THE SCIENTIFIC ACTIVITY OF J. W. von GOETHE

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It was a source of disappointment to Goethe during his own lifetime that his scientific work received so little recognition in comparison with his imaginative writing. In his maturity he was forced to witness the work of his youth, much of which had become quite distasteful to him, being praised beyond measure while the work into which his heart now went was either ignored or scornfully rejected as the dabblings of an amateur. Even to-day the extent of his researches, the sheer bulk, let alone the quality of his contribution to science, is little realized. When I studied his work at University there was hardly a whisper about it, beyond the usual clichés about "the last of the great all-rounders"—said with all the sham pathos of our divided culture. However the excessive emphasis on his poetry seems to be diminishing and the time will probably come, which he himself would have welcomed, when he will be known as Goethe the scientist and poet.

What brought Goethe to science, or more appropriately, what induced Goethe to give his experience of Nature scientific expression? Partly the answer lies in the growing incapacity of Western Europe to apprehend truth through art and religion. As he clearly saw, both the age of great poetry and the age of great religion were past, and we now live in an age of prose. It is clear that the discrepancy between what he found in poetry and what he found in his environment came very near to destroying him. In his early twenties his poetic genius seemed to be carrying him headlong for madness or suicide, which is indeed what befell a number of his angry young contemporaries. But by considerable good fortune his course changed. It is impossible to know exactly what happened to him, for all the abundance of factual evidence, but his subsequent poems give a few clues. His preoccupation with "magic" so clearly discernible in his early version of Faust was leading him to disaster; this was superseded by a mounting reverence for "work" which stayed with him for the rest of his life. Science was one of the principal forms that work took for Goethe. He was born with a lyrical gift, but he earned through effort his capacity for organized activity of which his science is one of the highest manifestations. Quite apart from its value in its own right, Goethe's science was indispensable to him as a balance against his poetic daemon, which so nearly overwhelmed him. There are those (such as Nietzsche) who imply that Goethe thereby impoverished his natural gifts; but Nietzsche's own end (and Holderin's) begs the question. To me it indicates the fundamental healthiness of his nature that with such undeniable lyric power running through him he did not become identified with it, but was able to see it as one factor in a complex which could only have meaning and value in its totality.

Before going to the Weimar court in 1775 at the age of 26, Goethe had already shown a lively interest in science, but as in many other fields (he was extraordinarily quick at learning languages) he was guided by enthusiasm rather than any profound contact with the subject matter. At Weimar this changed, in that he found additional motivation for the pursuit of science in the problems arising out of his administrative post. The needs of agriculture, forestry and mining in the little principality rearoused and amplified his interest in botany and geology. Eventually Goethe had the whole of the Weimar Court interested in these subjects much to the amusement of Schiller. In 1781 Goethe returned to anatomy which had interested him as a student, and in 1784 his treatise on the intermaxillary bone appeared—conclusive evidence that man was not different structurally in any way from animals.

In 1786 he left Weimar for Italy where both his poetry and his botanical studies received a new stimulus. It was here that, as he put it, “I gained for myself both the insight and the conception of the metamorphosis of plants. The metamorphosis of the animal kingdom followed closely after this and in 1790 it was revealed to me in Venice that the skull had its origins in the vertebrae”.

Returning to Weimar he became interested in optics and in particular in the phenomenon of colour. Twenty years later, in 1810, he published his famous work entitled: “Attempt to Discover the Elements of the Science of Colour”.*

** It should be noted that the customary translation of Farbenlehre as “Theory of Colour” is inconsistent with the scope and intention of this work. Goethe saw it as a field of scientific enquiry in its own right; and it is therefore preferable to refer to it as the science of colour.*

These are the principal fields in which Goethe made an imaginative contribution of the first order, but this is far from exhausting the scope of his activities which truly encompassed the entirety of the natural sciences at that time. Chemistry, meteorology, mineralogy and many other sciences were actively pursued often with great originality. What was notably lacking from the picture were the mathematical sciences. As he himself freely confesses: “Very early in life, prompted by circumstances and my natural leanings, I had to claim the right to contemplate, investigate and comprehend nature both in its simplest, most secret origins and in its most obvious and striking manifestations, without the aid of mathematics. This I have maintained throughout my life”. But he denies, perhaps with his tongue in his cheek, any suggestion that he thereby belittles mathematics—“which no one can value more than I do since it achieves precisely that which it has not been granted me to be able to do”. Mathematics was one blind spot; philosophy was another: “I have no organ for philosophy in the exact sense of the word”. It is probably these last-mentioned deficiencies as much as anything else that characterize the uniqueness of his approach in modem science; for people have come to associate science automatically either with a formula or a theory and it is difficult nowadays to conceive of a scientist who set relatively little store by either in his own work.

What then was Goethe’s conception of the scientific activity, and what tools did he use in his scientific enquiry? The following essay written by Goethe in 1793 will do much to clarify this.

