"*To get wise to the illusion of materialism, that is the important thing*" (Rudolf Steiner). Gene technology can be viewed as such, as an enormous illusion. It is an illusion that *res extensa* and *res cogitans* can be divided. It is an illusion that biographies can be deduced from matter, from genetic factors, and that illness can be accounted for solely by material factors. And the aim is to eliminate spirit, to canalize thought into one direction.

It is true that Rudolf Steiner also said that in the future we should learn to master the hereditary flow, but that only works when one includes the spiritual realities. In the further development of phenomenology and not by reductionistic abstractions, unjustified by the phenomena, can this task be accomplished.

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# A hypothesis-free science of inorganic nature

*Georg Maier*

## 1. *Introduction*

One hundred years ago, Rudolf Steiner published his first work: 'Theory of knowledge implicit in Goethe's world conception' (1886). By then he had already published the first volume of Goethe's scientific works (1883). The three additional volumes followed in 1887, 1890 and 1897, thereby opening up Goethe's method to the scientific world. However, little influence of this contribution is to be seen in the thinking of researchers in the 20th century. Yet even in the twenties a change was taking place in the field of physics which in my opinion leads right to the fundamentals indicated by Rudolf Steiner. In what follows I should like to begin by discussing the concept Goethe introduced of the 'primal phenomenon' (*Urphänomen*), in the light of comments by both Steiner and Goethe. I should like to do this at the outset in order later to consider the consequences of this concept for an understanding of the results of modern physics. After a detailed treatment of the fundamental position of Rudolf Steiner's theory of knowledge, the chapter 'Inorganic nature' shows the particular point of departure which is appropriate for the science of physics. I should first of all like to pick out a few standpoints of the chapter and to try to elucidate them with examples.

## 2. *Relationships determined by natural laws in primal phenomenal form*

In inorganic nature the phenomena arise from conditions which meet externally. Conditions or factors are to be understood as perceptible realities. Thus the physicist, when bringing about a particular phenomenon, for instance in an experiment, has to grasp *what it depends upon*. In this sense a primal phenomenon can be expressed in the form of a statement, which links particular conditions (if...) with the occurrence (then...) which arises from them.

When an evening storm front approaches from afar, muffled, rumbling and crashing, the flash of lightning, even though occurring independently, can seem like a phenomenon accompanied by thunder. Indeed, there are plenty of situations when distant sheet lightning, as yet without any sound, flickers over the horizon. But the nearer the lightning comes the sharper become the thunderclaps. They are increasingly separate from one another as individual sound forms. These take shape as abrupt phases like explosions followed by further reverberations, which can give the impression of great vaults echoing from a single clap. Only when lightning strikes nearby does thunder follow almost immediately. The visible impression restricted to the instant, and its subsequent sound form extended in time, are clearly two phenomenal forms of a single event. Many more sense qualities contribute to a characteristic picture of the development of a thunderstorm: the all-pervading darkness, vegetation stirred by wind gusts, torrential rain or even hail with their accompanying drumming, hissing and gurgling sounds.

However, we can seek the particular relationship between the visible flash of lightning and its subsequent audible revelation in the thunder without paying heed to the wealth of questions which arise with the passage of the storm. In so doing, we are picking a fragment out of the totality. But this fragment immediately produces new relationships, because the field of sound form development, under the most varied spatial conditions, now presents itself for study. And the idea that *sound perceptions occur later with increasing distance from the place of sound production, than a visible phenomenon connected with the event,* provides the key to understanding a host of acoustic phenomena. Human questioning selects one aspect from the web of relationships determined by natural laws for a single event. Looked at from this aspect many natural occurrences can be combined into a series of phenomena that in any particular instance depend on a very definite constellation of conditions. In the case of the relationship between lightning and thunder, we arrived at the idea that the temporal sequence of what was heard is dependent on the spatial distance. From this, with the help of the value for the 'speed of sound', a calculation of the temporal relationship can be made. Such a new insight, such a primal phenomenon, is interesting in that it yields a world of related yet dissimilar phenomena which are suitable for consolidating the question initially posed: One need only think of the stroke of a bell repeating in echoes, of the fall in pitch of a peal of bells when we hurry past the sound coming from a church tower, or even the rise and fall in volume of a distant sound with the wind. The idea of spatial extension is further developed by relating it to other phenomena. In this way our interest is increasingly directed to the relationship of sound to air.

In his *primal phenomenon,* Goethe described the situation in which the intended phenomenon occurs, but he tried to formulate it so that the way in which a condition is effective emerges from the description. He wished to give the natural law the form of a *rational description of nature* (Steiner 1919). He assigned to the individual human faculty of thinking the task of freeing the thought content from any particular mental image, especially when this thought content is recognisable in a totally different phenomenon.

### 3. *Phenomena as a web of primal phenomena*

Each phenomenon is in fact determined by occurrences acting in combination. But it shows us, through its modifications, how these occurrences are interwoven in it, how its web can be unravelled into isolated, 'simple facts permeated with spirit'. These facts are the primal phenomena, which as 'higher experience within experience' cannot be sought in their pure form in the sense world.

In our example of flashes of lightning and rolls of thunder we removed ourselves from the reality of the totality. In this totality the phenomena in question were to be separated only in thought. We lost sight of the process of the thunderstorm. Instead, chopping firewood would be sufficient cause to experience the interaction of sight and sound. Here the time lags in question would be shorter. The occurrence would be concentrated in space rather than spread out over a long distance and the experimental conditions would be easier to produce. There is obviously a multitude of possibilities for triggering a sudden noise. It is easy to see that the principle of propagation of sound in space is to be thought of separately from the processes of sound



external factors would be ineffective without the preserving role of DNA.

From the observation of the development of an organism one is forced to the conclusion that DNA is only 'one of the' determining factors and cannot be designated as 'the' (only) cause. How and in what way the heredity inherent in DNA is expressed, depends on the surrounding organism: DNA does not determine the organism, but vice versa. DNA by itself is not capable of anything, it does not determine the process of heredity, inheritance and development. An organism always reacts as a whole, not as a machine.

Watson and Crick did not unveil the mystery of life with their discovery of the DNA-structure. There is no such thing as a life-molecule. E.g. vitality is a quality of living beings, it is not based on a gene or a molecule. Genes and molecules have no characteristics. It is only organisms which have them. Genes are only one condition in the total structure of the creation and the existence of an organism.

### *DNA versus organisms*

DNA-thinking, which dominates present-day biology, is, as has been explained above, not a tenable hypothesis in view of the facts. There is no monocausality in living organisms. This way of thinking however has a purpose. The idea is to correct nature, to interfere, to manipulate, to change, according to the objectives of the moment. The approach of organicism does not see nature as something which is to be made, but as something which is given, and this implies quite a different responsibility. In this view the different species have their proper integrity which carries its own justification. The former approach reduces everything to an indistinguishable similitude, multiplicity is represented by a negligible quantity. Man is, as far as heredity is concerned, reduced to the level of an animal, animals to plants, plants to viruses and bacteria. Concepts such as the individual or a biography carry no weight. One can already notice the results in agriculture: new, constructed organisms have been severed from their environment, they have no natural habitat. So-called universal breeds are cultivated and developed according to economic considerations. Their home is nowhere, biotope becomes technotope. "Natural" nature is often hostile to such manipulated organisms, and only by regulating and strictly controlling the environmental factors are they able to survive.

Biologists have made great progress, but they are always being confronted by the limits of their progress: organisms refuse to be reduced in this way. Tomatoes, which have been made genetically resistant, exhibit undesirable qualities and loose their resistance. Mice in which the gene which has to do with hair pigmentation has been genetically engineered die of awful deformities. These symptoms are called by scientists side-effects, in which the principle effect is lost. It is believed that in the near future, it will be possible to come to grips with these problems and a few more billions are injected into this branch of science, while the other scientists, the developmental biologists, are out of work because their branch of knowledge is no longer represented at universities and research laboratories.

causes B. In this way of thinking, everything is equal: *on the basis of the universal structure of DNA there is no fundamental difference between a bacterium, a potato, a worm, a bird or a human being*. Such interpretations are the logical outcome of this reductionistic approach. In cognizable nature one encounters potatoes and birds and horses and people, all very different organisms, but in the laboratory cognizable nature does not exist any longer: DNA is primary, is paramount, the organism is secondary incidental, a derivative.

The crucial question in the scientific field is the following: is it scientifically sound to proceed in this reductionistic way, to equate such different things as DNA and organism? Does a scientific method, that intends to study and elucidate the cognizable world and that does not want to support hypotheses, lead to other findings?

*Life is more than DNA*

A field in which the development of an organism can be studied is embryology. Developmental biology, which studies the problem of how a fertilized egg-cell develops into an organism, throws a different light on the role of DNA. In the development of an organism one is confronted with the principle of difference and differentiation. What does this imply? A simple example will suffice: a three-day old embryo consists of a little ball of several cells (20), which are all more or less similar, with similar characteristics, and are thus equipped with similar genes. Only one day later is it noticeable that the outer cells are differentiated from the inner ones, which leads to the creation of an 'inner cell mass' with completely different characteristics and potentials from the 'outer cell mass'. The genomes in both types of cells are identical, but because of controlling influences in their environment (e.g. metabolic processes) the genome in the inner mass cells can develop only certain characteristics whereas those on the outside develop others. This phenomenon can also be detected in their subsequent development. It happens continually that outside circumstances "force" the genome in the cells in a certain direction. The totality of the developing organism remains, the parts differentiate. The genome is directed by environmental factors, the differentiation is a process that moves from the outside to the inside, and not the other way round. DNA functions as a constraint, viz. the conservation of potential possibilities. So it plays only a secondary role. DNA does not actually 'express' or manifest itself, it is determined from the outside to the inside. With every cell division the DNA is copied and the - let's say - constraining, determining influences are copied too. In an ongoing process of cell division DNA is at the same time that which forms and that which takes form. The outside influences are gradually incorporated in the course of time: the periphery is established in the nucleus. Blechschmidt, a great human embryologist of our time, formulated it thus: "Genes never act, they re-act". Whether it concerns enzymes in a cell or biological substances in a tissue: DNA is always active in the framework of an environment, an organism. That is to say: the process goes from the outside to the inside, in which the



production. We picture both as events following one another. But how do things stand with the unavoidable attendant circumstances of an event?

In the case of thunder, not only does its delay relative to the flash of lightning increase with the observer's distance from the thunderstorm, but also its sound changes from a sharp clap to a muffled rumbling. Such changes in the sound quality can only arise without substantial change in its propagation if sound muffling factors come into play. And of course there are also changes in the sound intensity connected with the changes in the sound quality because of the sensitivity characteristics of the ear. When examining the sound quality of thunder it is clearly necessary to consider *many* different relationships. Is this aspect of the phenomenon inseparably connected with the others? Or is it meaningful to investigate it further on its own? Where does one really aim when setting out to discover primal phenomena?

In unravelling the web of the phenomenon we move from the fullness of qualities experienced as being united in an occurrence to a very definite mental construct. Ultimately of course, the phenomenon in question should be seen as arising of necessity from the given conditions. And for that we concentrate on one relationship which can have significance for a broad field of experience. Should it be abstracted from any particular experience? The way physics has gone in recent times comes close to answering this question in the affirmative. With the abstraction of the natural law from the concrete situation, attention is switched to an imagined content, to a cause behind the phenomenon, which is not itself perceivable by the senses and which one thinks to be underlying the entire realm in which the natural law is valid.

4.0 *The thought content of the natural law requires the phenomenon as a 'carrier'*

Goethe introduced the concept of the primal phenomenon after he had described the atmospheric colours, established the conditions for their appearance and given examples for bringing about related phenomena experimentally. (Paragraph 174ff, Outline of a theory of colour, Goethe 1890):

> 'What we become aware of in experience are for the most part merely events which, with some observation, can be grouped into general empirical categories. These in turn can be subsumed under scientific categories which point to a higher level still. In this way we become more familiar with certain indispensable preconditions for what appears in the event. From then on everything is gradually ordered under higher principles and laws, which reveal themselves, not merely in words and hypotheses to our intellect, but just as much through phenomena to our intuitive observation *[Anschauen]*. We call them primal (archetypal) phenomena because nothing above them is to be found in the appearance, yet they are nevertheless so suitable that, just as we previously ascended, we can descend from them to the most common instances of everyday experience.'

It is clearly essential that the pure thought content, the 'higher rules and laws', be grasped consciously anew while having the mental image of the phenomenon in mind. It is in essence not communicable verbally, because the activity of thinking which 'sees' the principle in the phenomenon is a prerequisite for understanding nature. It is by no means advisable for the individual to formulate the thought content of a natural law 'in reserve' so to speak and separate it from its relation to perception:

> 'It does no good remaining far too long in the abstract. The esoteric only harms when it strives to become exoteric. Life is best studied through the living.' (Goethe 1897. Spruche in Prosa No. 171).

Rudolf Steiner's footnote to this:

> 'A concept is esoteric, when considered in relation to the phenomena from which it is obtained. It is exoteric, when it is considered as an abstraction on its own.'

### 4.1 *Interwoven images in the realm of shadow forms*

It is perhaps best, especially within the present context, to follow the advice above and clarify the problem of abstraction by means of an example. I shall refer to the half-shadow experiments developed by Michael Wilson (see G. Maier 1986). When we speak of casting shadows we usually have in mind a clearly outlined dark shape on a floor or on a wall. These we regard as images of the particular object casting the shadow. Whoever carefully observes shadows appearing in sunshine will see a transition between a fully illuminated and a fully darkened area, the half shadow zone. (Deeper shadows are formed when the sun shines into an otherwise dark enclosed space.) The half-shadow zone becomes broader when the shading object is further from the illuminated surface. One can say that the shadow is cast at its sharpest when the object casting the shadow lies directly on the illuminated surface. With a partial solar eclipse, when only a sickle-form remains of the sun's disc, sickle-forms appear everywhere in the play of shadows on the floor of a sparse woodland having openings in its leaf canopy. All outlines surrounded with half-shadows now appear unusually curved. One can become convinced that light sickle forms are produced by isolated openings in the shading object. (And conversely the shadow of an isolated spot becomes a dark sickle.) The imaging of the sky through a hole is of course nothing other than a 'camera obscura'. Shadow forms and their surrounding half-shadow zones cast by shading objects at various distances from the illuminated surface can interpenetrate one another thus drawing 'lumps' from within the fully shaded area.

The essential conditions to consider for the phenomenon in question are the illuminated surface, the shape and position of the shadow-casting object and the image of the sun in the sky. The natural law relationships can be expressed in the form of the statement: *'When an opaque body casts a shadow from a distance onto an illuminated surface, a half-shadow image arises which is determined by both the shape of the body casting the shadow and the shape of the light source, in such a way that the degree of shading of the surface depends on the extent to which the shading body covers the illuminating surroundings of the illuminated surface.'* Are we then dealing merely with a particular application of the more general primal phenomenon of the illumination of a surface from those visible surroundings? Is it sufficient to know how the light intensity at each point of the illuminated surface arises? When we restrict ourselves to this, we forget that we are dealing with a phenomenon of the images of shapes. We lose sight of the remarkable way in which *one* image appears with especial clarity whereas the *other* escapes our



(in people 46 pairs) and that they are halved during the so-called reproductive cell division. In the process of fertilization they are once more united in so-called diploid chromosomes (twice 23). Scientists suspected something in the nature of a hereditary substance or matter contained in the chromosomes, a carrier of heredity and hereditary qualities. Via experiments it was assumed that there must be particles located on the chromosomes which are linked to a particular quality. It is thought that the chromosome is made up of small particles, genes, which are the actual carriers of the genetic material, and it is thought that a particular gene is responsible for every characteristic of the phenotype. It has been estimated that the human genome - which is the sum total of all characteristics - consists of something like a 100,000 genes. These are distributed on the chromosomes in a characteristic sequence. In 1944 the substance Desoxyribo-Nucleic-Acid (DNA) was discovered. This substance was unanimously designated as the molecule of heredity, the carrier of characteristics. In 1953 Watson and Crick discovered the structure of the DNA-molecule. Through the discovery of the structure - which has the form of a tightly-wound double spiral with a length of 1.20 metres and a thickness of two millionths of a millimetre - the role of DNA as to heredity became clear. DNA is composed of nucleotides, which are referred to by scientists with the letter G, C, A and T. These nucleotides are interwoven in long strands, in which two such strands run parallel as the two uprights of a ladder. A proportion of these nucleotides (or: bases) form the rungs of the ladder, both strands are complementary. The order of the bases on the DNA-molecule forms the actual hereditary information, viz. the coded blueprint for the proteins in the human body. It is called the genetic code. This code determines the sequence of the amino acids, of which the proteins in a cell are built up.

