance of light and dark in the sky, in shadows, on asphalt, or whatever the perceptual predilection of the moment, is to enter into the living depth of colour.



The Prescience of COLOUR

/ Philip Franses and Andrea Thompson

1. Introduction

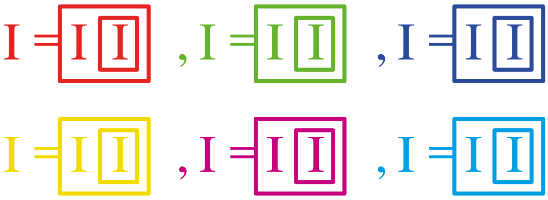
Andrea Thompson, a clairvoyant seeking to enumerate the qualities of her work and Philip Franses, a mathematician trying to heal the relation with spirit meet to discuss colour. On the day of being introduced Andrea, in illustration of her work, says she sees Philip as bright, predominantly blue but with a turquoise of an immediate disturbance. The experimental meeting asks whether colour can provide a bridge between mystery and logic.

The Goethean process concerns itself with differences, and how the in-between of these differences form together into an identity, shaping the parts to become the whole. Unlike the scientific method it does not focus down on what something is exactly, but asks "what is the quality to allow what stands between to fulfill itself as a whole illumination?" The nature of seeing changes. We do not see parts as finished products, but as qualities that hold the in-between signs of darkness and light to be read into the fullness of illumination. Colour holds a quality to be drawn from the in-between signs of nature into a full picture.

- Von Weizsacker a leading nuclear physicist writes: "Goethe speaks of 'phenomena' and his central concept is that of Urphanomen which is a non-reducible phenomenon, and it is precisely his view that to reduce phenomena to thought objects which we consider to be more real than the phenomena, and thus construct the phenomena, is to turn thinks upside- down. Light looked at through a turbulent medium (as the atmosphere) becomes blue (as the sky), and, this is a description – in Goethe's view – of a phenomena which you cannot reduce anymore." (Bastin, 324)

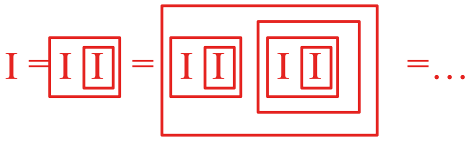
- Andrea: *"Starting point red sphere and from the red sphere comes light, which runs into golden light, the colour goes turquoise to green and then it goes to blue, around blue we go back to red, with roots like a cell. The very centre of it is smooth like a pearl, really thick, really dense, it is like the beginning, it's the never-ending source of everything, all colour."*

The colours are a vocabulary for the self-referential world. Colour holds to its own identity. The logic of self-reference through colour relates prior to a fully formed science. Framing the aspects of expression, we can write down the colours in the logic of self-reference as follows:

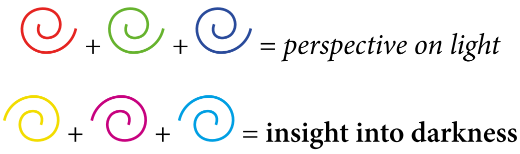


Colour is the content that it illuminates. One does not see colour or light, but what colour or light brings to presence.

We can take the form as an endless recursion into itself



This form never settles on an outcome. We see the world in redness keeping its own rhythm through time 



The auras seen by Andrea have the quality of not being there in any measurable exactness. The colours allow the in-between to be followed into a sense of the nature that identifies the different aspects together. To appreciate this article requires changing the lens we apply in reading from exactness of interpretation, to a reading of the in-between of difference. Colour becomes the in-between transparency to the process of illumination, as prophecy of nature.

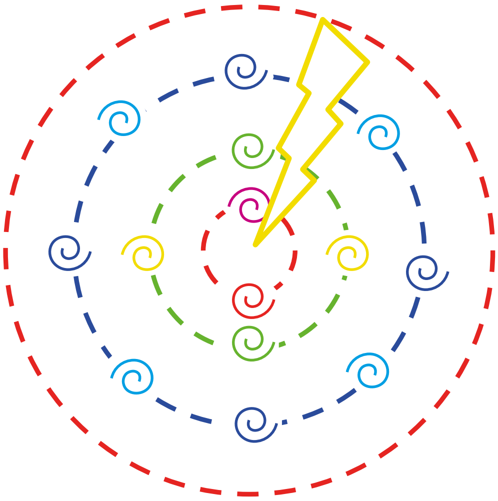
Very joyful red, creation, outer red, things coming to form. Without the red, all would all be in thought, would never manifest as form. Red key to creation, joyful, upbeat, no thought at all, just is, just grows, just does, - thought is gone, you cannot escape growth, created a long time ago, was created thousands of years ago, taken so much time to come through.

We open up red as a mystery that through its association with other colours builds into an illumination to the confrontation with the darkness of the unknown.

The nature of colour allows both the following interpretations:

- The origin of colour that we see all around us arises from the energetic jumps of electrons between different permissible orbits of the atom. Colour describes the in-between transitions of material existence.

- Goethe's method of inquiry approaches darkness of the unknown to engage the universal in the insight of illumination. The colours now stand at the threshold of how the darkness progressively gives up its secret to the centre of full illumination. The colours represent different stages of seeing, from first impression of outer red to cool, neutral blue, to dynamic yellow/ green, to the insight of red, through to illumination at the core.



The journey through colour to a core

- In the self-referential world of quantum theory, the colour of objects absorbing and transmitting light reflects the energy jump between orbits the atom makes through time.

- From a Goethean perspective, the harmony of different inputs comes to illumination through their association in a way that establishes matter as a means to resolve the riddle of their self-reference. The in-between relations of colour now bring into matter the whole story of their association. Each stage is a threshold our seeing has to pass through in order that the universal of illumination be received into the constellation of inquiry. .

2. Falling to the Centre of Colour

Elements of yellow take everything through time and space. Yellow is the facilitator, yellow is the current without which red cannot move. Creation cannot arise without the yellow, yellow is not in the roots, but it is the facilitator, the current. Yellow is essential, breath, the source and the illumination, spring, growth, new beginning, not one tad of sadness, completely right, not one thing out of place.

Earth on the outside, we are living today, bears no resemblance to the centre of ancient creation. What we have today was created a long time ago. Time does exist but in very different form from what we would expect, working towards something, defined all that time ago. Where we are today was created such a long time ago. Transparent, self-regulates, come from such a long time ago, so ancient, a long way back, and though it is created there is constant update.

Undercurrent around the outer red, which is almost alive, almost chattering, like a programme on wheels, underneath the red below the surface, there are numerous wheels of communication, lots of 0's and 1's wheels and wheels of them, moving in opposite directions, hive of activity, constantly reevaluating, constantly self-assessing, constantly making adjustments.

As human beings you have to pass through those wheels, genetic coding, you come through your DNA, as does everything that emerges on the surface, everything is coded. You pass *through that field on your way here. It is very difficult to pass through that coding. You have to be of a certain make-up. Everything comes through this coding. Nothing is by accident. Everything unfolds. There is no mistake in this system.*

- Newtonian physics ends with the atom which assembles into the molecules of the genetic code mechanically. The genetic code is seen as a static instruction, by which proteins are ordered around the cell, in order to execute as in a factory a manufacture of the organism.

- Goethe's *Metamorphosis of Plants* from 1790 (Goethe, 76–97) found the language by which the organs of leaf, sepal, petal, pistil, stamen and carpel joined together to form an identity of the whole organism that linked the parts together as living meaning. The being of the plant in time from spring to autumn self-references the different expressions of leaf, sepal, petal, pistil, stamen and carpel as these develop sequentially from seed to seed. 200 years later geneticists found the DNA language that switched the cells between the production of these different organs according to circumstance (Theißen et al.). The genetic code seen from this perspective are as switches that set the wheels of the cell-production along different tracks according to its circumstance within the whole development. The genetic code works within the internal order of guiding the ascent of steps to fulfil the whole identity.

The language of self-reference operates before existence is distinguished into subject and object. The language appears as informing subjective experience in the same way as that of the objective genetic data in the directing of the cells. Subjective and objective experiences of the plant are informed through the same operative self-referential riddle in their successive stages.

3. Moments

Musical notes within the computer program. Actually these are framed moments where the notes are so powerful, so strong. A set of events all happen at the same time, loud, clear, at a world scale. Those notes are golden, defining moments, as World War 2, which reshape the programme. Moments are needed, they don't happen randomly. A series of events crosses together at the same time and creates something extraordinary. World scale, notes from the red at the top right through the blue, fills all the cogs of numbers. Moments in history which define futures. Also a point where miracles happen.

When quantum theory experimented on the nature of the nucleus of the atom, in the 1930's, the potential to self-divide the elemental structure of matter was found to be self-stimulating. In using a neutron to divide one atom of uranium or plutonium from itself, two more neutrons would be produced, allowing the process to be amplified into a macros-scale device. The divisibility that had begun in the theory and crossed to matter in the principle of splitting the atom, replicated itself endlessly until an energy of destruction unleashed itself as a form given to the world to wrestle with thereafter.

In the splitting of the atom, every division became embodied in the act of this infinite regress of separation into a composite destruction. The acts that divide us from ourselves are in a way aspects of the separation that spelled the potential for global destruction. A universal identity of destruction represented every individual aspect expressing division in our everyday acts.

4. Silence

Silence is those moments where all the chatter stops. Impossible to find the space within the chatter. In theory there is no space as completely full. Fullness of space creates the nothingness, the coming together of perfect silence.

5. Nothingness

The space is just nothingness, yet so rich with information. Nothing there, beautiful space. You can learn to discipline your mind to enter, you have to understand the process to get to nothingness. That space opens and shuts, is not permanent place of being, it creates when the conditions are right but then it closes again. No structure in it, very difficult to navigate, for form hasn't appeared, so nothing tangible to hold on to. So easy to get lost. How to describe it – empty but full, not yet been created or distinguished, just is, nothing to tell your direction to find your way back.

Looking at nothingness without entering it. Last meeting, stepping into it was perfect, as I saw how lost you can become in it. Another level. Spiritual nothingness is different because you are held.

If I look around it, I see a series of symbols around the outer edge of it, triangular, all red and some spirals. The symbols are amplifications of entering or leaving this space. Entering or leaving is amplified infinitely. Way off the scale, in terms of trying to calculate any numbers involved.

The symbols are around the edge. I have to keep correcting where I am viewing it, as it is very easy to be drawn in. Where the red symbols are flat triangular [in snapshot] there is a huge amount of yellow, before you reach the next stage, yellow as rite of passage. There is a really wide bandwidth of yellow, incredibly difficult to produce this effect, it is a barrier.

6. Awakening

It is like an awakening through vibration of what lies dormant. There is a vibrational disturbance. It starts with a primal note and you have to have that primal note, that primal vibration, to begin colour. It is the starting point, the catalyst, the wake-up.

All colours are dormant in the beginning. There is no colour. There is an awakening. Darkness contains the light. As it awakens from the nothing, the light comes forth and colour is born. The colour was already there, but it had been dormant, and the vibration awoke the colour. But it didn't create it, for it was there in the first place.

Not visible but always there. Trying to trace back the origin of all things. Colour is infinite. Colour was there at the beginning. There is no beginning, just as there is no end. There is never a nothing because it is always there when conditions are right.

Darkness is a temporary state. Coming together of various conditions – time, place, inspiration, mind and purpose – all of these things – and when they are in place – colour is there. Beautiful. Golden strings. Colour itself the centre of the string. Plays its tune. Colour vibrates, becomes its own instrument. Strings are really fine. The vibration of colour, like everything, doesn't often come together at the right moment, you only see 20% or 50%. The full picture is very rarely seen. People have seen parts of the picture of colour from many different viewpoints, but it is only in the coming together that you see everything. It is so rich. It is birth. Birth of something that already existed. Eureka moment.

It is a Eureka moment. I can see it clearly, a Eureka moment. I don't see red, just yellow and light. There is that realisation and understanding of something you have started off with when it began, but then it comes to light. Colour goes through all those different spectrums and then comes to light The colours go through the spectrum of creation but then they

COME TO LIGHT.

The highest vibration is light, white and yellow. So pure, no deficiencies in it. Every little bit of it purified. All the colour disappears except the yellow and whites. A pure light being. If you had the process to purify colour, you could heal everything, because you could heal everything with that light. It is pure understanding, so clear, you could purify water, you could purify cells, could purify land, could purify everything. It is pure light. That goes back to the religious connotation.

You cannot hold on to what colour is even though they take you somewhere.

The very nature of light is to have been through so many colour spectrums, you could never be holier-than-thou and comprehend that light.

7. Structure and Portent

Colour holds the balance of the world at the threshold of darkness and light. The process brings us to a point where the aggregation of our knowledge draws the world at a point of disintegration and rebirth. The passage held by colour between the fall into nothingness and the coming into light fills out the structure and portent of time.

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Compresence and **Coalescence**

/ Louis H. Kauffman

1. Introduction

In this article I shall review Henri Bortoft's paper The Ambiguity of 'One' and 'Two' in the Description of Young's Experiment (1970) in the light of the present day quantum model for physics and in terms of points of view about recursions and second order cybernetics. Bortoft's work is linguistic and phenomenological, directed at description and how that description may be related to the observations that are possible in the experimental arrangement. The issues raised by Bortoft are in parallel with considerations of quantum physics and they shed light on quantum and cybernetic epistemology. The distinction between compresence and coalescence is central to Bortoft's work and to this paper. We shall describe this distinction below and then from a number of points of view.

A word about Henri Bortoft: The paper we concentrate upon in this essay was written in 1970. It was preceded by Bortoft 1966 and followed the next year by the "The Whole: Counterfeit and Authentic" (Bortoft 1971). This paper is, in the opinion of this author, an important companion piece to the 1970 paper and one of the deepest evocations of wholeness that I have encountered. Bortoft wrote a Master's Thesis on the philosophy of quantum theory in 1982 (Bortoft 1982). This thesis concentrates on the Bohmian theme of "Wholeness and the Implicate Order" and its relationship with Spencer-Brown's *Laws of Form* (1969), but does not hark back to the paper of 1970 on Young's experiment. After that Bortoft devoted his career to a study of wholeness in relation to the work of Goethe (Bortoft 1996 and 2012). The papers of 1970 and 1971 appear as the seeds of all his later work.

A key to quantum mechanics is the principle that *trajectories indistinguishable to an observer can give rise to interference at the point of observation*. A key idea in the work of Bortoft is that the point of observation giving rise to interference in Young's experiment is that place where the distinction between the two slits is indistinct for the optical observer. Paths from the two slits to that point are not distinguished by the observer. In Bortoft's phenomenology the observer is in coalescence with the observing apparatus and it is in this coalescence that the distinction is not present.

A key point in the foundation of the logic of recursion is that self-reference can arise when the operator of self-action is applied to itself. This application of an operator to itself can be seen to be a description of the act of coalescence where what is seen by an observer is determined by the connection of the observer to the act of perception. In the act of making a distinction the very boundary of that distinction can come to stand for the distinction itself. The boundary makes the distinction and in this sense is the distinction.

The boundary stands for the distinction and in this sense refers to the distinction. The boundary is sense and it is reference. Where sense and reference coalesce, the observer comes into being.

The world of actualities is, in the language of cybernetics, a world of eigenforms (Kauffman 2005, von Foerster 1981b). It is a world of objects that remain what they are when they are observed and yet the very process of observation can call them into existence. The world of quantum mechanics comes into contact with the world of actuality when a measurement produces an eigenstate, a special eigenform that meets the requirements of a physical model based in possibility. Here we examine the place where eigenstate and eigenform come together.

In this essay we will explore all of these points of view and discuss their relationships. They are not disparate, but the apparent necessity for clarity in scientific discussion has often separated them. Here we make a beginning in bringing these points of view together.

2. Quantum Mechanics

Quantum Theory is a radical method for modeling and obtaining information about physical processes that was discovered in the early part of the twentieth century. It continues to be the most powerful physical theory presently known, and remarkably can be described very simply. I will give a capsule summary of the theory. While it is not so hard to grasp the essentials of this theory, it uses principles that are different from the way we have been conditioned to think about the world.

We begin with an observer. In a cybernetics context this beginning is natural since cyberneticians accept that everything is said by an observer, and that all phenomena are actual only in the presence of an observer. In cybernetics we conceive that an observer and something seen by that observer arise together in a pair -observer/observed.

In the terms of this essay, the observer/observed pair is a *coalescence*. In looking through a telescope at the moon, the observer is in coalescence with the telescope and the moon. The moon seen is not independent of the position of the telescope relative to itself and the observer. Move the telescope to the right by a foot, keeping the observer fixed, and the relationship of the moon and the observer changes radically. The opposite of coalescence is *compresence,* where two things can be independently in the sight of the observer, and neither of them is integral for his observation of the other. See the discussion in Sections 3 and 4 for Henri Bortoft's use of these terms. In our cybernetic, semiotic, phenomenological point of view we do not usually consider the condition of a world prior to or independent of observation. The world is not seen as independent of the observer. The observer participates in the creation of the world.

In classical physics, models are constructed to describe the evolution of a causal world that is independent of any particular observer. Then one can insert observers into such a world. With an observer present, the classical models explain, indicate or predict what will be seen.

The quantum mechanical model invokes the deterministic evolution (via the Schrodinger equation) of a physical state **|psi**> that is a *superposition of possible observations.* This state is sometimes called the wave function. In fact, the wave function, being a mathematical entity, is neither a particle nor is it a wave. It can model both particle-like and wave-like properties of the quantum phenomena. This wave function, a superposition of possibilities, evolves in time.

An observation or *measurement* reduces the state **|psi**> to *exactly one of its possibilities*. Thus a measurement produces an actuality, a definite result in the world of the observer. Physical states can interact with one another independent of an observer. The key mode of combination of states is *addition* where **|psi**> + **|phi**> is a new state that is a superposition of all the possibilities in the individual states **|psi**> and **|phi>.** Interference can occur in such a summation so that possibilities in one state are cancelled by possibilities in the other.

For example, consider a state **|psi**> = **|0**> + **|1**>. Here **0** and **1** stand for two distinct possible observations. We leave exactly what they might be to your imagination. The state **|0**> + **|1**> is a superposition of the possibilities **0** and **1**. The superposition is not **|0**> and it is not **|1>.** When you observe **|psi**>, you will obtain either **|0**> or **|1>,** but not both.

If **|phi**> = **|0**> - **|1**>, then

|psi> + **|phi**> = **|0**> + **|1**> + **|0**> - **|1**> = **2 |0**>.

So when you observe **|psi**> + **|phi**> there is no possibility that you will see anything but **|0**>. The possibility for **|1**> has been erased by a destructive interference, just as waves on water, or light waves, can interfere to either add intensity or subtract intensity.

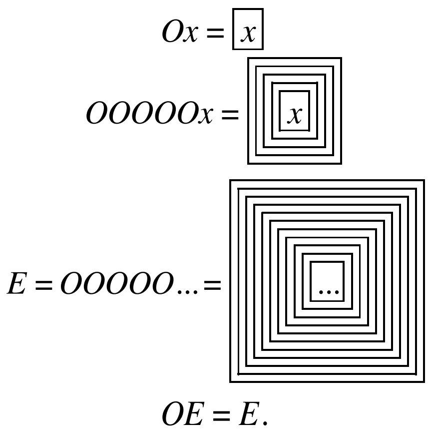
If the possible outcomes are **|0**>, **|1**>,…, **|n**>, then a state of the system is of the form

$$|S> = z_1|0> + z_2|1> + \ldots + z_n|n>$$

where z_i are complex numbers and $|z_1|^2 + \ldots + |z_n|^2 = 1$. Letting **O** denote the operation of observation one has that **O|S**> = **|k**> for some **k** with probability $|z_k|^2$. The probability of observing a particular state is the absolute square of its coefficient in the wave function **|S>.** The new observed state is then an eigenstate. This means that **|k**> is not changed by a further (immediate) observation. We have **O|k**> = **|k**> at the next instant. Observation leads to eigenstates in the sense that we produce entities **E** such that **OE** = **E**.

Recursion can also lead to eigenstates. Formally, if we desire an **E** such that **OE** = **E** , we can obtain it by forming **E** = **OOOOO…,** the infinite concatenation of the operator **O** upon itself. Then **OE** = **E** for the infinite composition. Here we see the result of the observation arising by recursion quite in analogy to the way the interference pattern arises for Bortoft in his phenomenological thought experiment (as we shall see in Sections 4 and 5).

A diagrammatic example of such an infinite eigenform is shown below.



We may think of the formation of a generalized eigenstate by recursion as the formation of an object for perception or cognition. An *object* is an entity that does not change under the effect of observation, and so if **E** is an object, we expect that **OE** = **E** where now **O** stands for a general process (not necessarily numerical) of observation made by a human observer. Thus when we view a tree in the forest it remains, for us, a tree and we find stability in both the naming of it as a tree and in the perception of the tree as a whole, and of its parts and their fitting into the whole. Von Foerster (von Foerster 1981b,c,d) suggested in his title "Objects as tokens for eigenbehaviours." that what we call objects have in back of them a recursive process whose stabilization is the perception of the object for a given observer. In some instances we are quite aware of such a process as in what we see when standing between two mirrors. In other situations the objects, for example - a familiar lamp on the desk, appear simply to have presence for the observer.

In a quantum experiment, the state of the system is a summary of the information known about the system. Thus we may have a state of the form

$$|S>=(|Up>+|Down>)/\sqrt{2}$$

where **Up** and **Down** denote two quite opposite possibilities. In the famous Schrodinger's Cat thought experiment, these two possibilities are that a cat is alive or dead. Before measurement, the physical state of the system is the superposition above. The cat is neither alive nor dead. The cat is in a superposition of these states. It might be thought that at least an observer **O** would resolve the difficulty, but alas consider (as did Wigner) that there could be another observer **O^** who does not see the result of **O**'s observation. Then for **O^** the system is in a new superposition

$$|S'>=(|O,Up>+|O,Down>)/\sqrt{2}$$

and it is only when **O^** makes her further observation that she can know Up from Down. Of course we have avoided the notion that **O^** might receive a report from **O** and other complexities.

Note that we might say that our knowledge of another observer is in a superposition of possibilities. But we do not say that our knowledge of a physical actuality is in a superposition of possibilities. We assume that our knowledge can be resolved to definite facts. This is, of course, a modus operandi for doing science. Someone may say that the superpositions are places where our knowledge cannot be so resolved.
We prefer to say that only the measurement has actuality in its definiteness and factual nature.

Quantum information does not become actual information until it is finally encountered/ measured by a specific human observer.

In speaking of quantum observation, there are two components to that observation. There is the measurement that takes the superposition of states to one particular state of a physical system. And there is that measured state as registered by a human observer and seen as an object, for example as a dot on a phosphor screen or a mark upon a photographic plate.

The quantum model bifurcates into the deterministic Schrodinger evolution of the states, combined with the re-setting of the state to only one of its possibilities by acts of measurement.

We end this section with one more example – the Mach-Zehnder interferometer. The diagram in this , shows the Mach-Zehnder interferometer to be a device made with two types of mirror, a half-silvered mirror, that we shall refer to as H, is depicted by a white rectangle. An ordinary mirror, that we shall refer to as M, is depicted by a black rectangle. Single qubit (quantum bit) states enter the half-silvered mirror on the left of the device. The half-silvered mirror reflects a |0> to a |1> and reflects a |1> to a -|0>, changing the phase in this case. H transmits |1> to |1> and |0> to |0>. The ordinary mirror M just flips |0> to |1> and flips |1> to |0>.