THE EXPERIMENT AS INTERMEDIARY BETWEEN SUBJECT AND OBJECT

As soon as man becomes aware of the objects around him he considers them in relation to himself; and rightly so. For his whole fate depends on whether they please or displease him, whether they attract or repel him, whether they are useful or harmful to him. This altogether natural way of looking at things and judging them seems to be as easy as it is necessary; and yet in this process man is exposed to a thousand errors which often humiliate him and make his life bitter.

A much more difficult task is undertaken by those who in their urgent desire for knowledge strive to observe natural phenomena in themselves and in relation to one another; for they soon feel the lack of the scale which came to their aid when as human beings they observed phenomena in relation to themselves. They lack the scale of like and dislike, attraction and repulsion, usefulness and harmfulness; this they must renounce entirely, and in their role of indifferent and as it were divine beings they must seek out and investigate what is and not what pleases. Thus neither the beauty nor the usefulness of plants should affect the true botanist; he must investigate their formation and their relationship to the rest of the plant kingdom ; and just as they are all equally charmed forth and shone on by the sun, in the same way he must look at and survey them all with the same calm gaze ; and he must take the scale for this knowledge not from himself but from the realm of the phenomena which he is observing. If we consider an object in itself and in relationship with others and neither immediately desire it nor despise it we will soon be able with calm attentiveness to form for ourselves a fairly clear concept of it, of its parts, of its relationships. The further we continue these observations, the more we connect objects among themselves, the more we exercise the gift of observation which is in us. If we are able to relate this knowledge to ourselves in our affairs, then we deserve to be called intelligent. For any well-organized man, who is either temperate by nature or by force of circumstances, intelligence is not a difficult thing; for life shows us the right way at every step. But if the observer is to apply precisely this acute power of judgment to the examination of the mysteries of nature, if, in a world in which he is as it were alone, he is to pay attention to every step he takes, guard against all over-haste and always keep his goal in sight, without himself leaving unnoticed any useful or prejudicial circumstance, if even in those areas where no one can very easily keep a check on him he is to be his own most strict observer, always suspicious of himself in his most enthusiastic efforts—then no doubt everyone can see just how severe these demands are, and how little one can hope to see them fulfilled completely, whether one makes them of oneself or of others. And yet these difficulties, one might indeed say this hypothetical impossibility, must not deter us from doing everything we can; and we will make most progress if we attempt to represent to ourselves he means in general whereby excellent men have been able to extend :he sciences, and if we point out exactly the wrong tracks they took and along which sometimes for centuries a large number of pupils followed them, until subsequent experiences finally led the observer lack on to the right way again.

No one will disagree that experience has and should have a very great influence on the natural sciences, as in everything that man undertakes, any more than anyone will deny the high and so to speak creatively independent power of the mental faculties in which these experiences are grasped, gathered together and developed. But how to gain these experiences, and how to make use of them, how to develop md use our powers, this cannot be either generally known or recognized.

The moment one draws the attention of sharp and fresh-witted people to any subject one finds them as willing to make observations is they are skilful in so doing. I have been able to observe this since I have been working with enthusiasm on the science of light and colour, and, as usually happens I have had discussions even with people to whom these considerations were previously unknown, concerning things which interested me very much at that moment. As soon as ever their attention became awakened, they noticed phenomena which in part were unknown to me in part had been overlooked by me; and thereby quite often corrected an idea which had been too hastily conceived, and indeed gave me occasion to make more rapid progress and to step out of the restrictions in which a laborious investigation often imprisons us.

And so what is true in so many other human undertakings also holds good here: that only the interest of several people directed on one single point is able to bring about anything of excellence. Here it becomes obvious that the jealousy which would like so much to exclude others from the honour of a discovery, and the immoderate desire to treat and develop a discovery in one's own particular way, is the greatest hindrance to the investigator himself.

Up to now I have found the method of working with a number of people too much to my liking not to continue with it. I know exactly to whom I am indebted for this and that insight on my way, and it will be a pleasure for me to make this public at some future time.

Now if simple people who are naturally attentive are able to be so useful how much more general must the profit be when trained people work together hand in hand. A scientific field is in itself so vast that many people together can cover it but no one person can cover it all at once. It is noticeable that knowledge, like contained but living water gradually rises to a certain level; and that the finest discoveries are made not so much by people as by the period; just as very important things are done by two or perhaps even several practised thinkers at the same time. And so if in the first case we owe so much to society and to friends, in the latter case we are even more indebted to the world and the century in which we live, and in both instances we can never sufficiently acknowledge how necessary communication, co-operation, reminders and contradictions are in order to keep us on the right way and bring us forward.

Hence in scientific matters one has to do precisely the reverse of what the artist finds advisable; for he is right not to let his work be seen in public until it is finished, because no one could very easily give him advice or encouragement; on the other hand, once it is finished, he then has to reflect on the praise or blame he receives and take it to heart and unite it with his experience and thereby develop and prepare himself for a new work. In science it is useful publicly to communicate each individual experience, yes even each supposition, and it is highly advisable not to erect a scientific structure until the plan and the material for it are generally known, judged and selected.

If experiences gained before our time, or experiences which we ourselves gain or others gain at the same time with us, are deliberately repeated and the phenomena which arise, partly accidentally, partly artificially, are again reproduced, we call this an *experiment*.

