Lili Kolisko with her daughter Eugenie
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The Path Lemniscate

Lou de Boer

In this journal there is no need to stress the importance of the lemniscate. Also, most readers will be aware of the existence of more than one type of lemniscate. The existence and importance of pathcurves does not need to be elaborated here either.

However, while classifying space-pathcurves (see [3]) I found a new kind of lemniscate, which is presented below.

In projective space $\mathbf{P}_3$ consider the projective map

$$A=\begin{pmatrix} e^{\alpha} & 0 & 0 & 0 \\ 0 & e^{\beta} & 0 & 0 \\ 0 & 0 & e & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad 0<\alpha<\beta<1$$

This map defines a so called tetrahedral system of pathcurves (the coordinate tetrahedron is invariant). For any real t the power of A is defined as

$$A^t=\begin{pmatrix} e^{\alpha t} & 0 & 0 & 0 \\ 0 & e^{\beta t} & 0 & 0 \\ 0 & 0 & e^{t} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad 0<\alpha<\beta<1$$

Since $\lim_{t\to-\infty} A^t\mathbf{v} = (0:0:0:1)$ and $\lim_{t\to\infty} A^t\mathbf{v} = (0:0:1:0)$ for almost all points $\mathbf{v}$, $(0:0:0:1)$ and $(0:0:1:0)$ are called source and sink of our map A.
Consider the 'root points'

$$\mathbf{p} = (1:1:1:1), \quad \mathbf{q} = (-1:-1:1:1)$$

Define the curve L by

$$\mathrm{x}_u=\begin{cases} (0:0:0:1) & \text{if} \quad u=-\pi/2 \\ A^{\tan u}\mathbf{p} & \text{if} \quad -\pi/2<u<\pi/2 \\ (0:0:1:0) & \text{if} \quad u=\pi/2 \\ A^{-\tan u}\mathbf{q} & \text{if} \quad \pi/2<u<3\pi/2 \end{cases}$$

L is a closed analytic curve. It consists of two branches of a pathcurve together with source and sink of our map A.

Project this curve from $c = (0:0:-1:1)$ on the plane $z = 0$ (3rd coordinate). If $-\pi/2 < u < \pi/2$ the line through $\mathbf{c}$ and $\mathbf{x}_u$ is

$$\mathbf{c}+\lambda(\mathbf{x}_u-\mathbf{c})=\begin{pmatrix}\lambda e^{\alpha t}\\ \lambda e^{\beta t}\\ -1+\lambda(e^t+1)\\ 1\end{pmatrix}$$

It meets the plane $z = 0$ for $\lambda = \frac{1}{e^t+1}$, where $t = \tan u$. The meeting point (i.e. the projection) is

$$\left(\frac{\upsilon^\alpha}{\upsilon+1}:\frac{\upsilon^\beta}{\upsilon+1}:0:1\right)$$

where $\upsilon = e^{\tan u}$. In a similar way we find projections for the other values of *u.* Now a parameter representation in cartesian coordinates of this projection is:

$$x=\operatorname{sign}(\upsilon)\frac{|\upsilon|^\alpha}{1+|\upsilon|},\quad y=\operatorname{sign}(\upsilon)\frac{|\upsilon|^\beta}{1+|\upsilon|}$$

where $\upsilon\in\langle\text{-}\infty,\infty]$. In polar coordinates:

$$r^2=\frac{|\upsilon|^{2\alpha}+|\upsilon|^{2\beta}}{\left(1+|\upsilon|\right)^2},\quad \tan\phi=|\upsilon|^{\beta-\alpha}$$

The curve is a new kind of lemniscate, different from

- that of Lissajous/Gerono: $x = a \sin t$, $y = b \sin 2t$
- that of Booth/Bernoulli: $r^2 = a^2 \cos^2 \phi - b^2 \sin^2 \phi$
- and from Watt's curve

$$r^2=b^2-(a\sin\phi\pm\sqrt{c^2-a^2\cos^2\phi})^2$$

For obvious reasons we propose the name *path lemniscate.*

References

[1] Frank Ayres, *Projective Geometry*, Schaum, McGraw-Hill introduction to projective geometry, including maps and matrices.
[2] Lawrence Edwards, *Projective Geometry*, Rudolf Steiner Institute; introduction to projective geometry, including pathcurves.
[3] Lou de Boer, *Classification of Real Projective Pathcurves*, 1997; classification of pathcurves in the plane and in space by linear algebra; it can be ordered at email address *lou.deboer@inter.nl.net.*

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9 with potentially devastating ecological consequences. This project bears a close relationship to the research orientation of the 20s in the field of earth magnetism and also to certain indications of Rudolf Steiner about the so-called 'Third Force' – a clear reference to the work of the inventor Nikola Tesla, whose patented ideas form the basis for HAARP (see for instance Angels Don't Play this HAARP: Advances in Tesla Technology, by N. Begich & J. Manning, Earthpulse Press, Anchorage, 1996).

Recommended reading (in addition to various biographies and recent publications about HAARP): Karl-Heinrich Meyer-Uhlenried, Rudolf Steiners dreifacher Atombegriff – Die geistigen Hintergründe des Atoms [Rudolf Steiner's threefold concept of the atom – The spiritual background of the atom], lecture manuscript, Burchau 1997.

In general, the fruits of Tesla's discoveries (as also those of the non-anthroposophical pioneers of etheric technology already mentioned) have only been recognised and applied in recent years, thus revealing the extent to which they represent the antitype of what was being worked towards in Stuttgart.