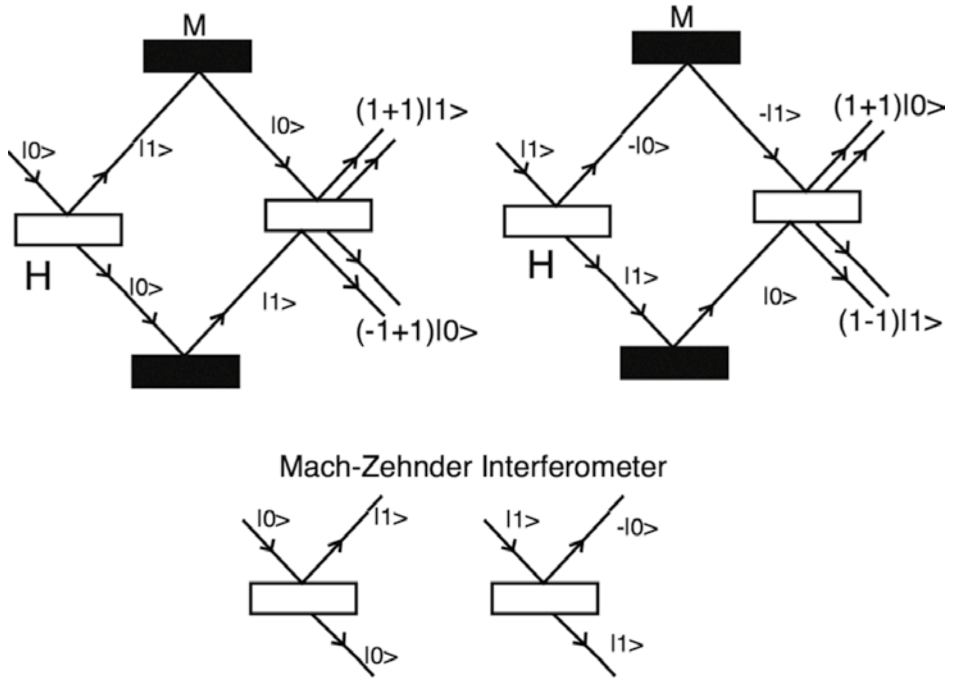


Figure 1 – The Mach-Zehnder Interferometer

The mirrors H and M represent quantum processes, and a mathematical representation of them is given by

$$H\,|0>=(|0>+|1>)/\sqrt{2}$$
$$H\,|1>=(-|0>+|1>)/\sqrt{2}$$
$$M\,|0>=|1>$$
$$M\,|1>=|0>$$

where the summation indicates that that H produces a superposition of states |0> and |1>. The superposition means that an observer of the state of the half-silvered mirror with input |0> will detect either |0> or |1> with equal probability.

The entire interferometer corresponds to the quantum process of first doing H, then doing M, and then doing H. The end result of a preparation of |0> or of |1> is illustrated in the Figure. You can follow the possible paths of the particle through the interferometer. There are a total of four paths, and with input |0> you can see from the diagram that two of them cancel at the top part of the diagram and the other two reinforce one another at the bottom. The conclusion is that for |0> as input, the interferometer will only show |1> as output. It will not be possible to detect |0> at the end of the process. Similarly with |1> in, only |0> will be detectable.

The key point about the interference that occurs in the interferometer is that the measurement that takes place at the end of the process can not involve any discrimination among the possible paths that the particle could take to get through the device. If the observer who makes the measurement had put a detector somewhere inside the interferometer to find out if the particle went on a preferred path, this would completely change our calculation of the contributions of all the paths, and we would get a different answer. For example, suppose that the measurement included a detector at the lower mirror. Then paths going through the lower mirror would be stopped at that mirror, and you can see from this that the detection at the right hand side of the interferometer would come out differently. It would be possible to detect either |0> or |1> while before one of them was forbidden.

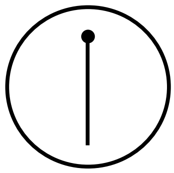
The basic principle of quantum mechanics is that if one considers, at a point of observation, the contribution of a collection of paths, then differences among these paths must not be detectable by the observer. From the point of view of the observer the multiplicity of paths can only be a unity.

This two part model of quantum mechanics separates the deterministic evolution of the wave function and the measurement, the resetting of the wave function to an eigenstate at the point of observation. The separation is inevitable. The measurement corresponds to the making of a distinction and it is intertwined with the coalescence of an observer with the knowledge of the measurement. From this point of view we see that an exploration of the eigenform creations of the observer is worth the pursuit, and may shed light on the relationship of these two essential parts of the quantum model.

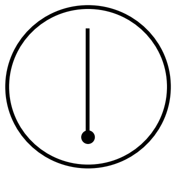
3. Bortoft – A First Look at Young's Experiment

Here are a pin and a lens in compresence. They are each objects and they are related to one another by their proximity in space to one another.

Here below are a pin and a lens in coalaesence. The observer sees the pin through the lens. The pin is seen by the observer through the intermediary of the lens.



To underline the essential difference between these two states, note that the same external relation of pin and lens could result in the pin appearing upside down if the lens were concave rather than convex. The condition of coallesence gives the observer a view that is dependent upon the structure of the coalescence.



In performing the double slit experiment the observer (in Bortoft's description of the optical version of the experiment) is in coalescence with an optical telescope and the slits through which the photons emerge. See Figure 2.

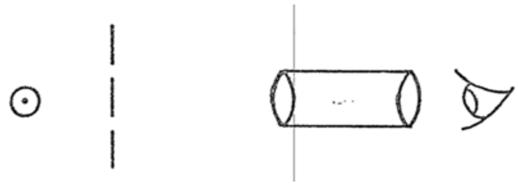


Figure 2 – Young's Optical Experiment

This coalescence may have the property that the observer can no make a distinction between the two slits. At this point the interference pattern emerges. For the optical version of Young's experiement this is the way of its world and Bortoft can state (our paraphrase of his conclusions):

(i) *Young's optical experiment has never been described.*
(without the correct discrimination of compresence and coalescence).
(ii) *Young's optical experiment can never be described in a language with the numerial singular/plural distinction.* (That is, one must have the (plural) slit in the compresence of the optical bench, but a single slit in the coalescence of the observer.)

Neither Bortoft nor this author can state that this confluence of One and Two causes the interference pattern. We can only observe that it is at this point, this nexus, that the interference happens. As we point out in the next section, this special place of NotOne/NotTwo can be expressed by a symbolic and self-referential fixed point P=[PP] whose associated recursion does indeed look like an interference pattern. In the next section we will discuss more about this aspect of the analysis.

Here I wish to ask further questions about the role of compresence and coalescence. In order to do this, let us move from Young's optical experiment to the quantum mechanical double slit experiment with electrons.

Now to the double slit experiment. Instead of a source of light one can take a source of electrons, and in the modern version of the experiment one can configure the system so that one electron at a time moves through the system. It is a figure of speech to say that the electron "moves through the system" since one only knows that one has an electron when it is measured for example as an excitation on a phosphor screen. Thus the eye and tube of the Young's experiment is replaced by a screen where the electrons can be detected. See Figure 3.

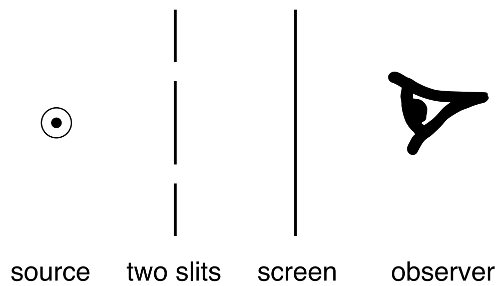


Figure 3 - Double Slit Experiment with a Screen

In this form of the experiment, single events build up on the screen over time. After some time the pattern of the events on the screen appears as in the Figure 4 taken from the well known Hitachi version of this experiment (Tonomura 2015).

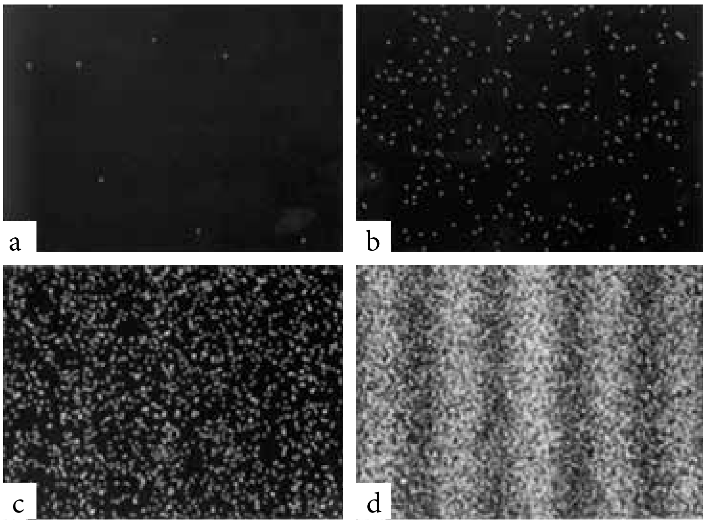


Figure 4 - Hitachi Double Slit Experiment

In the Hitachi photographic record the screen is blank at (a), the initial time of the experiment. Then at (b) we see some pattern of electron events on screen as dots. In (c) more dots are produced and in (d) we see the very remarkable final pattern of the experiment with its apparent interference pattern on the screen.

Indeed the experiment is arranged so that the observer in Figure 4 can never tell whether any given electronic event (dot on the screen) originated at one slit or the other. Furthermore the pattern that is eventually seen by the observer has been built up over time. It would appear that each electronic event on the screen is independently contributing to this interference pattern. The quantum mechanical model (in the usual interpretation) only gives the probability that electrons will appear on the screen at certain points. The statistics of these probabilities do predict the interference pattern, based on the geometry of the paths from the slits to the screen.

Return to Coalescence and Compresence

As we have seen, the standard construction and description of the electronic double slit experiment allows for the compresence of all the elements of the experiment including the screen. The observer need not stand looking at the screen throughout the duration of the experiment. Instead she can wait until the end and then view the screen in the state (d) of Figure 4. This view constitutes a coalsesence with the data and results in the perception of an interference pattern when the experiment has been set up so that no information is available about electrons going through or coming from given slits.

The coalescence of the observer with the screen and the experiment is available to any observer who would care to look at the screen. With this description of the modern legacy of Young's experiment, we can probe further the relationship of Bortoft's fixed point, self-reference, reentry at the point of NotOne/NotTwo and the emergence of quantum interference.

One interpretation of this interchangeability of observers is that physics is only concerned with compresence and not with coalescence. The definite and unchangeable data at level (d) in Figure 4 is available for the examination of any observer. The experiment has been performed in such a way that no distinction was possible to select one slit over the other. Quantal events happened individually at the screen separated by time intervals that show that only one quantum of energy was present in the system during each interval. All of this preparation for the data at level (d) required the laboratory observers who set up the experiment and constructed the equipment. But indeed, this part of the work is repeatable as well, and the apparatus can, after all that work, be set up so that the experiment goes forward just at the flip of one switch.

Nevertheless, the actual observing of the screen is eventually necessary. We have taken the screen to be the final placement for the human observer. It could have been more distant if we had constructed an artificial intelligence to scan the screen and test it for an interference pattern. Then the observer would only see a yes or a no, or a light that was lit or not lit. The observer would only see a mark or the absence of a mark. And even so the observer must in the perceiving of that mark be in coalescence with the mark.

This analysis shows us that the end place of any experiment will be a coalescence, a place where the observer and the mark of distinction are in the form identical.
That place of identity is a self-reference and it can give rise to an interference pattern at the level of this cognition. But we have argued that in this modern version of Young's experiment, the observer can be insulated (by automatic pattern recognition) from the phenomenology described by Bortoft for the optical Young's experiment.

In the modern version of the double slit experiment there remains the activity of the observers. Each observer sees a world in coalescence relative to his or her own being. Pattern recognition is necessary at all levels of an experiment, and even when the observation is an apparently binary one a distinction must be made by the observer. Thus we see that the fundamental property of the quantum model is that it does depend upon a stable observation, a distinction on the part of the observer.

4. Bortoft – The Two Slit Experiment and the Interpretation of Quantum Mechanics

Bortoft (1970) suggested that the interference pattern that arises from Young's optical two-slit experiment is the result of the observer being placed so that *two* (the two slits) *is indistinguishable from one* (the undetectability of the slit through which the electron did pass).

Place the observer at a distance where it is not possible to resolve the slits.
This is where the interference occurs.

Something curious is going on here. First of all, it is a fact of standard quantum mechanics (as we have explained in Section 2) that if we take all the trajectories that a particle may take from a point A to a point B, and regard all these trajectories as *indistinguishable* to an observer at B, then there is a way (the Feynman path summation or integral) to add up complex number contributions of all the disparate paths to find the interference of them at B, and to obtain the probability of finding a particle at the point B as the absolute square of this summation. Thus Bortoft's principle is directly related to a basic principle of quantum mechanics.

The interference that Bortoft suggests is one that arises from the self-referential recursion of setting “one” equal to “two” as in a formal equation

$$P =< P \mid P >$$
$$=<< P \mid P >|< P \mid P >>$$
$$=<<< P \mid P >|< P \mid P >>|<< P \mid P >|< P \mid P >>>$$
$$=<<<< P \mid P >|< P \mid P >>|<< P \mid P >|< P \mid P >>>|<<< P \mid P >|< P \mid P >>|<< P \mid P >|< P \mid P >>>>$$
$$=<<<< \ldots | \ldots >|< \ldots | \ldots >>|<< \ldots | \ldots >|< \ldots | \ldots >>>|<<< \ldots | \ldots >|< \ldots | \ldots >>|<< \ldots | \ldots >|< \ldots | \ldots >>>>$$

As the reader can see, illustrated above, we begin with P as "one" and equate it to a pair of copies of P. Then recursive substitution of the equality

$$P =< P \mid P >$$

leads to a pattern that we may call the interference pattern of "one = two".
Could this be a formal relative of the physical interference pattern of Figure 4 for the Hitachi double slit experiment?

Bortoft suggests that his recursive pattern is in back of the phenomenon of the Young's double slit experiment. It is not clear how to quantitatively relate the Bortoft recursive pattern with the path sum pattern of the quantum mechanics.
It is Bortoft's suggestion that the recursive and eigenstate properties of the observer finding objects as tokens of eigenbehaviour and the special quantum process of collapsing a superposition to a specific measurement are two sides of one coin.

The peculiarity is not over. We have to confront the question: Who or what is an observer? How is this question informed by Bortoft's discussion of the phenomenological, recursive observer?

What constitutes the knowledge of the observer?
The observer knows that he knows a given item of knowledge.
We shall handle this analysis in a schematic form.
Let us take the well-known quote of Heinz von Foerster (von Foerster 1981):

" I am the observed relation between myself and observing myself."

Let "observing X" be denoted by

$$\boxed{X}$$

and let XY denote "the relation between X and Y".
Then we can write von Foerster's quote directly and symbolically as

$$I = \boxed{I\boxed{I}}$$

and we see that this equation about the self is a direct relative of the Bortoft equation about P.

$$P =< P \mid P >$$

In the von Foerster statement the self occurs within itself in two levels as the I and the observed I. It is further implicit that the I observes itself. Indeed the von Forester sentence expresses the recursive self-interference that is, in form, identical with a self. We now see that Bortoft implicitly suggests the confluence of the domain of the self as observer and the domain of quantum observation.

It is necessary to see the context of the quantum model. One way to see it is to regard the world of actuality as a world of objects in the sense of eigenform (invariant under the act of observation), and that physical experiments are made in this world in a repeatable way that produces results that are recognizable as objects, such as a mark on a plate or a reading on a meter. Then it happens that certain experiments produce patterns in this world of objects that are fitted well by the quantum model. No interpretation of a "quantum world" is given. It is only that the method of complex superposition and probabilities as absolute squares of complex amplitudes is seen in many cases to give results that are accurate and predictions that are correct.

In this discussion we can take a second look at the Copenhagen interpretation (described above) and take the world of objects from the von Foerster viewpoint. Then each object, each distinction, each distinct entity is an eigenform, an eigenstate of a generalized operator that is, in form, identified with a human observer. That object, if modeled by the quantum model, then comes to have two eigenstates associated with it. One is the perceptual cognitive von Foerster state. The other is the eigenstate that resulted from the collapse of the superposition that described its quantum possibility.

Here, is our description of the dilemma. How does it come about that the quantum model with its eigenstates fits so well into the apparently more general world of the eigenforms and objects as tokens for eigenbehaviour? Here is a new possibility for reformulating the Copenhagen interpretation of quantum mechanics.

There is much to think about here. In the present paper we start, just with the notion of distinction and we unfold patterns that are related both to physics and to the understanding of recursion and re-entry. One can think of the present essay as a reflection on Bortoft's suggestion about the Young's double slit experiment.

5. Laws of Form, Re-Entry, Self-Reference and the Structure of the Precursor

Laws of Form (Spencer-Brown) is coextensive with the idea
that the world and existence arise from nothing (no thing).
Non-existence in itself does not exist.
The act of apparent distinction brings forth apparent existence.

Anything can arise from nothing, but a first distinction that would arise,
being first, can have no difference between its sides without further distinction and so is not a distinction.

Being not a distinction it
has no being, and so
disappears,
and again there is nothing.

This connotes a basic oscillation of the void.

If another distinction should occur beyond the first
(and how could it not?) then
Pandora's Box has opened.

One way to see how recursion/oscillation arises is to begin with the following operator J

$$JX = \boxed{XX}$$

When J is applied to any entity, it produces two copies of that entity. If there exist other entitities than J itself, then this is a prosaic occurrence of two compresent copies of that entity. If we apply J to itself, then we have

$$JJ = \boxed{JJ}$$

and now JJ is creative, producing a distinction around itself.

We have entered into self-reference by taking J to be an operator of self-interaction. J applies to X to give the action of X on itself. When we apply J to itself, J interferes with itself to produce recursion and self-reference. The combination JJ is a *coalescence* of J with J and produces a unique and singular result, just as the coalescence of awaress with itself is the state of awareness.

The Universe is constructed in such a way that it can refer to itself.
In so doing, the Universe must divide itself into a part that is seen and a part that sees. Here we could have taken U = UU, so that UU produces UU and UU collapses to the unity U. The universe becomes a duality that is a unity.

The Universe divides itself into two identical parts each of which refers to the universe as a whole. The universe can pretend that it is two and then let itself refer to the two, and find that it has in the process referred only to the one, that is itself.

The Universe plays hide and seek with herself, pretending to divide herself into two when she is really only one.

In Section 2 we have indicated that we can always produce a solution to an equation OE = E by taking E to be an infinite concatentation of O upon itself.
There is another way that avoids infinity, but one must allow an entity to act upon itself.

We define

$$Jx = O(xx).$$

Then

$$JJ = O(JJ)$$

and so we let E = JJ and we have O(E) = E.

We have used *a precursor* to the eigenstate E in the form Jx = O(xx).
The precursor to the self-reference or re-entry acts to make a pair of identicals acted upon by the given operator. Into this is inserted the structure J *as a whole*, and the self-reference, re-entry, recursion is the result.

In the quantum mechanical model, a superposition is observed and projects to a specific state that is then observed as that state. At that point of observation, the state has acquired the definiteness of an eigenform, in the moment of observation.

The buck stops with the observer. The observer is a *knower*, a system capable to produce an eigenstate in its knowing of itself as not one/not two.
"I am the observed relation between myself and observing myself."

6. Discussion

In this essay we have discussed eigenstates as they occur in quantum mechanics where a measurement occurs and there are states **|k>** stable under observation:

$\mathbf{O|k\rangle = |k\rangle}$. We have pointed out that given any form of observation, there is a natural way to produce an eigenform for that operation, either by concatenating it upon itself in indefinite recursion, or via the precursor **Jx = O(xx)**, yielding

$$\mathbf{JJ = O(JJ)}.$$

The precursor construction is a formal model of the emergence of recursion from coalescence since it is the coalescence of **J** as an operator with **J** as an operand that produces the fixed point, the eigenform, **JJ = O(JJ)**. The condensed mystery of this fixed point is close to the deeper mystery of our own talent of self-reference and knowledge in observation. We have seen that these forms of observation weave inextricably with the results of physics where indistinguishable trajectories lead to interference patterns at the point of observation. We have seen that the work of Bortoft continues to contribute to this discussion.

In this essay we have indicated that the relationship with oscillation is fundamental because the emergence of a distinction is necessarily related to oscillation. A first distinction requires further distinctions in order to stabilize. Thus in the limit of the emergence from a realm of no-thing, there will be primordial oscillation. It is the structure of oscillation that we have followed in this essay both in the form of Young's double slit experiment and in the structure of distinction.

We have reached the end of this essay. This work harks back to the beautiful papers of Henri Bortoft (1970 and 1971) where he identifies the zero-one oscillation as the condition of an observer who is placed in a condition where he cannot distinguish the whole from the part. It was Bortoft's intuition that this (in the context of Young's double slit experiment) was the nexus and source of the quantum interference. All the ideas from beginning to end are related to one another. The relationships we have articulated are but a hint in the further articulation of the possibility of a distinction.

7. Appendix on Laws of Form

In this section I will review the ideas behind G. Spencer-Brown's calculus of indications (Spencer-Brown). The Calculus of Indications (CI) is based on a single symbol and called the *mark*. We shall use the Spencer-Brown form of the mark:

⏋.

In this form, you should think of the mark as a shorthand for a box:

□.

A box has a definite inside and a definite outside in the plane upon which it is drawn, and it is seen to distinguish the inside from the outside. In the same way, the Spencer-Brown mark distinguishes an inside from an outside.

The mark can be seen as the boundary of a distinction and the mark can be seen as that which forms the distinction. The mark can be seen as a symbol of the very distinction that it makes. In this sense the mark is self-referential, and with the participation of the observer, the mark is in coalescence with itself and with the distinction that it makes. Here meaning arises.

What we have said about Laws of Form up to this point is sufficient for the themes of this essay, but the appendix will continue with a concise exposition of the calculus that comes from these considerations of the mark, and how that calculus is related to the production of a J such that $JJ = \langle JJ \rangle$ as we have described in the body of the paper.

A plane space with a mark drawn upon it is said to be *marked*. The reference is to that part of the plane that is outside the mark. The inside of a mark is empty and is said to be unmarked. Thus we have

$$\overline{\ \ }| = \overline{u}|\,m$$

where it is understood that "u" stands for the unmarked state (the empty inside of the mark) and "m" stands for the marked state (the outer space of the mark is marked by the very presence of that mark in the space).

In this way, we see the *law of calling:*

$$\overline{\ \ }|\,\overline{\ \ }| = \overline{\ \ }|\ .$$

The presence of two marks in the outer space of a mark makes that space marked no more than the presence of a single mark. With respect to markedness, two adjacent marks indicate the same state as one mark.

We make the following choice:

$\overline{a}|$ *denotes the state obtained by crossing from the state indicated by a.*

Note how this works.

$\overline{\ \ }|$ denotes the state obtained by crossing from the unmarked state.

Hence $\overline{\ \ }|$ denotes the marked state.

$\overline{\overline{\ \ }|}|$ denotes the state obtained by crossing from the marked state.

Hence $\overline{\overline{\ \ }|}|$ denotes the unmarked state.

We shall write the *law of crossing:*

$$\overline{\overline{\ \ }|}| = \ .$$

We allow two nested marks, with the innermost mark empty, to vanish from the notational plane. An apparent distinction, transfixed by the absence of any difference between its sides indicates nothing.

With this interpretation of the mark as a transformation from the state indicated on its inside to the state of its outside, we obtain clarity of evaluation. The mark is seen as making a distinction in the plane, as indicating the outside of the distinction that it makes, and as a transformation from the state on its inside to the state on its outside. All three of these interpretations are mutually compatible and compatible with the creation of a first distinction from nothing.

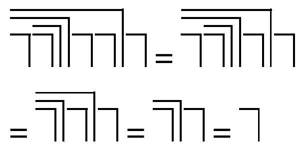
One watched carefully for a distinction to appear, capturing it in a plane space where its sides would be distinct. Without those actions, the distinction, like a fold in a silk scarf, would vanish as quickly as it had come forth. From whence came this apparent ability to capture evanescent events? This is a mystery in the shadow of nothing. Waiting for the next thought.

And so we have an arithmetic, without counting, that is generated by the laws of calling and crossing.

$$\text{Calling: } \overline{\;\;}|\,\overline{\;\;}| = \overline{\;\;}|$$

$$\text{Crossing: } \overline{\overline{\;\;}|}| = $$

It is an arithmetic in the sense that we can now calculate the value (marked or unmarked – only two values) of more complex expressions of distinction. Expressions in the mark are patterns of distinction so that any two marks in a given expression are either nested or adjacent to one another. Finite expressions can be reduced by calling and crossing uniquely to either the marked state or to the unmarked state.
For example:



The reader will observe that each change is mediated by an application of either calling or crossing. See Spencer-Brown (1969) for the proof of reduction and uniqueness.

The arithmetic that we have constructed (Spencer-Brown's *primary arithmetic*) is no ordinary counting arithmetic. Once the laws of calling and crossing are in place, every expression has only one value, marked or unmarked and that value is uniquely determined by reducing the expression as has been indicated.

Furthermore, in the context of the arithmetic the mark can be seen as an operator. If E is an expression in the arithmetic, then $\overline{E}|$ is another expression, and we find that whenever E is unmarked, then $\overline{E}|$ is marked. And whenever E is marked, then $\overline{E}|$ is unmarked, by an application of the law of crossing. Thus the mark, as an operator, is analogous to logical negation.