The current views on cell-biology can be summarized as follows: DNA codes the building of proteins, the proteins determine what a cell looks like and how it works, e.g. if it becomes a muscle-cell or a nerve-cell. The cells determine the characteristics of the tissue and continuing along these lines one ends up with the complete organism. The organisms with its characteristics is retraced to and deduced from the coded molecule. This reductionistic way of thinking is based on the belief that the design is incorporated in the genes and that an organism is the execution of the design: it is only the result. The individual is seen as the outcome of his inherent genetic programme.

### *Show me your genes, and I will tell you, who you are!*

As the conviction reigns that the whole of a human being with its illnesses, likes and dislikes, talents and abilities can be deduced from its genomes, thousands of scientists all over the world are working on the human genome. They want to discover the 'code of codes', so that they finally have the secret blueprint of mankind at their disposal. In this way of thinking the 'higher' develops from (and is explained by) the 'lower' and, moreover, no distinction is made between advanced stages and simpler structures. The only remaining hierarchy is *causality*: A is before B, so A

# What will mankind bring about by trying to gain control of heredity? The fundamentals of a world outlook based on DNA

Jaap van der Wal

*Not long ago, a working group was founded in the Netherlands with the title "Genetic Engineering and Judgment Forming" The group, which includes the author of the following article, consists of scientists from various disciplines, who are inspired by anthroposophy. The main objective of the group is to study and to comment on the scientific presuppositions of the new techniques involved. At a congress held in 1993 the group presented a report, which was sent to the Dutch Government, as well as to colleagues of the various disciplines that are confronted with gene technology. The response was overwhelming.*

The foundation for the present conventional approach in science was laid in the distant past by Descartes. He divided the cognizable world into the *res cogitans* and the *res extensa*. Consciousness and being were strictly divided, whereby being was exclusively limited to material qualities - it was measurable, weighable, tangible, physically expanding matter - and consciousness, thinking, believing, valuing were reserved for the other side: the subject. As a result science, especially natural science, concentrated on matter, on that with which from then on the "subjective" had no business. Usually there is no place for a comprehensive point of view, such as thinking in terms of organisms: nature is reduced to matter. The sharp division between body and mind demands different methods, and accordingly specific laws were formulated.

## *Heredity and Genes*

Modern biology, the science occupied with the subject under discussion, viz. genes and DNA-structures, is also based on these premises. It concerns itself primarily with the material substrate, the physical aspect of life processes. It is well-known that Gregor Mendel (1822-1884) discovered that the hereditary qualities were inherited according to very definite laws. In his experiments with the cross-fertilization of peas and beans, he discovered that the laws of heredity contained a constant, a conservative quality, which stores characteristics, even when they are not manifest (phenotype). Thus certain characteristics can "return" in a later generation, which were not discernible in the preceding one. Mendel concentrated his research on qualities that could easily be detected, such as colour and number.

At the beginning of this century it was discovered that during cell division the chromosomes emerge in the nucleus and that they are neatly split with every normal cell division. It was found that the number of chromosomes is specific to the species



attention. Thus with a silhouette the light source disappears, but with the image in a pinhole camera it is the shape of the shadowing object that disappears. Three special cases are worth attention:

a) The opaque body lies on the illuminated surface. Here a shaded area arises whose outline corresponds most exactly to the shading body.

b) The light is concentrated on a 'star' on a dark background. In this case sharp shadows arise even when the shading body and the illuminated surface are some distance from one another.

c) The shading body degenerates into a wide screen with a small opening in it. This projects from a distance an image of the illuminated surroundings onto the surface.

Now the question arises as to what extent a further abstraction of the principle in question may be required or necessary. One is indeed necessary if we can also discover the thought-form containing the phenomenon of the half-shadow image, discussed briefly above, in a different realm of phenomena.

## 4.2 *Interwoven images in the realm of real images*

When we refer to direct vision, we usually have in mind sharp visual images of things. These we understand as images of the particular object we are looking at. Everyone knows the limits of sharp vision. A finger held close to the eye shows a transition between an opaque core and the background surrounding it, against which it appears semi-transparent as it were. (The transition is more clearly visible when there is a considerable contrast between the dark finger and a light background.) The blurred region broadens when the object is further than the distance at which the eye is exactly accommodated. Thus one can state that the visual image is most sharply delineated when the eye is focused directly on the object. If we go into bright sunshine, visual acuity is less dependent on distance. Whoever usually needs glasses can quite easily do without them. The eye has acquired intense acuity. The eye is known to protect itself from too great a light intensity by involuntarily closing the pupil. And loss of acuity follows with the pupil opening. If a very small hole is made with a needle in a piece of black paper which is then held in front of a light background, the hole will appear as a bright point. If it is brought close to the eye, it expands to a circular disc giving a visual field through the hole. (A 1.5 mm diameter black spot on a transparent sheet when held immediately before the eyes also becomes an apparently 'semi-transparent' disc. The reflection of a bright light on a water droplet becomes, as a blurred image, a bright disc which even has a pattern, in which changes in the surface of the cornea are visible, for instance after blinking.) Even when a triangular hole is punched in a black sheet of paper with a triangular leather-work needle, a circular field of view arises. This field widens when the other eye is covered up or shrinks when it is exposed to brighter light. The field of view is therefore nothing other than a projection of the pupil aperture into the inside of the eye. Visual images bordered by blurred zones, which arise by looking at objects at various distances from the eye, can penetrate one another is such a way that 'lumps' are drawn out of the inside of the fully opaque zone.

The essential conditions to be considered for the phenomena in question are the distance of clear vision, the shape and position of the object which becomes visible and the image of the pupil of the eye. The natural law relationships can be expressed in the form of the statement: *'If a* *visible body is positioned outside the range in which the eye is accommodated, then a blurred visual image arises, which is determined by both the shape of the visible body and the opening of the lens of the eye. The associated degree of shading of the background depends on the covering-up effect of the opaque body and the pupil aperture.'* Here we are dealing with a particular extension of the primal phenomenon of image formation through a convex lens. This is because here it is just a matter of discovering the 'visual relationships' given through the lens opening between one point on the retina and points situated *extrafocally*. Here we can observe the remarkable way in which one image appears particularly clearly whilst the other escapes our notice. Whereas with a clear visual image of an object the pupil aperture in the lens of the eye remains hidden, when looking through a small hole, the hole's outline gives way to an image of the pupil aperture. Three borderline cases deserve attention:

a) The visible body is at the distance to which the eye is accommodated. We then see a clear visual image of it.

b) The pupil is concentrated on a very small artificial opening. Here fairly well defined visual images of the surroundings arise even if the objects in the field of view have totally different positions, i.e. the eye is definitely not focused on these objects.

c) The object seen as blurred degenerates almost to a point, for example a small hole in a wide screen. In this case, at a distance from the eye, the hole projects an image of the ocular aperture onto the retina.

We can of course place beside the 'subjective' observations on our own eyes, which in this section have been described as a series of phenomena, an analogous series of phenomena based on 'objective experiments': Those to some extent familiar with photography will recognise all the relationships described, or can observe them on the focusing screen of a camera placed at a particular distance. In principle the phenomena described can also be demonstrated with image formation through a projector.

4.3 *An ideal content existing in several phenomena*

We can compare with one another the series of phenomena described in the previous two sections. The reader will have already been struck by certain parallels in the presentation: The sun's disc corresponds to the lens aperture, the shadow-casting object corresponds to the imaged object and the distance of the shadow-casting object from the illuminated surface corresponds to the distance of the imaged object from the surface on which the eye, or the camera is focused. There is *one* idea common to both realms of phenomena. Both examples are valid for demonstrating it. Clearly, the common idea comes in two 'guises'. It could also be said that it is expressed in various 'languages'. Therefore the phenomenon could be understood as, so to speak, the *idea manifesting in the occurrence*.

5.0 *Mathematical procedures in the sense Goethe used them*

In his most important essay about his method in the field of inorganic nature 'The experiment as mediator between object and subject' Goethe (1890) pointed to the example of the way mathematicians work, which he had in mind when grasping the primal phenomenon:



on its surface.

People are on the point of looking for answers in the cosmos. The latest research on the creation of the nuclei of atoms which make up the rocks of the cosmos (Rocks of the continental and oceanic crust, micrometeorites, rocks brought back from the moon, photography of the surface of other planets) in recent years produced a comparative planetology forming the basis of a new theory of the condensing of the solar system. This cosmic questioning of our time sets the task of throwing a bridge between geology and Astronomy. At the moment this bridge is cosmo-nuclear physics.

In the light of this, Goethe's geological views are all the more relevant:

> 'The main difficulty of geology is connected with the point of view that we hold back for as long as possible the atomistic and mechanical, which admittedly under certain circumstances proves to be effective, and acknowledge the truth of dynamism, a coming into being, determined in conformity with law, a developing and transforming.' ('Dynamism in geology, p337)

His method could lead to truth when we carry out our work with the help of modern scientific discoveries and the proper power of observation (Anschauungskraft).

(Translation by David J. Heaf from *Zu den geologischen Schriften Goethes*, Elemente der Naturwissenschaft, 43/2, 1985, pages 1-21, with the author’s assistance.)

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## Summary Table

| 1. *The primal rock (Urgebirge)* | 2. *The stratified rock* (*Flözgebirge*) each placed one against the other |
|---|---|
| *General solution* | |
| Inclination to crystallisation: | |
| Relationships | Indifference of elements |
| Attraction | Mixing |
| Striving to each other | Existing side by side |
| Abstraction from gravity | In gravity |
| Chemical effects prevail | Contrast of mechanical formation |
| Simultaneously packed form | Free form in succession |
| | Decomposition and recomposition |
| Necessary | Chance/accident |
| Simple universality over the body of the earth | Strata |
| Bedrock & primitive granite rock | Alternating with clay, sand, lime |

Two outcomes, never completely separate, melting into one another

*3. The transitional rocks*
fitting in between the other two
*Moment of solidification*:
Primeval non-material separation
Separation of the mass into forms: symbolised by the cube
Isolated crystallisation within the mass
Requirement to concentrate itself and leave its neighbour
Crystallisation in freedom
Decision on the possibility of a successive becoming
*Manifestation of all characteristic properties:*
Completion of vein types, porphyry, metallic masses
Much feldspar, the kind oscillating between clay and quartz
Primal clay schist (Urtonschiefer) Quartz schist (Kieselschiefer)
Coal seams: Appearance of vegetation

> 'Thus we must...achieve for these pupils what I was already able to make clear to my workers at Dornach, that...an island such as the British Isles floats in the sea and is firmly held from outside by the forces of the stars...By and large, the forming of the continents and islands is in principle caused from outside by the cosmos...The earth is throughout a mirror picture of the cosmos, not something which is controlled from within...' (Steiner 1923)

Nowadays it is thought that continents float. In current plate tectonic theory, two main problems are being tackled: The cause of plate movement and the different behaviour of basalt and granite in crust formation. When people try to answer these questions they are strongly induced to derive support from conceptual models showing a magmatic activity controlled from within, for instance the one involving convection in the mantle and magma differentiation.

The revolution in geography thus comprises: the earth is considered as a whole; its geology is still living though declining; it has a differentiated formation which has gone through a sort of development in association with the appearance of organic life



> 'Such an experience, which is made up of several others, is clearly of a *higher* kind. It represents the formula by which countless individual calculations are expressed... We have to learn from the mathematician the careful cautiousness with which he proceeds step by step, deducing each step from the preceding one, and even where we employ no calculation, we must always proceed as if we are accountable to the strictest geometrician...'

What did Goethe have in mind? In the same volume there is a short chapter: 'On mathematics and its misuse' in which, after a brief introduction, Goethe quoted extracts from texts which seemed sufficiently important to him to comment upon them. As first 'witness' he chose d'Alembert, who, in the text in question, comments on how only a very small number of self-evident ideas, 'axioms' or '*primary* propositions' ultimately lead to the discovery of a huge wealth of mathematical statements. In order to elucidate what was meant, he used a metaphor: When a language develops in the course of history, there is a change in the expressions used to describe one and the same fact. A statement can be translated into several languages and yet have the same idea as its content. At this point Rudolf Steiner indicated in a footnote to Goethe the relationship of the concept of the axiom to that of the 'primal phenomenon':

> '*The primary proposition* is in mathematics what for Goethe in science is an experience of a higher kind. Also the way d'Alembert considered the ramifications of this proposition is completely analogous to what Goethe said about the relationship between experience of a higher kind and usual empirical experience.' (See also: R. Steiner 1920)

In other words: Primal phenomena are to physics what axioms have become since Euclid (1971). Accordingly they should be self-illuminating (evident) truths, that is, requiring no further evidence. Furthermore they should be of a fundamental kind, i.e. not deducible from other truths. And finally they should serve as a basis for deducing further truths.

### 5.1 *The Euclidean model*

Euclid distinguished three kinds of statement in building up his geometry: By *Definitions* he described first of all the concepts with which he proposed to work: 'A point is that which has position but no extension'. Then he stated the valid *Axioms*: 'Things which are the same as a single thing are also the same as each other.' And on this basis he dealt with *Propositions*. These can occur as problems whose solution is sought with the help of a deduction, or as theorems to be proved by means of definitions and axioms.

The field of inorganic nature differs from that of geometry in that, as content, all phenomena for the senses are considered in their external relationships. People are still accustomed to attribute the phenomena for the senses to preconceived material causes in space which ultimately, however, do not need to be sense perceptible. Such an external causation is not sought in geometry. Its axioms are of course related to experiences of the physical body, but no additional basis of their content is required. If Goethe wanted to follow the example of mathematics in this sense, then he broke with physicists and their need, deeply rooted since antiquity, to explain the phenomena by hypotheses, by models and by 'causes behind the phenomena'. There is an old saying for this: 'saving the phenomena'.

### 5.2 *Spinoza's 'Ethics'*

Prior to Goethe, Spinoza is an example of another who had summoned up courage to extend the mathematical method to a more comprehensive field. Following the example of geometry, he set himself the task of understanding the world as a spiritual-ensouled-physical unity. In his main work 'Ethics - presented according to geometrical methods' (1677) we again find *definitions* ('By cause I understand that, whose essence contains existence within itself, or that whose nature can only be conceived as existing.'), *principles* ('Everything that is either in itself or in another') and finally *theorems*, which can be proved from definitions and principles.

The reader of 'Ethics' will be struck by how in each definition it is expressly emphasised: 'I understand', 'it is called', 'I state', 'I call'. Here the man sets the definition as he wants it understood in what is to follow. On the other hand, amongst the formulation of the principles we can detect descriptions of experiences: 'Man thinks'. (Ethics II, 2nd Principle). They are always expressed as conclusions from the given which can be experienced. Now the mathematical form of 'Ethics' exists in an intimate relationship with its content. Rudolf Steiner (1914) explained Spinoza's procedure with respect to the latter's intention:

> '...Spinoza finds that we can only begin with something that is in need of nothing else for its being. He gives the name substance to this being. He finds that there can only be one such substance, and that this substance is God. If one observes the method by which Spinoza arrives at this beginning of his philosophy, one finds that he has modelled it after the method of mathematics. Just as mathematicians take their start from general truths, which the human I itself forms in free creation, so Spinoza demands that philosophy should start from such spontaneously created conceptions...'

When we visualise the essence of axioms, i.e. Spinoza's principles, it appears that there is something about them in common with the divine, namely neither requiring nor being capable of explanation.

Goethe was intimately familiar with Spinoza's 'Ethics'. Rudolf Steiner (1914) showed this relationship in a way which may specially interest us here:

> 'When, in 1811, Goethe read Jacobi's book, 'On Things Divine', it made him 'uneasy', 'How could the book of a so warmly beloved friend in which I was to see the thesis developed that nature conceals God , be welcome to me! My mode of world conception - purely felt, deeply-seated, inborn and practised daily as it was - had taught me inviolably to see *God in Nature, and Nature in God*, and this to such an extent that this world view formed the basis of my entire existence. Under these circumstances, was not such a strange, one-sided and narrow-minded thesis to estrange me in spirit from this most noble man for whose heart I felt love and veneration? I did not, however, allow my painful vexation to linger with me but took refuge in my old asylum, finding my daily entertainment for several weeks in Spinoza's 'Ethics''...'

### 5.3 *Newton's 'Optics'*

Whereas Spinoza's use of the geometric method could serve as an example for Goethe, he was displeased with the way Newton (1704) used geometry in his 'Optics'. So he devoted the extensive 'polemical section' of his 'Theory of Colour' (Goethe 1890) to 'Unveiling Newton's



3. The transitional rock embedded between the other two, characteristics of all three ('*Paralipomenon*' ['Going from one state to the other ' - *Trans*], p418)
The reader is left to piece together the necessary characteristics.