28. Author's italics.
29. On the financial preconditions for anthroposophical research, continuation of the foundation meeting of 31.12.1923, 10am, Meeting of the Members of the General Anthroposophical Society, presentations and discussions. In: Rudolf Steiner: The Christmas Conference for the Foundation of the General Anthroposophical Society 1923/1924, (GA 260) Anthroposophic Press, 1990, page 210.
30. "Those who are familiar with the history of the anthroposophical initiatives will be aware that the largest part of what constitutes 'practical' anthroposophy today can be traced back to the experiments and initiatives of those early years. We draw spiritual nourishment even today from what was begun then. The money invested at that time in research has proved to be the most worthwhile investment of the last seventy years. Without it there would be today no anthroposophical medicine, no picture-forming techniques of investigation (.....) If one thinks of the millenium, if one remembers Rudolf Steiner's words... then it is by no means absurd to imagine that we might aim to make such a drastic change over the next decade in the way the resources of the Society are used that by the year 2000 about a third of all the financial resources would be invested in genuine research.." From: Christoph Lindenberg, Wird genügend geforscht? [Is enough research being done?], Mitteilungen aus der anthroposophischen Arbeit in Deutschland, number 173 (1990), pp.179-183.

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Dornach) to solve the important questions about the Strader 'machines'.

Hans Kühn (see also note 18) called it the most important task of that time. The closing sentence of his article in Mitteilungen aus der anthroposophischen Arbeit in Deutschland, Vol. 25, number 4 (1971), pp.291-293 can hardly be overstressed: "If we pull together this train of thoughts, we are justified in describing the Strader machine as the energy source of the future, which Rudolf Steiner said would have to be invented within the next twenty years, otherwise the Ahrimanic 'double' of this machine would appear and be used for purely destructive purposes". Exactly when and where Rudolf Steiner said this is unfortunately not recorded.

There is firm evidence that P.E.Schiller, H.Dechend as well as the factory-owner Dr.Carl Unger had been entrusted with the development of a rotating disc to be used in the production of the mistletoe preparation. However, the suggestion that the famous Austrian forester and authority on vortices, Viktor Schauberger, was consulted on this, cannot be confirmed, despite efforts to secure relevant information from his descendants. See also Paul Schatz's 'Memorandum' of 28th May 1969 (unpublished, archived at Paul Schatz Gesellschaft, c/o Eva-Maria Blank-Schatz, Unterer Zielweg 117, CH - 4143 Dornach) which outlines a more 'gentle' procedure involving forces of levitation and which still awaits serious investigation.

21. From 'Der Kommende Tag, AG zur Förderung wirtschaftlicher und geistiger Werte, Stuttgart – Bericht über das zweite Geschäftsjahr 1921' [report on the second year of business of Der Kommende Tag AG], May 1922 (cf.note 18).
22. Viz. GA259, cf. note 16.
23. Letter to the author from Joachim Bramsch, 27.1.1997
24. Letter of 15.9.1964 from Paul Eugen Schiller to Joachim Bramsch. In passing it may be mentioned that the possession of a doctorate represented an essential 'seal of approval' in anthroposophical circles of the time. This can be seen in the way the work of such outstandingly innovative persons as Lili Kolisko (occasionally addressed as 'Frau Doktor Kolisko' on account of her husband's doctoral title) or Paul Schatz was generally appraised, leaving aside for the moment any prejudice relating to either gender or (specifically Jewish) race.
25. Rudolf Steiner referred in various lectures to the so-called 'Chladni sound-figures' and to certain formative forces which are thereby made visible. (GA101, Stuttgart 13.9.1907 [Occult Signs and Symbols, Anthroposophic Press, 1975]; GA102, Berlin 16.3.1908 [The Influence of Spiritual Beings Upon Man, Anthroposophic Press 1982, p.80] and GA123, Berne 3.9.1910 [The Gospel of St. Matthew, Rudolf Steiner Press 1985, p.59]. Hans Jenny's study of form is implicitly linked to these ideas.

    Similarly, references in various of Steiner's lectures can be linked to the 'ice-crystallisation method' (see H. Heinze: Einiges über künstliche Eisblumen, in: Ehrenfried Pfeiffer: Kristalle (Bericht aus den Arbeiten des Naturwissenschaftlichen Forschungslaboratoriums am Goetheanum, Sonderdruck aus der Gäa Sophia, Orient-Occident-Verlag, Stuttgart/Den Haag/ London, 1930, 25 – 31) developed by Dr.Hans Heinze and Ehrenfried Pfeiffer, which nobody after Joachim Schultz (see note 7) appears to have concerned themselves with, or to Johanna Zinke's study of the forms generated in the air by speech (see for instance Johanna Zinke: Luftlautformen, Beiträge zur Erweiterung der Heilkunst, Sonderdruck, 29(1), 1976 & 31(3), 1978, Gerabronn o. J.; and Die schöpferische Kraft der Laute, in: Die Christengemeinschaft, 56(1), Jan. 1984, 18-29.).
26. This debate must also include the work and the discoveries of Wilhelm Reich. A critical comparison of his and Rudolf Steiner's concepts of the 'super- and sub-natural worlds' has not yet been attempted.
27. As an example, Highfrequency Active Auroral Research Programme (HAARP) might be mentioned by name: this is the acronym for an enormous military project due to commence in 1998/

The Fruitfulness of Goethe's Approach to Science at the Present Time[1]

Jochen Bockemühl

1. Introduction

The current problems in the various fields of human and natural life are generated by a science of nature whose process of knowledge gives priority to what can be done with the results. In its one sided reductionist-mechanical outlook it attempts to come to a reality whose content lies outside human consciousness and experience and is able to continue working separately from it. Modern technology, a kind of reality within which we live to a certain extent, has arisen this way. It is 'value free', because we are not supposed to be 'in it' with our conscious experience. But as a result of this, it has tremendous repercussions for our lives and for that of nature (e.g. computers, genetic engineering, chemistry).