Recursion and Self-Reference

Having understood this structure of distinction and the basic interpretation of the mark as both operator and operand, it is natural to point out that there are ways to go into the inbetween of neither marked nor unmarked. One way is to consider an apparently paradoxical equation such as $G = \overline{G}|$. For then the equation asserts itself to be marked when unmarked, and unmarked when marked. It is tempting to construct an infinity of

nested marks as in $G = \ldots\overline{\overline{\overline{\overline{\overline{\;}|}|}|}|}|$ and then note that placing one more mark around the outside will no longer make a difference, hence $G = \overline{G}|$. This is the most elemental eigenform that occurs in this story. We have in this essay pointed out another way to make such a reentering mark by defining an operator J so that $Jx = \overline{xx}|$, and then $JJ = \overline{JJ}|$ and we could take G = JJ. The verification that $JJ = \overline{JJ}|$ happens so quickly that one feels that some magic trick has been performed.

In this essay we have seen that this magic trick is a formal image of the distinction of between compresence and coalescence. The two identical J's in the equation $JJ = \overline{JJ}|$ are in coalescence with each other with one acting on the other.
In the interior world of an individual one acts on oneself.

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Henri Bortoft and the Touch of *Wholeness*

/ Philip Franses

In an age where Western Science is increasingly thinking ponderously along straight lines, the move Henri Bortoft made to drop his PhD along with a career in academia as a prerequisite to restore a balance of freedom for inquiry, now feels especially relevant.

It began in 1963 when Bortoft was surprised to find how difficult the act of description was, when one did not lean on existing patterns of thought or explanations one wanted to impose. “You think when you describe something, that you look at what’s there and put it into words. Really it isn’t like that at all, because it isn’t there. You find it’s not there until I describe it. Describing it, distinguishes it and it appears" (Bortoft 2013, 31). A description is building a subtle web of inference upon which a sudden flash of insight illumines the whole with a picture of what is there.

Bortoft, over the next five decades, pieced together Western thought - from the question of the role of the observer in quantum physics, to phenomenological philosophy in the early 20th century to Goethe’s ground-laying work of the 19th century. Western thought is not to be approached as a commentary making its way to an ultimate explanation. The path of Western culture would be born out of the source of despair and darkness from which the illumination of reason happens.

The essential thinking of Bortoft’s approach when working on a PhD with David Bohm (Hiley, 23) can be found in the enigmatic title to his 1970 *Systematics* paper “The Ambiguity of ‘One’ and ‘Two’ in the Description of Young’s Experiment”. Young’s experiment is as crucial to the study of the particle as the prism experiment is to colour. The participation of the observer influencing the outcome of the experiment requires a description that is two fold. The mind switches between seeing the reductive apparatus of the double slit that the single particle passes through and the whole illumination of the aggregate result. The experiment, Bortoft concluded, could not be properly understood as a description of material elements interacting in the “language with the numerical singular/ plural distinction”. To go further into how an elemental nature unfolds a description of itself “we must pass completely into the optical [non-numerical] arithmetic [discovered by G. Spencer Brown]” (Bortoft 1970, 243–4). The optical arithmetic does not distinguish between “one” and “two”, until seeing brings the unfolding of a description and the materialising of a form generatively together (see Louis H. Kauffman's article "Compresence and Coalesence", pp. 24–39 in this issue).

Light, even in the everyday act of seeing, switches between the "one" of an undifferentiated whole picture and the analysis identifying the composition of parts in the "two" of categorised reason. The manner of thought that moves towards a description as an illumination (of Young's interference or Newton/ Goethe's prism experiments) complements the hardness or boundary that separates an object in its existence physically. Meaning arises through the polarity of nothing and something, the crossing of which gives the "one" of appearance.

Bortoft also widened his focus beyond science into philosophy. At one point when about to begin a series of workshops, he was struggling to see a clear plan of how to communicate with his non-specialist audience. He spent a long time on a bridge at the Sherborne Academy in Gloucestershire looking at the water of a stream flowing towards him, in nervous contemplation of what awaited him. With the stream still in his mind, on entering the classroom he heard himself say: "Our problem is that where we begin is already downstream, and in out attempt to understand where we are, we only go further downstream. What we have to do instead is learn how to go back upstream and flow down to where we are already, so that we can recognise this as not the beginning but the end" (Bortoft 2012, 18). "Upstream-downstream" consolidated what Henri Bergson had coined as "reversing the direction of the operation by which the mind habitually thinks" (Bergson, 69), so that one was *catching the seeing* in the act. The "two" Bortoft relates as "upstream" and "downstream" is analogous to the current of thought that establishes the flow of discovering something arising from the nothing of where it began. In bringing attention from the world of finished forms to this stream of thought, one encounters the true generative source that leads one to the world separable into identities and existences.

A similar movement is made by Goethe to include darkness as a dimension of equal weight to light. In Goethean practice, different modes of seeing - from rational observation, through dynamic imagination, to catching the identity of the whole - are woven together not as instruction how to see, but to guide the 'see-er' to leave open the relation of the "one" and "two" systemically through the study (Bortoft 1996, 67–8). Goethe encourages us to trust in the process taking us from the darkness of unknowing into the insight and light of illumination. From this perspective, we arrive at the characteristic movement by which the different aspects form dynamically together.

Bortoft would get exasperated if anyone would try to point out that this was already an Eastern concept. He was not trying to establish this to dissolve duality into an overarching oneness. His audience was the scientist, the artisan and the philosopher. His work was to keep existence in the act of its appear*ance* - what appears *in its appearing* (Bortoft 2012, 24) - so that neither "one" nor "two" had ground on which to be defined separate to each other, **until** the act of appear*ance*. He saw this as a new way of opening out the Western mind, over its entire journey from Greece, through the Roman era into the Arab culture and eventually to renaissance Europe.

Bortoft took this ambiguity of language as the key by which the journey of Western culture into the materiality of rational subject-object duality could redeem its own meaning. All early philosophers and scientists from Descartes, Leibniz and Newton presented a mixture of wholeness - of their intuition, of their belief, of their thought - with the reductive mechanisms they proposed. Only later did science separate analysis from experience. Scientific method hardened around Newton's optics, teasing out light into straight lines of material rays, passing from object to eye or source to illumination. Light was presented as acting like matter. The use of light rays to depict paths of light "illustrates how an explanation, once established, pre-forms subsequent description" (Bortoft 1970, 230). Light's quality to communicate the whole without needing to divide things out into separate material existences, came thereby to be overlooked. If one tries to reduce the appearance of seeing into diagrams of straight-line rays, one destroys the capacity of light to act as its own medium of disclosure.

"Shade and Darkness – The Evening after the Deluge" (1843)
Joseph Mallord William Turner

“Light and Colour (Goethe’s Theory) – the Morning after the Deluge – Moses Writing the Book of Genesis” (1843)
Joseph Mallord William Turner

Goethe's challenge of Newton, his reinstating of darkness, was to rescue light from its subordination to matter. Light shapes material development in giving temporal elements a part in the whole they compose together. The organism, in Goethe's terms, is a journey to illumination of its whole form. Seeing, making a description, coming to insight similarly rely on the capacity of light to bring the different aspects of a dynamic picture together into a composite illumination. *A description through matter limits observation* to an abstraction of the known essentials governing reality. *An optical description starts with a vision* - of wholeness, of being, of spirit - allowing one to penetrate through successive stages of experience. Only at the end when one *sees*, is the threshold lowered by the process of arriving at the form which receives into it the energy of realisation.

To make sense of Western culture, from Goethe, through phenomenology, to science, one must free light to shape and deliver experience to the goal of whole insight. The light of romanticism, or experience, or self, are not peripheral to the mechanical knowledge of existence; the meeting with the "one" in the despair of darkness is what illumines the disciplines of science, philosophy and psychology as these became statements in dualistic reason of the "two".

In 2011 on the MSc in Holistic Science at Schumacher College, Bortoft took the class through Goethe's prisms experiments, in order to experience the moment together of illumination. One sees the colours neither dissolving into light nor arbitrarily constituted but standing in the freedom to articulate the world at its darkening or lightening. Colour characterises freedom in the dissolution or establishment of form. Colour is the key translating the drama of a world between death and life. The language of colour lends the means by which shadow and illumination happen. The whole integrity of the world is seen in its capacity to conceal or reveal. J.M.W Turner, the great British painter, portrayed Goethe's Theory by depicting colour in the translation between darkness and light.

It was Bortoft who above all made accessible a path by which the whole secret of Western thought is seen in the current of discovery itself. The "upstream" and the "downstream" are the "two" that can run together into the "one" of appearance. The optical insight together with the laws of matter, through the lens of Bortoft, foresees the existential ground by which observation responds to the touch of wholeness.

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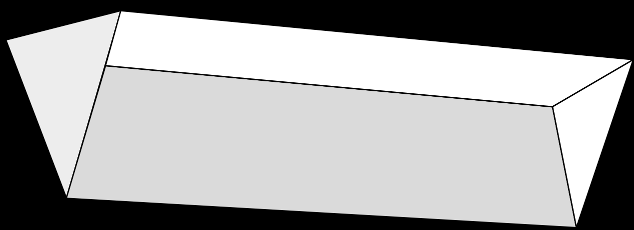
goethean science

// three colour experiments from Goethe's *Contributions to Optics*



Introduction

Goethe's *Contributions to Optics* does for colour what Euclid's *Elements* does for geometrical figures: it provides an exemplar of clarity, perspicuity and logic. Yet the fate of these two books could hardly have been more different. While the *Elements* became the most influential textbook ever written, the *Contributions* is all but forgotten. Nevertheless, this presentation of prism experiments has not been surpassed and Goethe's reflection on the method of the *Contributions* has become the most influential essay on Goethe's scientific method. In *The Experiment as Mediator Between Object and Subject*, Goethe remarks that "we must learn from mathematicians the deliberation required to place next in sequence only what comes next, or rather, to deduce what come next from what precedes". If we do this, we see connections between prismatic phenomena that are like the connections between stages of a geometrical construction or proof. In other words, we are able to see the logic of colour.

doing

*Goethean science**

Step 1

- Become accustomed to looking through the prism.
- Hold the prism horizontally, placing your fingers on the small triangles at either end, so that the apexes of the triangles are pointing down. (See Illustration 1)
- Look through the lower face of the triangle (not the top). Begin to adjust what you see through the prism until you are familiar with how objects are refracted and brought into vision. See figure 1 opposite.

Step 2

- Place figure 2 in front of the prism in such a way that the horizontal boundary between white and black runs parallel to the prism.
- On the horizontal boundary between white and black, coloured bands appear. On the left cyan appears below white and blue appears above black. On the right red appears below black and yellow appears above white. Horizontally, white appears opposite black, cyan opposite red, yellow opposite blue.

Step 3

- Place figure 3 in front of the prism in such a way that the white band runs parallel to the prism.
- Begin by looking at the illustration close up. The two edge spectra appear again, but this time one above the other: red and yellow appear above cyan and blue, with white in between.
- Move the prism away from the illustration. The yellow and cyan bands move towards each other and overlap to produce green.

Step 4

- Take figure 4 in place of figure 3 and repeat the procedure.
- Now the positions of the edge spectra are reversed, as are the colours of each spectrum: cyan and blue now appear above red and yellow, with black in between.
- Move the prism away from the figure. The blue and red bands move towards each other and overlap to produce magenta.

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* Adapted from Goethe's *Contributions to Optics*, §§ 45–50

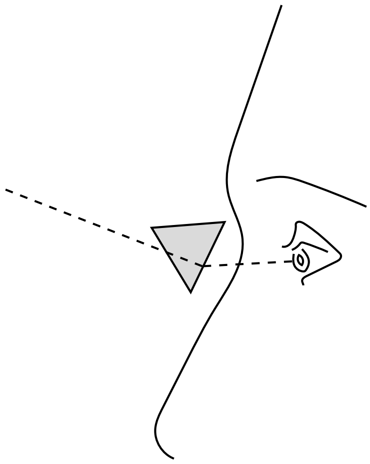

Figure 1

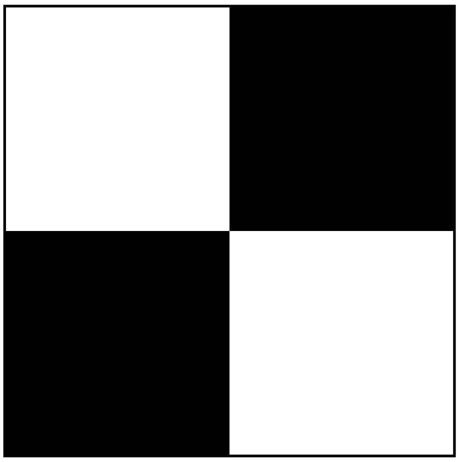

Figure 2

Figure 3

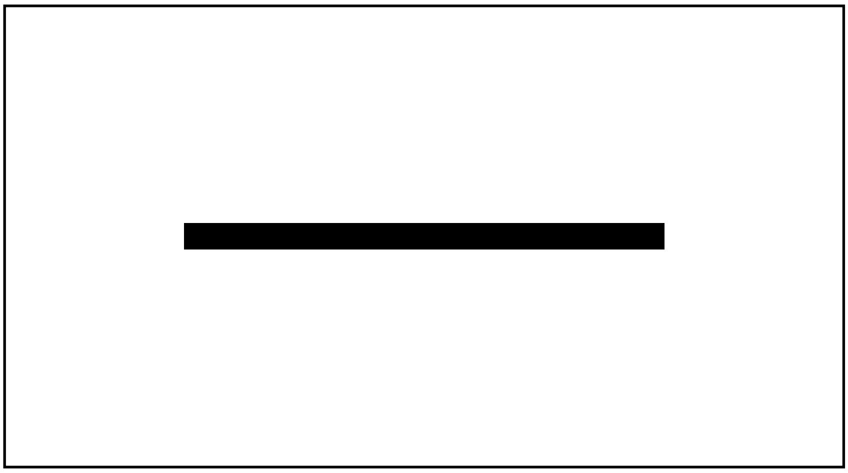

Figure 4

The polarity of prismatic colours

Step 2 shows colours appearing in the opposing pairs: white and black, cyan and red, yellow and blue. As each colour pair consist of a light colour and a dark colour, the polarity of light and dark is expressed in each pair. This is what Goethe's calls the polarity of colours.

On green and magenta

While the two edge spectra (cyan and red, yellow and blue) are produced by a single boundary of light and dark viewed through a prism, the colours green and magenta are produced by combining the two edge spectra in two different ways: by either bringing together the two colours that border white, or the two colours that border black. Step 3 and 4 show that where yellow and cyan overlap, green appears and where blue and red overlap, magenta appears. Here we have two kinds of mixing: one kind that mixes two colours by darkening, another kind that mixes by lightening. The two kinds of mixing are thus also polar to each other.

Goethe's colour circle

The two composite spectra in step 3 and 4 contain the following two sequences of colours:

red	cyan
yellow	blue
green	magenta
cyan	red
blue	yellow

Each colour of one sequence is the complement of the adjacent colour of the other sequence. Moreover, one sequence can be transformed into the other by interchanging white and black (light and dark). As each sequence contains the two edge spectra, they can be combined by placing each colour of the edge spectra together. This gives us the following arrangement:

magenta

red blue

yellow cyan

green

This colour circle represents the relations between the prismatic colours: colour pairs are diagonally opposite and adjacent colours in the edge spectra (left and right) are adjacent in the circle. The two colours produced by combining two edge spectra (top and bottom) are opposite each other on the circle and between the two colours that produce them. The colour circle represents relations that are internal to the quality of the colours themselves, not external relations that express a causal relation between a colour and something other than colour. This colour circle, then, represents the logic of prismatic colours. This is why Goethe's *Contributions to Optics* does for colour what Euclid's *Elements* does for geometrical figures.

further reading

Goethean colour theory

Most of the first part of Goethe's *Contributions to Optics* is published with commentary in Rupprecht Matthaei's *Goethe's Colour Theory* (Studio Vista, 1971). This compilation is a good introduction to Goethe's writings on colour. Dennis Sepper's *Goethe contra Newton* (Cambridge University Press, 1988) contains a clear presentation and insightful discussion of the *Contributions* and puts them into the context of Goethe's critique of Newton. Ludwig Wittgenstein's *Remarks on Colour* (Blackwell, 1977) develop this idea of a logic of colour. Jonathan Westphal's *Colour: A Philosophical Introduction* (Blackwell, 1991) develops Wittgenstein's logic of colour using insights from Michael Wilson's work on Goethe, reprinted in *What is Colour? The Collected Works*, (Logos Verlag, 2018).

Goethe's Farbenlehre from the Perspective of Modern Physics

/ Johannes Grebe-Ellis & Oliver Passon[1]

1. Introduction

"Of mine, they can destroy nothing", writes Goethe of the opponents of his *Farbenlehre* in his *Scientific Notebooks*; "for I have built nothing; rather I have sown, and so wide in the world that they cannot taint the seeds."[2] How does it stand today—roughly 200 years later—regarding Goethe's "optical seeds"? The influence of his colour studies on the development of technical, artistic and scientific aspects of colour research to the present day is undeniable. How does it stand, however, with his physical contributions to colour research? Instructive is the shift in the assessment of Goethe's scientific studies and the "seeds of thought" sowed within them brought about by Hermann von Helmholtz in the second half of the nineteenth century. In his 1892 lecture "Goethe's Premonition of Future Scientific Ideas", Helmholtz revised his judgment from 1853 that the *Farbenlehre* was a "failure", and, with a comparison with Faraday and Kirchhoff, gave Goethe a place in the community of physicists.[3] The case of "Goethe contra Newton" has since aroused much emotion; there is hardly a scientific controversy about which more has been written. The efforts of notable twentieth century physicists towards a recognition of Goethe as a pioneer of an holistic view of nature does not, however, change the fact that, from the perspective of physics, the *Farbenlehre* was considered a settled matter.[4]

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1. Originally published in a slightly different form in B. Steingießer, ed., *Taten des Lichts: Mack & Goethe* (Berlin: Hatje Cantz, 2018), exhibition catalogue. The footnotes have been reduced for this publication and German literature has been cited in English translation, where available.

2. *Ältere Einleitung* (Older Introduction), written probably early 1815 and published in the *Scientific Notebooks*. See J. W. v. Goethe, *Naturwissenschaftliche Hefte*, ed. D. Kuhn (Weimar: Böhlaus Nachfolger, 1962), 182.

3. H. v. Helmholtz, "Über Goethes naturwissenschaftliche Arbeiten", in Helmholtz, *Vorträge und Reden*, vol. 1 (Braunschweig: Vieweg, 1896), 1–40 (lecture to the German Society in Königsberg in 1853). Helmholtz, "Goethes Vorahnungen kommender naturwissenschaftlicher Ideen", in Helmholtz, *Vorträge und* Reden, vol. 2, 335–361 (lecture to the Goethe Society in Weimar in 1892).

4. See, e.g., C. F. v. Weizsäcker, "Goethe and Modern Science", in *Goethe and the Sciences: A Reappraisal*, ed F. Amrine, F. Zucker, and H. Wheeler (Dortrecht: Reidel, 1987), 115-32.

This consensus has been called into question in the last few years by new historical, philosophical and experimental investigations. Against the backdrop of a few remarks on the problematic reception of the *Farbenlehre* and the status of historical and philosophical research on it, the following presents the results of experimental research done over the last decade that have led to a new assessment of Goethe's contributions to physics in the *Farbenlehre*.[5]

2. Newton, Goethe - Who is Right?

Whoever takes up the topic of Goethe's *Farbenlehre* realizes that it is nearly impossible to speak on the strictly physical part of the *Farbenlehre* without at the same time taking a position on the "Goethe contra Newton" controversy. The question "Who is right?" is valid. It has a long tradition and ultimately goes back to Goethe himself, who initiated it with his polemic against Newton's *Opticks*, which he later came to regret. On the other hand, the history of the *Farbenlehre's* reception shows that an undue emphasis on this question leads to an *impasse*. From a modern perspective, the suspicion arises that the debate on the *Farbenlehre* and its relevance for physical optics has gone astray because it has remained limited to three positions: 1) "pro Newton", mainly advocated by physicists, 2) "pro Goethe", mainly advocated by philosophers, and 3) "both are right", advocated by philosophically inclined physicists, such as Werner Heisenberg, or Carl Friedrich von Weizsäcker, who attempted to "save" Goethe by advocating the thesis that the *Farbenlehre* presents a purely subjective, aesthetic view of reality, which can be granted its own domain of validity that is independent of the objective, physical reality described in Newton's *Opticks*.

If one studies the argumentation of the enumerated positions, one comes to the surprising result that the philosopher of science in Berlin, Olaf Müller, emphasizes in the following claim: Goethe's *Farbenlehre* has only been thoroughly studied by a few people, Goethe's discovery of the symmetry of spectral phenomena has been overlooked, and serious experimentation to investigate the complementarity of inverse optical spectra has not been carried out.[6] A few months before his death, Goethe informed Eckermann that his *Farbenlehre* "is very hard to communicate, […] for, as you know, it requires not

5. Sections of this article have already been published in the following articles: J. Grebe-Ellis, "Goethes Farbenlehre im Lichte neuer Experimente zur Symmetrie spektraler Phänomene", in Über *Goethes Naturwissenschaft*, ed. G. Böhme (Bielefeld: Aisthesis Verlag, 2017), 39-58; M. Rang, O. Passon and J. Grebe-Ellis, "Optische Komplementarität: Experimente zur Symmetrie spektraler Phänomene", *Physik Journal* 16, no. 3 (2017): 43–49; M. Rang and J. Grebe-Ellis, "Power Area Density in Inverse Spectra", *Journal for General Philosophy of Science* 49 (2018): 515–523.

6. O. Müller, *Mehr Licht: Goethe mit Newton im Streit um die Farben* (München: Fischer, 2015). Goethe was already aware of the relation of complementary colour pairs from his research on *coloured after-images* (successive contrast) and the phenomenon of *coloured shadows* (simultaneous contrast). In this context, he spoke of "opposing" (*entgegengesetzt*) and "mutually demanding" (*wechselweise fordernd*) colours and characterized the relationship between a colour and its opposite colour (*Gegenfarbe*) as a "totality" (See *Didactic Part*, §§48–80). In connection with his key insight ("prismatic aperçu") in May 1791, described at the end of the *Historical Part* of the *Farbenlehre* in the chapter "Confessions of the Author", Goethe discovered that the principle of "complementary colours" can also be found in the context of "prismatic colours" (See *Didactic Part*, §§195–247, 309–40). In this regard, note also the systematic nature of Goethe's subjective and objective experiments with optical contrasts in the second section of the *Didactic Part*, "Physical Colours", as well as their summary in the fourth section, "General Introspective Observations". In a supplement to the *Farbenlehre* published in the *Scientific Notebooks*, Goethe summarizes under the title *Complementary Colours* (*Komplementare Farben*) that "just like light and darkness, colours too immediately demand their opposite, so that, namely in thesis and antithesis, all are always contained. Therefore, the demanded colour has been called *complementary*" (*Naturwissenschaftliche Hefte*, 190).

only to be read and studied, but to be *done*, and this is difficult".[7] None of the physicists mentioned have heeded Goethe's request to not only study it theoretically, but also to test it experimentally—a request that Goethe was justified in making, seeing that he himself had fulfilled it with respect to Newton's *Opticks* by carrying out countless experiments in his forty years of involvement in colour research.

The question of which results are obtained by attempting to define Goethe's argument for symmetry more precisely and investigate it experimentally not only provides an escape from the *impasse* described above, it also leads into an area of research, which, by drawing on Goethe's research method, has led to a series of investigations in the last decade that can be understood as contributions to an optical image based, or phenomenological, exploration of optical phenomena.[8] To this area of research belong also the experimental developments which will be described below.

3. Goethe's Method in the Context of his Time

"Goethe's colour research can hardly be understood from the perspective of history of science if it is not taken seriously as a whole and placed in the context of its time." In a study from 2016, "Goethe and the Colour Research of his Time", Friedrich Steinle, an historian of science in Berlin, points out the astonishing fact that so far hardly anyone has taken seriously Goethe's aspiration to contribute to the science of his time with this *Farbenlehre*. "To this day," remarks Steinle, "we are lacking a picture of how Goethe's *Farbenlehre* from 1810 should be evaluated in the context of contemporary colour research".[9]

On the basis of an investigation over many years into the status of colour research at the end of the eighteenth century, Steinle comes to the conclusion that Goethe's work in the field of colour appears "in no way as an exotic undertaking," but rather "is situated squarely within the research questions of its time". Steinle shows that Goethe had taken up the most important strands of contemporary research, and convincingly and successfully developed a number of them further. It would appear that Goethe, when conceiving his *Farbenlehre*, was aiming at nothing less than an attempt to bring the technical and artistic practical knowledge, as well as the extensive scientific colour research of his time, "under an encompassing approach that unified all the individual areas under a single principle. In view of this primary goal, the polemical dispute with the dominant physical theories of light and colour was of secondary importance; a means to an end".[10] To bring colour in its relation to the eye, colour as the result of physical conditions, and colour as the property of bodies "under a common principle, which is most prominently expressed in the colour circle, was his central intention—far more important than the polemic" (see fig. 1).[11]

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7. J. P. Eckermann, *Conversions of Goethe with Eckerman and Soret*, vol. 2, trans. J. Oxenford (Cornhill, 1850), 410 (conversation with Eckermann on December 21, 1831).