The value of an experiment consists primarily in this, that whether it is simple or complex it can be reproduced at any time under certain conditions with known apparatus and given the requisite skill, as often as the specified conditions may be brought together. We feel just admiration for human intelligence when we look, if only superficially at the combinations it has brought together for this purpose and we consider the machines invented for this and which are invented every day.

But no matter how estimable an experiment may be considered individually, it only derives its value from being united and combined with others. But precisely this unification and combination of two experiments which bear a resemblance to one another, takes more strictness and attentiveness than even keen observers have often demanded of themselves. It is possible for two phenomena to be related to one another, but not nearly so closely as we think. Two experiments may appear to follow one out of the other, when in fact one would still have to make a long series of experiments between them in order to bring them into a fully natural connection.

Hence one can never be sufficiently cautious about drawing hasty conclusions from experiments ; for it is at the transition from experience to judgement, as if at a mountain pass, that all man's inner enemies are lying in wait for him: imagination, impatience, precipitiousness, self- satisfaction, obstinancy, formalized thought, preconceived opinion, idleness, frivolity, changeableness—whatever one likes to call the whole crowd of them and all they bring in their train. They are all there lying in ambush and unexpectedly overwhelm both the busy man of the world and the calm, apparently dispassionate observer.

As a warning against this danger which is greater and nearer at hand than one thinks, I should like to put forward here a sort of paradox in order to arouse more vivid attention to it. I venture to assert that one experiment, even several experiments taken together, prove nothing; in fact that nothing is more dangerous than to wish to confirm any proposition directly by means of experiments, and that the greatest errors have arisen precisely because people have not seen the danger and the inadequacy of this method. I must explain myself more clearly so as not to be suspected of just trying to say something extraordinary.

Every experience that we gain, every experiment by means of which we repeat this experience is actually an isolated part of our knowledge; through frequent repetition we bring this isolated knowledge to certainty. It is possible for us to know two experiences in the same field; they may be closely related, but may appear even more closely related; and usually we are inclined to consider them more closely related than they really arc. This belongs to human nature; the history of human understanding shows us thousands of examples, and I have noticed in myself that I often commit this mistake.

This error is itself closely related to another, out of which it also arises in most instances. Man actually derives more pleasure from the idea of something than from the thing itself ; or rather we should say: man only derives pleasure from a thing insofar as he can form an idea of it; it must fit into his way of thinking ; and no matter how high he raises his mode of conception above the common level, no matter how much he purifies it, it still usually remains merely an attempt to bring a large number of objects into a certain intelligible relationship, which strictly speaking does not exist between them. Hence the tendency for theories, terminologies, and systems to arise, which we cannot disapprove; since they arise as a necessary result of the way in which we are organized.

If on the one hand every experience, every experiment, by its very nature is to be seen as isolated, and on the other hand the power of the human mind is striving with immense force to unite together what is known to it and what is outside it—one can easily see the danger one runs if one tries to connect an individual experience with a preconceived idea, or if one tries to prove by means of experiments a relationship which is not entirely perceptual but which the plastic power of the mind has formulated.

The usual outcome of such endeavours is theories and systems which do credit to the shrewdness of their author, but which, if they find more approval than is appropriate, if they are retained longer than they should be, once again become a hindrance and harmful to the progress of the human mind which in a certain sense they do stimulate.

It is possible to notice that a good brain uses all the more art the fewer the data it has before it; and that as if to demonstrate its supremacy it selects as its favourites from that data which are in front of it only those few which flatter it, and that it manages to arrange the rest in such a way that they do not directly contradict it; and that it manages to complicate, twist and brush aside hostile data so much that really the whole is more like a despotic court than a free republic.

Someone who has so many merits cannot help but have admirers and pupils who become acquainted historically with such a fabric of events; they revere it, and acquire to the extent that this is possible the mode of conception of their master. A theory of this kind often gains the upper hand to such an extent that one is considered insolent and bold if one has the audacity to doubt it. Only later centuries would dare to approach such a sanctuary, to win back the subject under consideration for common human sense, take the whole thing a little more lightly, and repeat of the founder of the sect what some wit once said of a great natural scientist: “He would have been a greater man if he had invented less”.

But it may not be enough to take the danger to heart and to give warning of it. It is legitimate at very least to make one’s opinion public and make known how one thinks it is possible to avoid such a wrong turning oneself, or whether one has found someone else who avoided it before our time.

Previously I said that I considered the *direct* application of an experiment in the proof of a particular hypothesis to be harmful, and thereby have given to understand that I consider its *indirect* application to be useful, and since everything depends on this point it is necessary to explain myself clearly.

In living Nature nothing takes place that is not connected with the whole, and if experiences only appear to be isolated, if we are to consider experiments as isolated facts, this does not mean that they are isolated ; the only question is how are we to find the connection between these phenomena, these events?

We have seen above how the first to be subject to error were those who tried to connect an isolated fact directly with their powers of thought and judgment. On the other hand we will find that the people who have achieved most are those who never cease to investigate and work on an experience, an experiment, thoroughly, from every possible angle.