As a result, people increasingly seek a holistic approach to science and for it look to *Goethe.* The issue is basically how, faced with these developments, we can find for our understanding and actions a new and really significant relationship. How can Goethe guide us in this?

Goethe (b. 1749) was alive right at the beginning of the kind of science that looks for a mechanistic cause behind every phenomenon. He did not want to be part of such a science (see his criticism of Newton). His scientific principle was to form concepts in the context of his observations and not to use as explanations concepts derived from another field (e.g. from atomism). He did not want knowledge to be separated from the human being but rather to lift personal experience into consciousness at each step in the knowledge process. He was convinced that every phenomenon encountered has a corresponding way of experiencing connected with it.

Knowledge from this point of view means making conscious the circumstances in which a percept occurs. For any given person, a percept depends as much on his (sensory and spiritual) outlook as the context in which he is placed as observer. *Steiner* (1886) developed further the implications of such an approach to knowledge and stated that the way human beings perceive and think makes up the reality in which they live. This reality changes with the evolution of mankind and even with the development of each individual human being.

If we really accept reality as something within which we live with our perceiving and thinking, then we can experience 'wholeness' when both unite in the process of knowledge. The feeling then arises of having understood. Obviously, there are various sorts of 'wholeness'. A whole table is rather different from a 'whole person' or a 'whole world'. I confront the table, I myself am a human being and I am part of the world. And so too there are different kinds of perceiving and thinking. Goethe took it for granted that the scientist uses not only the analytical thinking of the intellect but also reason and fantasy in the sense of imagination. And correspondingly there are various ways of perceiving that we can consider.

What follows is not intended to be a philosophical discourse but rather a 'characterisa-

tion' in Goethe's sense, insofar as I understand it, of how our approach to knowledge can be taken into consideration.[2]

2. Goethe's approach to knowledge

Goethe described his scientific principles in his essay *The Experiment as Mediator between Object and Subject*: 'However, the individual desiring to set about his work with honesty to himself and others, will perform the individual experiments with utmost care and thus develop data of a high level. These data, placed side by side in concise and easily understood propositions, can then be arranged in the same order in which they developed one by one and can be brought into a logical relationship so that they stand unshakeable, singly and collectively, like mathematical formulae... But these materials must be arranged and set down in a natural series, not put together hypothetically, not arbitrarily systematised.'[3] This means that the observer must be insightful and open to new interrelations which arise when he makes use of his intellect, his powers of imagination and his 'wits'.

'We ought always to set to work as though we were under obligation to give an accounting to the strictest geometer....Thus mathematical proofs are always expositions and recapitulatioins, never mere arguments.'[3] Thus they are not proofs!

2.1 Forming concepts from observing inorganic nature

In his *Theory of Colour* Goethe[4] first showed, and later validated in his essay *The Experiment as Mediator between Object and Subject*,[3] how each condition that one produces in an experiment has a content which is at the same time both sense and thought (spiritual). Both are present in the experiment in that they are assumed and are part of what the observer chooses to look at. Therefore they deserve to be taken into special consideration. Light calls for a concept of it which arises immediately and clearly as thought from the context of the phenomena. Otherwise it would be meaningless for grasping this context. A concept is only useful for grasping the facts presented insofar as it produces, through thinking, the observed context and does not rely just on habit or reproducibility. In this sense light exists in the fact that things appear in an ordered fashion in forms and colours. The presence of light signifies illumination.

The result of an experiment is that a new phenomenon arises transparently out of the assembled conditions. It is possible through various arrangements to distinguish between active and passive illumination ('luminous' ['*selbst hell*'] and 'being illuminated' ['*mithell*']): a shadow occurs on the opposite side of an object being illuminated by a luminous object (lamp). The lamp cannot be seen from within the shadow (cf. Maier 1986).

One can have an experience of something having been proved when the conditions come together in the new phenomenon both sensorially and spiritually (i.e. in thought). Modification and repetition of the experiment serv step by step to allow the context under investigation to become increasingly clear to perception in contemplative thought and is different depending on whether I investigate the context of light or the context of mechanics.

In the field of *optics* I operate as knower in an assemblage of images which at the same time are presented to me sensorially. My concept of light is extended when I move from

13. All this can be seen as a reflection of the extent to which the expulsion (now generally acknowledged to have been illegitimate) from the General Anthroposophical Society in 1935 of Eugen Kolisko and many others found its way – even retrospectively in this case – into the 'official histories of anthroposophical research'. It was perhaps due to his 'omnipresence' that the physicist and mathematician W.J.Stein's place in the Schiller File was nonetheless secured, despite the fact that he had already emigrated to England at the time the Schiller File was put together.