8. See, e.g., the contributions to phenomenological optics in the book series Phänomenologie in der Naturwissenschaft (Berlin: Logos), whose program draws upon, among others, Gernot Böhme's concept of "phenomenology of nature". See G. Böhme, "Is Goethe's Theory of Colour Science", in Amrine, *Goethe and the Sciences*, 147-73. See further the optical image based writings of G. Maier, which explicitly build on R. Steiner's Goethe studies, in *An Optics of Visual Experience* (Edinburgh: Floris Books, 2011).

9. F. Steinle, "Goethe und die Farbenforschung seiner Zeit", in *Die Farben der Klassik*, ed. M. Dönike, J. Müller-Tamm, and F. Steinle (Göttingen: Wallstein Verlag, 2016), 255–289.

10. In an investigation of the structure of the *Didactic Part* of the *Farbenlehre*, Kühl and Rang have shown that the order of the six sections is not arbitrarily chosen, but rather follows a compositional principle that Schiller called a "model for scientific research" in a letter to Goethe. The structure can be understood as a general program for an interdisciplinary and multiperspectival approach to scientific research. See Kühl and Rang's article "A Model for Scientific Research", pp. 60–71 in this issue.

11. These topics are addressed in turn in the first four sections of the *Didactic Part*.

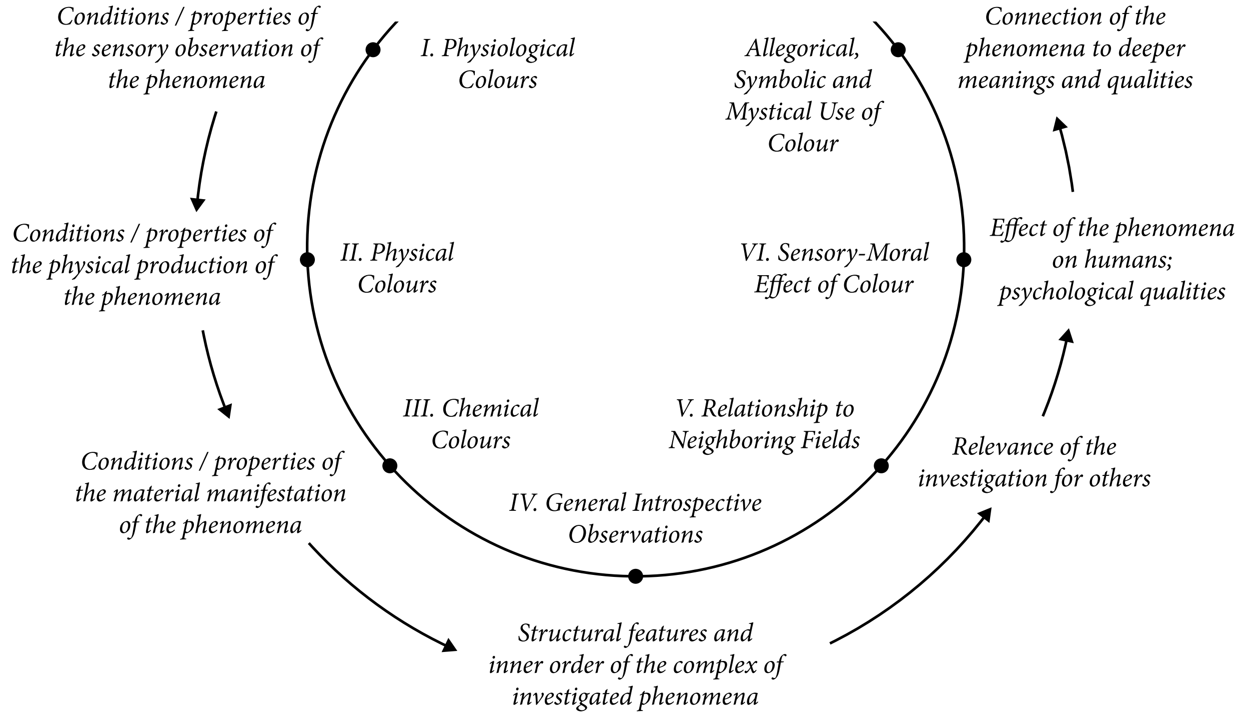

Fig. 1: The structure of the *Didactic Part* of the *Farbenlehre* as an outline of a genetic, multiperspective approach to research. *Inner circle*: The six sections of the *Didactic Part* with the addition of Rang and Kühl's suggested section "Allegorical, Symbolic and Mystical Use of Colour". *Outer circle*: Generalized formulation of the respective research perspective based on Kühl and Rang's "A Model for Scientific Research", pp. 60–71 in this issue.

A further aspect of Goethe's scientific research, which, although it has been partly investigated, has so far scarcely been viewed in an historical context, is his own research *method*. In connection with his chromatic studies, Goethe develops his own reflections on phenomena, theories, and experimentation, i.e., on the way that theoretical conclusions are drawn from observation and experimentation. The methodological writings which appear in this context show that he had greater concerns than critically reflecting on his own methodology and demarcating it from Newton's. They present an outline of a general method of experimental research, which contains considerations that are still relevant today for the conditions and possibility for acquiring knowledge based on experimental data.[12]

How these philosophical reflections of Goethe's relate to his own scientific practice and fit into the historical context of the French enlightenment has been investigated by Steinle in a comprehensive study, "'Experience of a Higher Kind': Goethe, Experimental Method and the French Enlightenment".[13] On the basis of the key mythological text, "The Experiment as Mediator between Object and Subject", Steinle reconstructs Goethe's epistemological critique of single experiments and sketches a method of "manifolding" (*Vermannigfaltigung*) the experiments through systematic variation of the parameters in the experimental setup. "According to Goethe's general thesis, the basis for theorizing first appears in the form of a

12. Beside dispersed methodological remarks in the "Contributions to Optics" from 1791-2 and in the *Farbenlehre* from 1810, two essays in particular are worth mentioning as key philosophical texts: "The Experiment As Mediator Between Object and Subject", in Goethe, *Scientific Studies*, ed. and trans. D. Miller (New Jersey: Princeton University Press, 1995), 11-7, and "Empirical Observation and Science", in Goethe, *Scientific Studies*, 24-5. For Goethe's conception of science see also R. Steiner, *Nature's Open Secret: Introductions to Goethe's Scientific Writings*, trans. J. Barnes and M. Spiegler (Hudson, NY: Anthroposophic Press, 2000), especially the chapter "Goethe As Thinker and Researcher", 166-91.

13. F. Steinle, "'Erfahrung der höhern Art': Goethe, die experimentelle Methode und die französische Aufklärung", in *Heikle Balancen: Die Weimarer Klassik im Prozess der Moderne*, ed T. Valk (Göttingen: Wallstein Verlag, 2014), 221– 249. See further F. Steinle, "'Das Nächste ans Nächste reihen': Goethe, Newton und das Experiment", *Philosophia Naturalis* 39 (2002): 141–172.

series of experiments adjacent to one another." For only *varying* the individual observations allows the functional relations of an observational context to become visible. This leads, following the example of "mathematical method", to a kind of experience composed of many others and which Goethe therefore called an "experience of a *higher* kind".[14] Only this "experience of a higher kind", which Goethe sometimes referred to as a "pure phenomenon", or "archetypal phenomenon", can present the basis of empirical rules and generalizing conclusions. By drawing a connection to the French Encyclopedists d'Alembert and Diderot, Steinle was able to show that Goethe's methodological considerations are "in no way as exotic as sometimes presented".[15] Regarding considerations of this kind, the question of whether there were, in addition to the connection to editors of the *Encyclopédie*, other parallels or possible exemplars cannot be conclusively answered at present. However, it is already "clear that Goethe, with his reflections on experimental practice and reasoning, was employing a practice that is encountered far more widely in science than has been assumed so far and therefore deserves a prominent place in a yet to be written history of the philosophy of the experiment".

4. New Experiments Confirm the Symmetry of Spectral Phenomena

Against the background achieved by looking at new historical and philosophical investigations of Goethe's *Farbenlehre*, we will return to the question raised at the beginning of this article of how the "optical seeds" stand today from the perspective of modern physics. The answer is given by experimental developments which have been elaborated in the last ten years by the physicist Matthias Rang.[16] They relate to Goethe's investigations in the second section of the *Didactic Part*, i.e., to the more strictly physical part of the *Farbenlehre*, which was the most important part for Goethe—and which also suffered the harshest rejection by physicists. Using technical optics, Rang shows how the unity of the complementary spectral phenomena, which was discovered by Goethe but remained neglected in optics, can be framed in terms of physics and demonstrated to be a fundamental condition of these phenomena.

The results of Rang's experiments can be summarized as follows: Goethe discovered *complementarity* as a symmetrical property of spectral phenomena. According to modern

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14. In the aforementioned essay "The Experiment As Mediator Between Object and Subject", one finds, among others, the statement: "From the mathematician we must learn the meticulous care required to connect things in unbroken succession, or rather, to derive things step by step. Even where we do not venture to apply mathematics we must always work as though we had to satisfy the strictest of geometricians. In the *mathematical method* we find an approach which by its deliberate and pure nature instantly exposes every leap in an assertion." Goethe, *Scientific Studies*, 16 (emphasis added). See further the section "Relationship to Mathematics" in the *Didactic Part*, §§722-29.

15. In the text from the archive "On Mathematics and its Abuse" (1826) Goethe quotes d'Alembert from the *Encyclopédie* and thus he himself gives an indication of the methodical parallels between his method of "manifolding" (*Vermannigfaltigung*) and mathematics. See further Steiner's footnote to the d'Alembert quote: "What the first proposition is in mathematics, is, for Goethe, an experience of a higher kind in science. Also, the way that d'Alembert thinks of this manifolding of the proposition is completely analog to what Goethe says about the relation between experience of a higher kind and normal empirical experience." Goethe, *Naturwissenschaftliche Schriften*, vol. 2, ed. R. Steiner, 4th ed. (Dornach: Rudolf Steiner Verlag, 1982), 47 (photomechanical reprint of the original Kürschner edition of Goethe's work (1883-1897).

16. M. Rang, *Phänomenologie komplementärer Spektren* (Berlin: Logos, 2015); M. Rang and J. Grebe-Ellis, "Komplementäre Spektren: Experimente mit einer Spiegel-Spalt-Blende", *Mathematisch Naturwissenschaftlicher Unterricht (MNU)* 62, no. 4 (2009): 227–231; M. Rang, O. Passon, and J. Grebe-Ellis, J. (2017): "Optische Komplementarität. Experimente zur Symmetrie spektraler Phänomene", *Physik Journal* 16, no. 3 (2017): 43–49.

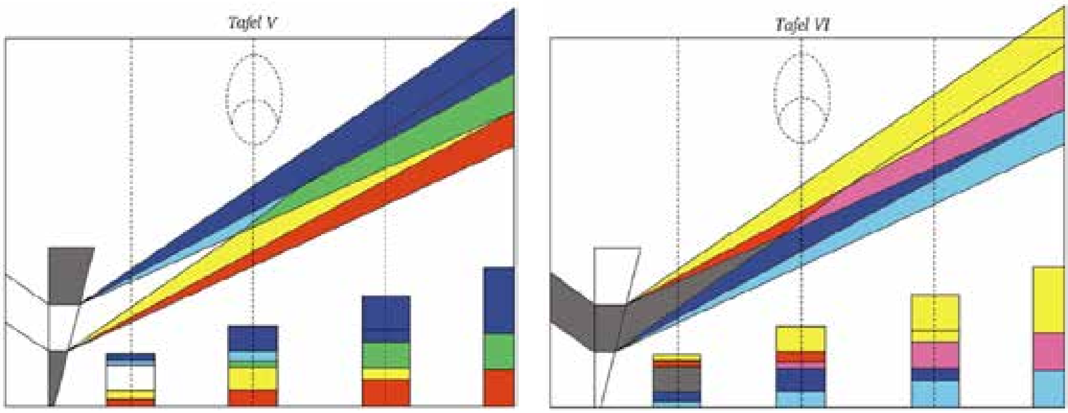


Fig. 2: Goethe's representation of the formation of complementary complete spectra by successive overlapping of complementary edge spectra as a function of the distance from prism. *Left*: slit spectrum. *Right*: the complementary case of the bar spectrum in which the slit is replaced by a bar, i.e., the light rays in a dark environment are replaced by a shadow in a light environment.

physics, complementary and inverse spectral states result from the conservation of energy of the optical system. Complementary spectra arise simultaneously at a mirror slit aperture and are dependent on each other functionally, like the transmission and reflection of a filter. The relevant experiments represent symmetrical extensions and generalizations of Newton's experiments.

How did Goethe arrive at the idea of the symmetry of spectral phenomena? He searched for the *observable conditions* for the appearance of colour. The most fundamental of these conditions appeared to him to be that colour only appears at optical contrasts, i.e., at boundaries of light and dark. By systematically varying and inverting these *contrast conditions*, Goethe arrived at the realization that producing images by passing inverse optical contrasts through a prism always results in isomorphic, complementary spectra.

Against the background of the presentation that he found in Newton's *Opticks*, this was an unexpected discovery. In light of the symmetrical conditions of appearance it seemed only consistent to Goethe to see the complementary spectrum as the equal counterpart to Newton's spectrum and to emphasize that the spectra belong together (fig. 2). And it is immediately understandable why Goethe could also see in the organizational schema of the colour circle an adequate representation of the lawfulness he found with respect to the complementarity and mixing of colour.

It seemed obvious to Goethe to expect a theory of spectral phenomena to take into account the symmetry that the phenomena show. Because of this he insisted on the observation that, for colour to arise, an interaction of light and darkness is always necessary. Newton's limitation to the slit spectrum awoke in him the impression of an arbitrary interference with the empirical data that resulted in the suppression of a whole class of phenomena and therewith a structural feature of spectral phenomena, which could be observed in other areas, such as atmospheric and polarization colour and therefore seemed of general significance.

Goethe could only provide qualitative and rudimentary experimental verification of optical complementarity as a symmetrical property of spectral phenomena. Nevertheless, with his experimentation and presentation of the arising of colour at inverse optical contrasts, Goethe sketched the methodological path which should, in principle, lead to such verification. It was the Norwegian André Bjerke who, in the 1950s, made the symmetrizing of spectral phenomena by systematic inversion, i.e., the interchange of light

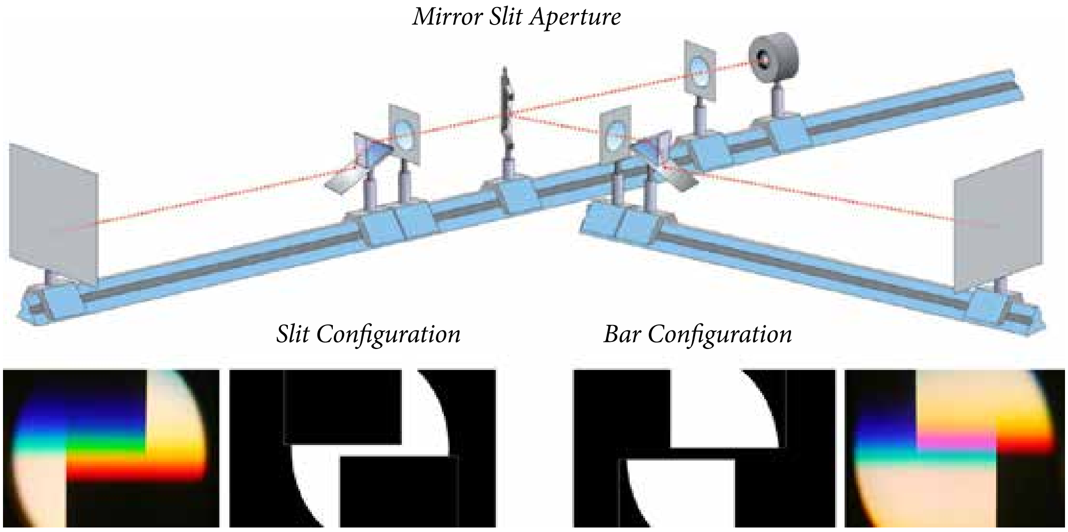


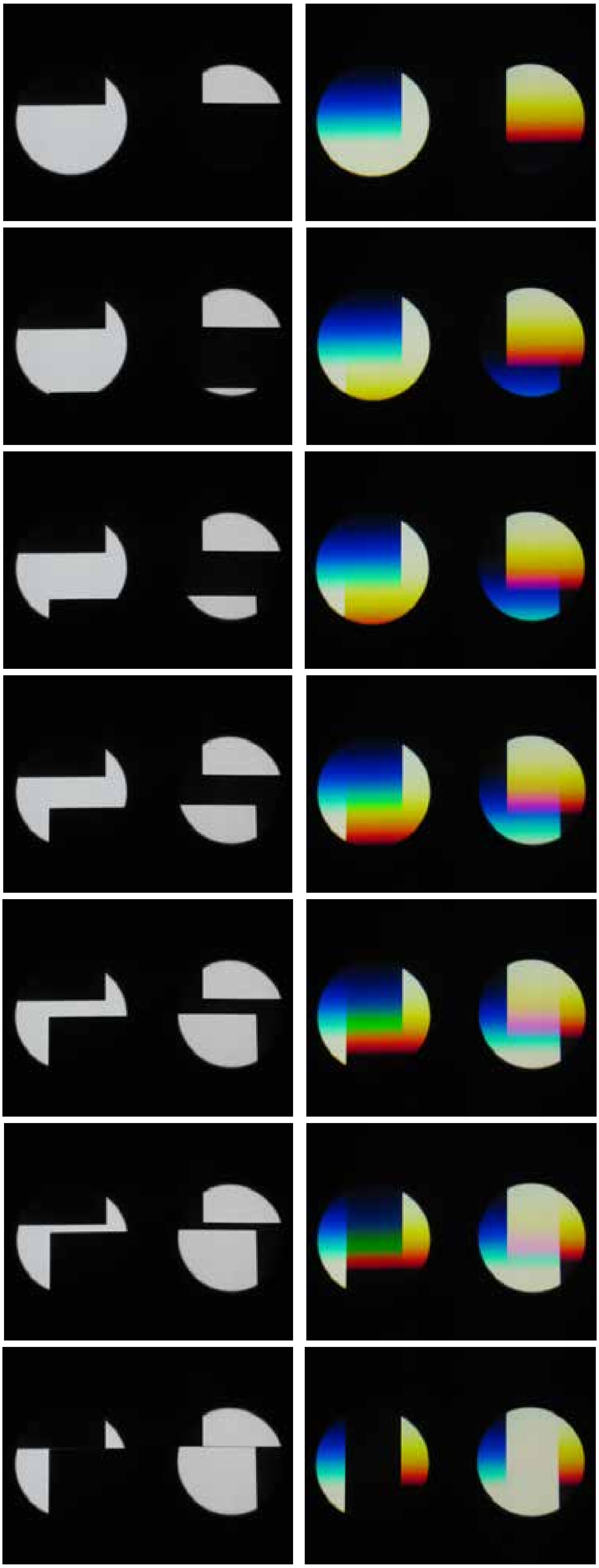
Fig. 3: Simultaneous production of complementary spectra using a mirror slit aperture. The optical transmission path (*left*) and reflection path (*right*) are constructed such that they are reflectionally symmetrical with respect to the plane of the mirror aperture. Without the prism, the mirror aperture appears as a *slit* in the transmission path and as a *bar* in the reflection path. Photos: M. Rang

and darkness in the most important of Newton's experiments, into a research program.[17] The decisive breakthrough that led to the success of this program was first made by Matthias Rang, who built on Torger Holtsmark's work with the introduction of a mirror slit aperture and the concept of an optical "lightroom" (figs. 3, 4 and 5).

On this basis, Rang was able to show in the last few years that, in principle, all of Newton's experiments can be inverted in the sense of Goethe's idea of polarity; the optical complementarity, as a property of chromatic phenomena that are produced with a strictly inverse setup, is preserved when the energy in the optical system under observation is conserved. In particular, this is also valid for the various versions of the *experimentum crucis*, an experiment that Newton conceived to prove the purity of spectral colours and essentially consists of two consecutively placed prisms (fig. 5 shows a variant of this experiment). Rang concludes that this results in a generalization of the concept of monochromaticity that relates the behavior of a selected spectral area, when tested for

17. With his suggestion of constructing a *mechanical* inversion of Newton's fundamental experiment, Goethe was able to give a perspicuous presentation of his discovery of the symmetry of complementary spectra. From a modern perspective, however, the impression arises that with this example of inversion Goethe also helped foster an uncomplete, mechanical understanding of inversion. In the twentieth century, this resulted in a tradition of attempts at inversion that were to remain ineffective so long as it was not recognized that the problem of inversion can be solved, in principle, not mechanically, but *optically*. It is nevertheless worth mentioning the work of Kirschmann, who, in 1917, was the first to show that the inverted spectrum can in principle be used spectroscopically in the same way as the slit spectrum. See A. Kirschmann, "Das umgekehrte Spektrum und seine Komplementärverhältnisse", *Physikalische Zeitschrift* 18 (1917): 195–205; Kirschmann, "Das umgekehrte Spektrum und die Spektralanalyse", *Zeitschrift für Instrumentenkunde* 44 (1924): 173–5. Significant preliminary work on overcoming the mechanical picture of inversion was carried out towards the end of the 1950s by Bjerke's research group in Olso; see A. Bjerke, *Neue Beiträge zu Goethes Farbenlehre* (Stuttgart: Freies Geistesleben, 1961). This led to Holtsmark's suggestion for the generalization of the *experimentum crucis*, which was realized experimentally by Sällström at the end of the 70s; see T. Holtsmark, "Newton's Experimentum Crucis reconsidered", *American Journal of Physics* 38, no. 10 (1970): 1229–1235; Holtsmark, *Colour and Image: Phenomenology of Visual Experience*, ed. J. Grebe-Ellis (Berlin: Logos, 2012); P. Sälllström, *Monochromatic Shadow Rays*, ed. J. Grebe-Ellis (Drucktuell: Gerlingen, 2010), DVD.

Fig. 4: Phases of the simultaneously produced complementary spectra of a high pressure xenon lamp with decreasing aperture. The left column shows the aperture; the right the corresponding spectra. Photos: J. Grebe-Ellis and Sebastian Hümbert-Schnurr



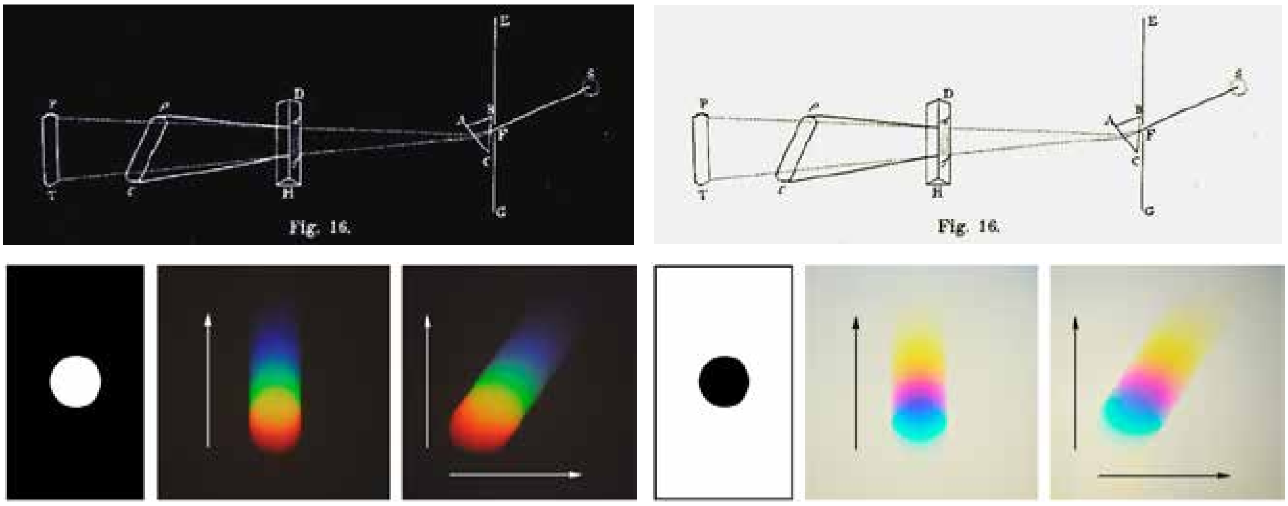


Fig. 5: Newton's *experimentum crucis* with crossed prisms (*left*) and the inverted version (*right*). Bottom row: The production (*middle*) and analysis (*right*) of the spectrum of a source similar to the sun with a dark background (*left*), together with the complementary spectrum of a "dark sun" with a light background. The arrows indicate the prisms' direction of refraction. Photos: M. Rang

spectral purity, to the context of its production: whether a colour behaves in a spectrally pure manner depends on whether it is *investigated in the environment in which it was produced.*

These results go far beyond the historical context of Goethe's *Farbenlehre*. They result from extended, modified and generalized variants of Newton's experiments and confirm Goethe's results with respect to the importance of the complementarity of spectral phenomena. The symmetry of complementary spectral phenomena is not limited to the region of the strictly optical part of the electromagnetic spectrum, but rather, being a general property of radiation energy, can also be demonstrated for the neighboring ultraviolet (UV) and infrared (IR) spectral regions. This has been done by Rang and Grebe-Ellis, using measurements of the complementary spectra of a high pressure xenon lamp (fig. 6).[18] In light of this research one can speak of ultra-yellow (UY) and infra-cyan (IC) regions of the complementary spectrum that correspond to the UV and IR regions of the normal spectrum. It remains to be seen whether, on the basis of Rang's techniques, spectroscopic applications can be developed that have advantages in specific cases over established methods.