Finally an additional remark by Goethe about the question of time within this sequence:

> 'Inorganic nature keeps all these capacities alive for aeons; however it pushes their sequence over onto one another like Napier's bones [rods, *Trans.*] and precisely that way, produces the incalculable phenomenon which brings with it the appearance of past, present and future.' ('Epochs of the formation of the world, 1817, p369)

### *Overview*

In the conclusion of the fourteenth lecture of the cycle 'Practical advice to teachers' (Stuttgart, 1919) by Rudolf Steiner, after reminding us of the approach to natural history teaching before the twelfth year, which should appeal to the child's feeling of being related to the animal and plant, a feeling not yet obscured by the faculty of judgement, we read:

> 'We keep the minerals until the last because for them almost nothing but the power of judgement is necessary and this does not call upon anything through which man is related to the outside world. And man is indeed not related to the mineral kingdom. It is the mineral kingdom more than any other that he has to dissolve...' (GA 294)

When we grown-ups take the trouble to get to know the mineral kingdom we look for a relationship with it. This arises only after we have somehow dissolved it.

The method Goethe used is a sort of spiritual dissolution process, in that it brings the phenomena of the mineral realm into such an interrelation that the idea is uncovered. Through the idea of the primal world of granite, Goethe was presented with that relationship in which his soul opened up 'the oldest, foremost, deepest feelings of truth'. The process of dissolution in the idea goes so far as to lead Goethe to the primeval living solution in which granite first crystallised.

The power of judgement used by the true scientific method is lacking in contemporary geology, which experienced a real revolution twenty years ago. The plate tectonic theory considers the earth as a whole. It draws attention to the fact that to understand the large scale geological processes, not only the continents, but also the oceanic regions with their world rift systems are of importance. The earth's crust is a granitic skin on a constantly moving, plastic, basaltic basement layer and this skin is stretched and compressed. In the course of earth history the continents have changed their position in relation to each other and to the poles, as postulated by Alfred Wegener.

Let us recall what Rudolf Steiner gave for the geography curriculum of the twelfth school year. On 25th April 1923 he said what should be dealt with when there is no compulsion to take into consideration the requirements of the examinations:

*4. General categories*

In order to grasp the individuality of the middle epoch whose main phenomenon is the formation of inorganic masses, Goethe produced a series of general categories in his short essay 'Origin of inorganic forms'. These can be used with all geological phenomena.

Only to the inattentive observer will everything material appear formless, for it has an 'irresistible urge to form itself'.

Goethe distinguished six categories. The first three relate to the threefold condition of the material before the forming, the last three to the threefold way that the material strove to form from out of these conditions.

'Before the forming, the material-physical can be thought of in a threefold condition:
- the *free* is the solution
- the *packed*, the dissolved, condenses before its solidification
- the *piled-up*, when the solidified individuals partly touch, without penetrating each other

Out of these three conditions the material strives towards form.

- the *most general,* when the material gives up its proper form and subjects itself to the most general determination. Then the round form arises.
- the *general,* when the material, giving up its proper form, subjects itself to the law prescribed for all inorganic masses.
- the *particular* form, when the material follows its own special laws. ('Origin of inorganic forms', 1817, p372)

The three forms are related to the concept of freedom:

The round form (the most general), like crystallisation (the particular form) requires the '*greatest freedom*'. Against this, the middle form (the general) is subject to *a general law*, according to which all material masses form themselves. It is this separation, this 'archetypal through-latticing' which characterises the 'transitional rocks'.

It is rather rare for Goethe to 'systematise' like this. With this it is mainly a matter of giving the middle form a basis which is in conformity to law in relation to the two others. Because, whereas the round form and crystallisation are undeniably recognised as free forms, the forms derived from his principle of formation are too little recognised and 'properly used'. This principle of formation was emphasised over and over again by Goethe and its phenomena were described. He regarded it as an important law discovered by him, because when it is 'properly used' it makes the invisible visible. The six categories were later shown systematically. They are thus helpful results of observations of the process of formation of the earth.

An attempt will now be made to reach an overview by means of a *tabular summary of the three main epochs (See page 8).* Goethe himself expressed them concisely in the following way:

Keeping to what is already familiar, there are three main epochs:
1. The primal rock (*Urgebirge*)
2. The stratified rock (*Flözgebirge*), each placed one against the other



Theory'. Here I shall only touch on aspects of the 'Optics'. I have the impression that it would in fact be profitable to investigate the way in which the classical form is handled in the 'Optics'. In the text, *Definitions* are given first. These are quite remarkable, because in them Newton puts forward the ideas he wishes to take as his point of departure. The first commences as follows:

> 'By *the Rays of Light* I understand its least Parts, and those as well Successive in the same Lines, as Contemporary in several Lines. For it is manifest that light consists of Parts, both Successive and Contemporary...'

The outlook indicated is so deeply rooted that, immediately before, it signified no contradiction to Newton to have stated his aim as follows:

> 'My Design in this Book is not to explain the Properties of Light by Hypotheses,...'

The 1931 edition cited here contains the following about *Axioms:*

> 'Axioms are principles, which are declared to be valid for the following discussion. In this respect they sum up the results of optics so far ascertained by experience. It would appear to follow from the foreword of 'Principia' (1687) that in Newton's view geometric axioms also arise from experience - a view, which can be justified.'

Again, as with Euclid, the *Propositions* come third. But these are not at all theorems to deduce from what has gone before, but those which are proved by experiment. In dealing with the propositions, the definitions and axioms are no longer explicitly cited. Did Newton inwardly turn his back on the 'geometric method'?

5.4 *Goethe's use of the 'geometric method' in his theory of colour*

Against the background of Spinoza on the one hand and Newton on the other the questions arise as to how a hypothesis-free science of inorganic nature based on Goethe and Rudolf Steiner is put together and the form into which such a science can be shaped. It is worth noting at this point how Goethe allowed Euclid's scheme to have some influence on his 'Outline of a theory of colour' (1890). We select the part where the 'dioptric colours (the first class)' is discussed: The initial paragraphs in fact have the character of definitions, from which he leads over to a preliminary description of what should count as a primal phenomenon (Paragraphs 150 & 151). Then follows the richness of observations. Phenomena are arranged 'in series', in such a way that the route goes from observation of the colours arising in the atmosphere to those arising in experiments with artificially prepared clouding agents. Thus each phenomenon discussed prompts its explanation out of the idea already indicated. The individual phenomena would in this sense correspond to the 'propositions', to the 'theorems', which were derived from the axioms and definitions. Here however the scheme breaks down. All explanations lead only to expressly pointing out the primal phenomenon. We might get the impression when going through the phenomena that the idea, in the sense put forward above, is made accessible in many experienceable 'garbs' or 'languages' so that ultimately the clue to the 'higher experience in experience' can follow. The new process to knowledge leads to the 'axioms' which are *not* for their part fixed in a final form. Indeed, one is clearly made aware of this, when in the next chapter on the 'Dioptric colours of the second class' one realises that these too should arise from the primal phenomenon, which, until this revelation, one would certainly not have seen in relation to the 'prismatic colours'. One is left with little choice but to search for the idea turns out to unite both realms of phenomena.

5.5 *Systems of axioms*

The individual axiom can be characterised with the phrase: evident, not for proof and a basis for later proofs. In reference to the system of axioms, nowadays the following properties for axioms are necessary: independence, completeness and freedom from contradiction. These conditions can be thought of as *ideals* which confront the researcher when he strives to understand inorganic nature as a *whole* (R. Steiner 1886). Through these requirements, each individual thought comes in relation to the others. If the requirements are fulfilled, something is really achieved which reductionism only promises. The latter would like to produce unity by resorting to 'matter', a hypothetical necessity, in each case thought of as fundamental.

6. *Rational empiricism*

In an essay entitled 'Experience and Science' directed to Schiller (Goethe 1798), Goethe expressed himself in the following way about his distinguishing three stages in his own method:

'1. *The empirical phenomenon*, which each person is aware of in nature and which afterwards is raised to
2. *the scientific phenomenon* by experiment, in that one demonstrates it under other circumstances and conditions than those by which it first became known and in a more or less successful result.
3. *The pure phenomenon* stands there at last, as a result of all experiences and experiments. It can in no way be isolated, but it shows itself in a continuous sequence of occurrences. In order to demonstrate it, the human spirit determines the empirically varying, excludes the accidental, separates the impure, disentangles the entangled, and of course discovers the unknown.

   If man would know how to be content, here perhaps is the ultimate goal of our capabilities. Because here we are not looking for causes but for the conditions under which the phenomena appear; its consistent sequence, its eternal reproducibility under thousands of circumstances, its uniqueness and its changeability are observed and accepted, its being determined is recognised and through the human spirit is again determined.'

Schiller (1798) answered promptly, possibly also referring to Goethe's essay 'The experiment as mediator between object and subject' (1887). What Goethe described as three stages of the phenomenon became for Schiller a sequence of three kinds of knowledge, three 'isms'. He distinguished them by investigating them according to the categories:

> '...Common empiricism, which does not go beyond the empirical phenomenon, always has (under quantity) only a single case, a single element of experience and therefore no experience; under quality it asserts only a particular existence, without distinguishing, excluding from it, setting anything against it, being referable to a single word; under relation it is in danger of incorporating the accidental as the substantial; under modality it remains restricted merely to a



In the moment of transition comes the development whereby new properties reveal themselves. One could also describe it as a moment of freedom which leads from the packed form of the first epoch to the freer form of the second epoch. This moment, as it shows itself in the metamorphosis of granite, causes the formation of inorganic masses. Then arises the essential solidifying process:

'One must regard the moment of solidification of greatest significance...In solidifying, in the transition from softness to rigidity, there occurs a *separation*, be it of the whole or taking place in the inmost of the mass.'
('Rock formation as a whole and in detail', 1824, p381)

We must picture this separation as a *'non-material archetypal through-latticing (ideelle Urdurchgitterung)'*. Goethe used the following image: A latticework goes through the stone masses and differentiates them as an ideal, as a potential, as a possibility. This differentiation is therefore 'as much committed to remaining eternally inactive as it is to an earlier or later appearance.' The lattice work goes through the stone masses trilaterally, so that bodies are cut off, cubic, parallelepiped (triclinic), rhombic, rhombohedric (orthorhombic), columnar or plate-like.
  The following remark of Goethe shows how concrete his concepts are:

'By this concept [of non-material archetypal through-latticing] the artist too becomes capable quite independently of *'making the invisible clear through the visible*.' ('Formation of large inorganic masses', 1824, p375)

Out of this concept, Goethe developed a whole '*theory of mineral veins*':

'Fissures in which the contents of a rock set themselves free, which become filled up....crystallise.' (idem p405)

The porphyritic comes into existence at the same time as this separation. The porphyry as well as the rock veins is an effect of free crystallisation and occurs as a result of a tendency which Goethe called 'a requirement to concentrate itself and to leave its neighbours' (p413).
  This separation is thus primeval. It is to be understood as a:

-'decision on the possibility of a successive becoming
- becoming in separating
- becoming after separating...' (collected key-words from sketches, p400ff)

The 'most important events' mentioned above correspond to new properties of development:

-'manifestation of various types of earth
- lime - much feldspar - quartz rock - lime
- primal clay-schist (*Urtonschiefer*) - siliceous schist (*Kieselschiefer*)
- strata and the appearance of vegetation
- limestone and the appearance of animalisation...' (collected key-words, idem)

- abstraction from gravity
- chemical activity prevails.' In Goethe's sense chemical activity is to be understood thus: it rules 'the living play of the elements and their attractions in the moment of coming into being.' ('Dynamism in geology', p337)
- 'necessary
- the first epoch of granite is simple and universal over the whole world.' (Key words collected from various notes)

The crystalline rocks belong to the first epoch.

*2. The second main epoch, a feature of which is the 'stratified rock', worked against the first main epoch.*

The first two epochs are to be considered as two endpoints:

'The further it gets away from granite, the more *gravity* takes the upper hand, until finally with the strata or seams only a trace of crystallisation remains. ('Theory of layering of rocks', p355)

The characteristics of the second epoch work polar to the first:
- in gravity
- contrast of mechanical formation processes
- free form comes into being by succession
- by chance or accident(zufällig)
- the elements become indifferent, mix together, exist side by side
- decomposition and recomposition
- layering
- developing their form according to occasional purpose or determination

Results of the second epoch: the system of red sandstones and shales - alternating clay, sand, limestone - origin of fertile ground. The first two epochs are not to be understood as after each other in time, but rather more as an essential polarity. The following later remark of Goethe shows this unambiguously:

'Two outcomes, which blend into one another.
Two outcomes, never completely separated.'

It comes to light that the connection between the primal rock (Urgebirge) and the 'stratified rock' (Flözgebirge) searched for since the Illmenau days is an original polarity.

*3. The third main epoch is the 'transitional rock'*, situated between both others. This third or middle epoch can also be derived from the concept of granite. Goethe's observations in Karlsbad are referred to once again:

'A complete separation is visible with all these phenomena. Each part claims the predominance, where and however it can and we find ourselves *at the threshold of the most important events.'*



particular reality, without foreseeing the possible or even leading knowledge of it as far as a necessity. As I conceive it, common empiricism is not exposed to an error, because the error arises only in science. What it observes, it really observes, and because it does not feel the longing to make laws out of its observations, its observations can, without any kind of danger, remain isolated and accidental.

b. The *scientific phenomenon* and the error arises only with *rationalism*. In this field of course the faculties of thinking come into play, and arbitrariness enters along with the freedom of these faculties which would substitute themselves for the object.

Under quantity, rationalism always combines *several cases*, and as long as it is content not to give up the plurality for the totality, i.e. to make objective laws, it is harmless, even useful, because it is the *way* to truth...

Under quality, rationalism places the phenomena side by side, as is proper, it distinguishes and compares; which is equally (like all rationalism) praiseworthy and good and is the only way to science. But this despotism of the faculties of thinking shows itself here immediately by *one-sidedness*, by *rigidity* of differentiation, and as above, by *arbitrariness* of connection. It risks firmly separating what in nature is connected, just as above it combined what nature separated. It makes divisions where none are etc.

Under relation comes the eternal striving of rationalism to ask about causality of the phenomena and to combine all qua cause and effect...Here rationalism appears especially to fail in that it skimpily takes into account merely the length and not the breadth of nature.

Under modality, rationalism forsakes reality without achieving necessity. Its most extensive field is *possibility*, hence the unlimited hypothesising. Thus the function of reason is ... *conditio sine qua non* of all science, because only via the possible is there,... a way of getting from the real to the necessary. Therefore I fight as hard as I can for the freedom and authority of the theoretical faculties in the field of physics.

c. The *pure phenomenon*, which in my judgement is united with the objective natural law, can only be reached by *rational empiricism*. But, to repeat, rational empiricism cannot itself begin from empiricism, without first rationalism on each occasion coming in between. The third category arises each time from the linking the first to the second, and thus we also find that only total effectiveness of the free powers of thinking with the purest and most extensive effectiveness of the faculties of sense perception leads to scientific knowledge...

Under quantity, the pure phenomenon must grasp the universality of the instance...

Under quality, rational empiricism always *limits*, as would the example of all true natural historians show, who refrain equally from an absolute affirming or denying.

Under relation, rational empiricism gives equal attention to causality and independence of the phenomena. It sees the whole of nature in a reciprocal interaction, everything determined in turn, and it therefore guards against giving validity to causality merely according to a simple skimpy *length*, it also always includes the breadth with it.

Under modality, rational empiricism always penetrates to necessity.

Rational empiricism as it is conceived is of course never at risk of misuse, as with the two previous methods of knowledge; but it is nevertheless necessary to warn against a false, a so-called, rational empiricism...'

With the steps described by Goethe and critically commented on by Schiller, we shift from an as yet unconscious activity of thinking, via a 'voluntary' use of it, to endeavouring to 'create' the thoughts out of experience (Rudolf Steiner 1909). But it clearly follows from Schiller's commentary that forming concepts independently in the sense of 'rationalism' forms the basis of the comprehension of the 'pure phenomenon'. Thus we can define a concept on a trial basis without having already to have decided whether or not it leads to the understanding of a concrete phenomenon. The seeker after knowledge moves between the world of ideas in which he operates freely and the world of the percepts to which he devotes himself, thereby losing his free faculty of thinking. Rudolf Steiner (1919) draws attention to this, in that he points to the boundary which we cross when we move from pure mathematical activity to bodily interaction with a mechanical force: We lose the clear faculty of thinking, our waking consciousness fades, as soon as we devote ourselves to sensory qualities (R. Steiner 1919). A hypothesis-free understanding of inorganic nature, in Rudolf Steiner's sense (1886), is to be developed on the basis of the three modes of knowledge developed by Goethe and Schiller.