    According to Ernst Lehrs, Stein's crucial question about the nature of warmth was the instigation for Rudolf Steiner's second scientific course (see note 5). Stein remains a figure of key importance for the understanding of many of the issues raised by the Schiller File.
14. Extract from a letter dated 8th March 1948, Spring Valley, published in: Marie Steiner, Briefe und Dokumente [Letters and Documents], Rudolf Steiner Nachlaß-Verwaltung, Dornach 1981, pp. 268-269. Details of the book referred to by Marie Steiner: Râma Prasâd: Nature's Finer Forces - The Science of Breath and the Philosophy of the Tattvas (1894), Kessinger Publishing Company, Montana/U.S.A.
15. First described in Ernst Marti's essay 'Über die notwendige Unterscheidung der ätherischen Bildekräfte von den Ätherarten', Beiträge zu einer Erweiterung der Heilkunst nach geisteswissenschaftlichen Erkenntnissen, Vol.13, number 1 (Jan/Feb. 1960) available in English as 'On the necessary distinction between the etheric formative forces and ethers' in: Ernst Marti, The Four Ethers, Shaumburg Publications, 1984. Günther Wachsmuth's empty response can be found on p.78 of Vol.13, number 2 (March/April 1960) of the same journal.
16. Sources: Rudolf Steiner Das Schicksalsjahr 1923 in der Geschichte der Anthroposophischen Gesellschaft (Vom Goetheanumbrand zur Weihnachtstagung,Ansprachen – Versammlungen – Dokumente, Januar bis Dezember 1923), GA259, Dornach 1991. [1923: Year of Destiny in the History of the Anthroposophical Society (from the Goetheanum Fire to the Christmas Conference, addresses – meetings – documents, January to December 1923, not yet available in English.]. Also the letter referred to above from the scientists in Stuttgart to the Goetheanum cf. Note 7.
17. It may be assumed that the other personalities mentioned in the Schiller File did not have a direct connection with the Kommende Tag laboratories. The titles of 'Dr.' etc. refer in some cases to a later period and should therefore be seen in that context.
18. From the 'Anlage zum Prospekt über M.35,000,000 – neue Aktien der Firma Der Kommende Tag AG zur Förderung wirtschaftlicher und geistiger Werte, Stuttgart', [advertisement for the sale of shares in Der Kommende Tag AG] reproduced in the appendix of the book by Kühn (Hans Kühn, Dreigliederungszeit – Rudolf Steiners Kampf für die Gesellschaftsordnung der Zukunft, Philosophisch-Anthroposophischer Verlag am Goetheanum, Dornach 1978, Chap. IX, 'Der Kommende Tag', 101-124.).
19. In the brief 'Mitteilungen des Bundes für freies Geistesleben' [Reports of the Union for the Free Spiritual Life], Anthroposophie, Vol.4, number 25 (1922), p.6 and in a whole-page Kommende Tag advertisement two issues later (number 27 (1923) p.8). Leinhas refers to a physics/scientific research institute concerned with optical experiments and research into plant colours and peat fibres. Kühn (see note 18) places the latter two within the Physics Institute.
20. This is noteworthy insofar as there is the possibility that work was carried out here on the so-called 'Strader machines', about which – significantly – almost nothing meaningful can be established (cf. Schiller File, item 20). The same is true of a team going by the name of 'Rhythmus und Maschine' [rhythm and machine] in the Stuttgart of the 1920s.

    It is difficult to decide how best to describe the Strader idea – as 'invention', 'motor', 'machine', 'device', 'appliance' or even 'mechanism'. An unsuccessful attempt was made in issue number 107 (1991) of the Beiträge zur Rudolf Steiner Gesamtausgabe (Rudolf Steiner Verlag,

positiver und negativer Materialität (14 lectures, Stuttgart, 1 – 14 March 1920, Rudolf Steiner Verlag, Dornach, 1982) A. Strakosch refers in his memoirs – presumably mistakenly – to a meeting of the Board of Trustees of Der Kommende Tag A.G. which took place in the spring of 1921 and at which he and R.Maier (who "first had the idea for a research institute") were supposedly appointed joint directors.

6. In 1936 Lili Kolisko moved her institute to England, where she continued till the end of her life the work she had begun in 1920.
7. There are reliable reports that Albert Steffen and Günther Wachsmuth, both significant decision-makers after Rudolf Steiner's death, showed no interest in supporting the continuation of the work of the Stuttgart institute. We have no such reports concerning the other members of the Vorstand, in particular Dr.Ita Wegman (1876-1943) and Dr.Elisabeth Vreede (1879-1943).