Since everything in nature, and especially the more universal energies and elements, is in perpetual action and reaction, it is possible for us to say of any phenomenon that it is connected with innumerable other phenomena, in the same way that we say of a freely suspended point of light that it emits its beams in every direction. And so when we make a certain experiment and have gained a certain experience, we cannot investigate with sufficient care what borders *immediately* on it, what follows *straight away* out of it. We have to pay more attention to this than to what is related to the experiment. And so the elaboration of each individual experiment is the actual duty of the natural scientist; his duty is the exact reverse of a writer's ; the latter will arouse boredom if he leaves nothing for the reader to think about; the former must work tirelessly as if he wanted to leave his successors with nothing to do ; were it not for the fact that the disproportion of our understanding to the nature of things straight away gives him a timely reminder, that no man has the faculties to settle any matter once and for all.

In the first two parts of my *Optical Studies* I have attempted to set up such a series of experiments which bonier on one another and touch one another. In fact, if one knows and examines them all exactly they constitute, so to speak, a single experiment, and portray a single experience in its manifold aspects.

Such an experience which consists of a number of others is obviously of a higher kind. It represents the formula according to which countless individual problems are expressed. To work towards these experiences of the higher kind is what I consider to be the highest duty of the natural scientist, and it is in that direction that the example of the finest men who have worked in this field points.

We have to learn this painstaking method of arranging one thing next to another, or rather of deducing one thing from another, from the mathematicians, and even in cases where calculation is of no use to us, we must still go to work as if we were being held to account by the strictest of geometricians.

For actually it is the mathematical method which on account of its caution and purity demonstrates every step in the assertion, and its proofs are really only formal statements that what was put forward in a connected way was already there in its single parts and in its entire succession, and that it has been examined in its entirety and found to be correct and irrefutable under all conditions. And so its demonstrations are always more of expositions or recapitulations than arguments. Since I make this distinction here, I must be permitted to recapitulate.

One can see a big difference between a mathematical demonstration which carries the first elements through so many combinations, and the kind of proofs which a clever speaker could deduce from arguments. Arguments may contain quite isolated sets of relationships and yet by dint of shrewdness and imagination be gathered together into a single point, and the appearance of right or wrong, truth or falsehood may be produced to an astonishing degree. In

-the same way it is possible to assemble experiments just like arguments for the sake of some hypothesis or theory and produce a proof which is more or less dazzling.

Whoever on the other hand is concerned to set about things honestly with regard to himself and others, will work through the individual experiments with the utmost care, and thus attempt to develop experiences of a higher kind. These may be expressed by means of short, intelligible statements, may be placed next to one another and as they are gradually developed they can be ordered and brought into such a relationship that they stand unshakeable like so many mathematical theorems whether taken individually or together.

The *elements* of these experiences of a higher kind may subsequently be examined and tested by anyone; and it is not difficult to judge whether the many individual parts may be expressed by means of a universal principle; for there is no arbitrariness here.

But with the other method, where we try to prove something which we claim by means of *isolated* experiments as if they were argument's, the conclusion is often reached in an underhand way, even if it does not actually remain in doubt. On the other hand if one has assembled a series of experiences of the higher kind, then understanding, powers of imagination and shrewdness may be exercised on them as much as one likes: it will not do any damage; in fact it will be useful. That initial work cannot be undertaken with sufficient care, zeal, severity, yes, even pedantry, for it is undertaken for the world and for posterity. But these materials must be arranged and laid down in series, not assembled in a hypothetical manner, not applied to a systematic form. It then is open to everyone to connect them in his own way and develop a totality from them which is more or less acceptable to the human mode of conception. In this way that is distinguished which is to be distinguished, and one can increase the collection of experiences more rapidly and efficiently than if one had to leave later experiments unused on one side like stones that are disposed of after a building has been completed.

The opinion of the greatest men and their example lead me to hope that I may be on the right path, and I also hope this explanation will satisfy my friends who sometimes ask me what my purpose really is in my optical studies. My intention is this: to collect all the experiences in this field, to carry out all the experiments myself and perform them with the greatest possible variety, so that they may easily be repeated and not be removed from the field of vision of so many people; then to set out the propositions which express the experiences of a higher order, and then wait and see to what extent these also may be ranged under a higher principle. If meanwhile imagination and cleverness sometimes run impatiently ahead, then the method of procedure itself gives the direction of the point to which they have to return again.

This is a fair account of Goethe's own procedure. He would assemble a vast amount of material, arranging it in series from the most simple to the most complex. In the case of botany, zoology and geology the material took the form of specimens, and in his optical and colour studies it consisted of the individual experiments he carried out. The aim was not to prove any hypothesis but to subject one's own experience to the sharpest possible scrutiny and eventually to experience on another level the variegated individual experiences as a totality with a reality of its own.

Thus in his botanical studies Goethe progresses from minute "botanising" a la Linnaeus to two distinct what he calls here "experiences of a higher order". The first is his famous, almost hermetic utterance: "Hypothesis: all is leaf, and through this simplicity the greatest diversity becomes possible". That the leaf is the fundamental theme of the entire plant kingdom, the *Urform* or primary form of vegetable life". The second is his experience of all organic life on earth as an entity with a life of its own.