7.0 *A new threefold structuring of physics*

Let us return once more to the rudiments of the edifice of physics. We shall start with *Definitions*. In these, the concepts to be used should be made clear. In Schiller's sense we are dealing here with an activity which creates out of the powers of 'rationalism'. As it happens, Rudolf Steiner illustrated this with the example of the concept of inertia in the chapter 'Goethe and modern science' in his introduction to Goethe's scientific works (1890):

> '...This is usually defined as follows: Without an external cause, no body can alter its existing state of motion. This definition creates the impression that the concept of a body inert in itself has been abstracted from the phenomenal world...But this is completely untrue. The concept of the inert body comes into existence purely through a conceptual construction. As I apply the term 'body' to what is extended in space, I can conceive such bodies as are altered by external differences and such as bring this about through their own impulses. If now I find in the external world something which corresponds with the concept I have formed of a 'body which cannot alter itself without an external impulse', I call this *inert*, or subject to the law of inertia. My concepts are not abstracted from the sense-world, but freely constructed out of the idea, and it is with their help only that I find my way in the sense-world. The only correct phrasing of the above definition would be: A body which cannot of itself alter its state of motion is called an inert body. And, when I have recognised as such a body under consideration, I can then apply it to everything which pertains to an inert body.' (O. D. Wannamaker translation)

We have to *declare* in definitions the way in which we understand physical concepts. Theoretical physics works with the 'constructed' concept. Thus awareness that this arises from the idea need not be present. Theories are freely put together and then, especially in the latest research, some experiments are planned supposedly to supply the empirical element. Thus we are dealing with a scientific method comprising two components. The capacities necessary for 'empiricism' and 'rationalism' are exercised to a high degree. With respect to the evolution of consciousness, both the sentient soul and the intellectual soul are employed (R. Steiner 1904, 1910). This was possible before the beginning of the modern age. The model for a mathematical make up of the edifice of science stems from ancient times.

In the 'conversation' between Goethe and Schiller, it is a matter of adding a third stage to 'empiricism' and 'rationalism'. This is only necessary and possible when *new demands* are placed on the creative edifice of science. If we are to get closer to 'rational empiricism', 'pure phenomena' and 'higher experience in experience', we must take a different way. Now it is very impressive how Goethe deals with phenomena. Each phenomenon is experienced individually.



*III. Outlines of a history of formation of the earth.*

As to the formation of the earth's crust, Goethe confined himself to fragmentary comments. Amongst these, we can find important essays ('Theory of layering of rocks' - 'Shaping of large inorganic masses'), though more often, simply lists of key words which make up the various outlines of a geological-geognostic synthesis. These only become comprehensible to the reader who has occupied himself with the complete writings connected with this subject. However, the fragmentary comments are just the places where Goethe expressed himself most significantly and most profoundly.

Let us visualise the point of departure: the primal rock (Urgebirge) and the 'stratified rock' (Flözgebirge) of the Illmenau mine, which are completely separate phenomena with no transition. Goethe succeeded in bringing them to an inner connection in that he was led to distinguishing *three main epochs* in the history of the formation of the body of the earth:

*1. The first main epoch in the formation of the earth.*

*The point of departure is the granite concept:*

'Granite came into existence by crystallisation. In it there is no evidence of gravitation.' ('Theory of layering of rocks', 1785, p355)

Goethe meant that it is true that in granite attractive forces were at work, which, however, were something other than gravitation. They were the forces of crystallisation. *What are these crystallisation forces?* At the beginning of its formation, the mass of the earth was in a more or less fluid condition. We can perceive Nature's power of intimate combination especially in granite:

'When one sees how intimately Nature combines, one can form an idea of the intimate solution in which the bodies must have been held before they became solid and bodies.' (idem, p352)

Thus, the original condition of the earth is a 'general solution'. This solution was maintained by an inner fire, 'that is not comparable with a melting fire'. (idem p352)

Goethe pointed to a denser atmosphere, which was neither a 'burning', nor a 'wave-pounding area of sea', but a 'giving rise to heat and fermentation'. Goethe protested as much against gross 'neptunism' (the wave-pounding area of sea) as against gross 'vulcanism' (the melting fire).

*First of all, granite crystallised from this general solution. That is the first epoch of the formation of the earth*, that is characterised thus:

-'inclination to crystallisation - relationships - attraction - striving to each other
- developing themselves together
- interpenetration, forming
- packed form in simultaneity

possibly be determined to something other than granite itself, thus a reverse determination, a re-ordering of this something to granite is likewise not totally unthinkable. ('Dynamism in geology' p338)

*The most significant aspect* of Goethe's ten-year geological contemplations is what he called his '*main maxim*':

'*All geological considerations should begin with granite.* (On natural science in general, p275)

Granite is an *archetypal phenomenon.* In this sense he gives all geological considerations their conformity to principle. In granite, the archetypal phenomenon of the realm of rocks is perceptible to the senses. Thus it has the hallmark of inorganic nature. However, the essence of the archetypal phenomenon does not appear as the active physical cause of other types of rock but in the *idea*. The 'distinguishing concept' is not yet the idea, but out of the pure concept, the idea is perceived as the fundamental creative principle in thought.

'What Goethe was seeking is just what is lacking in present-day geology: that is the idea, the principle, which constitutes granite before it has become granite; and this idea is the same as that which underlies all other processes of formation.' (Rudolf Steiner, 'Goethe's fundamental geological principle', Introduction to Volume 2, [Translator's note: see also 'Goethe the Scientist' Trans. Olin D. Wanamaker 1950 Anthroposophic Press, New York, p 196])

Thus, we are dealing with a theory of metamorphosis similar to that underlying organic nature. *As a visible archetypal phenomenon*: granite has the characteristic of inorganic nature. *Raised to idea*: granite corresponds to the type (Typus), which is the general form of the organism.

Granite is the visible primal rock (Urgestein) and a type which has become fixed or hardened, whereas the type in the plant or animal world is in no single instance formed outwardly. Living nature is an entity which is becoming, which is seen in the present. With the mineral world we must learn *to see the past in the present*: how the earth has shaped its form, the 'osteology of the earth' as Goethe put it.

'The osteology of the earth...for those who would aspire to knowledge of organic nature, it is indispensable.' ('Formation of the earth's crust', p412)

Through observing, Goethe came to the clear concept of something which has already become. Corresponding to this concept, the power of imagination was summoned in order to show how it was formed:

'Only in the whole body of the earth, however, can that rock-forming principle, with all that it [in Goethe's view] implies, come to full fruition. The primary thing for Goethe, therefore, was the history of the forming of the earth's body, and each detail had to be fitted into this. (R. Steiner, idem)



But Goethe detests remaining at the level of 'empiricism'. He moves from one phenomenon to the next. He presents his readers with series of phenomena. And the 'higher experience in experience' arises from this activity. When it is put into words, in order to be communicated as a 'rational description of nature' (Rudolf Steiner 1919), the formulation does not arise without the power of rationalism. The 'higher experience in experience' is not bound to particular mental images. It is the activity of the 'consciousness soul'.

'Goetheanism' can be elaborated into a system of theories wholly from definitions, formulated primal phenomena and the two taken together following the model of 'theorems'. And with such a system one can be sure how to deal with the 'rationalism' step. At least this way, unnecessary materialistic ideas are avoided. In addition however, the aim of a hypothesis-free science of inorganic nature will follow the demands for knowledge which arise in modern times, but which cannot be satisfied with the two-component method described above.

### 7.1 *Primal phenomena in modern physics*

Only with regard to the field of modern physics do we learn rightly to appreciate the scope of 'rational empiricism'. It harmonises with the researcher's approach, if he makes various aspects of the totality of inorganic nature come to light, by bringing certain conditions together in an experiment. To him, 'wave aspect' and 'particle aspect' are just results of particular configurations from which arise the phenomena that necessarily correspond with them. There follows an attempt to compare the special nature of both aspects with each other. I have put my view of the primal phenomenal character of the relevant area of phenomena in the form of propositions in the following headings.

### 7.2 *The 'wave aspect' concerns the relationship between bodies in space*

It is known that the function of the human eye is imitated by the camera. In both, a lens serves to form a real image on a 'light-sensitive' surface. As we saw, the wider the pupil or the camera aperture, the more accurately must be made the eye's accommodation or the focusing of the camera's objective on the distance of the object to be imaged. With increasing lens cross-sectional area, the relationship between 'thing' and 'image' becomes more and more specific. There is an increasingly closely delimited zone of sharp image formation corresponding to each image distance.

At the same time the lens can mediate with greater detail between the interrelated surfaces. Then, the 'resolution' is said to increase. On the other hand a drastic contraction of the pupil to below 1mm diameter, or a corresponding closure of the aperture, does not lead just to darker images and less differentiated image depth. Without exception, the image which arises seems more blurred. By enlarging their aperture, astronomical telescopes can produce increasingly detailed pictures of the sky. Their aperture relates smaller and smaller areas of a photographic plate to an individual star.

Early on, physicists were aware of the significance of 'optical path lengths' (See G. Maier, 1984 & 1986). Direct sight is of course sight at shortest distance. And equally the 'indirect path' through a plane mirror is the shortest indirect path of all possible indirect paths. Furthermore, the principles of vision through water or glass are comprehensible as soon as the path length through an optically denser medium is given correspondingly more 'weight' than that through air

(Fermat). With this it would be noticed that visual relationships at the minimal (more exactly at the *'extremal'* [See Maier 1984]) distance are at the same time those by which *a field of neighbouring paths of practically uniform lengths* arises. The decisive criterion is what is meant by 'practically uniform'. In this sense the glass convex lens in forming a real image enables a field of uniform optical distances to arise between 'point on the thing' and 'point on the image'. The greater the lens cross-sectional area, the more narrowly the criterion 'practically uniform' optical distances limits their hitherto permissible distribution. The image of a star is a small disc whose diameter is *inversely* related to the diameter of the perfectly ground lens. Around the disc occur alternating concentric light and dark rings with regular spacing, similar to the momentary picture of a stone thrown into water.

This phenomenon is extraordinarily surprising considering what is meant by fixing a direction: When aiming through sights one of course assumes that a direction of sight is defined by a narrow aperture. In this respect, optics was formerly pursued on the basis of the concept of 'light rays'. And yet the contrary must hold for the visual relationship. The need arises for an 'explanation' which makes the surprising facts plausible, which spares people's amazement. Very near the beginning of the 19th century Thomas Young noticed that analogies exist between the principles governing visual relationships in space and those governing the propagation of waves on the surface of water. Thus *waves* became models for the ideas applicable to visual relationships. One would say 'light waves' were discovered. But with the phenomenon of image formation under discussion here, no movement occurs whatsoever. Yet for their calculation, 'wave functions' are formulated, from which it transpires, however, that the time dependency disappears. It is said that the problem is one of 'statics'. Furthermore, at the beginning of the 20th century it became increasingly clear that the wave analogy was not an appropriate idea for grasping the principles of the effect of incandescent bodies on light sensitive bodies. Since then, they have learnt to give up regarding the idea of light waves as describing something physically present and the expression 'wave nature' gradually became established. As part of our present intention, another short characterisation of the phenomenon in question is now necessary.

### 7.3 *The 'particle aspect' concerns processes between matter and matter in time*

In a camera, the real image cast by the lens on the 'light sensitive' film is effective in that subsequent chemical development takes place to varying degrees according to the variously exposed parts of the image. Coarser effects of illumination occur when pictures printed in colour are left out in the sun for a while. The yellow and peach blossom (magenta) pigments disappear leaving shades of only blue and black behind. Damp white washing left in the sun is re-bleached to white. In all these processes we are referring to 'photochemical effects'. The most significant effects of this kind take place as 'photosynthesis' in the plant world. Here I would like to go more thoroughly into the physical phenomenon of 'photo-effects'.

If a zinc sheet charged 'negatively' with a PVC tube rubbed with wool is exposed to sunlight, it can discharge without an electrical conductor being involved. This does not happen when it is positively charged, e.g. with a glass rod rubbed with leather. For this, sunlight is required, just as it is for browning or reddening the skin and oxidising a freshly rubbed down zinc surface. Little discharge occurs with surfaces showing little tendency to oxidation such as copper or even gold, or when illumination is through a glass sheet. Obviously two conditions are needed above all for



*Predominance of mica reveals the principle of foliation, becoming leaf-like: The mica forces the rock itself to form a sheet.*

*2. Feldspar predominates*

- *in porphyritic granite* the feldspar forms noticeably large crystals inside the granite mass
- *in porphyry* the large and even very large crystals are set in a groundmass in which the other crystals are no longer distinguishable to the naked eye. A second kind of feldspar frequently occurs and mica tends to be absent.

*The predominance of feldspar reveals the principle of individualisation: The crystal wants to form the whole rock.*

- *in pegmatite all crystals want to dominate*. Pegmatitic granites are conspicuously coarse-grained mixtures of minerals.

*3. With quartz* hardly anything shows when it begins to play a major part. It seems much more as if quartz adapts itself to both kinds of transformation. It is more in the manner of its formation to escape from the totality of the rock. One could describe this escaping as a polarity: on the one hand quartz occurs as milky quartz and forms entire rock masses, and on the other hand it occurs as tiny, free, perfectly formed crystals glistening on the surface of a gneiss-like rock.

*4. Formation of minerals in which quartz ultimately disappears.*

From the point of view of granite metamorphosis one could describe the sequence of so-called 'greenstones' in the following way: from *syenite*, which is still like granite with a low quartz content, via *diorite*, where the black mica gives way to the dark-green amphibole, finally to *gabbro* and *peridotite*, in which quartz has totally disappeared and heavier green-black minerals make up the whole mass, which in the case of gabbro is like *basalt* only not so fine-grained.

Quartz seems to have its own set of rules, which already leads to a polar way of looking at the so-called basic volcanic rocks.

Figure 2 is an attempt to make the whole thing clear. Of course, it is a scheme, but it appears to be a fruitful way to gain a real first approach to the world of rocks. This 'picture of development' of the rock types still has nothing to do with their coming into being. For that, other concepts are needed, which Goethe developed in his 'geognostic synthesis'.

They were also new views on the so-called metamorphosis of rocks. It should be noted that with his basic principle, Goethe could conceive of the possibility of anataxis:

'In it (the giving up of its character in granite) we see that the elements which produce granite can

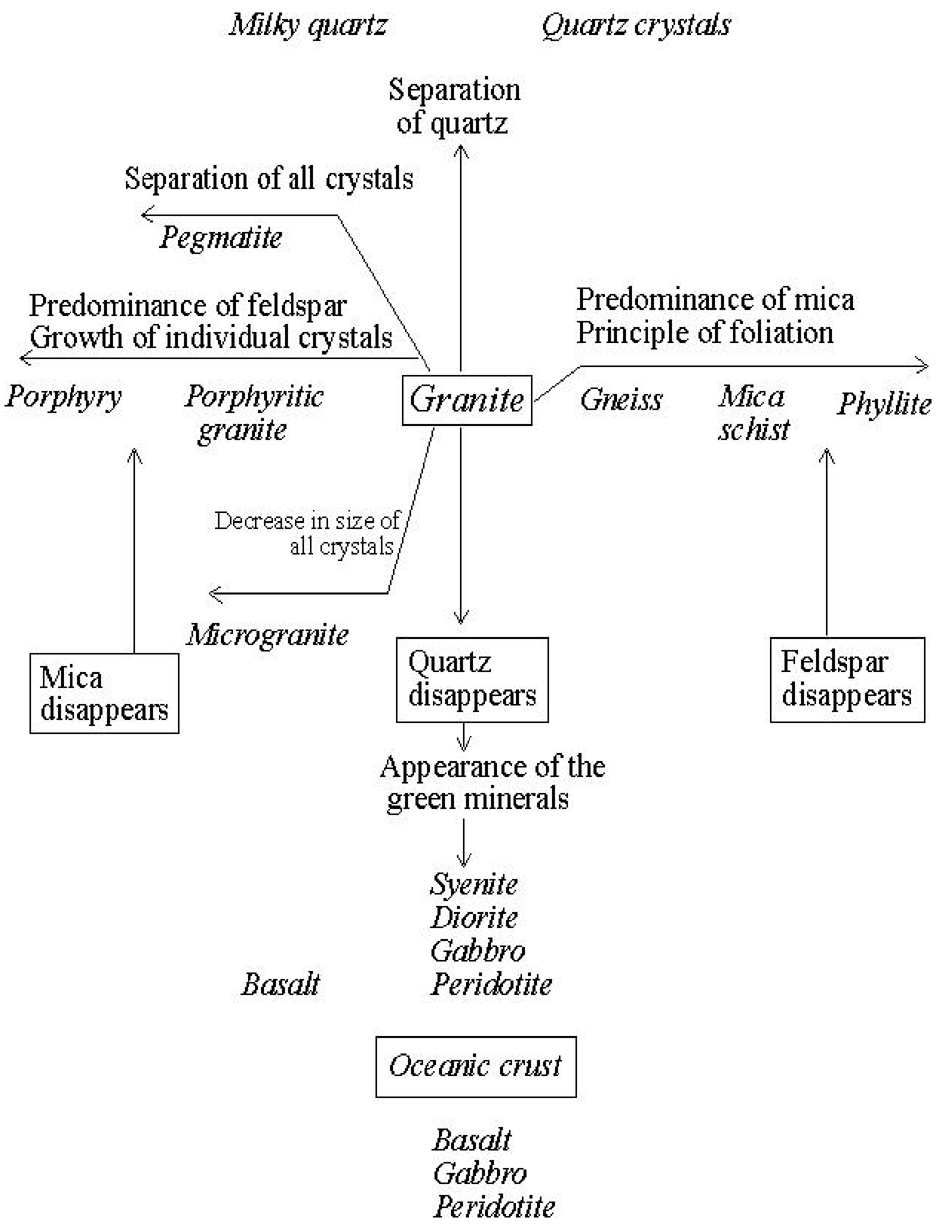


Figure 2. Diagram of the morphological development of rock types according to the principle of granite metamorphosis.



the effect in question: On the one hand a chemically effective 'light source' is required, and on the other hand a metal surface which is sufficiently active, which easily tends to oxidise in air. Even alkali metals, such as caesium can be applied *in vacuo* as films to electrodes. These, combined with a second electrode, can be made into a 'photocell' which, despite its containing a vacuum, forms a charge like the chemical cell of a battery as soon as the coated surface is illuminated. The coated illuminated electrode takes the positive sign. With this arrangement, illumination through glass, though less chemically active, is sufficient.