   It is interesting to compare the fate of Dipl. Ing. Joachim Schultz (1902-1953), revealed in his own notebooks from the time. The above-mentioned request dated 5th March 1924 and signed by eight persons can be found in the KommTag-Mappe Nr.28 der Rudolf Steiner-Nachlassverwaltung under the heading: 'Wissenschaftliches Forschungsinstitut und biologische Abteilung'. This small collection of only a few documents reveals some more fragments of the picture relating to the transition period of 1924.
8. The term 'new way' was used predominantly by the many members who were fundamentally nostalgic for the old 'theosophical' era of the general Anthroposophical Society, which had supposedly been characterised by a refusal to challenge the dominant scientific world-view or to carry the impulses of spiritual science into practical daily life. Note also Rudolf Steiner's references to an 'inner opposition' or to the 'curule chairs' concerning the affairs in Stuttgart.
9. For information on the experiments in Einsingen see Stephan Clerc's Kommentaren zur Schiller Mappe (Commentary on the Schiller File) and the bibliography to this, which are due to be published in the 'Beiträge zur Rudolf Steiner Gesamtausgabe' (Vol. 122). See also the note on the title page of this article.
10. We learn from a recently received copy of a letter with reminiscences written by Hertha von Dechend (1892-1971, wife of Hermann von Dechend, née Schepp) how it was that P.E.Schiller managed to move his work to Dornach in spite of the rejection of the appeal from Stuttgart mentioned earlier. The former assistant to Hermann von Dechend had succeeded in securing funding from "an anthroposophical industrialist". Another surprising revelation concerns the fact that, as leader of the Physics Section at the Goetheanum, Günther Wachsmuth had apparently originally invited Hermann von Dechend to move to Dornach, but that "at the last moment", Wachsmuth had written to withdraw this offer and had asked Dechend to destroy the letter.
11. Known co-workers are: Dr.Otto Eckstein (1894-1944, chemist, who moved in 1926 to work in the chemistry/biology laboratories at the Goetheanum); Frieda Bessenich (1892-1969, who as a result of her friendship with Ehrenfried Pfeiffer moved to Dornach in 1938 and who took over the blood crystallisation department when Pfeiffer emigrated to the U.S.A.); Dr.Heinz Castelliz (dates unknown. Castelliz and P.E.Schiller published an essay on gas jets for use with sensitive flames [Akustisch Zeitschrift 2, Jan. 1937, 11-17]); and Wilhelm Wolf (1905-1984, mechanic by training, who produced the first hand-assembled model of the later patented revolving mirror stroboscope and was also involved in the experiments on the so-called 'sensitive flame').
12. Precise details can be found in the books by G.Wachsmuth and A.Selawry/E.Pfeiffer (cf. Bibliography, [see note 1] and the biography: Ehrenfried Pfeiffer: Ein Leben fuer den Geist, Thomas Meyer, Perseus Verlag, Basel, 1999, ISBN 3-907564-31-6). It is uncertain from which date formal designations were introduced for the various 'departments' of the Natural-Scientific Section at the Goetheanum.

the elementary phenomena of light and shadow to more complex ones such as images produced by a lens.

Through my experience of the *mechanics* of my own body I partake of the mechanical aspect of the world. From the experiences of my own limbs I connect with mathematical precision to load, support and balance in construction.

We encounter another kind of context in *chemical* experiments. The properties of mineral substances are determined by form, colour and composition. Their chemical properties manifest and are given up when they come into contact with other substances. The substances before and after the reaction cannot be observed at the same time. Between them is a temporal, transformational context which compared with a spatial one needs quite a different penetration. In each of these three fields new things can be discovered through a variety of individual encounters.

2.2 Formation and transformation in organic nature

In contrast to an experiment in physics in which a phenomenon is grasped solely out of external laws combined with the conditions found in thinking, one has quite a different reality to deal with in an experiment with plants (or animals). Whereas for the discovery of principles in optics or mechanics, one determines the order of phenomena oneself, with organisms the order of phenomena goes considerably beyond that arranged by the experimenter as instanced by growth and development of a plant or an animal. Here an experience arises of an autonomous whole taking form in the sense world and giving expression to itself.

Goethe wrote in his *Metamorphosis of Plants*: 'When we become aware of natural objects to the extent that we desire to gain an insight into the nature of their being and function, we think we can best arrive at such knowledge through separating the parts.' He valued the advantages of this process, but realised what resulted from this approach: 'The living is indeed dismembered into its elements, but one cannot put it back together again and make it come alive.'[5]

In the sense of onlooker, reductive consciousness, one could say that life has its own conditions and boundaries through which it is accessible to perception according to *its* effects. But as such it belongs to another level of experience, another reality, which only yields to a way of observing that is appropriate to life itself.

Thus for Goethe it is a matter of '...seeing the living forms as such and grasping them in their outward, visible, tangible parts in interconnection, taking them as indications of their essence and thus in contemplation encompassing the whole so to speak'.[5]

He leads our gaze to our capacity to understand a *context of transformation* in what a plant presents to the senses over a period of time or in its sequence of leaf forms. This is different from the *context of the phenomena* with light or the *interaction* of the parts in a mechanism. Life is conceived through this very different way of experiencing. This can best be compared with the way of experiencing the transformational interrelations in chemistry in the sense characterised above.

'How closely this scientific requirement relates to art and imitative instinct probably

does not need to be elaborated'.[5]

But here, for the sake of clarity, we shall do just that, because we do not usually see 'art and imitative instinct', i.e. including fantasy, as being connected with the process of knowledge.

3. Goethe's relationship to the concepts of development of his time

Goethe's knowledge of plants was obtained above all through his excursions with the botanist *F. G. Dietrich* and from the writings of *Linnaeus*. Like most scientists of his time, Linnaeus' understanding of the reality of organisms was one that arose from ideas of creation. Scientists concerned themselves with delineating and systematically ordering these organisms through their outward features. They experienced in this order the world of ideas of the Creator. That the individual organisms developed was obvious and not questioned further. While investigating the systematic ordering they found the morphological interrelationships that run through it and the transformation of simple to more highly organised forms. So they placed this evolution in the world of ideas of a Creator who like an artist in the process of creation from time to time learns to improve his creations.

Goethe too mastered the delineation of the species through exact observation of their characteristics presented to the senses. But in just this way he realised each time how, with the method he was developing, he concretely grasped growth and development as the 'drive' for the observable facts. For him it was not a matter of placing this developmental drive arbitrarily outside the organism. His way of looking at things saved him from separating this drive from his idea of the 'archetypal plant' or 'type' and looking for it elsewhere than in the observed organism. This is described in his writings on form (*Gestalt*) and formation (*Bildung*).