The implication is that for Goethe the work itself is everything. What is actually produced, whether or not it proves to be true, beautiful even useful, is subordinate to this. Eckermann records him as saying: "What would l know about plants and colour if I had had my teaching handed over to me ready-made and I had simply learned both by heart. But thanks to the fact that I had to look for everything myself and even make the occasional mistake, I can now say that I know something about both subjects and *more than is written down on paper, at that*". [my italics] Clearly the statement, "All is leaf" has a value directly proportionate to the intensity of contact which one has oneself with the plant world; and the same goes for all Goethe's statements of "experiences of a higher kind"; to know what they mean for him one has to know the work out of which they arise, and it is possible that they are merely the palest reflection of the first-hand experience which work undertaken in the Goethean spirit produces.

This throws much light on Goethe's role and motives in his famous attack on the Newtonian theory of light and colour—to which there are frequent implicit references in the essay translated above. Probably what spurred Goethe on more than anything to investigate this field was the fact that one single experiment should be allowed to carry such weight and that his contemporaries should so universally accept it without considering for a moment its weakness as a scientific experiment. To Goethe, Newton's approach and particularly the historical effect of that approach, was unfortunate on a far more profound level than the factual. I le could never have become so passionately involved in this dispute as he was if it had been for him simply a question of the facts of the case. As he himself says : "the highest would be to realise that all facts are really theory" and he adds "let man seek nothing beyond the phenomena, for they themselves are the teaching". It was really on ethical grounds that Goethe put so much energy into combatting the Newtonian theory "that light consists of rays, differently refrangible". (One feels that had gravitation interested Goethe, and not colour, he would still by his very nature have had to cross swords with the Newtonians.)

Basically Goethe's accusation is this: that Newton set up a theory of light and incidentally of colour, which was apparently so conclusive, so successful, that it tended to exclude further investigation of the phenomena out of which the theory was carefully (and selectively) built up. Goethe contended that a wrong emphasis on the theory and the one central experiment connected with it had robbed science of its contact with the phenomenon of colour in itself and of the particular "teaching" which this phenomenon has to offer when confronted by a mind free from 'facts'. This he saw as a very dangerous tendency which could lead science away from the attempt to experience phenomena as clearly as possible, towards the pursuit of abstractions on the one hand and sheer technological power on the other. Furthermore Newton's *experimentum crucis* Goethe finds inadequate, being on the one hand needlessly complicated, and on the other hand relating to a very specialized situation, one of the most important aspects of which (namely that the presence Of a *dark border* around the source of light is an indispensable factor in the arising of the array of spectral colours) is entirely overlooked by Newton.

The further accusation is made that Newton was not entirely honest in front of the situation, and by ignoring valid objections which were raised to his theory at the time allowed it to gain a popularity which it did not deserve. Goethe discusses in detail one such objection which a certain Anthony Lucas raised in a letter recorded in the Philosophical Transactions of the Royal Society of London for 1676.

> "He (Lucas) puts forward a very intelligent experiment which is in direct contradiction with the Newtonian theory, and which we repeated in the following way:
>
> One obtains a fairly long sheet of metal which is painted with the colours of the prismatic image in their order. Black, white, and varying shades of grey may be added at the ends.
>
> We put this sheet, in a rectangular box of sheet metal and placed ourselves so that it was completely obscured to view by one side of the box. Then we had water poured into the box and the row of colours rose evenly above the edge; whereas if the colours had been variously refractible some would have been bound to appear before others. This experiment completely destroys the Newtonian theory".

Newton replied to Lucas in the same issue of the Transactions:

> ". . . Concerning Mr. Lucas's other Experiments, I am much obliged to him that he would take these things so far into consideration, and be at so much pains for examining them, because he is the first that has sent me an experimental examination of them. By this I may presume that he really desires to know what truth there is in these matters. But yet it will conduce to his more speedy and full satisfaction if he will a little change the method which he has propounded, and instead of a multitude of things try only the *Experimentum Crucis*. For it is not the number of experiments, but weight to be regarded, and where one will do, what need many?"

When one considers this last sentence in the light of Goethe's essay translated in these pages, it becomes understandable that Goethe should have opposed the Newtonian approach so energetically, for it could hardly have been further removed from his own.

A further point that Goethe makes is that the very success of Newton's theory had resulted in the Science of Colour being relegated to a subordinate position in the field of optics, whereas in reality it is an independent field, differing from optics in that it is for the most part not susceptible to mathematical treatment. He points out that for an optician colour is basically a nuisance, and that his own more positive attitude comes from the fact that he approached it via an interest in painting.

The head-on collision between the Goethean and the Newtonian view of colour may partly be explained by saying that Newton approached the subject from the standpoint of Physics whilst the centre of gravity of Goethe's optical and colour researches lies in physiology. In this sense it becomes clear what Goethe meant by describing the Newtonian "error" as a god-sent inheritance for him. As a direct result of plunging into this controversy he virtually opened up for western science the immense field of physiological optics ; and although all his findings have since been substantially extended and refined it may be said that it was he who largely initiated work in that direction.