The potential of the uncharged cell is dependent on the colour of the illumination, but not to its intensity.

The photocell can serve as a diode which becomes conductive when the coated electrode as the cathode is illuminated. Current flow is determined by the intensity of illumination.

### 7.4 *No refuge in 'causes behind the phenomena'*

The spatial relationship mediates the process aspect of the relationship between the illuminated and the illuminator. Both aspects interweave themselves and our interest can go in both directions. What connects both aspects is the link between the energy quantity 'frequency', which is definitive for both the process and the value of the wavelength, the criterion for the uniformity of optical paths. The product of these is equal to the 'speed of light'.

People used to explain the linking of both aspects by an underlying 'radiation', which an energy flow carries through space by means of a wave process. The energy flow has a quality given by the colour of the illumination (proportional to 'frequency') which determines the potential in a cell devoid of current flow. This is however independent of the spatial propagation of this energy flow. In order to be able to imagine this relationship, people have resorted to the idea of 'energy quanta', which contain the energy flow like little particles, and in each case carry with them the energy necessary for setting free from the cathode an electron with an energy corresponding to the neutral charge of the cell. Here however the intensity, subject to influence by the spatial arrangements, i.e through the optical image formation, is nothing other than the *number* or the density of these quanta in the energy flow.

Of course, this way people reached plausible models, which as 'thinking crutches' seemed helpful. But at the same time they had two contradictory ideas of the 'nature of light': It should be both wave field and particle stream at the same time. And with this contradiction, gone was the experience of reality, which people up to that point had promised themselves by positing matter as a basis. Thus there arose in the 20th century an unsatisfied yearning for reality.

### 7.5 *Experiencing primal phenomena as gestures*

The clearer it is to us how a phenomenon arises from the conditions which 'summon' it into appearance, the easier it is for us, aside from the external encounter, *inwardly* to build up the particular situation. And then we can investigate the specific gesture which is given in a primal phenomenal relationship. We devote ourselves to that which of course remains 'inexpressible' in the sense of that set out above. What can be experienced of it can be clad anew in imagery. In what follows, I should like to explain what I mean using the examples developed above.

With the two series of phenomena shown in sections 4.1 and 4.2, their gesture can be discovered as follows: Two entities join in forming the phenomenon. One of them, itself refraining from showing up as an image, helps the other to appear. It is made clear to us that this particular gesture is not exercised one-sidedly, but is based on reciprocity, according to what is possible.[1] Certainly, the particular reciprocal relationship of two beings is encountered everywhere in the field of optics. An experience of this kind can at any time be renewed and made concrete with an actual example. And the involvement of two sense perceptions together, as we experienced in the case of lightning, can take on symbolic significance. In lightning we experience most dramatically, that something *appears*, that perceptual content occurs as an elemental event, without having been announced by anything previously. And the two sides leading to the so-called 'wave aspect' and the so-called 'particle aspect' can much more easily be distinguished in accordance with the facts when one manages to reflect on the actual situations which correspond to them. Neither the wave nor the particle idea leads any further in that direction. They are no substitute for the experiences which can be had by those who themselves have actually set up and carried out the relevant experiments and who can create thereby a clear picture of what *matters* in each case.

In the above sense, all observation of nature and all experimentation, by a corresponding cultivation of reflection, is a 'becoming aware of the idea in the reality'. Through the 'limitless possibilities' of our technical civilisation we have to rely on making ourselves competent to judge the essence of the processes which offer exploitation. In my opinion, a field of work opens out here that is immediately related to the burning issues of our time.

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1. The above mentioned gesture is a key to understanding complementarity: For the essence of the uncertainty principle lies in the fact that as one aspect becomes vague, the complementary one becomes more distinct. The aspect that becomes vague does not disappear, i.e does not cease to be associated with the situation. The conditions are such that it only becomes unobtrusive.



separation is visible with all these phenomena. Each part claims predominance, where and in whichever way it can, and we find ourselves *at the threshold of the most important events.'* (On natural science in general, p273)

These observations repeated on the large scale and in detail led Goethe to *the concept of the 'metamorphosis of granite.'* The basic principle of granite and, from out of that principle, its ability to metamorphose, were described in the clearest and most concise way in the discourse on 'Dynamism in geology' (1812):

'The deepest underlying rock we have found on the earth is granitic. Its distinguishing concept is having no *continens* and *contentum*, but a complete 'being in each other' (Ineinandersein), a complete threefold unity of parts. They exist as equals in it and none of them has a definite predominance over the others.

If the granitic gives up this characteristic then this gives rise to one of its parts gaining predominance over the others, making its properties hold sway and forcing the remainder to conform to these properties. Therefore, where granite gives up its character it involves not one but several kinds of transition...This giving up of its character in granite, this *metamorphosis*, can be looked upon as a stepping out of itself, a crossing over...' ('Dynamism in geology', 1812, pp337,338)

These fundamental ideas can be made clear by trying to use them to build up a *morphological developmental picture of the crystalline rock types* (see Fig. 2). The components of granite can be recognised by their form (mica is rather foliar, feldspar slab-like, quartz grainy). In such forms one sees that their association is only possible in that granite originally came into being through a packed, restrained crystallisation. The transition occurred together with a free crystallisation which reacted differently from the original association, *according to one or other component becoming 'free'*. From this standpoint, both sets of conditions will make an essential characteristic of the minerals clearly perceptible.

### *1. Mica predominates*

- *in granite-gneiss*, mica forms sheets, The whole has a loose parallel structure, yet the product is still similar to granite.
- *in banded gneiss*, the mica sheets are pressed together and on top of each other. It develops a simple banded or schistose pattern with variable light layers (of feldspar and quartz) and dark layers (of mica and quartz).
- *in augen gneiss*, the tendency to drive out the feldspar crystals predominates. They do not let themselves be squeezed out but remain as 'eyes' in the gneiss.
- *in micaceous schist*, the crystals of the feldspar component become fewer and fewer. They even totally disappear. Only thin alternating layers of mica and quartz remain.
- *in phyllite* the mica is so fine-grained that the individual scales can no longer be distinguished with the naked eye. The quartz too is finely divided. Layers are no longer visible and the whole has a silky, green or green-grey coloured sheen. The rock itself has become sheet-like or foliar.

as the highest and the deepest, thus we respected it and took the trouble to get to know it better.' ('On natural science in general...' p273)

The experience of the dignity of granite seems to have been a stimulus to Goethe in two ways, poetically and scientifically. At this time (1784-1785) he had the intention of writing a novel based on geology called 'The Universe'. A part of it is the essay 'Granite' which was dictated on 18th January 1784. If we want to cultivate this feeling for the dignity we should read it. Here, only an extract is given. One which was often quoted by Rudolf Steiner particularly for the Waldorf teachers. The experience of the primeval world of granite, its summits and its depths, 'before all life and above all life' gives the soul a 'sublime comparison', in which the experience of truth and the experience of granite become one:

'So lonely, I tell myself, gazing down from this entirely bare summit, and hardly seeing in the distance at its foot a scantily growing bit of moss, so lonely, I say, is the mood of a man who desires to open his soul only to the oldest, foremost, deepest feelings of truth. Indeed, he can say to himself: here, on the oldest, eternal altar, built directly on the depth of creation, I offer a sacrifice to the Being of all Beings.' ('Granite', 1784, p323-324)

The scientific necessity of learning to distinguish this kind of rock from another led Goethe to a complete *perceiving concept of the granitic*, to the uncovering of the second secret. Granite differs from all other rock types in that it consists not of one component, but of three visible components which are put together in a mysterious way:

'The main characteristic was emphasised: that it [granite] is composed of three intimately associated parts, related in composition, but differing in appearance, namely quartz, feldspar and mica, which exercise equal rights in being there together; one could not say of any single one of them, that it is the containing, or that it is the contained; indeed it can be observed from the great variety of shapes that *one part can gain predominance over another.'* ('On natural science in general...', 1820, pp272,273)

'These parts are not held together by a third agent...They do not appear assembled or brought together, but came into being at the same time as their totality, that they go to make up.' ('Granite as the basis of all geological formation', 1784, pp326,327)

*The metamorphosis of granite*

In contrast to the plant being, the being of the mineral does not unfold itself in time, but in the variety of its forms in space. It is a fact that a delicate balance is a prerequisite for something occurring. This was clear to Goethe in that for years he directed his attention especially at the variety of granitic forms. Thus part of the concept of granite is that 'one part can gain predominance over the other'.

Goethe made countless observations of this phenomenon, especially in Karlsbad where large crystals of feldspar were the main component of the granite. It is also worthy of note that there the other two parts detach themselves from the association:

'Now mica begins to play a main part, it lies in sheets and forces the remaining components to do likewise. However, the separation goes on and on; we find... mica and quartz completely separate in large stone masses, until finally we reach rock faces which consist entirely of quartz...A complete



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# Mathematics as a spiritual science
# Philosophical investigations into the significance of mathematics with reference to Plato, Goethe and Steiner

Renatus Ziegler

*Introduction and overview*

Mathematics is one of the necessities of modern life. There is hardly an aspect of life in which mathematics does not play a more or less significant part via scientific and technical achievements. Mathematics occupies an increasingly important position even in the everyday life of university humanities departments.[1] A characteristic of this is that people *apply* mathematical concepts to areas outside mathematics without in each case taking into detailed account its deeper significance.

Precisely because mathematics has become an almost all-pervading instrument of scientific and technical process, there is at the present time a need for a consideration of the subject's inner nature, its possibilities and its limitations. For instance, the important question arises in ordinary cultural life of whether there may be some ways of dealing with mathematics, hitherto seldom considered, which could be cultivated alongside both the development of pure mathematics as well as its extension to the mathematical models of the applied branches. Mathematics by and large serves and has served the private or institutional acquisition of knowledge, or it is studied as an indispensable body of knowledge for getting to grips with the demands of life in modern occupations; ultimately it is used above all as an instrument for the progress of modern civilisation. If mathematics should not just be useful, but of real significance for deepening human *culture* and *education*, then other ways of cultivating mathematics must be sought.

In presenting this unusual approach to mathematics I shall tie in with Plato and Goethe[2]. However, these authors serve only as a point of departure for an investigation independent of this connection.

Mathematics was for Plato a means of diverting the soul from contemplating the objects of the senses to becoming aware of the spiritual ground of existence. Mathematics itself cannot give information about the divine, but it can prepare the soul for beholding it (theoria). Can a start be made with this view nowadays? Are Plato's comments to be understood merely in the sense of a myth or do they still, or once again, have a real foothold in the potential experience of people today?

With reference to Plato, Goethe saw in mathematics first and foremost a training instrument which leads people to exactness and methodical certainty in the process of cognition. No other science leads to such complete certainty of method and content as mathematics. Thus Goethe was aware that in cognizing the world it is not only a matter of *applying* mathematical content, but also of practising the *mathematical method*. In addition, the fundamental occupation with mathematics leads according to



The investigation of the Thüringian region touched on the continuation of the Illmenau copper seam, the series of layers, the summit composed of porphyry and the granite protruding from the porphyry in very many places. Through this Goethe and his colleague were able to reach the conviction:

'...thus we ventured to allow the porphyry, and deeper, invisibly, the granite to continue under all layers...' (idem p23).

*II. The quest for interrelations - The establishment of the basic principle - Granite and its metamorphoses.*

The year 1785 is significant - Goethe was 35 years old. Ten years earlier, he had started the mineralogical observations which he continued untiringly. He announced genuine results, that is those giving rise to laws, though at first kept these secret: 'I am beginning to get results, which until now I was keeping to myself so that they would not be snatched away from me.' (from a letter to Merck, 1784, p128) 'My speculations on rocks are going very well. I see very much more than those who occasionally guide me and who are also aware of this fact, because I have discovered some *basic laws of formation*, which I am keeping secret...' (from a letter to Ch. von Stein, 1784, p99)

By this time he had a collection which proved very helpful to him. He always strove to find the transitions from one form of rock to another: 'I have carefully sought out and by luck found the smallest differences and shades which bring one form of rock closer to another and which are the cross borne by the systematiser and collector because they do not know where they fit in.' (from a letter to Herder, 1784, p128)

This strenuous effort can be seen from a catalogue of a series of numbered samples (this is the collection referred to as 'The bedrock attacked by the gas of the spring at Marienbrunn'): '1. Coarse grained granite with black mica. 2. Fine-grained granite. 3. Fine-grained granite with a schistose texture. 4. A piece of medium grain. 5. Quartz vein in which the cells of the feldspar are still visible. 6. Granite with quartz predominant. 7. Three smaller pieces of the same. 8. Medium grained gneiss. 9. The same, somewhat coarser. 10. The same, coarser still. 11. Almost the same, only finer. 12. The same, very light. 13. The same, from the very finest. etc' (p319)

In such a series Goethe had the intention of *relating to the formative tendency*, which cannot be found in the bare, over-differentiated or mature products.

*What is this secret?* Actually, we must guess it. It is the granite itself. It is a double secret and each one a threefoldness. The first reveals itself over the whole earth. The second is revealed in the rock itself. The first is to be found in the fact that *the oldest, the deepest and the highest is granite.* When we picture this fact in imagination and allow our imagining to intensify to reverence, then the second secret discloses itself. It is the secret lying in granite itself.

'At the time when the physical earth began to interest me scientifically...in those days we were shown a definite point where we should stand and what more could we have wanted; we were directed to granite

'The book will show you that in mineralogical matters we have not been idle, but have viewed our little bit of land from all corners'. (From a letter to Merck, 1781, p27)

During these journeys mineralogical descriptions, sketches and collections were made. Above all, a scientific terminology was developed. At that time this was derived from the language of the mountain folk, it was indeed living, interesting and poetic but often inexact and together with other expressions caused a great deal of confusion. Goethe himself was no expert and yet had absolutely no inclination to learn geology from books. He found it a great help to have the cooperation of a young man, J. C. W. Voigt, who was studying mining at the Freiburg Academy, 'and had brought with him an exceptionally pure nomenclature and an extensive knowledge of details...' (from a letter to Merck, 1780, p20).