5. Conclusion

This presentation of recent historical, philosophical and physical investigations on Goethe's *Farbenlehre* shows that the image of Goethe as a scientist and colour researcher has been reanimated in recent years. The research on the *Farbenlehre* is in no way finished. On the contrary, the studies presented above clearly show that we are in many ways at the beginning—and that this beginning is promising.

18. M. Rang and J. Grebe-Ellis, "Power Area Density in Inverse Spectra", *Journal for General Philosophy of Science*, 49 (2018): 515–523.

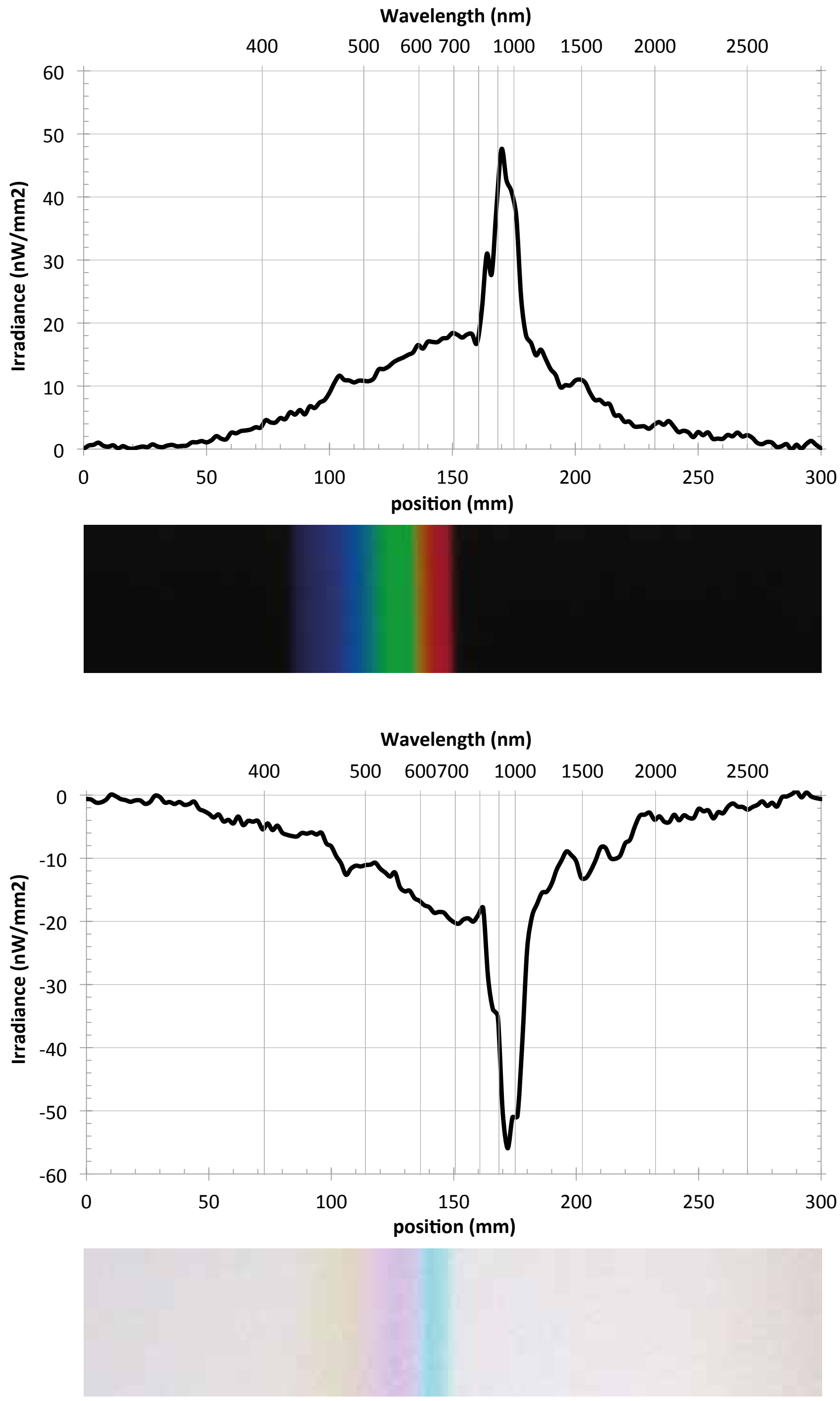
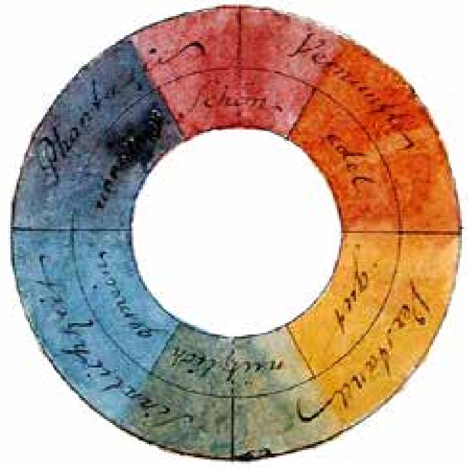


Fig. 6: Intensity of irradiation in the slit spectrum (*top*) and in the complementary bar spectrum (below) of a high pressure xenon lamp.

A Model for Scientific Research

A Consideration of Goethe's Approach to Colour Science



/ Johannes Kühl & Matthias Rang[1]

Your long work with colours and the seriousness with which you treat them should certainly be rewarded with much success. Since you can, you must establish a model of how to treat physical research; and such an undertaking needs to be didactic with respect to both its treatment and its profit for science.

Schiller (Goethe and Schiller, 706)

1. Introduction

In this quote from his letter to Goethe, we see that Schiller had hoped for, and even encouraged, a methodologically exemplary work from Goethe's colour studies. Unfortunately he was no longer alive to witness the final outcome, Goethe's *Farbenlehre,* published in 1810, five years after Schiller's death (Goethe 1982; 1995).

In the present paper we explore a possible meaning of Schiller's expectation and consider the *Didactic Part* of the *Farbenlehre* as a model for a Goethean science of inorganic nature. The very title "Didactic Part" indicates that not just the content but also the *manner of presentation* was consciously chosen. We investigate this idea using the structure of the *Farbenlehre*, which Goethe presents in a specific sequence of six sections.[2] In his introduction to Goethe's scientific works, Rudolf Steiner dedicates an entire chapter to this

1. This is a revised English version of the article: "'ein Muster..., wie man physikalische Forschung behandeln soll... '", *Elemente der Naturwissenschaft 100* (2014): 152–171.

2. Gögelein emphasised a different aspect in his investigation of the structure of the *Farbenlehre*. Among other things, he discusses to what extent the *Farbenlehre* can be understood "as symbolism of the process of attaining insight" (Gögelein, 149ff). A series of works on the philosophical basis of Goethe's scientific works and the problems concerning the theory and history of science arising in that context can be found in Amrine et al. and Seamon & Zajonc. These collections contain works that follow and further develop Goethe's scientific method in different areas, especially biology. Works that are limited to the fields of optics can be found in Grebe-Ellis & Theilmann.

structure titled "The System of Goethe's Colour Theory", although he mainly addresses the first three and the sixth sections. He concludes:

> Thus, Goethe advances from observing color as an attribute of the phenomenal world to a study of the phenomenal world itself as it appears with this attribute. In his section on the *sensory-moral effects of color* he then finally proceeds to the observation of the higher relationship between the colored physical world and the world of the human soul.
>
> This is the rigorous, strict path of science—going from the subject as condition back to the subject as it finds its satisfaction in and with the world. The impulse of the age that led to the architecture of Hegel's whole system is obvious in this path moving from subject to object and back again. (Steiner 2000, 183)

We attempt to show how the first stages of Goethe's work, found in the first three sections, lead to a "material" science, as is the case in conventional scientific approaches. However, Goethe does not stop there but adds three further stages. We believe that the six sections of the *Farbenlehre* demonstrate that Goethe was able to approach his topic from six different perspectives. Thus one characteristic of Goetheanism is a "multiperspective" approach that is only made whole through the different points of view. This becomes clearer if we treat the final subsection, "Allegorical, Symbolic and Mystical Use of Colour", as a nascent seventh section whose content Goethe only hints at, namely a kind of meditative approach to colour.

2. The Descent into "Matter"

> The desire for knowledge first stirs in man when he becomes aware of significant phenomena which require his attention. To sustain this interest we must deepen our involvement in the objects of our attention and gradually become better acquainted with them (Goethe 1995, 163)

Thus Goethe begins his introduction to the *Didactic Part*. According to this, scientific activity can be kindled by everyday experiences in the world: looking out of the window or going on a walk in the fresh air on a nice Easter Sunday. This is followed by a transition from a fortuitously seen phenomenon to an intentionally created phenomenon in an *experiment*—scientific activity starts with the experiment. In the first three sections of the *Farbenlehre* Goethe describes a plethora of different groups of experiments in a particular order.

Physiological Colours

Goethe begins with the simplest of experiments: looking at a coloured object and observing the effect. The result of this experiment is that the perception of a coloured object is followed by the perception of a complementary coloured afterimage of the object.

The crucial difference between the experiment and an everyday experience is that the conditions for the appearance of colours are intentionally and consciously created in an "experimental setup". A further difference from everyday experience is that, for the experiment to be successful, the observer must have a certain level of awareness or attention: they must focus on the object for a specified time and suppress the urge, which immediately arises, to let their gaze wander over the object and the surrounding environment.

Changing the conditions of the experiment, e.g. the form or colour of the observed object, also changes the results according to a lawfulness which can be determined through extensive variations of the experiment.

As Goethe notes, experiments of this kind satisfy a criterion of scientific experiments: they can be created at any time and are thus repeatable. Anyone can carry out these experiments anytime and anywhere if they employ the necessary diligence.

A possible objection might arise that for a given colour different observers may see an afterimage with a slightly different colour. However, since the *eye of the observer itself is part of the experimental setup*, this does not change the objectivity of the results: the differences correspond to the slightly different properties of each observer's eyes and thus are part of the variations of the experimental setup. Since Goethe did not use the title "individual colours" but "physiological colours" for this section, we can assume that he was aware of this possibility and approved of the generalization from the individual to the universal case. As Wilson and Brocklebank have shown, the colour of the afterimage is closely and systematically related to the corresponding complementary colour for additive colour mixing (Wilson & Brocklebank).

Physical Colours

Goethe does not, however, move on to introspective observations of the objects under consideration. Instead, he transitions to optical experiments in which the observer's eye plays a diminished role in the experimental setup. He thus takes the path which has been followed by the sciences for centuries, i.e. the observer becomes more and more removed from science.

Goethe proceeds to describe increasingly complicated experiments from various areas of optics. He calls colours that arise in colourless conditions "physical colours". He begins with colours of the cloudless atmosphere — the blue of the sky and the colours of sunrise and sunset — and the appearances due to refraction. These are followed by corresponding experiments with prisms, diffraction colours of microscopic structures and lastly interference and polarization experiments.

Goethe's experiments with physical colours, which occupy the largest portion of the *Didactic Part*, cover nearly all the colour phenomena known in his time. He carried them out using the technological means of his day and acquired a large collection of apparatus with which he not only repeated the experiments described in the literature but often varied or extended many of the parameters. Although it has been claimed otherwise, Goethe was definitely not adverse to using technology.[3]

Common to all physical colours is that they are not produced by the observer's eye but rather by the physical properties of the experiment. They belong to outer nature as appearances. Hence, without exception, they can all be reproduced such that the observer's eye is no longer part of the experimental setup. Goethe implements this detachment and often replaces the human eye as the imaging instrument of vision with an imaging optical element or "technical eye" (Goethe 1995, §299–305). This is consistent with a shift from what Goethe calls "subjective experiments", such as looking through the prism at a

3. After the publication of the *Farbenlehre* in 1810, Goethe continued experimenting until his death in 1832, and maintained a keen interest in new scientific reports and discoveries of his contemporaries. Several critics of the *Farbenlehre* attribute to Goethe a negative attitude towards technical experiments or technology in general and base their claims on different passages (e.g., Carrier). However, Goethe's reservation refers to an unreflective handling of the results of observations gained through the use of technical devices. For example, in *Wilhelm Meisters Wanderjahre* Goethe's Wilhelm says that a "higher culture" is needed to get the right picture of the disproportionately close image seen through a telescope (Goethe 1987, 183). Other passages to which Linnemann calls attention indicate that Goethe had a positive relationship with many technical achievements of his time and even tried to introduce them in the different institutions where he worked in Saxe-Weimar (Linnemann).

contrast, to what he calls "objective experiments", such as projecting a contrast through a prism onto a screen.

Physical colours, which are characterized by Goethe as "nascent", do not exist as substances, but are transient and vanish without a trace as soon as the experimental conditions for their appearance are no longer fulfilled. However, they can all be detected and verified technically, e.g., photographically, or spectroscopically as characteristic intensity distributions. They have a factual nature in the observed world.

Chemical Colours

Goethe understands "chemical colours" to be the colours of objects, pigments and dyed materials. He begins by looking at the colours produced by tempering steel as a kind of transition from physical to chemical colours. For Goethe, understanding always arises from following the process of how an appearance arises. With coloured substances, however, this can be limited if one is not able to penetrate complex areas of chemistry. Goethe is able to follow this process to a certain degree with the influence of acids and bases on plant juice colours. He then describes the colouration of metals produced by chemical reactions and finally the colours in the different realms of nature. He concludes the section with a few paragraphs on chemically produced variations of refraction in glass. In the final paragraph he mentions how desirable it would be if his research on chemistry, for which he can only give "rough indications", could be worked on by chemists in the future "in a general way that is consistent with science as a whole" (Goethe 1995, §687).

3. The Bottom of the "U"

As the physiological colours are, so to speak, facts of perceptual processes and the physical colours are facts of observable physical processes, we could say that the chemical colours are facts of matter, as they exist as properties of substances in the external world. Thus, the first three sections of the *Farbenlehre* "descend" from perception into a material science of colour. This is equivalent to a narrowing of the natural diversity of phenomena through the scientist's experimental apparatus and an increasing control of the conditions under which these phenomena appear. This narrowing occurs even with physiological colours through the attention or awareness required by the observer. In this respect, the *Farbenlehre* does not differ from the usual procedures in science.

However, even though Goethe conducts physical and chemical experiments using apparatus, he takes utmost care not to describe any phenomenon partially or in isolation. In particular, he varies the conditions within an experiment as extensively as possible in order to prevent a phenomenon from being reduced to a partial phenomenon. Clearly, Goethe did not see a problem in an experimental treatment *per se* of the arising of colour. Rather, such a treatment becomes problematic only when a partial phenomenon is observed and then accorded more significance than other partial phenomena.

Goethe's prismatic experiments are well suited to illustrate this point. His *Contributions to Optics*, the didactic and polemic parts of the *Farbenlehre* and many other small studies, some only published after his death, show that Goethe carried out all the prismatic experiments known at the time, especially Newton's experiments. What he criticizes in Newton's approach is that he prioritized some observations over others as primary observations and used them to derive the others as secondary (Goethe 1951, 285ff; 1957, 420; 1958). Regarding Newton's basic experiment (Newton 1704, 13ff), for instance, he points out that Newton does not vary the distance between prism and screen, but singles out one individual situation, which he uses to derive all the others (see Müller). Furthermore, without any justification based on experiments, Newton prioritizes the well-known solar spectrum over its reverse or complementary spectrum (see Bjerke; Holtsmark

1969; 1970). One can say, that with this *empirically unjustified* prioritization Newton provides grounds for Goethe's objections.

Goethe is not opposed to colour research at a certain stage reducing a phenomenal domain to *its measurable quantities*, but rather to the reduction of a phenomenal domain to a *subset of phenomena*. At this stage of the treatment the "holistic nature" of Goethe's approach is preserved *within* the phenomena that are reduced to what is measurable. This difference from traditional methods of science is linked to Goethe's demand for a pure empiricism at the stage of empirical phenomena and his view that a theoretical conclusion based on an isolated phenomenon is problematic (Goethe 1932).

General Observations Looking Inwards

Goethe's *Farbenlehre* does not remain with an empiricism of the material aspects of colour, but adds another three sections, which start from "matter" and gradually widen the focus to include the overall context.

Goethe chose the rather enigmatic title "General Observations Looking Inwards" for the fourth section, which follows "Chemical Colours". Rudolf Steiner comments on this title:

> General observations looking inwards, i.e. towards the shared natural grounds from which the colours emerge. Goethe is never satisfied with the mere observation of external facts, but looks for the underlying inner grounds, i.e. grounds which are no longer perceptible to the senses, but only to reason (Footnote by Steiner in: Goethe, 1982, 266.)

These words indicate that what belongs to the "essense" in a field of research are not only the outer facts, but also the concepts, ideas and context with which they are connected. These are found by an inner activity, not outer observation. So it is mainly here, after the first half of the book, that Goethe explicates concepts such as "polarity" and "intensification" and fully develops the colour circle. Remarkably, his expositions at this point hold not only for the physiological, but also for the physical and chemical colours. Even though everything presented in this section applies equally to physiological, physical and chemical colours, the content of the section could not be developed out of any one of these areas. This developement is only possible because Goethe eschewed reduction to partial phenomena in the earlier sections.

If we bring the course of the book so far before our mind, this section appears — as the heading suggests — to be something we colloquially refer to as a "U-turn". In this section, the step-by-step descent into the "material", outer aspect of colour, which is accompanied by specializations, is now at a turning point, which will subsequently lead to the general introspective observations, the "underlying inner grounds ... which are no longer perceptible to the senses, but only to reason" (ibid). They are "general" only in that Goethe develops them out of an overview of *all available empirical observations*. Were this not the case, we would have to speak of "generalized observations" that undertake, on a conceptual level, what Goethe avoided on an experimental level, namely giving more significance to a particular interpretation of a subset of phenomena and a subsequent derivation of other phenomena from this interpretation. In this respect, the complete specialization and temporary narrowing to the material is a precondition for ensuring that the subsequent search for inner coherence does not become subjective or misguided.

The concepts and order of appearances described in this section are not specialized for *specific* cases of observation and therefore do not lend themselves to a quantitative or mathematical treatment, as Holtsmark showed (1971). If this is desirable – as it is often the case for physical or chemical questions – it can be done within the treatment of physical (or chemical) colours. No contradiction arises between a quantized statement and the general statements if the mathematical treatment phenomenologically describes the empirical data. The colour circle, as a geometric system, allows quantitative statements that are tailored to a specific field, e.g. to physiological colours, of which a mathematical treatment shows that the colour circle either does not stay circular (CIE-Diagram) or needs to be presented in a curved colour space within which the diameters are no longer straight lines (Gschwind).

In this section, no new observations of the sense perceptible world are added, but rather conceptual observations based on sense observations. Goethe called this form of knowledge "experiences of the higher kind" (Goethe 1932, 23).

4. The Ascent into the "Essence"

Although a continuous specialization of the observations was necessary and desirable in the first three sections of the *Farbenlehre*, this specialization must be overcome in order to advance to the "essential" characteristics of colours. These "essences" are developed in the "General Observations Looking Inwards" insofar as they can be approached from external observations. Two more sections follow in which "the essence" is given two further meanings.

Relationship to Neighbouring Fields

After dealing with the interrelation of colours in the previous section, Goethe considers the interrelation of colour science and other scientific and cultural activities. He dedicates several paragraphs to its relationship to the fields of philosophy and mathematics, but also to physics as a whole, dyeing, music theory and others. Here Goethe extends into a larger context the considerations that in the previous section stayed within the phenomena of the first three sections. Thus there is a transition from epistemological concerns to those of application and practice. In summary, this section investigates how colour science becomes meaningful within other fields and cultural activities.

Sensory-Moral Effect of Colour

In the remarkable final section of the *Farbenlehre* Goethe, develops an "aesthetics of colour" (footnote by Steiner in: Goethe 1982, 289) or, as we would say today, a psychology of colour. He does not, however, use the method of the external observer who carries out experiments on people who do not know the background of these experiments, as is sometimes the case in psychological studies. Rather, when observing colours, Goethe practices a "self-observation of the soul" and describes the moods he experiences. We might only realize his mastery if we attempt such formulations ourselves, or compare his descriptions with the everyday language we use when attempting to express a personal reaction, rather than an individual perception, by using such phrases as "I feel good" or "that annoys me" etc. The subtitle Rudolf Steiner gave his *Philosophy of Freedom*, "Some Results of Introspective Observations Following the Methods of Natural Science" could be given to this section of the *Farbenlehre*.

Firstly, Goethe characterizes colours individually, then he investigates the impression of colour combinations: he calls pairs of complementary colours "harmonic" combinations. Pairs of colours obtained by passing over an intermediate colour in the colour circle, e.g. blue and yellow, he calls "characteristic" combinations. Adjacent colours in the colour circle, such as yellow and green, form "characterless" combinations. Lastly, he derives the potential aesthetic effects of these combinations for the artist (Goethe 1995, §848ff).

This part of the *Farbenlehre* is noteworthy because Goethe is looking for a relationship between the way colours are produced and what one feels in the moods associated with colours. He is looking for a bridge between "feeling and science" – between *Poetry and Truth* – the title of his autobiography and a central motif in Goethe's work.

Compared to the section "Relationship to Neighbouring Fields", which was more concerned with external relations and applications, he now turns to the internal relation, to the human being. Even if we look at a coloured surface, the observation is introspective with the aim of finding a characterization that complements the external colour phenomena. In other words, after showing the essence of the sensible colour phenomena in "General Observations Looking Inwards" and the essence of colours with respect to their significance and application for the arts and sciences in "Relationship to Neighbouring Fields", the "Sensory-moral Effect of Colour" deals with the essence of colour for the human being.

In the last paragraphs of the *Farbenlehre*, under the heading "Allegorical, Symbolic and Mystical Use of Colour", Goethe briefly indicates one further intensification of this perspective by seeking an expression of spiritual beings in colours – after which he withdraws to safer grounds once more:

> We must grasp how yellow and blue diverge, and should reflect especially on the intensification in red where the opposites incline to one another and merge to create a third element. Then we will certainly arrive at the mystical and intuitive perception that a spiritual meaning can be found in these two separate and opposite entities. When we see them bring forth green below and red above, it will be hard to resist the thought that the green is connected with the earthly creation of the Elohim, and the red with the heavenly creation. (§919)
>
> But we had best not expose ourselves to suspicions of fantastic imaginings at the end; all the more so since a favourable reception of our colour theory will enable allegorical, symbolic, and mystical applications and interpretations to emerge in keeping with the spirit of our age. (§920)

In §919 we can see that Goethe expresses how the awareness of phenomena observable in the sense world can lead to a "mystical and intuitive perception", which opens a door to the being of colour. With Goethe's final words in mind, we could interpret Steiner's suggestions for meditations on colour, especially the "rose-cross meditation" described in "*An Outline of Esoteric Science*" (Steiner 1997, 291ff), as the missing seventh section to the *Farbenlehre*.