The commonly-held view of Goethe's optical work, which is shared by Magnus in his excellent book,* is that he is to be unreservedly thanked for his work in the direction of physiological optics and forgiven (though many people, including Friedenthal** in his recent volume, seem unable to do this) for his polemical incursion into physical optics as established by Tsaac Newton. A small minority, among them Rudolf Steiner,*** has all along resolutely and unconditionally affirmed that Goethe was fundamentally on the right track in his work on colour, but until recently this has merely led to their alienation from the mainstream of "bon-ton" science and their dismissal to that disquieting hinterland called "mysticism".

** Rudolf Magnus: "Goethe as a Scientist", Collier Books, New York, 1961.*
*** Richard Friedenthal: "Goethe, his Life and Times", Weidenfeld, 1965.*
**** Rudolf Steiner: "Goethe's Conception of Nature", Anthroposophical Publishing Company. 1928; "Goethes Naturwisseneschaftliche Schiften", Philosophise!! Aulhroposophischer Veslag, 1926; et al.*

But there are signs that the scientific world is coming to a point where it will be able to give more credit to Goethe's approach than the usual: "pass in physiology, fail in physics". On the one hand science is verging on maturity, and scientists are becoming more able to standback from all the most basic assumptions of natural philosophy; and on the other hand they are realizing with increasing desperation that all their attempts to learn .. *was die Welt/Im innersten zusam- menhalt"* (What holds the world together in its innermost core) have merely created yet deeper problems ; and a growing number of scientists are reaching a point where the words of Faust's opening monologue might indeed have passed from their lips :

"*Da steh ich nun ich armer Tor*
Und bin so klug als wie zuvor"
(And here I am at last a very fool,
With useless knowledge curst,
No wiser than at first".)—Dr. Anster's Translation)

For what are physics and physiology after all, if they provide us with such irreconcilable data? Goethe's refusal to admit that there was any ultimate boundary between the two remains a challenge to our assumptions which must be confronted. We may say: "Newton's view of colour is physically orientated, Goethe's physiologically"; but this is verbiage: the question remains what is colour?

It is an exhilarating experience to read a treatment of the Goethe- Newton controversy by a mature (and desperate) scientist. Wilhelm Heitler, Professor Ordinarius in theoretical physics at Zurich University, devotes a whole chapter to it in his small book.* Its theme expressed from a scrupulously "scientific" platform, is the immense potential which science has if only it can balance its present tendency towards a casual, quantitative approach to the world with a complementary teleological, qualitative standpoint.

** W. Heitler: "Der Mensch un die naturwissenschaftliche Erkenntis", Fr. Vieweg & Sonn, Braunschweig, 1964.*

Heitler discusses the supremacy of measurement, i.e., quantitative observation, in western "exact" science, which postulates that only quantitative phenomena belong to its field, qualitative phenomena belonging to physiology, and that furthermore only these quantitative phenomena belong to the outside world. All that may be said for these postulates is that they have proved successful; it is doubtful whether they have any other validity.

Colour, taste, smell are strictly qualitative and are relegated by science to our inner life. But unbiased observation leads us to ascertain that in general we perceive things entirely as if colour belonged to the outside world. In fact one could say that something so directly given as colour is more objective than something which demands lengthy operations of thought.

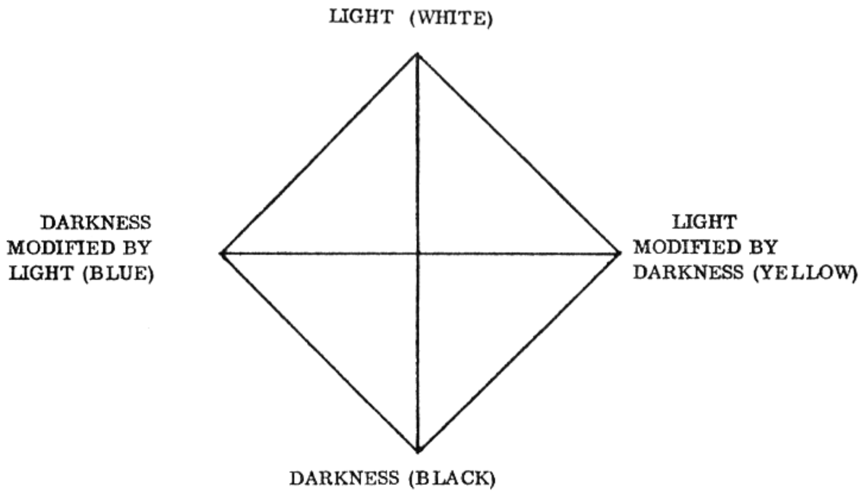
Where then does the boundary lie between the internal and the external worlds? Is it fixed once and for all?

This question is probably the deeper reason for the violent polemic which Goethe directed against Newton on the question of colour. He took a standpoint which was at odds with Physics. For him our perception of light is so to speak the definition of light. Thus human experience is central.