'The German language has the word "*Gestalt*" to designate the complex of life in an actual organism. In this expression the element of mutability is left out of consideration: it is assumed that whatever forms a composite whole is made fast, is cut off, and is fixed in its character.

However, when we study forms, the organic ones in particular, nowhere do we find permanence, repose, or termination. We find rather that everything is in ceaseless flux. This is why our language makes such frequent use of the term "*Bildung*" to designate what has been brought forth and likewise what is in the process of being brought forth.

In introducing a science of morphology, we must avoid speaking in terms of what is fixed. Thus, if we use the term "Gestalt" at all, we ought to have in mind only an abstract idea or concept, or something which in actuality is held fast for but an instant.

What has just been formed is instantly transformed, and if we would arrive, to some degree, at a vital intuition of Nature, we must strive to keep ourselves as flexible and pliable as the example she herself provides.'[6]

Goethe draws attention to two levels of knowledge: One is the *form* which we grasp *intuitively* and hold onto in thought. The other is the *formation* through which we involve ourselves in the mobility shown to us in sense observation by what is 'held fast for but an instant'.

say, I might refer to it only as an illusion: that it would really be possible to achieve in only five or ten years what will take fifty or seventy-five years if we continue to work at the speed at which we are forced to work, the speed at which we are able to proceed through the dedication of such workers as Frau Dr. Kolisko. And I am convinced that if we were able to provide the necessary apparatus, the necessary institutes, to find however many co-workers it would require who could collaborate in greater numbers in the true spirit of the work – that we would be able to achieve in five or ten years what otherwise would take fifty or seventy-five. We would need only around 50 to 75 million francs. We could perhaps then get the necessary results in a tenth of the time. As I said, I put this forward not as a wish, not as a possibility, but only as an 'illusion' – but as a very 'real' illusion. If we had the 75 million francs, we would really be able to achieve what is absolutely necessary. This is something which could at least be considered."[29]

The author of this article would like to take up this 'illusion' and, in conclusion, firstly ask his readers to assist him in further 'pathfinding' by making available any hitherto unseen relevant material, and, secondly, encourage them to take up the practical impulses mentioned in the articles. However, we recognize that the success of any such endeavours still depends on the creation of the necessary supportive framework.…[30]

Notes

The introductory quotation from Simone Weil is taken from her book: 'La Pesanteur et La Grâce' ('Gravity and Grace', Arthur Wills (Translator), Gustave Thibon (Introduction), 1997, University of Nebraska Press. ISBN: 0803298005 p/b.)

(Where English versions of documents are traceable, full bibliographic data are given. In other cases titles are translated. The abbreviation 'GA' followed by a number refers to the volume in Rudolf Steiner's collected works published by Rudolf Steiner Verlag.)

1. Please refer to the bibliography of Beiträge zur Rudolf Steiner Gesamtausgabe, Volume No. 122 (Rudolf Steiner Verlag, Dornach, 1999) listed under the heading: 'Anthroposophical Science and the Research Institutes of Der Kommende Tag A.G. and of the Goetheanum', which contains a complete list of all the documents so far recovered in which there are details of the context of the research and of the specific work undertaken. This is also available, with some additions and a current address list, on the Internet at: http://ourworld.compuserve.com/homepages/Institout/Heft_121.htm.. This web page (in German) gives the fuller version of the footnotes which accompanied the first draft of this essay.
2. Refers to the title and scope of enquiry of the essay under the same title by Walter Johannes Stein, published in: Versuche zu einer Soziologie des Wissens, Max Scheler (ed.), Duncke, Munich/Leipzig 1924, pp. 376-388.
3. A planned publication in the series Rudolf Steiner-Studien (Rudolf Steiner Verlag, Dornach) will contain all the existing documents relating to the research institutes. Brief biographies of all the researchers and further information on their unpublished works will also be given.
4. See Note 1.
5. Rudolf Steiner's second science course, published in English as Warmth Course (Mercury Press, New York,1988), is published in German under the title Geisteswissenschaftliche Impulse zur Entwicklung der Physik, Zweiter Naturwissenschaftliche Kurs: Die Wärme auf der Grenze

subjected to an almost samizdat-like treatment as regards publication. The work of George Adams (formerly George Kaufmann; 1894-1963), who must also be considered as one of the pioneers of research into the etheric, has in part received the same lack of attention as that of Pfeiffer or Erbe. The books of the internationally famous doctor and founder of 'Cymatics'[25], Hans Jenny (1904-1972), are almost all out of print. Further, only recently – on the occasion of the centenary of his birth – did it become apparent that in the work of Paul Schatz (1898-1979) a form of etheric technology ('inversion kinematics') has existed for decades, is used throughout the world in industry and is only waiting for further development.

Again and again one comes across the remarkable phenomenon that in the time following on those years of the '20s the various exponents of anthroposophical research were preoccupied with their own particular fields and thus rarely joined together in the kind of team-work which is common in so-called 'mainstream' science and which often seems like a sine qua non of success. Numerous anecdotes reveal the existence of a considerable degree of indifference towards other, even closely related, endeavours of scientists working in non-anthroposophical institutions.