5. External and Internal Perspectives

If we investigate the questions posed in each section independently from the topic of colour we find the following questions:

1. What are the properties of the perception granted by the organ that gives us access to the phenomena in question?
2. What are the physical conditions and properties that allow the phenomena to arise?
3. What are the material conditions and properties that enable a "complete manifestation" of the researched field?
4. What is the inner order of the researched field?
5. What significance does the research have for others?

6. How do the phenomena affect the human being and what inner observations are possible when we experience them?
7. What deeper relations, qualities and beings can express themselves through the phenomena?

Through these questions we find the multiperspectivity that allows Goethe to write one *Farbenlehre* and not several on the "Physics of Colour", the "Physiology of Colour Perception" or "Colour Psychology". For a holistic science of colour, all these different aspects are significant.

However, "multiperspectivity" is not meant to imply that we can obtain different, independent perspectives of the object of observation in an arbitrary order, and simply add or leave out other perspectives. Rather, these perspectives are internally related – as has been shown – and form a process of development or an evolution of the cognition of this field.

If we understand this process as taking place in stages that correspond to each section, it begins with the physiological phenomena in an integral overarching nexus. On the one hand, a coloured object or a pigment (a fixed colour) is involved in these phenomena and, on the other hand, an optical image in the "frontal eye" and a physiological reception of colour in the "rear eye".[4]

A more analytical approach begins in the next two sections. Basically, we can say that in the physical colours the frontal eye is recreated using optical elements and Goethe does this in manifold ways. Today, we can replace the rear eye with technical detectors (which was not possible in Goethe's time), e.g., with the sensor in a digital camera. Thus, at this stage the human eye is replaced – to a certain degree – by a "technical eye" – as part of the experimental setup. This process of "separating" the eye from our individual organization leads, on the one hand, to detaching the phenomenon from ourselves. On the other hand, this separation allows us to share the phenomenon with others *under the same conditions* (whereas in the physiological colour experiments observation was only accessible to one observer under the same conditions). Thus, in the first stage of the process, conditions and characteristics of the rear eye are studied, whilst the focus in the second stage is on the frontal eye, including its detachment from the human organism.

In the third stage, the section on chemical colours, the focus is placed fully on the phenomenal by "analysing" the coloured object itself. Here, the eye is not included in the experimental setup of any of the experiments described by Goethe. Gone are the elusive appearances of the physiological colours. Gone are the transient appearances of the physical colours that disappear if generative conditions are no longer fulfilled. Rather, all appearances are properties of matter.

Metaphorically speaking, we can compare the process thus far, i.e. from the first to third stage, to a gradual "closing" of our organic eyes. We do not perceive the phenomena in the later stages as directly as we did with the earlier physiological appearances, but rather adopt a manner that is more practical than observational as we engage in a specializing and analyzing laboratory activity.[5]

4. Georg Maier made this distinction between the "frontal" and "rear" eye (private communication, see: Maier, 219). What we call imaging corresponds to the physics of the frontal eye. The rear eye, which, unlike the frontal eye, is supplied with blood, is the living (or etheric) part of the eye and enables us to sense brightness and colour (Maier, 219).

5. It is interesting to compare this activity with the term "optics without an eye", which Johannes Grebe-Ellis coined for physical optics (Grebe-Ellis, 21f). It is worth mentioning that Goethe would probably have rejected "optics without an eye", but not optics that develops an "optics with a detached eye" alongside an "optics with an eye". However, according to Goethe's approach "chemistry without an eye" seems to be both appropriate and necessary.

This is the situation we call the bottom of the "U", which represents a "material" science of colour. Using the metaphor of fully closed eyes at the "U-turn" – i.e., at the transition to the fourth stage – the "General Observations Looking Inwards" section then corresponds to opening our eyes, but this time inwardly! Before the mind's eye we survey everything that has been demonstrated experimentally and review the individual, specifically arranged (or modified) appearances in order to develop what Steiner, carrying Goethe's idea forward, characterized as a "*higher experience* within experience" (Steiner 1988, 82). So within our metaphor, closing our outer eyes is the prerequisite for opening them inwardly.

In the fifth and sixth sections the inner eye gradually opens further. Whilst the introspection in the fourth section, "General Observations Looking Inwards", stayed within the realm of experimental results, we now take account of the scientific work in relation to the sciences, arts and culture in the "Relationships to Neighbouring Fields" section. Thus, in the final stage, we can develop the introspective observation further into an observation of the soul, which can discover internal characteristics as essences of colour.

It seems to us that just as the previous stages formed a developmental process and each necessarily builds upon the preceding ones, this final stage would also not be possible without the other stages. First of all, the preceding work enables one to know the external conditions and properties of colour and therefore creates the prerequisite for having something "in view"– as a kind of afterimage – when opening the eyes inwardly. For observation of the soul, the external conditions and properties become an aid for, on the one hand, discovering the internal conditions and properties and, on the other, for separating them from our own "conditions and properties" (e.g., one's personal mood on a specific day). The latter represent *not constitutive but modifying conditions* for the observed colour and its psychological qualities. If this separation does not occur, there is no scientific activity according to Goethe. In other words, at this stage we apply the scientific method to inner observation.

This might explain why Goethe does not jump directly from "Physiological Colours" to "Sensory-Moral Effect of Colour", even though both rely on the same experimental setup, i.e. observing a colour and noticing the result. In that case, the subsequent optical experiments could appear as a detour or even as the wrong turn. For us, however, this indicates that after the "Physiological Colours" the conditions necessary for undertaking an observation of the soul in a scientific manner are not yet fulfilled. In this respect it is worth mentioning the work of Kees Veenman, who makes an introspective observation during the observation of physical experiments that leads to the "essence" and a qualitative characterization of colour (Veenman, 2009).

It becomes apparent from the whole process that a holistic or Goethean science is not an "alternative" to a specialized or "instrumental" science. On the contrary, it seems that the latter is a condition for the former, a necessary activity without which it is not possible to advance to the "essence" of the field.[6] It may be an obvious objection that considering the state of present day technology it would be impossible for a single person to complete

6. We recommend the excellent summary which Amrine and Zucker wrote as a postscript to a "round table" at Harvard University in 1982. They summarize different problems and possibilities relating to the question of whether Goethe's approach to science offers an alternative *for* modern scientific endeavours, an alternative *within* modern scientific endeavours or no alternative at all (Amrine & Zucker).

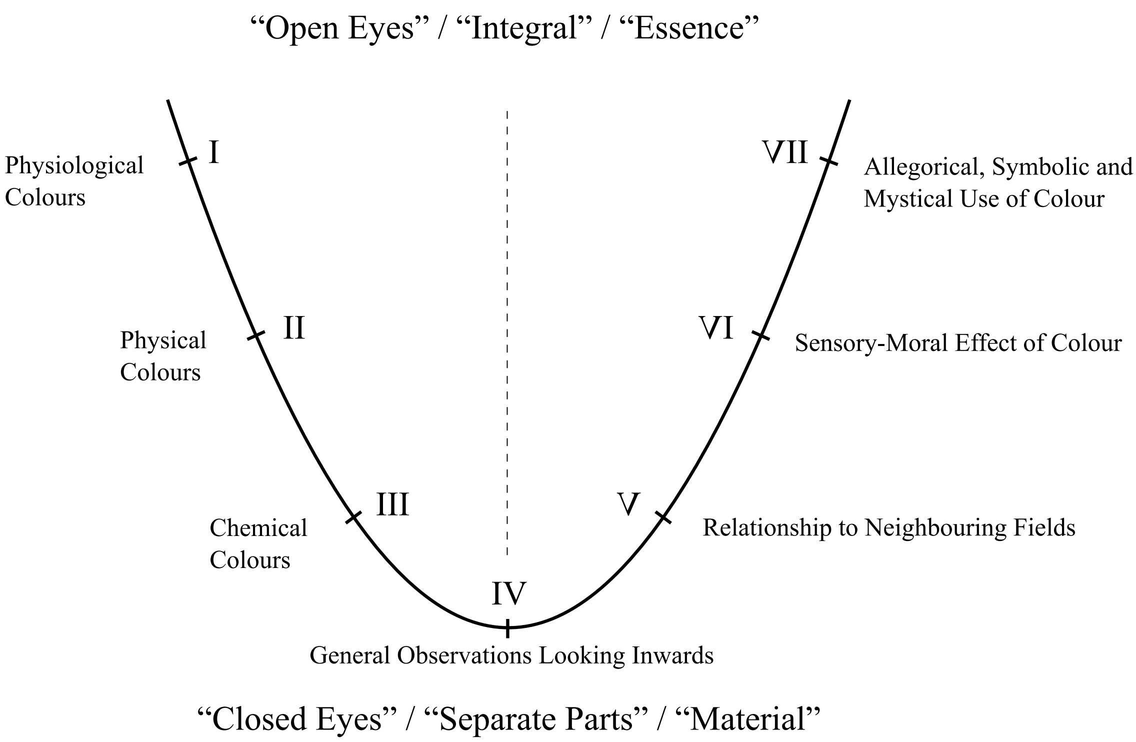


Fig 1. The structure of Goethe's *Farbenlehre* as a developmental process or evolution of scientific knowledge. The seventh stage, which appears here as "Allegorical, Symbolic and Mystical Use of Colour", is not an independent section as are the other sections but the final subsection of the section "Sensory-Moral Effect of Colour".

all the different stages *in detail* – that was not possible even in Goethe's time and he was conscious of that fact (Goethe, 1957, 412ff). However, Goethe did not have a single ingenious researcher surpassing all his peers in mind – instead he tried to build a network of researchers working together in scientific cooperation.

Figure 1 shows the process of scientific development in a "U" shape with the clearly marked U-turn. This form of representation reminds us of the stages of human development as Rudolf Steiner presents them in his *Outline of Esoteric Science* (Steiner 1977). We have developed this form independently and it applies to evolution as well, namely, it begins in an integral nexus, leads out of this to the disintegration of the nexus (wherein humans no longer have access to the spiritual in the world, though this separation does allows freedom) and in the future will lead to a new, but in this case consciously experienced, integral nexus, which would not have been possible without the preceding stages.

As scientists today we are shaped by material physical science. In this sense, we are at the lowest point, the bottom of the "U". In view of the above, however, this is a good thing! It is possible to not only consider the structure of the *Farbenlehre* as a methodological model for a scientific project but also to understand it as an evolutionary history of the scientific activity of humanity. In a way, the research of the first three stages is behind us. It seems to us that the task is, first of all, to continue this process with all its possibilities into the present time and then make the U-turn, i.e., take the first steps that lead out of "material" science towards a more "integral" science. In this sense the later sections of the *Farbenlehre* are our future.

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Newton, Goethe and the Mathematical Style of Thinking

A Critique of Henri Bortoft's *Taking Appearance Seriously*

/ Troy Vine

I always carry Spinoza's Ethics with me; he brought mathematics into ethics, as I did into the science of colour [Farbenlehre]. That means there is nothing in the conclusion that is not grounded in the premise.[1]

- Goethe

1. Introduction

Johann Wolfgang von Goethe's approach to science is often characterized as holistic. The popularity of this characterization is due, in no small part, to Henri Bortoft's influential interpretation based on the idea of two kinds of unity.[2] Bortoft concludes *The Wholeness of Nature* by contrasting what he refers to as Goethe's "holistic" approach to science with the "analytical" approach of experimental science (328–330). In his most recent book, *Taking Appearance Seriously*, he contrasts the "concrete" nature of Goethean science with the "abstract" nature of experimental science. Experimental science is abstract because of the abstract nature of not only mathematics, but also of the mathematical style of thinking that is reflected in a twofold experimental method.

Bortoft's focus on the twofold method in experimental science, which proceeds from experience to theory and from theory back to experience, brings out an important aspect for understanding Goethe's approach to science and its relation to experimental science. I argue, however, that this shows not a difference between these two approaches,

I would like to thank Sonja Dorau, Philip Franses, Charles Gunn and Thomas Raysmith for comments on drafts of this essay.

1. Goethe (2007, 621). My translation. Goethe made this comment in 1815 in conversation with the German art historian Sulpiz Boisserée.

2. For an historical account of these two kinds of unity in Kant and their development in Goethe, see Förster (2012).

but rather an important similarity which is often overlooked. The difference between the two approaches cannot therefore be characterized by Bortoft's distinction between concrete and abstract, which is based on a distinction between the mathematical and the hermeneutic styles of thinking. Using the example of colour, I show that this difference is best captured by the distinction between relations that are necessary and those that are contingent, which Bortoft calls "internal relations" and "external relations" respectively.

In section 2, I present Bortoft's account of the mathematical style of thinking in the history of experimental science, in which he distinguishes experimental method and the application of mathematics as two separate causes of abstraction.[3] In section 3, I compare Bortoft's example of exact sensory imagination with his example of geometrical proof. This shows that both examples are based on the idea of seeing internal relations. In section 4, I present the methodology of Newton's and Goethe's prism experiments. This shows that both Newton and Goethe use the twofold method and thus both exemplify the mathematical style of thinking. Bortoft's contrast, then, between and the abstract nature of the mathematical style of thinking and the concrete nature of Goethe's approach is mistaken. Then, in section 5, I compare Newton's and Goethe's prism experiments. This shows that the distinction between external and internal relations captures the difference between the two.

2. The Mathematical Style of Thinking in Experimental Science

In *Taking Appearance Seriously*, Bortoft identifies two kinds of unity with two kinds of thinking. The focus of the book is on what he calls the "hermeneutic style of thinking", in which "instead of the abstract universal of the mathematical style, we have the concrete universal" (168). The mathematical style of thinking is not just reflected in mathematics, but also in the twofold method employed in experimental science since its inception in the twelfth century. For Bortoft, the transition from the mathematical style of thinking to the hermeneutic style occurs in Goethe's approach to science, with Newton's and Goethe's prism experiments exemplifying this transition. In this section, we will consider Bortoft's historical overview of the twofold method in experimental science and his contrast between the abstract nature of the mathematical approach and the concrete nature of Goethe's approach.

Bortoft's historical account of experimental science is based on Alasdair C. Crombie's classic study *Robert Grosseteste and the Origins of Experimental Science*. Central to Crombie's study is the idea that "as in the thirteenth and fourteenth century, so in the later period, scientific method had two main aspects, the experimental and the mathematical" (296). Regarding the experimental aspect, Crombie states that:

> According to Aristotle, scientific investigation and explanation was a twofold process, the first inductive and the second deductive. The investigator must begin with what was prior in the order of knowing, that is, with facts observed through the senses, and he must ascend by induction to generalizations or universal forms or causes which were most remote from sensory experience, yet causing that experience and therefore prior in the order of nature. The second process in science was to descend again by deduction from these universal forms to the observed facts, which were thus explained by being demonstrated from prior and more general principles which were their cause. (25)

This twofold method is put forward in Aristotle's *Posterior Analytics*, which was rediscovered in the twelfth century and employed by scientists such as Robert Grosseteste

3. Bortoft also identifies a third cause of abstraction, namely mechanization. While I do not discuss mechanization in this essay, it is central to understanding not only the difference between Descartes and Newton, but also Goethe's critique of Newton's theory of colour.

and Roger Bacon in the thirteenth. They called the two stages "*resolutio*" and "*compositio*", which are Latin translations of the Greek "analysis" and "synthesis". Crombie comes to the conclusion that "the conception of the logical structure of experimental science held by such prominent leaders as Galileo, Francis Bacon, Descartes, and Newton was precisely that created in the thirteenth and fourteenth centuries" (3). As a result, "the history of the theory of experimental science from Grosseteste to Newton is in fact a set of variations on Aristotle's theme" (318).

The general principles determined by analysis—the first part of the twofold method—are not necessarily mathematical, and Francis Bacon gives "the most complete account of the non-mathematical side of the theory of experimental science" (300). Bortoft, too, includes Bacon among the scientists in whom "we find methodologically the same double procedure that had been developed since Grosseteste" (31), and thus follows Crombie in distinguishing between the application of the twofold method and the application of mathematics itself.

Bortoft calls the twofold method the "mathematical style of thinking" because, "although this double movement, from experience to theory and from theory to experience, is formulated by Aristotle expressly for science", it is "derived from the kind of reasoning which he observed being practised by the mathematicians (30).[4] The twofold method has "the effect of shifting attention away from the phenomenon" (31), with the result that "science becomes theory-centred instead of phenomenon-centred" (32). Moreover, "this is particularly the case when mathematics begins to play a fundamental role in science" and we "discover mathematical proportions and relationships in nature which lead us away from the diversity of sensory appearances towards the discovery of a unity which is more abstract" (32).

This idea of what Bortoft also calls an "abstract universal" led "to the remarkable idea that there are universal laws of nature" (32). As we have seen, Bortoft distinguishes between the application of the twofold method and of mathematics. Thus, while the abstract universal is an expression of the mathematical style of thinking, it is not necessarily itself mathematical. In a later passage on biology, for example, Bortoft contrasts the concrete universal of Goethe's archetypal plant (*Urpflanze*) with biologist Richard Owen's "abstract universal of a static generalisation" (83), which is a "minimal commonality from which all the specialised organs required by actual living organisms have been excluded" (84).

The distinction between the abstract nature of both mathematics and the mathematical style of thinking and the concrete nature of the sensory is a recurrent theme in Bortoft's book: "It is evident that, by its very nature, mathematics takes us away from the concrete into abstraction. But this in itself does not necessarily undermine the value of the sensory" (32). He also remarks that "although the mathematical style of thinking in physics leads us away from the experience of the senses as such, there is no intrinsic reason why this should make us think of the world as experienced through the senses as being inferior in any way to the relationships in nature discovered by means of mathematics" (32). While in the first passage Bortoft is contrasting mathematics itself with the sensory, in the second passage he is contrasting the twofold method with the sensory. For, as we have seen, we do not discover relationships in nature "by means of mathematics", but by means of the twofold method. This opposition between the sensory and both mathematics and the mathematical style of thinking shows that Bortoft considers both to be abstract by nature, in contrast to the concrete nature of the sensory.

Bortoft uses this distinction between the mathematical style of thinking and the sensory

4. I'm simplifying Bortoft's account slightly because he does not seem to be aware that Aristotle modelled what became the twofold method of *resolutio* and *compositio* on the twofold mathematical method of analysis and synthesis.

to contrast Goethe's approach to that of experimental science. He begins by stating that Goethe "returned to the senses and put sensory *experience* first instead of the mathematical" (53). And, in the context of plants, he remarks that:

> The movement of thinking here is indeed very different from looking for uniformities and commonalities in order to find a 'general plan common to all organs', which is the approach so often wrongly attributed to Goethe. The dynamic idea of the unity of nature that we find in Goethe is also very different from the kind of unity we find in the universal laws of nature, which came from the mathematical approach in science. (58)

In the second quote, Bortoft is contrasting two approaches to understanding plants, neither of which apply mathematics. So here he is using "the mathematical" and "the mathematical approach" to refer to the twofold method and the mathematical style of thinking. Thus, when Bortoft contrasts Goethe's "concrete" approach with the "abstract" mathematical approach, he is not merely contrasting Goethe's approach with mathematics, but with the mathematical style of thinking reflected in the experimental method. Characteristic of the mathematical style of thinking is the movement from phenomena to a general principle that is an abstract universal.

Bortoft claims that Goethe's approach to science is concrete compared to experimental science, which is abstract because it is based on the mathematical style of thinking. We will assess this claim by comparing, in the next section, Goethe's approach with mathematics, and then, in the following section, Goethe's approach with experimental science.

3. Exact Sensory Imagination and Mathematics

In the last section, we considered Bortoft's claim that Goethe's approach to science is concrete, whereas mathematics and the mathematical style of thinking reflected in the twofold method are abstract. In this section, we will assess this claim by juxtaposing Bortoft's example of exact sensory imagination with his example of geometrical proof.

Bortoft presents Goethe's method as having two stages, which he calls "active seeing" and "exact sensory imagination".[5] In the first stage, we put "attention into the sensory experience itself, entering into the lived experience of sensory perception, so that rather than just being 'sensory' in the empirical sense, it is better described as the 'sensuous' experience, or perception, of the phenomenon" (53). By becoming "aware of the sensuous quality of each colour", we transition from an empirical experience to sensuous experience (54-5). Bortoft says of Goethe that by "redirecting attention into sensuous experience he plunges into the sheer phenomenality of the phenomenon" (54).

In the second stage, we transition to a "sensuous-intuitive experience of phenomena" (53). This brings us "into contact with what is living, so that we begin to experience the phenomenon dynamically in its coming into being" (55). Bortoft gives the following description of exact sensory imagination:

> Now we put aside the physical manifestation and work entirely in imagination, trying to visualise what we have seen as exactly as we can. As we move through the colours at a boundary in imagination, we begin to experience their sensuous quality as if we were within the colours — one student described this as feeling like she was swimming through the colours. We find there is a dynamic quality in the colours at each boundary. What we experience is not separate colours — red, orange, yellow, or pale

5. Although the term "exact sensory imagination" is used by Goethe to designate the capacity for artistic activity, he does not relate it to scientific activity (1988, 46).

> blue, deeper blue, violet — but something more like ‘red-lightening—to—orange—lightening—to—yellow’ as a dynamic whole, and similarly with the darkening of blue to violet. There is a sense that the colours are different dynamic conditions of ‘one’ colour. This dynamic quality gives us an intuition of the wholeness of the colours at each boundary. This is not given directly to sense perception, but appears when sensuous perception is sublimed into intuition through the work of exact sensory imagination. In this way the sensuous-intuitive mode of perception replaces the verbal-intellectual mode. The colours are no longer thought of as being separate (verbal-intellectual) but are experienced as *belonging* together (sensuous-intuitive). The way to the wholeness of the phenomenon is through the doorway of the senses and not the intellectual mind. We find there is the sense of a *necessary* connection between the *qualities* of the colours at each boundary. It is not just accidental, for example, that the order of the colours is red, orange, yellow — and not red, yellow, orange — but is intrinsic to the colours themselves. (55–6)

When we transition from sensuous experience to sensuous-intuitive experience in exact sensory imagination, we see a necessary connection between colours—e.g. we see that orange *must* lie between red and yellow, not that it merely happens to do so. As Bortoft calls this necessary connection an “intrinsic relation” or “internal relation”, the intuitive nature of sensuous-intuitive experience can be characterized as the seeing of internal relations.

Later in the book, Bortoft presents an example from mathematics to show “the difference between the mathematical and the empirical” (158). His gives the description of the proof that the sum of the interior angles of a triangle equals two right angles:

> A proof which would be mathematically acceptable would be one that did not involve measurement at all. It would be given entirely in terms of relationships between the angles without any need to refer to the actual size of the angles in a particular triangle. Consider any triangle ABC with angles *a*, *b*, and *c* (see Figure 1). Extend the side BC [Bortoft means AB] into a straight line, and draw a line through vertex A [Bortoft means C] parallel to this line (see Figure 2). Angle *a* equals angle *a*' because they are alternate angles between parallel lines. Angle *b* equals angle *b*' for the same reason. But angles *a*', *b*', and *c* must add up to 180° because they make a straight line. Hence it follows that angles *a*, *b*, and *c* must add up to 180°. In such a deductive proof we see that the angles of a triangle *must* add up to 180°. This is entirely different from just saying that the angles of a triangle do in fact add up to 180°. It's not that they happen to do so — as if this were an empirical discovery — but that they cannot not do so. (158)

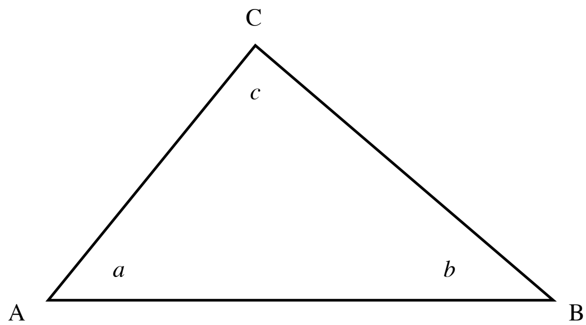

Figure 1. Triangle ABC. (Bortoft 2012, 157)

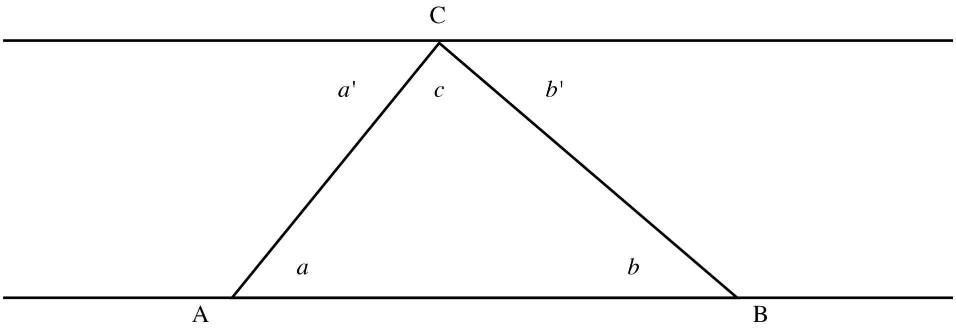

Figure 2. Triangle ABC with side AB extended and parallel line passing through vertex C. (Bortoft 2012, 157)

Central to this description is the distinction between a contingent relation between the angles, which we could determine empirically through measurement, and a necessary connection: we *see* that the angles of a triangle *must* add up to 180°, not that they merely happen to do so in this particular case. The nature of geometrical proof, then, is the seeing of internal relations. To complete the proof, we need to add the stage that allows us to see that alternate angles between parallel lines must be equal. To do this we can extend line AC to see that angle *a* must be equal to angle *a*'' (see figure 3). Then, by rotating the line AC about vertex C in our imagination, we can see that *a*'' must be equal to *a*' and thus that *a* must be equal to *a*'. Similarly for *b* and *b*'.