Goethe had nothing but admiration for the science of measurement as applied to mechanics and geometrical optics, but considered that applied to colour it only shows the "dead bones of light". Of course his attempt to refute Newton is irrelevant. He obviously did not see that a purely quantitative science is logically and practically possible, and also unconditionally valid within its own limited domain. But this is not the whole point: Goethe demonstrates that it is entirely possible lo hold the view that colour belongs to the outside world, thus moving the frontier set up by Physics between inner and outer. We can even go so far as to think that a shifting of the frontier in the sense described is not only thinkable and possible, but will actually be necessary if we ire ever really going to gain an understanding of the qualities which manifest themselves in our sense-impressions. This means that it will be necessary to treat these qualities as objects of the external world, which is just what naive consciousness does. It is possible to imagine that we will one day succeed even in understanding the connections between quantities and qualities (e.g. between wave and colour) if we treat the latter as an objective phenomenon, thus putting them both on the same footing.

The foregoing is a summary of the arguments put forward by Professor Heitler in his chapter "Goethe versus Newton". As he rightly points out, Goethe's stand against the Newtonian viewpoint has a deeper significance than the mere facts of the matter. Publishers, who possibly out of an excessive reverence for Goethe's good name, omit the "polemic" section of his Science of Colour, fail to recognize the deliberation and purposefulness with which Goethe set about raising this fundamental question of Where to draw the line between subjective and objective. Likewise, Friedenthal, who imagines Goethe to have been motivated by a deep hatred for Newton, misses the point: it is not Newton who is being pilloried, but his historical legacy of assumptions which eventually become fossilized into scientific axioms. Goethe's own attitude is plainly stated in a notice he wrote concerning his work on colour: "Indeed we could wish for nothing better than that human understanding, being quickly convinced of the true situation in Nature— to which we emphatically return time and time again—'will soon be able to declare our polemic section superfluous."

How does Goethe see "the true situation in Nature"; what is his "experience of a higher order" in the field of colour? For him, light is a *primary phenomenon* (*Urphanomen*) not reducible to any other, not composed of colours as the Newtonian theory implied. Colours are the "deeds and sufferings", or to give the German words a more sober latinized ring, the active and passive modifications of light". Light and darkness, white and black, are polar, and from their interpenetration the colours emerge:



Red is never a pure colour, always tending towards blue or yellow. Green he saw as simply the combination of blue and yellow, but he went as far as to add that "the eye as well as the mind depend on this colour as if it were a primary."

It must be emphasized that it is impossible to do justice to this conception except in the vast context of meticulous experimentation out of which it slowly emerged. This is at once the great strength and weakness of Goethe's science: it demands to be *done* in order to be fully appreciated. What we have here described is not a theory but an attempt to formulate experience.

However, despite these reservations about our ability to evaluate the full *content* of this conception unless we have done the work, there is still much to be gained from examining its *form*. It has a startling simplicity: light and darkness, black and white, are the sources of the whole array of colours we experience. In fact it seems too simple. How could such gorgeous and subtle tones arise from black and white? But the possibility that this conception may indeed be basically correct becomes easier to entertain if one considers an astonishing experiment conducted by Land in 1959.*

** Edwin H. Land: Experiments in Colour Vision, Scientific American, May, 1959.*

From two photographs of exactly the same scene, one taken through a green filter and one through a red filter, Land obtained two black and white transparencies. He then projected the transparencies on to a screen in such a way that the images coincided. When light of a long wavelength was passed through the transparency which had been obtained through a red filter, and light of a shorter wave-length was passed through the green-filter transparency, there appeared on the screen *the whole range of colours* which were present in the scene orginally photographed. This effect was obtained even when two bands of yellow light were used with only a very small difference in wave-length, or when red light was projected through the red-filter transparency and white light through the green filter transparency.

The fact that an array of colours having once been reduced to black and white can subsequently be resurrected in all its original variety not only deals a severe blow to practically all the theories of colour mixture which have enjoyed popularity since Newton's time, but also strongly vindicates Goethe's approach to the field of colour. First it would seem to lend support to his basic notion described above of the polarity of light and darkness; and secondly it does much to clarify what the real issue is in the controversy between the Goethean and Newtonian viewpoint. Land deduces the following from his experiment:

> "Is something 'wrong' with classical theory? This long line of great investigators cannot be mistaken. The answer is that their work had very little to do with colour as we normally see it."

The last phrase is crucial. Goethe was dealing with colour "as we normally see it" ; while Newton, Young, Helmholtz, etc., were trying to study colour in isolation from the phenomena which it usually accompanies. Thus according to the latter red and white light superimposed should only have produced pink light, which is of course what happens when simple spots of red and white light are superimposed. But the intervention of a configuration shaded in varying degrees, i.e. the most fundamental component of our visual space-structure, is sufficient for the full gamut of colour to arise which we originally experienced. The full implications of this experiment outrun the scope of this paper. But it does seem possible that the door on which Goethe has been banging since 1790 is finally beginning to swing open.