Thus, the first step is an exact description with clear concepts:

'I now have the most universal idea and certainly a pure concept of how all these masses are situated and lying on top of each other, without the pretension of saying how they came on top of one another.' (from a letter to Merck, 1780, pp20,21)

The concepts which arose from this were called by Goethe 'perceiving *(anschauende)* concepts', in contrast to 'scientific [concepts]', which already belong to an explanatory system:

'It is more often than not stupidity that those who on describing a couple of mountains immediately want to contribute something about the creation of the world...in this matter, as in a thousand similar, *the perceiving concept is infinitely preferable to the scientific...'* (from a letter to Duke Ernzt II of Gotha, 1780, p26)

Scientific activity as such is *looking*. Looking is a schooled, deliberate activity of the observer, which when properly carried out by many people, opens the whole earth to the individual:

'Because he wants to float over the whole earth he is as freely disposed as the air which surrounds everything. Neither fable nor history, neither theory nor opinion prevents him from *looking.* He carefully separates what he has seen from what he conjectures or concludes. Every properly recorded observation is priceless for his successor, in that it gives him *perceiving concepts* of distant objects, which extend the sum of his own experiences and those from several people finally make a totality..' (idem p24)

In 1780, five years after Goethe took up his post, we find several such letters, in which the emphasis is laid on showing the method and the initial results of the practical investigation of the district of Thüringia using this method.

*The method* comprises:

- looking for a clear terminology,
- avoiding opinions, theories, assumptions, conclusions,
- forming perceiving concepts based on observations, sketches, small areas of land, collections.



Goethe (1792) to experiences 'of a higher kind', which are connected with the development of an organ the objects of which do not belong to the material world.

I will show here that both Plato's and Goethe's points of view can be concretely related to the views of modern mathematics. For this we shall turn first of all to the concept of symmetry which plays a prominent part in pure mathematics, in classical and modern physics, in other sciences and in philosophy.

By mathematical examples it will be shown that by looking for symmetry it is a matter of *invariant structures*, that means properties which are not subject to change. At the basis of every change, whether or not it takes place in time, there is a *principle* of transformation, which itself does not change. This principle is an invariant structure in the flow of change. It is that concrete principle according to which the way the change takes place is determined. From the standpoint of the cognizing subject, such a principle is needed as a conceptual standpoint in order to be able to grasp changes at all.

Principles or structures found in this way belong to a realm which, as I shall show, lies beyond all changes. It can be referred to as the realm of *ideas* or *laws*.[3] In this sense, mathematics belongs to the spiritual sciences or humanities, because they are concerned with a content which only manifests by means of the thought activity of the human spirit. This realm is related to the realm of forms in the Platonic sense. The Platonic forms however have an additional property. They are ideas at work in nature.

This difference between an idea present in individual thought (concept) and an actively creating form at work in nature surfaced in the Middle Ages in the term *universale post rem* and *universale in re*. These are to be distinguished from the self-existent and self-supporting *universale ante rem* which unfolds its effectiveness out of nothing but itself. Nominalists deny at least the existence of universals at work in the phenomena, and often even the universally objective nature of the idea. Realists of ideas on the other hand are of the opinion that ideas not only have an *objective existence,* but also an *immanent effectiveness*.[4]

In dealing with mathematical laws, their universal objective nature usually poses one no problem. There is however also the possibility of properly demonstrating the *effective* nature of the idea, that is to say the concrete constitution which is active in the form or being. This is done by starting from the mathematical thoughts which are actually at work. Thus mathematics can be a point of departure for a science of the spirit *as it is active*, thereby supplementing traditional spiritual science, which is a science of *products* of the spirit which have arisen in the past and stay in existence after the spirit is active. This science of the currently-active spirit must meet Goethe's requirement as regards *method*, thereby extending the realm of objects, however, to a content Plato referred to which is no longer accessible to the usual senses. This is the particular task of the anthroposophical spiritual science developed by Rudolf Steiner.

*1. Plato: Mathematics between form and image*

In nature Plato distinguished the objects and processes from the living principles which produce them. The former are the *images* which come into existence and remain susceptible to change and the latter are the creative principles, the *forms*, eternally existent and ever the same.[5] This differentiation according to *objects of cognition* corresponds to a distinction in *methods of cognition*. Images appear to human consciousness in the form of ready made concrete mental representations or judgements (doxa), whereas the forms involve the living cognitive process of reason, the intuition of ideas (theoria). Between these two kinds of experience lies the intellectual cognitive process concerned with the objects of science, its abstract concepts and ideas. Mathematical thinking belongs especially to this domain. Mathematics shares with the rest of science the property of being ultimately derived from preconditions (postulates, axioms) which cannot be deduced (proved) out of themselves.

However, the objects of mathematics are not images, because mathematical concepts are not concerned with the specific properties of *single* objects, but with structures to which a whole class of objects belongs. For instance, in determining the concept circle it is not a matter of including in this concept the position of the centre or the length of the radius of any particular circle, but of singling out a general principle which forms the basis for *all* circles. Although such a principle can then fit all circles, it is not the only one which has this property. Thus for instance, the following definitions of a circle are equivalent to each other to the extent that each circle in the sense of one definition is a circle in the sense of the other and vice versa:

| *Distance definition of a circle* | *Right angle definition of a circle* |
|---|---|
| A circle is the geometric set of all points P of a plane which have the same distance from a given point M of the plane (Fig. 1) | A circle is the geometric set of all points P at the foot of the perpendiculars from point S of a plane to those lines of the plane which pass through point R ≠ S (Fig. 2 |

Proof of the equivalence is shown immediately by Figure 3 which shows a special case of the given properties, a rectangle inscribed in a circle. If K is a circle in the sense of the distance definition and if P,Q and R,S are pairs of points which lie on K, then ½RM½ = ½MS½ = ½MP½ = ½MQ½. The quadrilateral RPSQ is rectangular because its component triangles are isosceles triangles. Thus K is a circle in the sense of the right angle definition. If on the other hand K is defined in the latter sense, then one can select point M on RS so that ½RM½ = ½MS½ = r; point Q is the foot of the perpendicular parallel to PS through R. Thus the



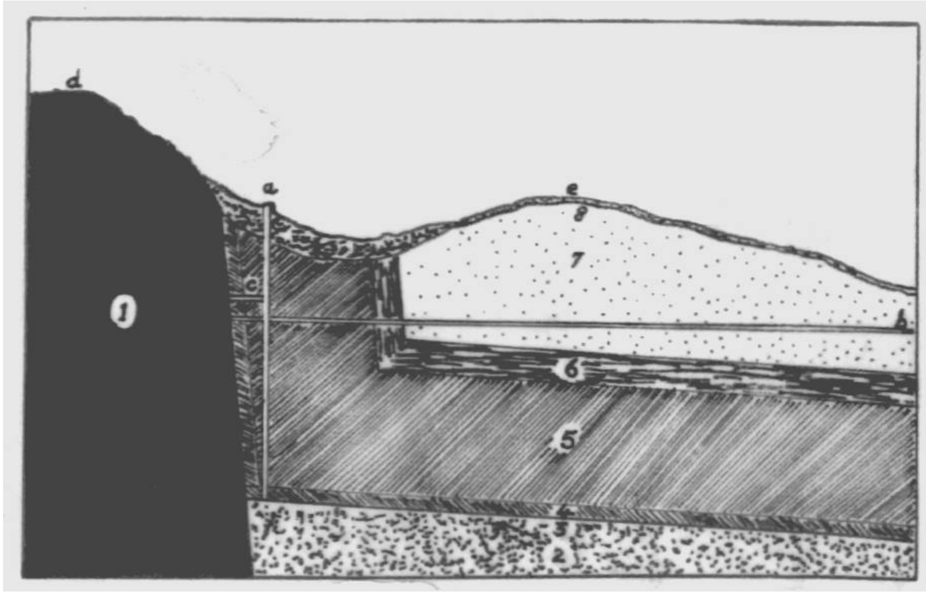


Figure 1. Cross-section of the Illmenau rocks
(redrawn and scanned from *Elemente der Naturwissenschaft)*

KEY:
1. Bedrock, which here is porphyry
2. System of red-sandstone/shale (*Das Rotliegende*)
3. Schist seam
4. Slate
5. Gypsum, in which the '*Neue Johannes*' shaft is sunk to the slate
6. Stinkstone (Athraconite)
7. Sandstone
8. Drift (*Die Damm-Erde*)

a) The *Neue Johannes* shaft
b) The deep *Martinröder* tunnel
c) The upper tunnel
d) Heath
e) The *Ober-Pörlitzer* heights

(Taken from 'First report of the continuation of the new mine at Illmenau', 1785, p43)

also 'Goethe the Scientist' Trans. Olin D. Wanamaker 1950 Anthroposophic Press, New York, p 195])

Various writings from 1780 clearly express Goethe's method of investigation. The composition of the mountain at Illmenau had first to be brought into connection with the varied surroundings. This required working systematically and practically. Goethe produced a book called 'Mineralogical journeys through the Duchy of Weimar and Eisenach':

At Illmenau, a seam rich in copper and silver was being mined. Because of political conditions the enterprise had stopped about fifty years previously. Its resurrection was one of the main concerns of Karl August, the Grand Duke of Weimar. In June 1776 Goethe entered the Weimar civil service as a privy councillor. He spent a month at Illmenau with Karl August and von Tebra, the mine manager, in order to set the resumption of mining in motion. In November the same year all the mining matters were assigned to him. At this time Goethe had no interest in geology, rather an aversion to it. He later wrote of the visit he made to the natural history collection at Einsiedeln monastery during his Swiss journey (1775):

'At that time I had little idea of the value of such things. As yet the most praiseworthy, yet nevertheless dismembering geognosy, had not yet attracted me to the impression of the beautiful earth's surface confronting the gaze of the spirit. Still less had a fantastic geology entwined me in its error...' ('Poetry and Truth', p17)

The subsiding of the schist seam required an expert investigation. Goethe did it himself with what was known on the subject. Soon, closer observation of the various Thüringian seams at the Illmenau mine was needed. Goethe, who rejected 'the dismembering geognosy', yearned for a creative geognosy.

'We have climbed the highest peaks and crawled into the depths of the earth and would really like to discover the marks closest to the great formative hand ... We have discovered very beautiful things which stir the soul and expand it to truth. Now we shall *also* soon be able to give work and bread to the poor moles here (Illmenau)...' (From a letter to Ch. von Stein, Illmenau, Sept. 1780, p29)

Solving the technical problems of a metal deposit to the advantage of a group of people caused Goethe to direct his soul and spirit to truths presented as a riddle in the creation of the surface of the earth.

In a letter to the geologist von Klöden Goethe wrote:

' ..induced by the mining of the seams, I have become acquainted with geognosy. *I devoted several years of my life to studying the logical consistency of this mass of layers stacked on top of each other.'* (Outline of a letter to von Klöden, 1830, p746)

How far the key to Goethe's geological researches lies in this sentence can best be seen from the cross-section of rocks at Illmenau which Goethe supplied to the Grand Duke for the mining commission one year after the opening of the mine.

Perhaps we can imagine what is immediately experienced of the composition of the earth's interior by descending into a mine: down through the shaft the horizontal series of piled-up masses, or in through the tunnel to the uplifted folds of the vast uniform crystalline bedrock. Such a violent contrast gives the impartial observer the overall impression of random, disconnected events. Goethe strove especially at 'working his way upwards to such a view that *what he saw in a state of separation might become manifest in inner necessary connection*.' (Rudolf Steiner, 'Goethe's fundamental geological principle', Introduction to Volume 2, [Translator's note: see



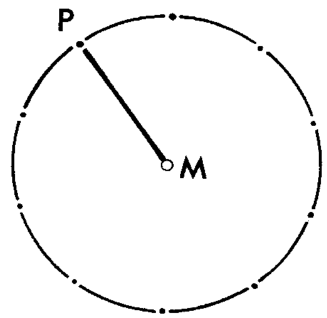


Figure 1

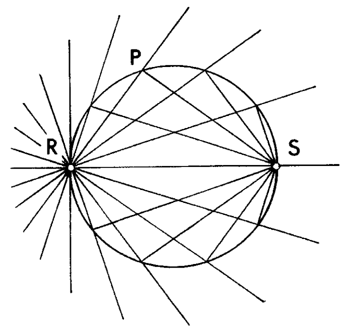


Figure 2

quadrilateral RPSQ is rectangular and it follows that ½PM½ = r for all points P at the foot of perpendiculars.

A mathematician can find many other equivalent definitions of a circle, thus revealing many insights into how the circle principle fits into the framework of geometric concepts. The higher unity of all these circle principles (definitions), the general structural principle or *law of the circle* that underlies them is not itself an immediate object of mathematics. It is presupposed by mathematics and occurs in it

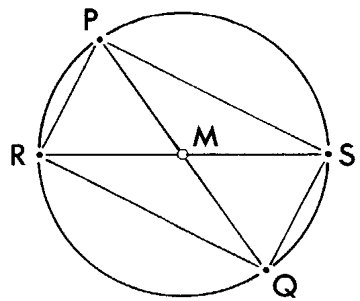


Figure 3

only through the mediation of particular conceptual conditions. The law of the circle always appears in mathematics in already concrete relationships, for instance to certain geometric concepts such as distance, right angle etc. on the basis of axioms which likewise are presupposed.

In this sense, the objects of mathematics are not self-supporting and self-sufficient forms. On the one hand they are based on presupposed axioms and on the other they reflect the particular conceptual context of the components of the relevant definitions.

From the self-supporting ideal *content* of the Platonic form, which is the superior structural principle of all images, it is necessary to distinguish that dynamic and creatively real *effectiveness* which is active in producing concrete images and really, i.e. not only ideally, underlies their existence. The philosopher's schooling in the sense of the *Republic* (Book 7) has as its aim his preparation for grasping in cognition the creative forms. By means of a schooling in the 'mathematical sciences' (arithmetic, geometry, harmonic theory and astronomy) the philosopher's soul was attuned to beholding the forms. However, as Plato wrote in his *Seventh Epistle* (342a-344b), these sciences are not immediately appropriate for grasping the highest objects of knowledge, the creative forms. But practising them prepares the ground or develops the faculty for being able to set eyes on their creative quality.

Plato did not detail this path (problem of the 'unwritten theory') because he trusted that those who see through the problem of cognition of the forms would also find their way to them.

## *2. Goethe: Extent and limits of mathematics*

What Plato indicates, Goethe clearly expresses: Grasping the laws of nature requires a corresponding organ, a kind of 'higher experience within experience'.[6] With this, Goethe extends the domain of phenomenology to an area hitherto excluded from it. Not only is an experience or phenomenon grasped only with the senses valid, but now also one produced through thinking. For Goethe, the latter is not beyond the bounds of nature but within it. Insight into the lawful working of nature can be achieved by careful contemplation of the phenomena. This means through the development of ideas, which reveal that self-supporting essence which remains unchanged in relation to the whole diversity of the natural phenomena and of the experiments people perform. These ideas are the universal principles which structure every individual phenomenon.

The ability to develop and perceive ideas can be cultivated especially through mathematics. For the aim of mathematics is directed to showing not individual examples but general principles. It can therefore serve to train *pure intuition* divested of all specific sensory elements. It is this faculty which is necessary for grasping natural laws. On the other hand, as Goethe pointed out in his essay 'The objective and subjective reconciled by means of the experiment' (1792), practising mathematics also helps one to learn a methodical discipline which exhibits a firm basis for knowledge of nature. With respect to both these areas, the mathematical approach in Goethe's view is of utmost importance. His oft cited backwardness in relation to mathematics concerns the application of the content of mathematics and not on the subject per se or the mathematical method. Goethe was however not in principle against the application of mathematical content to the processes of nature. He even wished it for extending his own researches. However, he discovered many misuses in this field, especially a concomitant restriction of outlook to quantitative relations to the exclusion of qualitative aspects.



way:

Volume 1. *Writings on the formation and transformation of organic nature*

> 'We must start with Goethe's studies on organic nature, *because he began with them*'. (R. Steiner, 'The arrangement....., Volume 2)

Volume 2. *Writings on the principles of natural science and the scientific method*

> 'The essays combined under this title contain Goethe's views about the general truths pertaining to knowledge of nature. We believe that these are in their right place here in the middle of the whole, because for their true appreciation not only is the content of volume 1 essential, but also they show what follows in its proper light.'

*Writings on Mineralogy, Geology and Meteorology*

Volume 3. *Contributions to Optics, Theory of Colour...*

The fact that the geological studies are placed in the middle, directs one's attention to the following question: What concepts correspond to natural phenomena of geology and mineralogy situated as they are between the organic realm and the physical phenomena?

Goethe's actual geological writings are given the overall title 'Knowledge of the mountains of Bohemia' This title encompasses the massif lying north-south between the Weser and the Elbe: The Harz mountains, the Thüringian forest, the Fichtel and Erz mountains, the Bohemian forest and the Moravian heights. These mountains were easily accessible from Weimar where Goethe lived from 1775 to the end of his life and from Karlsbad where he often stayed.