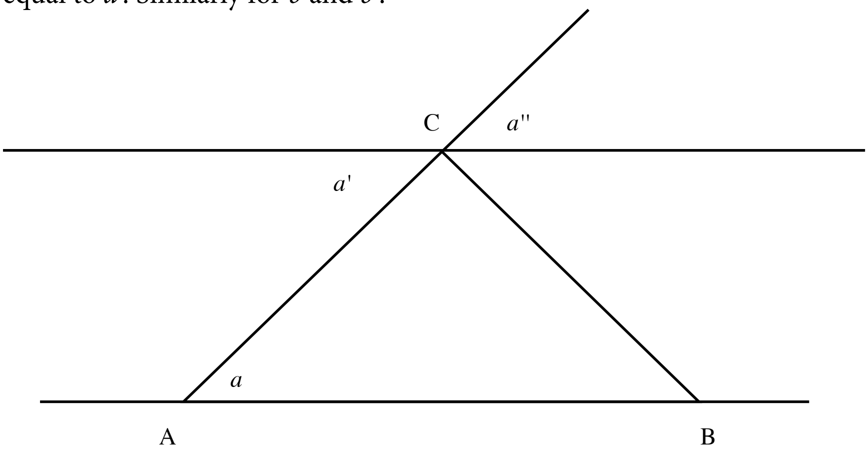

Figure 3. Triangle ABC with side AC extended to show that alternate angles between parallel lines are equal.

By juxtaposing Bortoft's example of exact sensory imagination and of mathematics (in the book they appear at the beginning and the end respectively), we can see what they have in common. In both examples, we begin with an empirical experience of an object containing contingently related parts: in the prism experiment, we see individual bands of colour produced by a prism, in the mathematical proof we see individual vertices. We then abstract the qualities in question in sensuous experience: in the prism experiments we abstract the individual colours from their "physical manifestation" (or "put aside" in Bortoft's euphemism); in the geometrical proof we abstract the lines that constitute the vertices. We then move between the different parts of an image: in the example of colour, we move between the different colours; in the example of the triangle we move between different vertices. Then, in a sensuous-intuitive experience, we see that the parts *must* be related in a certain way: we see necessary connections, or internal relations, that we did not see before.

In these two examples, there are no obvious criteria which allow us to apply the term "abstract" to one and "concrete" to the other. The only criterion for applying these terms would seem to be the movement from seeing external relations between empirical objects to seeing internal relations between properties of objects (i.e. primary and secondary qualities), which could be regarded as a process of abstraction. Bortoft remarks in a footnote that:

> Plato's achievement was to show that what is truly *mathematical* does not depend on working from sensory images of geometrical figures — for example, the discovery that the sum of the interior angles of a triangle is equal to two right angles (180°) does not depend on measuring the angles of drawn triangles, but follows directly from the very idea of a triangle. (184)

The comparison above, however, suggests a different account. In the example of colour, we work from a sensory image (we can consider exact sensory imagination to be sensory because we "visualise what we have seen as exactly as we can"). As Bortoft characterizes seeing internal relations not as an empirical experience but as a sensuous-intuitive experience, Plato's achievement could, therefore, be better described as showing a way of working from sensory images that is not empirical.

Plato's achievement, then, was to show that seeing external relations is distinct from seeing internal relations, or, to put the same point differently, that empirical experience is distinct from sensuous-intuitive experience. Even if it did "follow directly from the very idea of a triangle" that the sum of the interior angles is equal to two right angles, the idea itself consists of internal relations between geometrical elements (lines, points, etc.). The empirical diagram on the page is not the concept of a triangle, but it does represent the concept when we see the internal relations between the parts. The fact that Bortoft presents a proof with diagrams suggests that, rather than being an unnecessary detour, working from sensory images is necessary for grasping that very idea. The question, then, is not whether we need to work with sensory images in geometrical proofs, but how we work with them.

When we grasp the concrete unity of colours, "instead of abstracting unity from diversity, we have the intuition that the diversity is within unity" (57). Triangles, however, are an example of mathematics, and therefore, according to Bortoft, an abstract universal. Yet in the geometrical proof above we do not abstract unity from diversity—this would only be the case if we found empirically that the sum of the angles of a triangle are equal to two right angles. Rather, as with the example of colour, we can grasp the triangle "dynamically in its coming into being". This can be made clearer if we move vertex C of triangle ABC in our imagination: There is a sense that the triangles are different dynamic conditions of 'one' triangle (substituting "triangle" for "colour" into the description of exact sensory imagination above).

Let us consider the example of figure 4. How many triangles are there? If the concept triangle is an abstract universal—i.e. formed by abstracting what is common to the five figures—we must say that there are three triangles, because, as Bortoft notes, "all triangles are three-sided" polygons (218) and only three of the five figures have this property in common. However, if we grasp that the sum of the interior angles of a triangle is equal to two right angles we can say that there are five triangles: we can see the straight line AB as representing a triangle with one straight angle *c* and two zero angles *a* and *b*, as well as the line AB with two lines extended at right angles from the ends as represent a triangle with two right angles *a* and *b* and zero angle c. Moreover, we can see the five figures as five representations of one triangle—i.e. the concrete universal—dynamically in its coming into being.

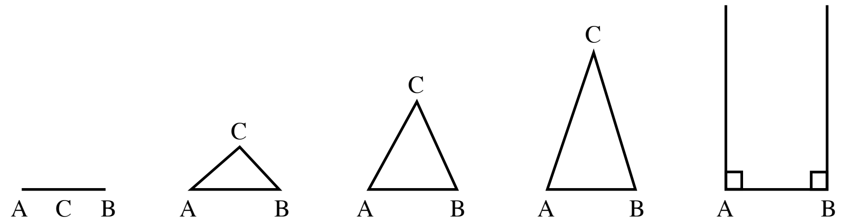

Figure 4. Three triangles ABC, five triangles ABC, or one triangle ABC dynamically coming into being.

Bortoft claims that in the mathematical style of thinking:

> every possible triangle is subsumed in advance under the universal concept 'triangle, of which any triangle is therefore a particular instance. Everything is included in the universal concept, so it is unthinkable that the universal itself could be enhanced by any *particular* triangle. The movement is only from the universal to the particular and never the other way round, so there simply cannot be any enhancement of the universal by the individual case. (125)

According to Euclidian geometry, a finite line AB with two lines extended at right angles from both its ends is not a triangle because parallel lines do not meet. But if we see an internal relation between this figure and a triangle—e.g. by extending the vertex C of the triangle in our imagination—, then we have an example of a particular triangle that enhances the universal. Thus, not only is an "enhancement of the universal by the individual case" conceivable, we have just done it!

The universal is enhanced, however, by abandoning the parallel postulate and thereby opening up the possibility for entirely new kinds of geometry. If we abandon the parallel postulate whilst retaining the possibility of measuring angles, there are two options. The first option is to retain the idea that the sum of the interior angles is equal to two right angles and extend Euclidean geometry to include ideal points. The second option is to allow the sum to be less than two right angles, which gives hyperbolic geometry, or greater than two right angles, which gives elliptic geometry (these two names are misleading because the triangle remains a three-sided polygon with straight sides in non-Euclidian geometry).

This example shows that Bortoft's static conception of mathematics is mistaken. Rather, as Michael Beaney and Robert Clark have shown, the idea of seeing internal relations "sheds light on the historical development of mathematical concepts" (2018, 133). This does not mean, however, that we must give up the distinction between the abstract and concrete universal; we just need to keep in mind that mathematical entities are not based on abstracting commonalities from empirical objects, and therefore not abstract universals.

Bortoft's examples of exact sensory imagination and geometrical proof show that there is no essential difference between them. His distinction between the abstract nature of mathematics and the concrete nature of exact sensory imagination is, then, a distinction without a difference. We will now turn to his contrast between Goethe's method and the experimental method.

4. Newton's and Goethe's Methodology

In section 2, we considered Bortoft's claim that modern science is abstract due to the abstract nature of not only mathematics, but also of the twofold method—i.e. the mathematical style of thinking. In section 3, we saw that mathematics is not by nature any more abstract than exact sensory imagination. A further problem for Bortoft's contrast between Goethe's concrete approach and the abstract approach of experimental science is created by Goethe's view of the relation of his method to that of mathematics. In a methodological reflection on his prism experiments, which we will consider in detail in the next section, Goethe describes sensuous-intuitive experience as follows:

> Such an experience, composed of many others, is clearly of a higher sort. It shows the general formula, so to speak, that overarches an array of individual arithmetic sums. In my view, it is the task of the scientific researcher to work toward experiences of this higher sort—and the example of the best men in the field supports this view. From the mathematician we must learn the meticulous care required to connect things in unbroken succession, or rather, to derive things step by step. Even where we do not venture to apply mathematics we must always work as though we had to satisfy the strictest of geometricians. (1988, 16)[6]

Bortoft's contrast between Goethe's approach to science and the mathematical style of thinking is therefore at odds with Goethe's own description of his method. In this section we will assess Bortoft's contrast by considering the methodology of Newton's and Goethe's prism experiments.

The most detailed description Newton gives of the methodology of his prism experiments is in an unpublished draft preface of the *Opticks*, which was first published in 1704:

> As Mathematicians have two Methods of doing things which they call Composition & Resolution & in all difficulties have recourse to their method of resolution before they compound so in explaining the Phaenomena of nature the like methods are to be used & he that expects success must resolve before he compounds. For the explications of Phaenomena are Problems much harder than those in Mathematicks. The method of Resolution consists in trying experiments & considering all the Phaenomena of nature relating to the subject in hand & drawing conclusions from them & examining the truth of those conclusions by new experiments & drawing new conclusions if it may be from those experiments & so proceeding alternately from experiments to conclusions & from conclusions to experiments untill you come to the general properties of things [& by experiments & phaenomena have established the truth of those properties]. Then assuming those properties as Principles of Philosophy you may by them explain the causes of such Phaenomena as follow from them: which is the method of Composition. (McGuire, 184–5)[7]

In this description, Newton is explicit about the relationship of his twofold method to the mathematical method of analysis and synthesis: analysis determines general principles; synthesis explains phenomena.

In the *Opticks*, Newton remarks that in the first book he "proceeded by this analysis to discover and prove the original Differences of the Rays of Light in respect of Refrangibility, Reflexibility, and Colour" (Newton, 405). He continues with the remarks that "these Discoveries being proved, may be assumed in the Method of Composition for explaining the Phaenomena arising from them" (Newton, 405). An example of composition is his explanation of the rainbow. Newton's prism experiments, then, are an example of the mathematical style of thinking in experimental science and a good example of Bortoft's distinction between the application of the twofold method and the application of mathematics. Mathematics can only be applied to colour once the general principle that equates colour with refrangibility has been determined by analysis. The analysis itself,

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6. I have modified Miller's translation to render the German "*Erfahrung*" as "experience", rather than "(piece of) empirical evidence".

7. The square brackets are Newton's additions. For an overview of the history of these passages and their relation to Newton's methodology, see Shapiro (2004).

then, is not the application of mathematics to colour, but the application of the mathematical method *by analogy* to determine general principles.

We will now turn to the method Goethe used in his prism experiments. A couple of months after publishing the second part of his *Contributions to Optics* in 1792, Goethe wrote a short methodological essay, quoted from above, which he later published with the title "The Experiment As Mediator between Object and Subject". In it, Goethe states that:

> My intention is to collect all the empirical evidence in this area, do every experiment myself, and develop the experiments in their most manifold variations so that they become easy to reproduce and more accessible. I will then attempt to establish the axioms in which the empirical evidence of a higher nature can be expressed, and see if these can be subsumed under still higher principles. (1988, 17)

Here we can discern three stages: experimentation (variation of the experiments), seeing internal relations (experience of a higher kind), and determining general principles. In a short methodological essay called "Empirical Observation and Science", written in 1798, these three stages are summarized under the rubric of "empirical phenomenon", "scientific phenomenon" and "pure phenomenon" (1988, 25). These correspond to Bortoft's three kinds of experience that we saw in section 3, namely empirical, sensuous, and sensuous-intuitive experience. However, while Bortoft describes sensuous experience as a plunge "into the sheer phenomenality of the phenomenon" (54), Goethe's describes scientific phenomena as seeing relationships that are "fully perceptible" (1988, 14-5). Bortoft's active seeing and exact sensory imagination are the transitions from empirical experience via sensual experience to sensuous-intuitive experience.

Goethe gives a methodological description in the *Didactic Part* of the *Farbenlehre*, published in 1810, in which he introduces the idea of an archetypal phenomenon as the general principle:

> In general, events we become aware of through experience are simply those we can categorize empirically after some observation. These empirical categories may be further subsumed under scientific categories leading to even higher levels. In the process we become familiar with certain requisite conditions for what is manifesting itself. From this point everything gradually falls into place under higher principles and laws revealed not to our reason through words and hypotheses, but to our intuitive perception through phenomena. We call these phenomena *archetypal phenomena* because nothing higher manifests itself in the world; such phenomena, on the other hand, make it possible for us to descend, just as we ascended, by going step by step from the archetypal phenomena to the most mundane occurrence in our daily experience. (§175/1988, 194-5)

Goethe's method proceeds from phenomena to general principles, which Goethe calls "archetypal phenomena" (*Urphänomene*). Once these general principles have been determined, they can be used to explain other phenomena. Goethe says that the principles show themselves not to reason, but to intuitive perception. In other words, the principles are seen, not merely thought. This corresponds to the idea of seeing connections and Bortoft's distinction between the verbal-intellectual and sensuous-intuitive mind.[8]

The similarity between Newton's and Goethe's methodological description is striking. Goethe is clearly using the twofold method in a manner similar to Newton. In a short essay called "Analysis and Synthesis", written in 1829, Goethe explicitly states that in his *Farbenlehre* he "used the analytic approach", which he characterized as presenting "every

8. For an account of Goethe's method in terms of Wittgenstein's idea of seeing connections, see Vine (2018).

known phenomenon in a certain sequence so that we could determine the degree to which all might be governed by a general principle" (1988, 48).

These passages show that Goethe is using the twofold method of analysis and synthesis in his prism experiments. Thus, both Newton and Goethe are using the mathematical method of analysis and synthesis by analogy. Goethe's method, like Newton's, is based on the mathematical style of thinking. Bortoft's contrast, then, between Goethe's approach to science and the mathematical style of thinking in experimental science is mistaken, and so we need another distinction to capture this difference. In the next section, we will turn to Bortoft's distinction between external and internal relations by considering Newton's and Goethe's prism experiments.

5. Newton's and Goethe's Prism Experiments

In Bortoft's description of exact sensory imagination in section 3, we saw that his account of Goethe's prism experiments is based on the idea of seeing internal relations between colours. Bortoft continues this description by comparing this approach to Newton's:

> This kind of connection between the qualities of the colours is missing from the Newtonian theory which asserts that light consists of colours which are separated when it is passed through a prism. In this case there is no intrinsic necessity in the order of the colours, but only an order that is imposed extrinsically by the attribution of a wavelength to each colour. (56)

Bortoft's contrast between Newton's and Goethe's account of colour is based on the distinction between external and internal relations. We will develop this idea by considering Newton's and Goethe's prism experiments.

In 1672, Newton published his "New Theory about Light and Colors" in the *Philosophical Transactions of the Royal Society*.[9] He begins by developing the following problem. Having allowed a narrow beam of sunlight to enter his darkened room through a small aperture in the window shutters and pass through a prism, he noticed that the image that fell on the wall opposite was coloured rather than white and five times longer than it was wide. He was able to calculate this difference to be much greater than Descartes' theory of refraction could account for. Thus, he was able to show not only that there was a hitherto undiscovered geometrical problem about light, but also that this problem was bound up with the problem of colour. By combining the geometrical problem with the chromatic problem in this way, a solution to the geometrical problem provides a solution to the chromatic problem. Moreover, the solution to the chromatic problem is in terms of geometry, rather than hypothetical corpuscles.

Newton's solution is his *experimentum crucis*. Placing a board with a small aperture just after the prism and a second about twelve feet away allowed him to select which part of the coloured spectrum passed through the two apertures by rotating the prism. His selection was refracted a second time by a prism placed behind the second aperture before it fell onto the wall opposite (see figure 5). Newton found that light from the violet end of the spectrum was refracted by a greater amount by the second prism than light from the red end. As the path of the light remained the same (it passed through the same two apertures), he came to his famous conclusion that "the true cause of the length of that [original prismatic] Image was detected to be no other, than that *Light* consists of *Rays differently refrangible*" (3079).

9. Cohen (1958, 47–59). The page number given for citations refers to the original publication of Newton's Letter.

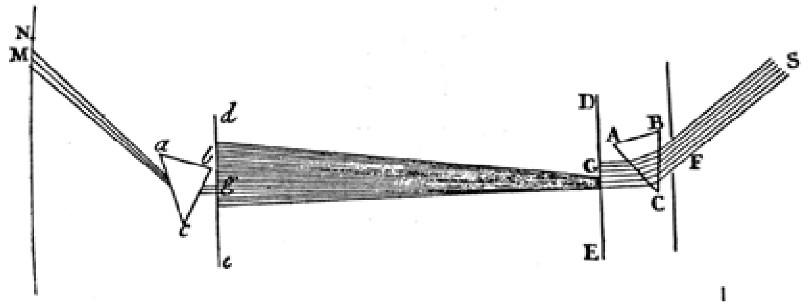

Figure 5. Newton's *experimentum* crucis. Light from the sun S passes through the aperture F in the window shutters and the prism ABC to produce a spectrum on board DE. Rays from a region of the spectrum are selected by aperture G in the board DE and aperture *g* in the second board *de*. The rays passing through both apertures pass through the second prism *abc* and fall on the screen at point M. Different regions of the spectrum are selected by rotating prism ABC (Newton, 47).

Newton uses the *experimentum crucis* to show that a geometrical property of a light ray—the amount by which it is refracted—is related to the colour it produces on the screen: "As the Rays of light differ in degree of Refrangibility, so they also differ in their disposition to exhibit this or that particular colour". Moreover, "to the same degrees of Refrangibility ever belongs the same colour", and "this Analogy 'twixt colours, and refrangibility, is very precise and strict" (3081). Thus, Newton solved the geometrical problem by showing that refrangibility is a property of light that is different for different kinds of rays, and solved the chromatic problem by equating colour with refrangibility. Newton managed, then, to give an account of colour in terms of refraction, and an account of refraction in terms of geometrical rays.

Newton's account of colour is a geometrical account: he uses his *experimentum crucis* to equate the colour caused by a ray with the ray's refrangibility. Nevertheless, this principle expresses an external relation of cause and effect, rather than an internal relation. As a result, we see *that* the degree of refraction is the cause of a particular colour, but we cannot see *why*: it does not show us that the rays that are refracted least *must* cause red. The order of the prismatic colours is therefore contingent, rather than necessary. In other words, it is conceivable that the order of the prismatic colours could be otherwise.

Newton's account of colour, then, leaves a gap in our understanding; for while we can see that refrangibility is the immediate (proximal) cause of colour, we can still ask for a further (remote) cause to explain why a given degree of refraction causes the particular colour that it does.[10] As a result, despite being a geometrical explanation rather than a mechanical explanation—in Newton's terminology a theory rather than an hypothesis—, it nevertheless opens the door to mechanical explanation. It is thus not surprising that beside the geometrical account of light and colour in the *Opticks* we find a mechanical account, although the two kinds of explanation are kept distinct.

We will now turn to Goethe's prismatic experiments. In 1791, Goethe published the first part of the *Contributions to Optics*. Despite being his first publication on colour, it contains his most perspicuous presentation of prism experiments. The presentation is based on observing black and white patterns through a prism.[11] It begins by showing that a homogenous white or black card seen through a prism remains unchanged (§41) and that a boundary between light and dark is necessary for prismatic colours to appear (§42).

This is followed by a number of complex forms presented that produce different colours, including black with white bands that produce Newton's spectrum (§44).
In order to "analyze these wonderful appearances", Goethe decomposes Newton's

10. For an account of proximal and remote causes in Newton's method see Ducheyne (2012, 18–47).

11. The first part of *Contributions to Optics* is in Goethe (1951, 6–37). My translations.

spectrum, which is produced by two boundaries between light and dark, into two spectra each of which is produced by a single boundary (§45). A horizontal boundary of black above white produces a distinct band of red above a distinct band of yellow, whereas a horizontal boundary of white above black produces a distinct band of blue above a distinct band of violet (§47-8). Goethe then provides a card with both situations next to each other so that the two edge spectra can be compared: blue appears opposite red and violet appears opposite yellow (see figure 6). This "shows that the colours do not follow one another, but "oppose one another" as "two opposing poles" (§§55, 72). Goethe has shown that the prismatic colours are governed by a principle of polarity.

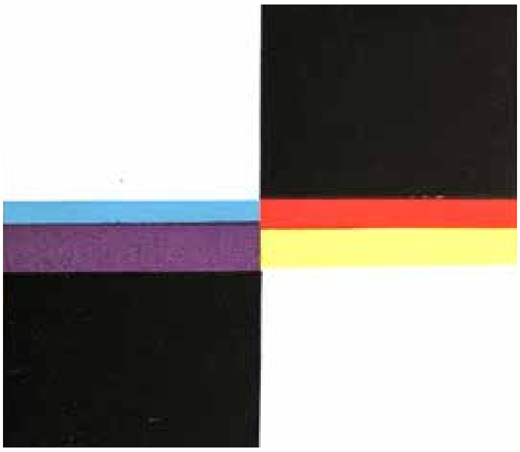

Figure 6. Goethe's illustration of the two edge spectra produced by looking at a boundary between black and white through a prism. *Contribution to Optics*, Card 14 (Goethe 1951, Plate VIII).

To produce Newton's spectrum, the two boundaries are brought together by viewing the black card with a horizontal white band first close up and then moving it further away. The two edge spectra separated by the white boundary come together, and green appears where the blue and yellow bands overlap (see figure 7). The next card is white with a horizontal black band, and the situation is reversed. This time magenta, or what Goethe calls "peach blossom", appears where the violet and red bands overlap (see figure 8). By moving the cards still further away, "the mixtures peach blossom and green [...] totally extinguish the colours of which they are composed" (§59).

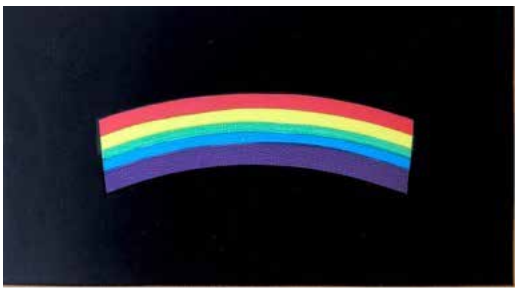

Figure 7. Goethe's illustration of the spectra produced by viewing a black card with a horizontal white band through a prism. Green appears where yellow and blue overlap. *Contributions to Optics*, Card 9 (Goethe 1951, Plate V).

Figure 8. Goethe's illustration of the spectra produced by viewing a white card with a horizontal black band through a prism. Goethe has not reproduced the magenta band that appears where violet and red overlap. *Contribution to Optics*, Card 10 (Goethe 1951, Plate V).