After this it is hardly necessary to emphasize the predominantly visual character of Goethe's mental processes:

> "I had the gift that whenever I closed my eyes and with my head downwards thought of a flower in the middle of my organ of sight, it did not simply remain there for a moment in its original form, but it unfolded, and from within it yet more flowers unfurled from out of coloured, occasionally green, leaves; these

> flowers were not natural but fantastic; and yet they were regular like the rosettes of sculptors. It was impossible to fix this streaming forth of creation; on the other hand it lasted as long as I pleased, neither weakening or strengthening".

This power of visualization accounts for his near-mania for collecting and arranging specimens and experiments. He really could see the connections between the varying outward forms, and the underlying primeval form (*Urform*) of which the divers outward forms were partial manifestations. But his exceptionally strong grasp of pattern in nature went hand in hand with a deep suspicion of both causality and teleology of the anthropomorphic variety.

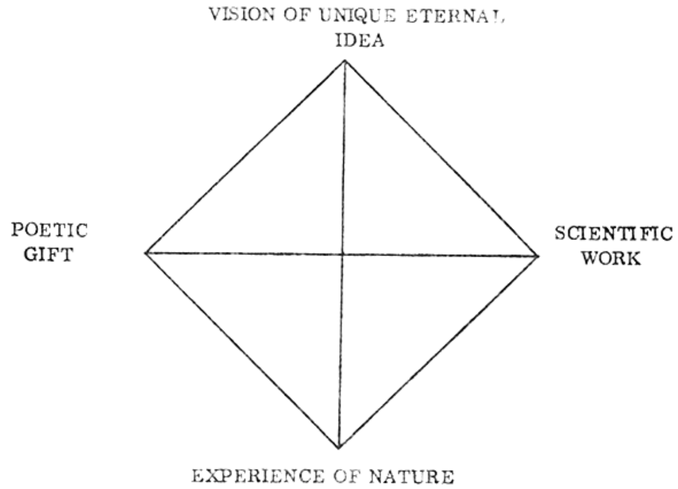
He clearly saw the relationship, formulated by J. G. Bennett as *time-eternity-hyparxis*, at work in the plant and animal kingdoms. The "type" is established at the outset (eternal pattern). External factors determine its specific modifications (actualization in time). The law of correlation keeps the whole in harmony (hyparchic regulation). In studying plants and animals he observed the tension between internal and external, inner impulses inherent in the type versus outer impulses; and saw that in each plant and creature there was a specific budget to cope with this, which it was impossible to exceed. One quality is developed in a species at the expense of others. "The Eternal Mother therefore would never create a lion with horns, even with the exercise of all her power."

There is only room here to mention a few of the specific insights and stimuli which Goethe contributed to science. His notion of metamorphosis is sometimes mentioned as a precursor of Darwinian theory, but in reality it is much more than this, in that it avoids all facile attempts to explain the elaboration and proliferation of biological forms as arising one out of the other or out of a common source, and concentrates on trying to fathom organic life, indeed the whole of nature, as a single great organism guided by a single Idea:

> "The Idea is eternal and unique; that we also use the plural is unfortunate. All things that we perceive and of which we can speak are but manifestations of the Idea; we utter concepts and to this extent the Idea is also a concept".

It would be false to impute to Goethe a kind of synthetic pantheism, for this would be to ignore the opposite pole of his work—the meticulous analytic study which preceded and gave birth to "experiences of a higher order". In his own words:"... for only both (analysis and synthesis) taken together, like breathing in and out, constitute the life of science". Nor should it be imagined that he was an enemy of hypothesis; on the contrary he regarded it as necessary, but in the same sense that scaffolding is necessary while a building is being erected, but is discarded once the real structure is arrived at. But, if anything, Goethe preferred that there should be several conflicting theories rather than that one should monopolize people's attention as did Newton's theory of light. "A false hypothesis is better than none at all—but when it becomes fortified into an article of faith about which no one has any doubt: this is the ill from which whole centuries suffer".

Enquiry is the dominant motive in Goethe's scientific work : the emphasis is on doing rather than knowing. Seen in terms of his own dictum that what is fruitful is true, his achievement has a validity independent of the extent to which mainstream science has so far assimilated and made use of it. His remark to Eckermann, that as long as he remained active, Nature was duty bound to provide him with some kind of body in which to work, seems anything but idle chatter; especially when one considers he was always deeply scornful of orthodox ideas of immortality. I have no doubt that he penetrated to the "eternal and unique Idea", and that in the fresh guise of western science and the ancient guise of poetry there was effected the timeless alchemical process of transformation. The much-discussed notion of his "completeness" may be made more concrete by the following diagram:



Anyone who reads *Faust* will see that the pursuit of science did anything but impoverish his greatness as a poet; and anyone who reads his scientific writings cannot fail to recognize the poetic sensitivity which permeates his rigorously methodical procedure. These two poles of his experience created the requisite tension which could enable him to transmute what he once described as the "obscure urge" common lo all men of goodwill into an increasingly purposeful activity of transformation, a transformation primarily of his own nature, but, seen historically, a transformation equally of the world in which he found himself.