In the essay 'Goethe's fundamental geological principle' (Introduction to Volume 2) Rudolf Steiner gave a main connecting thread for the study of Goethe's geological writings. From it the following themes were selected:

I. The point of view from which Goethe approached geology - his method of investigation.

II. The quest for interrelations - The establishment of the basic principle - Granite and its metamorphoses.

III. Outlines of a history of formation of the earth.

## *I. The point of view from which Goethe approached geology - his method of investigation.*

In 1830 Goethe wrote the following to the great geologist/geographer of that time, K. F. von Klöden:

'The background from which a person comes in life, the side from which he approaches a subject gives him a lasting impression, a certain direction of his course thereafter. This is both natural and necessary. But, led to it by the mineral mine, I have become acquainted with geognosy,...' (Draft of a letter to K.F. von Klöden, 1830, p745)

# An overview of Goethe's geological writings

by Christine Ballivet

*Introduction*

The main part of a year's work at the teaching seminar in Dornach in 1984 forms the basis of the present article, which was reworked following the discussion which took place at the meeting of geologists in Dornach in November 1984.

First of all, Goethe's geological writings will be presented in summary. The source for this was Goethe's collected works and other writings which were published in twenty-two volumes by the successors to the Cotta book company. The relevant volume, 'Writings on geology and mineralogy - Writings on meteorology' is the twentieth and comprises 1200 pages. All quotations from Goethe were taken from this volume and reference is made to the corresponding page number. Within these quotations some words are emphasised in italics by the present author. The volume referred to presents a large variety of documents in which is assembled all that Goethe wrote on geology, including sentences from letters. In it first and foremost an attempt has been made at completeness, with the help of seven indices. Such a collection is especially useful to anyone occupied with considering, from various standpoints, Goethe's involvement with the mineral world.

In contrast to that, Goethe's scientific writings, which were edited by Rudolf Steiner in three volumes (in the historical-critical Goethe edition of Joseph Kürschner's German national literature), contains merely the essays which Goethe himself regarded as those of his works which had a purely scientific purpose. The second volume, containing the geological writings, has 400 pages.

Goethe's intention to make a comprehensive theory of nature could not be realised. However, from 1817 to 1824 he published six booklets: 'On natural science in general, in particular on practical experience of morphology, observation and drawing conclusions linked with living phenomena.' Each book contains a morphological and a general natural scientific section. The general section contains work on the geology of Thüringia and Bohemia, supplements to the theory of colour, the meteorological theory, aphorisms on nature and scientific theory. Apart from the supplements to the colour theory, which are given a place at the end of the third volume, they form the content of the second volume of the natural scientific writings edited by R. Steiner.

Rudolf Steiner frequently spoke about the way he arranged his edition of Goethe's natural scientific writings ('Overview and arrangement of Goethe's natural scientific writings', in the introduction to the first volume. 'The arrangement of Goethe's scientific writings' in the second volume and in the twelfth chapter of 'The story of my life', 1925). This arrangement is intended to correspond to the way the Goethean view of nature has arisen. Rudolf Steiner divided Goethe's writings in the following



As Goethe understood it the first and foremost task of mathematics is to serve as an instrument for the clear structuring of scientific thinking in order to work out in a surveyable and clearly organised form the invariant structures or ideas which correspond to the phenomenal world. According to Goethe these structures themselves have an experienceable character. Following on from Goethe (in the absence, to my knowledge, of Goethe having expressed this explicitly in such a form), it may be asked whether ideas are merely invariant relative to ordinary experience and nevertheless share with ordinary experience the property of changeability or whether in their essence they are also invariant relative to individual consciousness. The problem arises of whether the 'higher experience within experience' can be investigated also in the same exact and experiential manner as both the mathematical and the phenomenological methods demand in their application to the objects of nature and whether their constituent invariant properties can be discovered.

*3. Symmetry and invariance*

In this section we shall look at mathematics itself and the activity it involves. We shall not go into any recorded observations *about* mathematics, but instead develop the relevant insights from handling mathematics.

In the examination of the concept of symmetry in the sciences it emerges that it is difficult to unite the various meanings of 'symmetry' under a single viewpoint. But two aspects can be distinguished which are to be found in almost all approaches to the clarification of this concept. On the one hand there is the conception of symmetry suggested by mathematics as an *invariance* with respect to certain transformations or changes, and on the other hand the practical significance of *symmetry-breaking* or asymmetry.[7] The latter reveals itself on closer inspection as an expression of a higher symmetry or harmony; with this the subordinate symmetries are generally 'broken' or 'destroyed' by a transformation which leaves the higher symmetry invariant.

We shall consider an elementary example. The structural principle of a triangle contains three different points not lying on the same straight line as well as their connecting lines. As subordinate structures we can further distinguish acute angles, right-angled and obtuse-angled triangles according to whether all angles are less than, equal to or greater than 90° respectively. Each individual triangle has properties included by these structures. But it also has properties which do not immediately belong to the specified structure such as position as well as precise lengths of sides and angles. This is characteristic for the relationship of an object (thing) to its structure. The former has accidental properties additional to and not contained in the structure which embraces the essential properties, but which precisely distinguish it as a particular object.

The symmetry transformations of objects with a particular structure embracing the essential properties comprise those alterations of the objects which concern only the

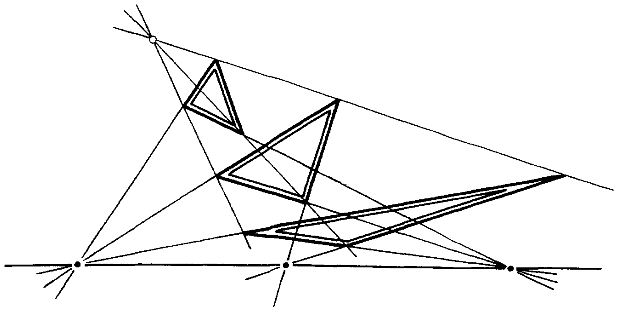

Figure 4

accidental properties. If in our example we stipulate, as the basis of the primary structural features, the above classification of the triangle, then the only symmetry transformations we are concerned with are the Euclidean congruence transformations and similarities. A transformation which converts a right-angled to an obtuse- or acute-angled triangle is, in relation to *these* structural features, a breaking of symmetry, in particular, a homology (Fig.4 shows such a transformation, a perspective collineation). This is so, because the transformation does change the essential properties of this structure. But from the point of view of the mere structure of a triangle, those kinds of transformations are also symmetries because they leave the triangle as such invariant.

We can see that the changes or transformations mentioned in no way affect the structure as such, only the objects or things which are subsumed under this structure, i.e. which are phenomena of it. Also with symmetry-breaking the subordinate *structure* is not broken, but the *objects* which are part of the structure are changed.

*Transformations* of a set *X*, meaning a one-to-one correspondence between elements of *X* generally form a group. A *Group* **G** is a set *G* of elements with an operation defined on G ('multiplication'), which sends any two elements $g_1$, $g_2$ of *G* to an element $g_1, g_2$ of *G*, such that the following properties hold:

1) Associativity: $g_2(g_2g_3) = (g_1, g_2)g_3$;
2) Existence of identity: There is just one element e in *G*, such that $eg = ge = g$ for all *g* in *G*;
3) Existence of inverses: For each element *g* in *G* there is just one element $g^{-1}$ in *G*, such that $gg^{-1} = g^{-1}g = e$.

An example of an finite group, meaning a group with a finite number of elements, is given by the group **S** of symmetries of an equilateral triangle *ABC*. These symmetries transform any such triangle only in its position not its structure.

Let *s*, *s'*, *s''* be the reflections on the three axes of symmetry of an equilateral triangle and *r* the 120° rotation anticlockwise around the middle point M (Fig. 5). The combination *rs* signifies that first *r* and then *s* is applied. Clearly then $s' = rs$ and $s'' =$



(Translation with the author's assistance by David J. Heaf from a contribution by the author to a conference on *Goethe Scienziato* in Castelgabbiano, Italy, 20-22 May 1994)

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- (1993) *Goethes Ideen zur Mathematik. Materialien zu Goethes Mathematikverständnis.* Dornach: Philosophisch-Anthroposophischer Verlag am Goetheanum
- (1995) *Selbstreflektion. Studien zum Problem des Selbstbezuges im Denken und Erkennen*. Dornach: Philosophisch-Anthroposophischer Verlag am Goetheanum


*Notes*

1 c.f. Radbruch (1989)
2 For a traditional perspective on mathematics, which differs substantially from ours, see for instance Grauert (1986)
3 So far as these are present in human thinking they are also referred to as *Concepts*. With this is not meant the words, the symbols, the spoken expressions, but their conceptual *significance* or conceptual content.
4 For an application of this viewpoint to the interpretation of modern developments in molecular biology, especially in genetics, see Heusser (1989).
5 Plato, 'The Republic', 509-511. For a further discussion of Plato's view of mathematics see for instance Ziegler (1992, Ch.II), and Mittelstraß (1985).
6 Goethe (1792). A more thorough documented treatment of Goethe's views indicated in this section can be found in Ziegler (1993). See also Dyck (1956, 1958) and Ziegler (1992, Ch. VI)
7 See for instance Wille (1988) or Mainzer (1988)
8 In order to avoid misunderstandings, we wish to emphasise that what is meant here are the laws of *pure mathematics*. Therefore, we are not dealing with the problem of agreement of mathematical models with a realm of reality lying outside mathematics.
9 Maddy (1990, Ch. 1) gives a brief succinct overview of this problem and the various attempts to solve it in modern mainly Anglo-American philosophy. He includes a comprehensive bibliography.
10 This has been made especially clear by Quine (1951, p 44-5) and (1948, p. 18-19).
11 See Essler (1990).
12 The natural language is the meta-language of all formal or symbolic languages (like programming languages). c.f. Essler (1990).
13 Bieri (1992), for example, deals with the difficult hitherto unsolved problem of tracing the phenomenon of human consciousness to physiological data.
14 This term stems from Quine (1969). See also Maddy (1990, Chaps. 1 & 2)
15 Edmund Husserl opposed a naturalisation of philosophy and psychology, albeit without lasting success. See for instance Husserl (1911).
16 Gödel's own characterisation is made unnecessarily complicated by his developing it by analogy with sense perception. A discussion of various objections and associated attempts at a naturalised solution can be found in Maddy (1990, Sections 1.3 and 2).
17 From this fact can be explained the largely unproblematic understanding within the international mathematical community.
18 Here, a distinction is made here between *invariance* and *invariability* in that whereas the former is absolute, the latter applies to the human being alone.
19 See Steiner (1884-7), (1886/1924) and Ziegler (1993)
20 See in particular Steiner (1894/1918), (1908/18) & (1911)
21 St einer (1904). See also Ziegler (1992) where thoughts merely indicated here are more thoroughly developed and justified. See also Ziegler (1995).
22 See for example Steiner (1894/1988, Ch. V, p.59, Ch. IX, p.103ff & Ch. X, 122).

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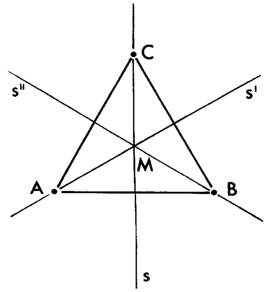


Figure 5

$r^2s$. If we now introduce the identity operation *e* which leaves everything unchanged we have as elements of the group: $S = \{e, r, r^2, s, rs, r^2s\}$. Furthermore we have $sr = r^2s$, $r^3 = e$ and $s^2 = e$. With these formulae the table of all interrelations of the elements can be worked out (Cayley table):

| | $e$ | $r$ | $r^2$ | $s$ | $rs$ | $r^2s$ |
|---|---|---|---|---|---|---|
| $e$ | $e$ | $r$ | $r^2$ | $s$ | $rs$ | $r^2s$ |
| $r$ | $r$ | $r^2$ | $e$ | $rs$ | $r^2s$ | $s$ |
| $r^2$ | $r^2$ | $e$ | $r$ | $r^2s$ | $s$ | $rs$ |
| $s$ | $s$ | $r^2s$ | $rs$ | $e$ | $r^2$ | $r$ |
| $rs$ | $rs$ | $s$ | $r^2s$ | $r$ | $e$ | $r^2$ |
| $r^2s$ | $r^2s$ | $rs$ | $s$ | $r^2$ | $r$ | $e$ |

With a little consideration it should be clear that this group is structurally similar (isomorphic) to the group **P** of transformations, or *permutations* (rearrangements) of an finite set of three elements. If for example we take the first three natural numbers 1, 2 and 3, then these can be arranged in six different ways:

{1, 2, 3}, {2, 3, 1}, {3, 1, 2},
{2, 1, 3}, {1, 3, 2}, {3, 2, 1}.

We are interested in those operations (transformations, rearrangements or permutations) by which from {1, 2, 3} all other arrangements can be deduced. Through the operation r of cyclic transposition, meaning the operation 1→2, 2→3, 3→1, the arrangement {1, 2, 3} becomes (2, 3, 1}. The transition from {1, 2, 3} to {3, 1, 2} is produced by applying r twice, i.e. by rr = $r^2$. The arrangements {2, 1, 3}, {1, 3, 2} and {3, 2, 1} are derived from {1, 2, 3} by keeping one element fixed and switching the two others, i.e. through the operations:

s: 1→2, 2→1, 3→3;
s : 2→3, 3→2, 1→1;
s : 1→3, 3→1, 2→2;

We understand by the operation rs the consecutive execution of the operations r and s, thus the following can easily be verified: s' = rs and s″ = $r^2$s. Further, sr = $r^2$s, $r^3$ = e and $s^2$ = e where e is the identity operation 1→1, 2→2, 3→3. Thus we obtain as elements of the group of operations (permutations) *P* = {e, r, $r^2$, s, rs, $r^2$s}. With these formulae the table of all relationships of group elements to one another (permutations) can be drawn up:

| | e | r | $r^2$ | s | rs | $r^2$s |
|---|---|---|---|---|---|---|
| e | e | r | $r^2$ | s | rs | $r^2$s |
| r | r | $r^2$ | e | rs | $r^2$s | s |
| $r^2$ | $r^2$ | e | r | $r^2$s | s | rs |
| s | s | $r^2$s | rs | e | $r^2$ | r |
| rs | rs | s | $r^2$s | r | e | $r^2$ |
| $r^2$s | $r^2$s | rs | s | $r^2$ | r | e |

By comparison with the symmetry transformations *r, s* and *e* of an equilateral triangle and the corresponding multiplication table, the group table above shows that these operations in fact have the same multiplicative structure as the permutations r, s and e of a set of three elements {1, 2, 3}.

From this it follows that with these two concrete groups we are dealing with realisations of one and the same structural principle, a so-called *abstract group.* In this, only the special multiplicative structure and not the concrete nature of the elements is considered. In addition, this is to be distinguished from the *notion of a group as such* given above which underlies all special abstract groups as a common structural principle.

The domain within which a variation takes place is thus in each case the domain of



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a science of the spirit in action, and this with a clarity which does not sink below the level of mathematical intuition, but rises above it. For, we are not dealing here with a kind of mystical enlightenment, but with a process which can be carried out with mathematical precision by any individual who wishes to. That there may be other experiences of the same kind with other contents, i.e. experiences in the same clarity of other active beings, can be expected on the basis of these facts, but cannot be forced from them. In any case however, such an experience cannot be excluded at the outset. Rather does it depend on the life and world circumstances - just as with corresponding events in the sense world, where the experience of certain facts, for instance a particular type of animal in Africa, is determined not only by the human being but also by circumstances not within his control.

Rudolf Steiner's founding anthroposophical spiritual science is directly connected with this ‘I’ experience in the framework of mathematical intuition and makes it a point of departure and criterion of all further spiritual knowledge which penetrates other realms.[20] In this context he regarded mathematics as an appropriate and fundamental preparation for the path of knowledge in anthroposophical spiritual science[21] and rejected all cognitive methods which made do with less than the clarity and strictness of mathematical intuition. Ultimately mathematical intuition is not a matter of *mathematical* contents of concepts but of non-mathematical contents in the form of cognition proceeding according to mathematical intuition. In his 'Philosophy of Freedom' (1894/18) Steiner used the term 'intuition' essentially for that process we have here called mathematical intuition.[22] Thus Steiner realised in the fullest sense and in mathematical clarity the Platonic ideal of intuiting a being, the soul having been prepared by redirecting it through mathematical cognition. In addition he underpinned the whole of spiritual science with a methodological principle which combines Goethe's insistence on mathematical rigour with the training of a higher organ for supersensible perception.

It can be gathered from this presentation that Rudolf Steiner's spiritual science is neither a utopia or an unattainable myth. It is an improper hypothesis, i.e. a reality achievable in principle by everyone who can involve themselves with mathematical intuition.