Goethe has demonstrated, then, that the Newtonian spectrum can be produced by combining two edge spectra. In addition to producing the familiar Newtonian spectrum, Goethe uses the principle of polarity to produce a complementary composite spectrum in which all the colours of the familiar Newtonian spectrum are replaced with their opposite, or complementary colour. Moreover, the inner two bands of the edge spectra, which overlap to produce green or magenta, disappear completely, leaving just three coloured bands: red, green and violet for the Newtonian spectrum; blue, magenta and yellow for the inverted spectrum. It thus appears as if the two inner bands of colour mixed to produce a new colour.

Bortoft suggests, as we saw in section 3, that the order of the prismatic colours "is intrinsic to the colours themselves" (56). We can apply this idea of internal relations between colours to understand Goethe's account of Newton's spectrum. As we have seen, Goethe's account of the two composite spectra is based on the idea of colour mixing. Therefore, there are two parts to an account based on an internal relation between colours. Firstly, we must show that there is an internal relation between the colours of the edge spectra, and, secondly, that there is an internal relation between the two colours that overlap and the colour they produce. As Bortoft's account presented in section 3 only addresses the first part, we have not yet seen that the colour produced when the two interior colours of the edge spectra overlap is internally related to the two interior colours.

Goethe's account is based on the polarity of light and dark. This refers to the polarity not only of white and black, but also of light colours and dark colours. We saw, in figure 6, not only that white is opposite black, but also that a light colour is opposite a dark colour. As the relation of light and dark is an internal relation, we can use it to see that Goethe's account is based on an internal relation between colours. We also saw that the edge spectra appear at a boundary between light and dark. They consist of a light colour (yellow or blue) next to white and a dark colour (red or violet) next to black. Thus, both edge spectra have the structure: white, light colour, dark colour, black. The one edge spectrum is therefore the opposite of the other in terms of the relation of light and dark. Thus, the internal relation that hold between white and black also holds between the two colours of the edge spectra: Yellow is lighter than red, blue lighter than violet; conversely, red is darker than yellow, violet darker than blue. Figure 6 shows that there is an internal relation between the colours of the edge spectra.

We have also seen that when two light colours overlap in the Newtonian spectrum, a dark colour is produced. Conversely, when two dark colours overlap in the complementary spectrum, a light colour is produced. Thus, two kinds of mixing occur, which are polar with respect to light and dark: a mixing that lightens two dark colours when they overlap, and a mixing that darkens two light colours when they overlap. Figures 7 and 8 show that there is an internal relation between the two colours that overlap and the colour they produce.

These two kinds of mixing are usually referred to as additive and subtractive mixing. However, this conception is misleading if one thinks of it as the addition or subtraction of coloured lights. An account in terms of rays would be a causal explanation, and therefore an empirical account based on external relations. Rather, when referring to a mixing of two colours, Goethe has in mind a mixing of the property of colour that is analogous to adding and subtracting the property of number. The statements "1 + 1 = 2" and "2 – 1 = 1" are not empirical statements about objects, but logical statements about numbers. Similarly, the statements about the mixing of colours by overlapping are not empirical statements about coloured lights, but logical statements about colours.[12]

We are now in a position to derive the form of the Newtonian spectrum from the polarity of light and dark. Because it is composed of two edge spectra whose light colours combine to produce a dark colour, it must consist of five coloured bands, starting with a dark colour and alternating between a light colour and a dark colour. We have thus given an account of the form of the Newtonian spectrum in terms of the internal relation of light and dark.

A comparison between Newton's and Goethe's prism experiments in terms of external and internal relations brings out an important difference: in Newton's approach, we are able to see a relation between an angle of refraction and a particular colour, but it is only in Goethe's that we are able to see an internal relation between the colours themselves. For Newton, the order of the colours appears contingent, but Goethe shows that it is necessary. Put another way, in Newton's theory it is conceivable that the order of the prismatic colours could be different, in Goethe's it is not. Thus, despite Newton's approach being geometrical, this comparison shows that Goethe's approach is closer to mathematics, because it is based on internal relations.

In the last section we saw that both Newton and Goethe use the twofold method to determine general principles, and then use these principles to explain other phenomena. In this section we have seen that Newton uses analysis to determine an external relation between the refrangibility of a light ray and the colour it causes, and then uses synthesis to explain why sunlight creates a coloured image when passed through a prism. Goethe, on the other hand, uses an analysis of prism experiments to determine internal relations between prismatic colours, which are expressed in the principle of polarity. He then uses synthesis to explain the composition of Newton's spectrum. As in the last two sections, Bortoft's distinction between concrete and abstract seems inapplicable here. Bortoft's distinction between external and internal relations, on the other hand, brings out an essential difference between Newton's and Goethe's account of colour.

6. Conclusion

We began by considering Bortoft's account of the history of experimental science and the supposed abstraction due both to the application of mathematics and to the mathematical style of thinking reflected in the twofold method. Juxtaposing Bortoft's example of exact sensory imagination with his example of geometrical proof showed that the difference between them cannot be captured by the contrast of concrete and abstract, because both examples are based on seeing internal relations between properties. Similarly, our juxtaposition of Newton's and Goethe's methodological descriptions showed that both Newton and Goethe used analysis to determine general principles and synthesis to explain phenomena. Goethe's approach cannot, therefore, be considered concrete in comparison to a supposedly abstract mathematical style of thinking.

12. For an account of additive and subtractive mixing in relation to Goethe's prism experiments, see Wilson (2018).

Our comparison of Newton's and Goethe's prism experiments, on the other hand, demonstrated that while Newton shows that there is an external relation between prismatic colours and refrangibility, Goethe shows that there is an internal relation between the prismatic colours themselves. Goethe demonstrated, then, that the order of the prismatic colour is not contingent, but necessary. Our investigation shows that Boftoft's distinction between internal and external relations is able to capture the difference between Newton's and Goethe's approach to colour. In addition, it shows that rather than representing a break with experimental science, Goethe's approach to science expresses the diversity within the unity of the mathematical style of thinking.

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Afterword

/ Satish Kumar

From Monologue to Dialogue

Coronavirus may be the voice of the Earth. What is our response to her?

The world is engulfed in an unprecedented Coronavirus crisis. I am 83 and I have never experienced such a situation in my life. Wars are initiated by humans and can be controlled or ended by humans. But Coronavirus is a show of nature's power and beyond human control. Modern humans believed that through science and technology we can conquer nature. But through Coronavirus nature is speaking to us loud and clear that the talk of conquering nature is sheer human arrogance.

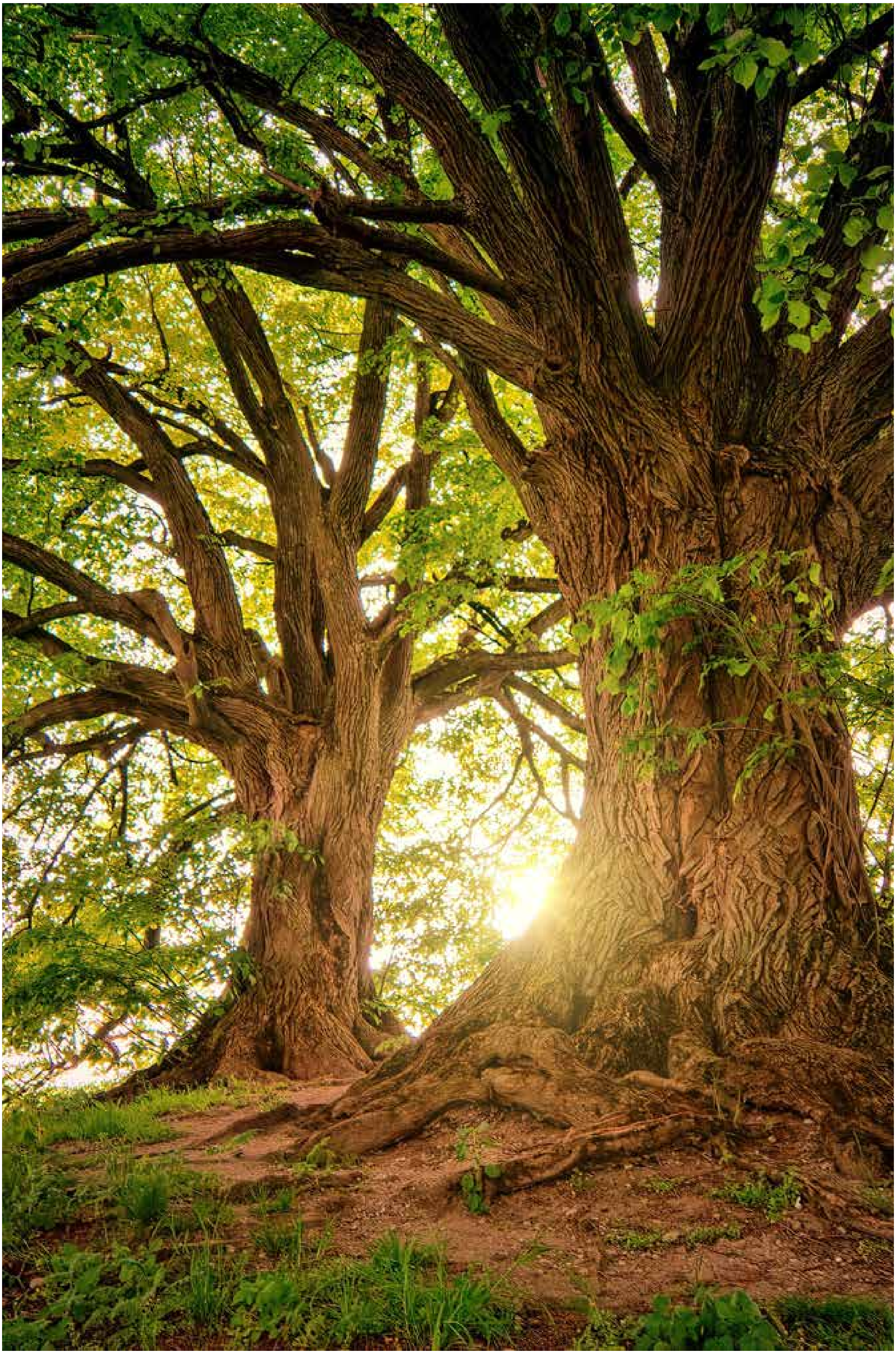
Human desire to conquer nature comes from the belief that humans are separate from nature. This dualistic thinking is at the root of our problem. Humans are as much a part of nature as any other form of life. Therefore living in a harmonious dialogue with nature is the urgent imperative of our time and the very first lesson we, humans need to learn at the moment of Corona crisis.

The second lesson of Corona crisis is to learn that all human actions have consequences. In the past hundred years human activities have been the cause of diminishing biodiversity, increasing carbon emissions and producing greenhouse gases which is causing climate change. Our oceans are polluted by plastic, our soil is poisoned with artificial chemicals and our rainforest are disappearing at an unprecedented speed. This is anything but a dialogue with the Earth. It is an oppressive human monologue. All these negative human activities are bound to result in some disastrous consequences. Coronavirus maybe that. Nature is fighting back.

In the short term we have to accept that nature is trying to send a strong message through this crisis. This is her monologue! But a crisis is also an opportunity. Corona crisis may be a wake up call. We need to slow down and with humility listen to the voice of the Earth. We need to face this crisis with resilience, patience, solidarity and equanimity. There will be suffering. But as the modern human civilisation has inflicted untold suffering and damage on nature we have to accept the consequences of our actions.

But nature is kind and generous, benign and caring. In nature everything passes. So, this Coronavirus too will pass. So in the long term humanity collectively must respond to this crisis in a positive dialogue and use it as an opportunity to redesign our economy, our political systems and our way of life in a noble conversation with the Earth. We need to learn to respect the place of wilderness. We need to learn to celebrate the abundant beauty and diversity of life. We need to realise that humans are an integral part of nature. So, what we do to nature we do to ourselves. We are all totally interconnected and interrelated. Therefore we need to be in a constant, creative and congenial conversation with the Earth. Trees may not speak English, so we have to learn to speak with them in Treenglish!

In the evolutionary process of nature there have been many Crises. Life has evolved through struggles over a long period of geological time. Who knows, maybe this Corona crisis is here to give birth to a new consciousness, a consciousness of unity of life flourishing in diversity, a consciousness in which mutuality, reciprocity, and yes, dialogue is the foundation of human nature relationship.



Afterword

/ Aonghus Gordon

A Fructification of Insights

I would like to thank all the contributors to our first edition of *In Dialogue*. It brings perspectives at a difficult time when a fructification of insights comes together to form an emerging body of knowledge. This is a time when polarisation and opinion seem to be the overriding insight.

It is here, on the very ground of polarity that Goetheanism, and its way of seeing the world and the human being, can bring much needed new perspectives. It is all too easy in today's climate of thinking to seek to solve problems merely through instrumentation and the application of pre-existing knowledge. It is the human being who understands and knows the world, and only in the human being therefore can the answer be found.

One of imperatives of Goethean science is that of human development and an enhanced arena of sensory skills, for the human being is also an instrument. When our capacities are enhanced through inner training and reach out in dialogue, new possibilities emerge.

With an expanded consciousness, discoveries pertinent to our time may be found. It is in the revolving door of self-referencing in our reductive modality of thought that solutions, born out of the limited consciousness itself, appear increasingly not to make a contribution. Through communities of practice, with enhanced perspectives, for example in colour, we bring diversification into long-established habits.

To translate these new perspectives into healthcare, education and ecology requires, however, a new political and social endorsement. A new will has shown itself to be present not only in a youthful generation, but also in school children themselves. No doubt the media, as well as their own conscience, drives a necessity for reform. Paradoxically, the anthropomorphic perspective of the human being at the centre of the universe is challenging but increasingly correct – we ourselves have the freedom to make decisions on our future.

Our motivation in the intent for our future now rests with those who have renewed perspective, provided they are in dialogue.

Aonghus Gordon is the Founder and Executive Chair of Ruskin Mill Trust.

Pictured right is the Field Centre, the research hub for Ruskin Mill Trust. Ruskin Mill Trust provides students with learning differences and/or behavioural problems with holistic learning by role modelling positive relationships in the fields of arts, crafts, commerce, agriculture, nutrition, living skills and the environment. By immersing students in the productive aspect of our curriculum, they learn to care for their own wellbeing and development, and overcome their barriers to learning. Students learn to recognise their capabilities and positively contribute to society.

The Trust's method of *Practical Skills Therapeutic Education* is a practice-based and research-led methodology which draws on the insights and indications of several paradigms:

Pedagogy • Rudolf Steiner's Spiritual Science • Goethean Science

Research is undertaken at the levels of doctoral degree research (PhD/EdD), Master's degree in education (MEd) and through an embedded action research culture. Research outcomes generated in this way serve to develop staff practice for the benefit of and impact on student progression.

Holistic Science Journal

the quest for perception in lived experience

A unique and independent journal uncovering the living dynamic in the facts of science. The Holistic Science Journal is transformative in starting out from the unique way life presents itself in the wonder of the particular. That is the starting point of the inquiry for which Holistic Science Journal provides a platform.

At the core of Holistic Science is The Creative Relation of Whole and Part.
Visit holisticsciencejournal.co.uk to read the full paper.

"Our starting point is a simple shift in the relation of whole to parts. Normally we imagine the whole as something already there and the parts as the logical constituents. We follow a long tradition, where the whole comes into being through the part; and the part is representative of the whole. The whole and the part are in a dynamic interaction. There is no whole without the part, and no part without the whole. The relation of parts to the whole inhabits the novel, which is thereby given the means of expression.... "

Contributors of the Holistic Science Journal

Basil Hiley, Iain McGilchrist, Craig Holdrege, Henri Bortoft, Brian Goodwin, Philip Franses, Martha Blassnigg, Stephen Buhner, Anna Breytenbach, Fritjof Capra, Shantena Sabbadini, David Peat, Mike Wride, Philippa Rees, Chris Clarke, Jules Cashford

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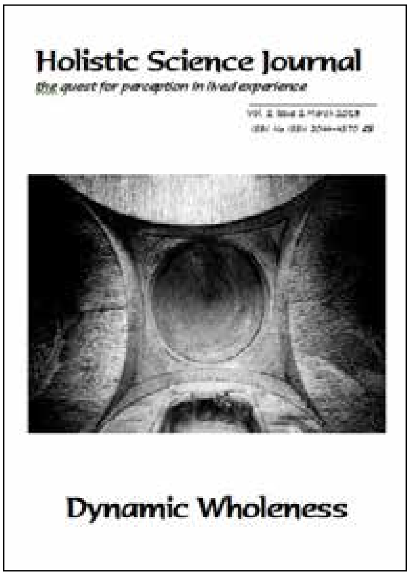
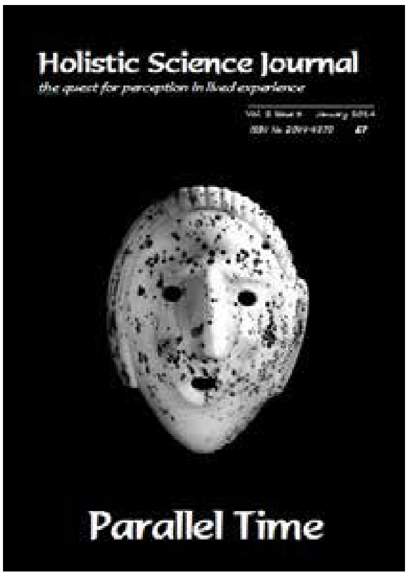




thefieldcentre

JOURNAL OF RESEARCH AND PRACTICE

Overview

The inauguration of The Field Centre took place on Michaelmas day, 29 September 2013. The opening was a culmination of 28 years of work within Ruskin Mill Trust, serving the needs of young adults with developmental challenges. During this time, numerous workshops and public lectures took place for staff and the community, with international practitioners and researchers. This work is now gathered, housed and given its identity in the Field Centre.

In 2018, in recognition of the first five years of operation of the Field Centre, our original journal *inlsis* was redesigned and renamed simply as *The Field Centre Journal of Research and Practice*. Electronic copies of the journal can be downloaded from: thefieldcentre.org.uk

Research

Research at the Field Centre directly supports the charitable objects of Ruskin Mill Trust (RMT). It aims to improve our practice with students, evidence the benefits of our approach, and deepen staff understanding of the theoretical underpinnings of our *Practical Skills Therapeutic Education* (PSTE) method. We further these aims through three kinds of research:

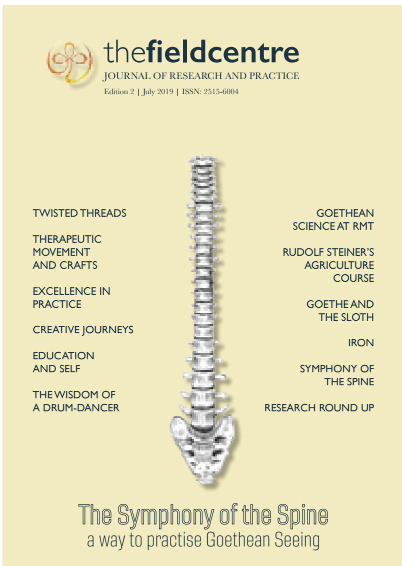
- Practitioner research by staff for staff
- Goethean research to develop our theoretical basis
- Outcomes-oriented research for external stakeholders

The Field Centre Management

Our research consultant Dr Laurence Cox, and applied researcher Dr Gill Nah provide the research infrastructure that supports over 20 active researchers, both from RMT and other external researchers.

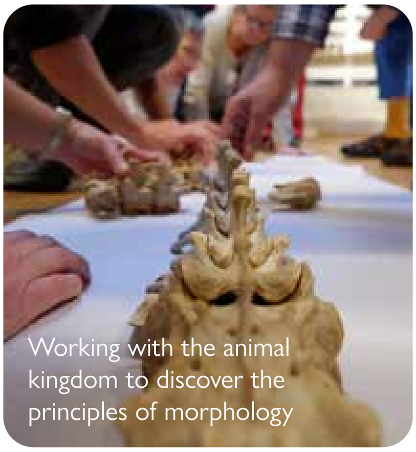
Associate researchers

The Field Centre hosts two associate researchers, Dr Judyth Sassoon (University of Bristol), and Dr Troy Vine (Humboldt University of Berlin). Both Judyth and Troy are primarily based in other academic institutions, and carry out research in their specialised fields for the Field Centre.



Goethean Science

5-day course


Working with the animal kingdom to discover the principles of morphology

This introductory five-day course offers the opportunity to engage in the theory and practice of Goethean science. Goethean science recognises that knowledge of the world and knowledge of ourselves cannot be separated because they are codetermining. Through a new way of seeing, Goethean science brings together the observer and the observed.

The course facilitates this process and works with practices that develop the capacity for rigorous observation of phenomena, exact sensory imagination and morphological thinking, through collaboration. The course works with the genius loci of where it is delivered. After an introductory day, one day is dedicated to each kingdom of nature: the inorganic, the plant, the animal, and the human.

Faculty

Simon Reakes MSc, Dr Troy Vine,
Dr Judyth Sassoon

Dates and locations

2020: 26-30 Oct at the Field Centre
2021: 31 May - 4 June at the Life Science Research Centre

Course information and application

External course fee: £300
RMT staff: no fee
Information: thefieldcentre.org.uk
Booking: info@rmlt.org.uk

Polarity in Goethean Science

3-day course


A participatory relationship with science

This three-day Goethean Science course is designed to help develop knowledge and understanding of the Goethean method as a way of observation and research through a taught programme. Central to Goethe's scientific studies is the idea of polarity. This idea is reflected not only in the content of his scientific work, but also in the method. We will engage dynamically with the idea of polarity through observation, reflection and contemplation.

The course is accessible to all levels of knowledge.

Faculty

Simon Reakes MSc, Dr Troy Vine,
Dr Judyth Sassoon

Dates

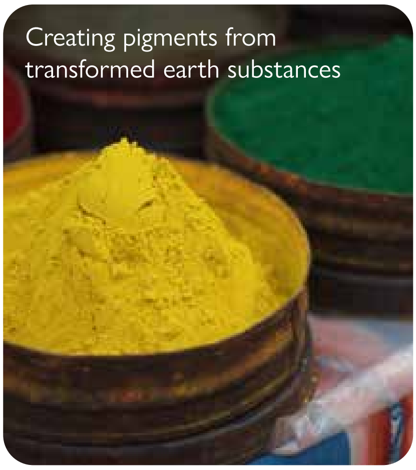
7-9 May 2021 at the Field Centre

Course information and application

External course fee: £150
RMT staff: no fee
Information: thefieldcentre.org.uk
Booking: info@rmlt.org.uk

A Journey of the Soul into Colour

Delivered over 18 months



This course is aimed at those who want to further explore their understanding of therapeutic education through biography as a *work in time*, art therapy as a *new sacred space,* and the creation of pigments from *transformed earth substances.*

It is open to all, but will be of great interest to those who wish to deepen their interest in Steiner's indications and for craft people seeking to gain an insight into colour in a therapeutic context and personal biography. The course addresses the theme of the human being as a work of art in time and space. It does this from three perspectives.

Faculty

Dr Susanne Hofmeister (art therapist) , Karin Jarman (art therapist), Anna Willoughby (textiles tutor), Richard Mace (history of art tutor)

Dates

2021: 29-31 Jan, 16-18 Apr, 18-20 June, 3-5 Sept, 26-28 Nov
2022: 28-30 Jan

Course information and application

External course fee: £900
RMT staff: no fee
(inc. course materials, meals & refreshments)
Information: thefieldcentre.org.uk
Booking: info@rmlt.org.uk
Venue: The Field Centre, Nailsworth, Gloucestershire GL6 0QE

Holistic Science in dialogue

The Legacy of Bortoft, Colquhoun and Goodwin

3-day conference

This conference revisits the lasting contributions to holistic science made by Henri Bortoft, Margaret Colquhoun and Brian Goodwin.

In the seventies, physicist Henri Bortoft, biologist Margaret Colquhoun and mathematician turned biologist Brian Goodwin began a dialogue about wholeness in their respective areas of research. Taking the scientific studies of the German poet Johann Wolfgang von Goethe as their model, they developed a language for expressing the living relationship between the whole and the part, and thereby established a new interdisciplinary field of research. By revisiting their legacy through presentations and discussions we will carry forward the dialogue they initiated.

Hosts

Philip Franses, Dr Troy Vine

Dates

12-14 Feb 2021 at the Field Centre

Course information and application:

Fee: Free to attend
Information: thefieldcentre.org.uk
Booking: info@rmlt.org.uk

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The front cover and centre pages of this journal are designed to be interactive and are an invitation to engage with Goethean science.

Step by step instructions are provided in the centre pages. All you need is:

- A glass prism
- 15 minutes
- An inquiring mind