Notwithstanding all provisos, people of our own generation find this attitude incomprehensible. They look back to the time of their grandparents, to what the Schiller File reveals, to what the 'first-generation' scientists and researchers have bequeathed as their testament. They are also very much aware of what is going on in the 'non-anthroposophical' world, of the research questions of the '20s which in the meantime have become the subject of serious study or the fact that the concept of 'ether' (under the names 'orgone', 'ch'i', 'prana', 'vril', 'morphogenetic fields' etc) has become increasingly widely used.[26] In many other respects, too,[27] the need for a clearly differentiated understanding of and convincing evidence for the existence of the formative forces and rhythmical processes which underlie the natural world has become more and more pressing. The year just past – 1998 – is the very one which emerges from the 'calculation' Rudolf Steiner made at the end of 1923:

"But all these efforts are, from an anthroposophical point of view, fundamentally parts of a greater whole, a scientific whole which is urgently needed in our time – as urgently as at all possible. And if the work in our research institute proceeds as it has done so far, then it will take perhaps fifty or seventy-five years to reach the point which actually needs to be reached: that the many parts join to become a whole.[28] This greater whole will then be enormously significant not only for a path of knowledge, but for the whole of practical life.

People today have no idea of the enormous impact these things can have on everyday practical life, on the production of useful materials and objects and especially on therapeutic methods and products and the like.

Now you may say that human progress has always been slow and that it will be the same in this field also. But it may well be that with the brittleness and liability to fracture of our current civilisation we would not manage in those fifty or seventy-five years to make the necessary connections in order to achieve what it is absolutely essential we do achieve. And so I may perhaps express it – not as a wish, not even as a possibility, but as – I might

The observer can only grasp such an *inner* mobility through the inner activity of participating in the transformation. Through this active mobility the idea 'archetype' or 'type' becomes real in the form of the phenomenon presented to the senses. Indeed Goethe saw how growth and development in nature can only be known through one's mind immersing itself in the transformation of the relationship of the sensorially observed to the conceptually grasped. In this way, development and type were for Goethe directly connected.

Goethe's thinking remained largely with the observation of forms. His efforts to grasp formation wholly in looking at them contemplatively led him beyond the forms to an inner contemplation of transformation which he saw as related to chemistry. Thus he arrived in his studies of the metamorphosis of plants at the 'refining of the saps'.

When people today interpret Goethe's archetypal plant (or type in general) as the '*Bauplan*' or 'systematic scheme' in the sense of Troll's morphology, which can be applied to organisms with the help of variable proportions, it certainly requires a mobility of thinking, but one ultimately has only the static-reductionist reality of the type in consciousness. This way, the specifically living which is only accessible to fantasy is not yet grasped as a characteristic of the type at work in physical substance. It is because people have not taken this chemical aspect of the type seriously enough that there exists an unbridgeable gulf between morphology and physiology.

In fact modern biology has long devoted itself to a field of observation where the relation of chemical knowledge to the immediate appearance of organisms has become lost.

In the following examples of my own work on plants, special value is placed on the methods of observation and thinking in achieving knowledge. It is a matter of noticing how we are connected existentially with a particular reality through a mode of observation as well as what we gain through it and yet how through it we also come up against a limitation to knowledge. In a particular case the question then becomes one of what new perceptions contribute to experiencing the limit as such and going beyond it.

4. Aspects of plant formation

4.1 The intuitive anticipation* of the plant as a starting point

We have at some time in perceiving a plant grasped what it is intuitively. This happens in such a way that for a moment we are totally 'in it' and can return to this initial experience at any time. We can notice how catching sight of an Alsatian dog first of all awakens in a young child the concept 'bow wow' and how a little later the same is uttered for a cow lying in a meadow or a fly crawling on a window pane. Only later does the child learn to discriminate. Adults usually proceed in the reverse: first they see the special example and then rise through abstraction from many individual observations to the general concept.

However, in Figure 1 first of all we see a plant and in it the characteristics of the species nipplewort (which perhaps we would not be able to name) as well as its particular form. The particular is always seen through the mostly unconscious focus on the general.

By intuition I mean an experience that arises just as determined and undetermined as the

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* *'intuitive Vorgriff'*, first impression, *Tr.*

perception of our own self for which we use the word 'I'. As regards my self, I can list only some features or other that I consider are mine. But what this thing is that I call 'I' cannot be expressed. With the 'I' we are dealing with an experience of a limit which also immediately arises when in the same way I think 'plant' (or 'animal'). I am in a very particular *inner* relationship to it. If I want to express what 'plant' is, I am in the same situation as with 'self'. I can only call upon other things so as to lump them together, so to speak, thus forming the concept and fixing it in a particular way from without. I would like to call the initial experience the intuitive anticipation or the first lighting up of the idea in consciousness. As vague as the plant idea (and that of the 'I') is, as definite and certain it is for all subsequent plant observations. Through it the sensory perception immediately becomes an image of the idea simultaneously perceived in one's own being. We direct our individual observations and the approach we take to them to the plant idea or the archetypal plant. It is the illumination in whose light we make these observations and through which we gain an ever richer and changing consciousness. It is like light in that it is itself invisible and we only get to know its real nature gradually through our interaction with the world of phenomena. But in contrast to the idea 'light' as a context of phenomena in simultaneity, 'chemistry' as a context of phenomena in succession (transformational context) or 'mechanics', we have a different, more direct relationship to the archetypal plant. It always appears to us as something formed with a definite formative tendency with at any one time an inner and outer relationship to the kinds of phenomena that belong to it, namely 'light', 'mechanics' and 'chemistry' in the sense characterised in the introduction.

Figure 1. Nipplewort (*Lapsana communis L.*) in flower.