If man is in essence a spiritual being and it can be shown that he has a direct access to this essence, then this has fundamental consequences which in many respects makes current scientific approaches seem in need of broadening. Mathematics can play an important role as a path to this insight. Perhaps this role will one day be appreciated as the crucial contribution of mathematics to culture.

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objects of the transformation, here meaning the set $X$ in which the transformation operates. In the above example it was an equilateral triangle, a subset of elements of the plane, as well as a set of three elements {1, 2, 3}. Thus for every variation of a (not necessarily finite) domain of elements that conforms to a particular principle, i. e. a particular transformation, on the one hand there is something structural forming a basis which remains invariant through the transformation and on the other hand, all transformations of this kind generally form a concrete group which itself exhibits a higher structural principle for all transformations. This structural principle is in turn a particular case of an abstract group and the latter an example of a group.

### *4. Universal content and the individual's ability to experience mathematical laws*

How can something experienced in individual consciousness have a universal character independent of this consciousness? This is the fundamental problem that is to be solved for the proof of the objective existence of mathematical laws.[8] To solve this, both direct and indirect methods have been suggested.[9] By *indirect methods* it is a matter of proving that without the acceptance of the reality of mathematical laws a meaningful and elegant science which is as plausible as possible to the human intellect would not be possible. Such *indispensability arguments* ultimately lead to *hypothetical* realism, a sort of myth about the reality of specified entities which *in this sense* cannot be distinguished from other myths, legends or creeds.[10]

By *direct methods* for the proof of the reality of mathematical laws, it is a matter of analyzing the immediate manner of experiencing these laws. Experience is part of individual consciousness. It is thus only accessible to introspection and for this reason has so far been rejected by many authors as suspect, unclear or unscientific. From the apparent failure of all attempts by means of introspection to come to objective results, in contrast to subjective enlightenment[11], it is almost exclusively the indirect method that is still taken seriously. In this essay it will be shown that the possibilities of the direct method are in no way exhausted or sufficiently researched - not to mention the fact that a consistent scientific consciousness can never and must never be satisfied with mere, albeit rationally-based, belief in a myth.

Before positive proof of the reality of mathematical concepts can be tackled, a few prejudices must be cleared out of the way.

*First prejudice:* The content and the process of mathematical thinking arise from convention. - The origins of conventions are not necessarily of a conventional nature: a 'convention' established for the first time cannot arise from an agreement, because it is initially known to nobody but the subject who establishes it. If it is possible however for this subject who establishes the convention to have an unconventional approach to thought, then is not clear why this should not be possible for other subjects too. In addition, agreements between people, which are communicated explicitly, inexplicitly or otherwise, require individual insight into or assent to the meaning of the agreement. Otherwise, in passing on conventions, one is merely dealing with blind faith or obedience.

*Second prejudice:* The subjective experience of mathematical thinking (introspection, intuition, inspiration etc.) is of an inexpressible nature and thus lies outside science. - Here is a confusion of thinking with communication, or rather the muddling of the content of thinking and the expression of this content in a language. In order to think, one neither has to talk to oneself nor communicate with oneself in any other way. In addition, the meaning of linguistic expressions cannot ultimately be inferred from a language; the investigation of the meaning always stops with the *individual* insight into the meaning of the expressions of the (natural) language.[12] Therefore, if what cannot be expressed in language cannot be exactly understood, then ultimately the source of knowledge of scientific investigation would be removed and thus science would only be able to be established through extra-scientific personal experiences.

*Third prejudice:* The experience of mathematical thinking belongs exclusively to the subject. It has no significance beyond the subject. - The determination of the subjective character of the experience of mathematical thinking occurs through the subject himself and results from the experience of his own activity which is connected with this experience as well as from the fact that only I myself experience directly what I think and no other person has an immediate part in my unspoken thinking. But this only means that the activity as well as the consciousness of the thought content belong to the subject; however this yields nothing about the constitution of the content. Here there often exists a further prejudice:

*Fourth prejudice* The subject produces the content of mathematical thought. - Not a single *direct* observation based on mathematical thinking has so far been advanced for this hypothesis. All phenomena which apparently support it concern the consciousness of contents, but not the contents themselves.

*Fifth prejudice:* The contents of mathematical thinking are determined through the structure of the psycho-physiological cognitive apparatus. - For immediate confirmation of this thesis it must be shown that for establishing and deducing mathematical laws the structural principles of the cognitive apparatus must of necessity be explicitly enlisted. In the direct experience of mathematical *thinking* (*not*: the formal-symbolical representation of this thinking) there are however no grounds for such an incompleteness or dependence of mathematics *in principle*. In addition, all arguments for the dependence of mathematical thought contents on the structure of the cognitive apparatus concern the *consciousness of* the contents, not these *contents* themselves. Finally there is the evident incompatibility and diversity of the contents of consciousness of mathematical thinking and the results of observation obtained by means of investigation of the cognitive apparatus.[13]

For a deeper insight into the structures of argument used here we shall introduce the distinction between proper and improper hypotheses. A hypothesis (model, theory, structure) with respect to a realm of facts is *improper*, when there are observations lying immediately inside this realm which justify the hypothesis. There must not merely exist inferences for confirmation of the hypothesis. A classical example for



produced and related one to another.

The state of being of the critically implemented principle is thus something essentially different from the conceptual contents produced with it. The former is actively at work and the latter is passively resistant.

Thus we have found an active and effective principle that does not belong to the world of sensory experience. As there is no *directly* experienceable evidence of such a dependence in this activity, there is no cause to postulate one - unless one wants to state a proper hypothesis. Furthermore, nothing belonging to or taken from the sense world appears in this activity. Everything must first be produced through the activity itself. So far as I am aware, all the evidence for the dependence of such an activity on the psycho-physiological constitution of the human being relates to the consciousness of this activity, not to the activity itself.

This active and effective principle has a property which has so far not been specifically mentioned: It is not itself active but is activated. For, mathematical intuition does not of itself become active within us, but it is we who activate it. In other words: the source of the thinking activity lies not inside but outside the law of thinking. This source of the activity is called the 'I'. Thus the properties of self-activity as well as the activation of other laws must be attributed to the I. In this sense the I as the source of the activity of thinking is a self-activating principle which also has the means to activate other principles (especially the thinking). This points to a principle which is not only effective by itself but also brings about other laws.

## *7. Spiritual science*

The spiritual sciences as university subjects, i.e. the humanities, are concerned with the *products* of the human spirit. Following Goethe and especially his concept of an experience 'of a higher kind' (1792) Rudolf Steiner (1861 - 1925) developed anthroposophical spiritual science.[19] He followed Goethe only in the historical sense and developed a systematic exposition of this science, based on its own foundations, on direct observation and independently formed concepts. Thus, this science was directed above all to the spirit *actually at work*, i.e. to spiritual principles active and effective out of themselves, principles which in addition are active in the world.

The philosophy of the Middle Ages called the contents of mathematical intuition *universalia post rem*, also *universalia in mente*, meaning phenomena of universal laws in the individual human consciousness. From these are to be distinguished the principles at work in the phenomenal world, especially in nature, the *universalia in re*, as well as the principle effective for itself, in itself (and not in another), *universalia ante rem*.

In keeping with the foregoing discussion, with the principle denoted by 'I', we are dealing with a *universale in re*, that is with a principle active in thinking. With this the existence of *one* such principle is demonstrated and thus too the real possibility (and not merely the conceivability in the sense of a hypothesis or ideal possibility) of concepts. Following the above discussion, this cannot mean a self-changeableness of concepts, but a flexible or living perspective of the thinking subject relative to the self-determined and unchanging contents of laws.

To conclude this section, attention should be drawn to the fact that it is not in the nature of the principle of mathematical intuition that it can only be used on mathematical contents. It cannot be denied from the outset that there are also concepts lying outside the domain of mathematics which can be manifested in the *form* of mathematical intuition.

### *6. Laws as active principles*

In the previous section, two realms of experience in the process of mathematical intuition were indicated. One comprises the activity of the subject and the other the constitution of contents. We now turn to the activity. Firstly, in the process of mathematical intuition the focus of attention is directed to the content of thoughts. But in doing this a clear consciousness of the activity can also take place. This enables the transition from *naive* to *critical* thinking. In critical thinking one is conscious of the laws of ones activity, whereas in naive thinking, although one is active in accordance with these laws, the attention is exclusively devoted to the contents of thought. By critical thinking we do not therefore simply mean that the law of thinking is made the *content* of thinking. This is certainly necessary as a preparation, but for actual critical thinking it is insufficient.

If one has become aware of this law from observations of thinking and has clearly grasped it in thinking, then in subsequent acts of cognition one can consciously base the thinking process on it. This having actual hold of the law of thinking with regard to the thought content is critical thinking - and from now on only this critical mathematical thinking will be understood by the term *'mathematical intuition'*.

What comprises this law of thinking? It contains the requirement that only those conceptual contents will be considered as thought content which have been brought to manifestation by the conscious activity of the thinking subject. This concerns the components linked together in a concept as much as the connections themselves. The pure laws arising in the form of mathematical intuition in no way result from their own activity. They are totally passive yet nevertheless have an individual existence expressed by their invariability and invariance (see section 5). The invariance of these contents of intuition forms the basis of the constitution of thinking which is determined within itself and is not subject to arbitrariness (see sections 1 & 3). If this fact is not taken seriously then the actual nature of thinking in the form of mathematical intuition cannot be grasped as an imaginative creative process which at the same time occurs totally out of its own necessity.

In contrast to the contents of the process of mathematical intuition, there is the principle, effective and actually active, according to which this process occurs. For, by means of and in accordance with this principle the contents of thought are



an improper hypothesis is the following statement: The period of swing of a freely swinging pendulum is dependent on the length of the pendulum.

A hypothesis with respect to a realm of facts is *proper*, when there are no immediate observations within this realm which justify the hypothesis. There exist only methods of inference which, from the factual material available, suggest the existence of something which is not itself part of this material. Any *indirect* method for the confirmation of realism is an example of this.

In the following investigation, strict attention will be paid to whether we are dealing with proper or improper hypotheses. This is of fundamental significance, because we are not dealing with the investigation of any arbitrary object, but with something which plays a fundamental role in all scientific activity, namely thinking, in particular in its strict form of mathematical thinking.

The natural sciences, especially physics, deeply depend on mathematical laws. If these are not to attract the criticisms of arbitrariness and inconsistency, the manner of experiencing mathematical thinking must itself be established inside the domain of science. In the sense of *naturalized epistemology*[14] this means that this experience should be traced back to processes, especially physiological ones, which can be understood scientifically. On more thorough inspection this shows itself to be a *proper* hypothesis, because nothing experienceable *within* mathematical thinking itself confirms it. In this connection, one should also take into consideration the discussion of the fifth prejudice.[15]

Therefore, it seems reasonable to investigate more closely the independent mode of experience appropriate to mathematical thinking (and to thinking in general). Following Gödel (1947/64) we shall call the process of insight in mathematical thinking 'mathematical *intuition*'. In using this term we are not committed in every respect to the details of Gödel's definition, but we shall by means of experiences of mathematical thinking itself develop more precisely in the following section what we think should be understood by it.

Gödel understands by mathematical intuition, not primarily an immediate knowledge, but a kind of forming of ideas by means of something immediately given. Gödel has not given a more exact definition of the function of or the elements of this intuition; his definition of the concept of intuition was thus challenged from various quarters and rejected as unnecessary.[16]

### *5. Mathematical intuition*

Mathematical intuition must first be distinguished from *idea*, taken here in its usual sense as something that occurs to the individual mind (having an idea etc.). In previous sections we used this word with different connotations following Platonic tradition. Idea in its most common sense means, however, a content which is given to the thinking subject without him having contributed himself *directly* with his own conscious activity to the process of this content being given. Such ideas certainly play an important part in the life of a mathematician, but they come 'by chance' and are not subject to the control of individual consciousness. As a rule however, a fruitful idea is preceded by an intensive occupation with mathematical contents in the 'neighbourhood' of the contents of the idea. Furthermore, following the idea there is the task of finding the actual evidence, i.e. the concrete pattern and detailed interrelating of the contents of the idea with contents already known, for instance, axioms and theorems derivable from them.

What should be understood here by *mathematical intuition* are only those phases of the mathematical work by which the mathematician has a complete clarity and overview of his actions, i.e. where he knows exactly his point of departure and how he reached the contents he is actually thinking about. This implies no devaluation of other phases of mathematical thinking (heuristics, ideas, analogies, games etc.), but these are of a preparatory nature and are not determinative for the ultimately intuitive insight.

Mathematical intuition is bound by two conditions: One concerns the purity of the content produced in thought and the other the manner of its production. By purity of content we understand the complete freeing of mathematical thinking from concrete examples from the world perceived by the senses. Thus, in section 1 it was not a case of any particular circle existing anywhere, but of the principles which govern and constitute all circles.

The manner of production is concerned with the degree of comprehensibility and clarity of the insight into the inner necessity of a thought content being dependent on the extent to which the subject participates in the thinking process. We can comprehend completely only that which we ourselves bring about, bring into existence. Everything given without the subject's own activity is initially a problem for the attentive subject. In mathematical intuition, no content is given to the thinking subject without his having produced it. However, this does not mean that mathematical thinking itself produces its content (see previous section). Rather it means not only following every step of the process, but also *performing* these steps autonomously.

Inside mathematical intuition, two realms of experience can be distinguished from one another: one concerns the subject's activity (see following section) and the other the constitution of the content.

Within the process of mathematical intuition, three properties can be distinguished as regards the *contents of mathematical thinking*, i.e. the contents of mathematical concepts, here also called laws. These properties play a fundamental role in the judgement of the constitution, i.e. of the ontological make-up, of these contents. Attention has been drawn above to one of these properties, namely inner *necessity* and complete *comprehensibility* (see sections 1 & 3). Another concerns the *unchangeability* or *invariability* of the laws by the thinking subject. The laws offer a (passive) resistance to a corresponding test and cannot in their content be either changed or arbitrarily linked with other laws. Put metaphorically, mathematical thinking is 'guided' by the laws in maintaining its state of intuition - like someone's hand consciously feeling a marble relief. The relief does not press the hand, but it does not allow itself to be changed by it. Every apparently successful alteration of a



law leads either to a new one or is confined merely to the concrete relationship of the subject to the thought contents. So-called extensions of concepts or conceptual generalisations (e.g. of the laws of multiplication) are not variations of a concept as such, but an expression of a different perspective of the thinking subject to the corresponding realm of laws.

The independent and self-supporting character of mathematical laws is revealed in mathematical intuition. They are, in fact, in the sense of section 3, invariants of the operations of individual mathematical thinking.[17] A structural principle higher than the operations carried out by the individual subject forms their basis. This is the universal principle of mathematical intuition used, indeed, by all mathematicians, but which none of them own privately.

Here the question arises as to whether mathematical laws are invariant only relative to the thinking subject, or whether they are generally (absolutely) invariant. The *invariance*[18] of laws means that their content cannot be subjected to a change by another being or by themselves. The invariance of laws implies their unchangeability or invariability, but the reverse does not hold true.

It must first be established that there is no experienceable, i.e. not only proper hypothetical, basis for the assumption of a variance or a changeableness of mathematical laws. What changes is at most the individual grasp of or the consciousness of these laws, but not the laws themselves.

The understandable psychological resistance to the invariance of laws is not primarily directed at mathematical laws, but at the acceptance of unchanging laws in general. This appears to be confirmed by so-called everyday experience. But here we do not make it sufficiently clear to ourselves that the acceptance in principle of a variance or changeableness of all laws has the consequence that there must be one or more 'super laws' which do not change and which exhibit with each concretely demonstrable change the structures which remain invariant (the invariants). For, given that law A transforms to law B, i.e. that A is changed in that it becomes B, the question arises: On the basis of which property can B be determined as coming from A? This is only possible when there is a predicate C which is common to both A and B, whereby B, as something still connected with A in some way, can be recognised as related with A. For this however, C must show an invariant property relative to the transformation of A to B, i.e. cannot be subject to change. Therefore the principle C is unchanging and A and B thus do not belong to the realm of laws.

It could be objected that here we are dealing with a proof of only *relative* variance or unchangeableness, but not one of absolute unchangeableness. That is not however the case, because the assertion behind this objection that all is relative is, taken in the absolute sense, necessarily self-contradictory.

From this it follows that the realm of change is not to be established in the realm of laws, but in the realm of phenomena, i.e. the place where these laws operate or take effect. The situation here is totally analogous to the relationship of abstract groups to the elements of their domain of possible transformations. The operations of the groups concern only these elements or sets of such elements (see section 3). - Sometimes the objection arises here that there might also be 'flexible' or 'living'