It is important for the following discussion not to forget our relationship to the reality of the plant. If we forget it we arrive in a realm of different realities. These may perhaps be interesting too, but initially they have little to do with the plant. They must be investigated only according to *their* starting points and contexts (e.g. chemical composition, genes etc.).

4.2 Mobility in observing the spatial form

In observing the spatial form of a plant (see Fig. 1), the more we go into the details of the shapes the clearer become the indications of mobility as 'traces of the inner'.

Most noticeable is probably the 'transformation' that we find in the series of leaf forms when they are removed,

work was also mentioned in a positive light. Other than this, however, little emerged from the Stuttgart institute which offered the promise of fulfilling within a useful period of time the hopes which had initially been placed in it. Little was forthcoming of the published material which Rudolf Steiner insistently requested. It is in this light that we can perhaps interpret Steiner's ironic comment that it appeared as if the employees of the institute were merely 'going for a stroll'. And we can perhaps view in the same light the recorded discussions in the so-called 'Dreissigerkreis'[22] and the memoirs of Ernst Lehrs, Alexander Strakosch and the Kommende Tag director, Emil Leinhas, the main motif of which is the failure to break free of a certain stodgy, uncreative conservatism and formalism and to find new, radical and adventurous lines of approach. The opportunity of making a decisive breakthrough had not been seized with both hands before the venture had been overwhelmed by the financial problems which had prevented further progress.

It is also evident that 'formalities' and 'social obligations' played a significant role in preventing a number of the tasks Rudolf Steiner set the researchers from being properly understood or acted upon. The following quotations – relating to P.E.Schiller – are symptomatic of this disabling formality:

> "Mr. Schiller told me that he still regrets not having asked Rudolf Steiner any further questions on this point, but that such a failure [to ask important questions] was not uncommon at the time – out of awe of Dr. Steiner!"[23]

> "Unfortunately, I have been prevented for some considerable time from carrying out my practical work in the laboratory because of my preoccupation with matters relating to the Society. There is now some hope that this situation will change at Michaelmas. I would be very happy if I could return to the laboratory and resume the investigations already begun."[24]

However, it is not yet possible to identify with any clarity what precisely was achieved during the four relevant years, nor exactly what experiments were carried out. We must therefore withhold any final evaluation of the social-psychological context and its problems and attempt to shed some further light on aspects of the situation subsequent to what has almost universally been judged the failure of the Stuttgart initiative.

A sketch of an anthroposophically-inspired research into formative forces and rhythmical processes

That the objections of E. Pfeiffer and Ernst Marti quoted above have not yet been taken on board in many quarters has contributed to the fact that there is still no consistent anthroposophical teaching on the ethers and etheric formative forces. A further problem is that the work of exceptionally gifted scientists and inventors such as Ehrenfried Pfeiffer (who as far back as the 1950s – as well as much other valuable work – invented a process for composting agricultural and industrial wastes) or Hugo Erbe (1895-1965, who worked on specialised preparations for agriculture and on the breeding of novel varieties of grain) has only recently been accorded its due respect. Their important writings still tend to be

"These experiments were demonstrated by Dr. Steiner during his second scientific course, which was held at the Waldorf School in Stuttgart from 1st to 14th March 1920. They show that it is possible, by virtue of placing certain solutions in front of the prism, to exclude the effects of three of the etheric forces: warmth, chemical and light. They therefore demonstrate that these forces can be distinguished from one another purely empirically-phenomenologically, though all are imponderable. Efforts to isolate from the spectrum also the fourth etheric force indicated by Dr. Steiner – the life ether – are being pursued at the Stuttgart research institute of the Kommende Tag AG. Once these experiments have produced the expected results, we will have demonstrated the fourfold nature of the etheric as consisting of warmth, light, chemical and life ethers. It will then be necessary to develop a physics of the etheric. This will of necessity proceed in such a manner as to show that physical matter is the 'ponderable' stuff of three-dimensional space, which exerts pressure, is subject to centrifugal forces and to which the concept of potential can be applied, whereas the imponderable etheric exerts a force of suction*, is subject to universal, cosmic forces and resists the application of the concept of potential."

From: Walter Johannes Stein, 'Vorstellung', 'Begriff' und 'Urteil' in der Lehre Rudolf Steiners, in: Änigmatisches aus Kunst und Wissenschaft – Anthroposophische Hochschulkurse der Freien Hochschule für Geisteswissenschaft (Goetheanum in Dornach vom 26.9. to 16.10.1920), Vol.1,Verlag der Kommende Tag A-G, Stuttgart 1922.

*i.e. where there is the etheric, space is 'emptier than empty'. It contains 'negative materiality' (modern physics so far lacks this concept) and therefore 'sucks'. The result of this suction is that a being makes its appearance. Something that has the nature of Being appears within the phenomenal world. This can be thought of in the same way as the process which takes place when a tone sounds in space i.e. 'appears' as a result of the shaping of the air by an instrument. The 'being' of the sound (the qualitative element) appears within the wave form of the air.

name only – to a fifth, Technology Department.[20]

As regards the rooms used, we know that part of the initial research institute began its life in the basement of the first temporary buildings of the Waldorf School at Kanonenweg 44 (now Haußmannstraße). Later on, the institute was able to move into its own rooms at 44/2 Kanonenweg. Unfortunately, no photographs appear to exist of these premises; there do exist photos of the administration building of the school, in which at the start Lili Kolisko was able to make use of a simple room. The scanty records also reveal the following:

"New laboratories were set up for the chemical, physico-chemical and technical research. A new building has been erected for the physical experiments and for the biological section and will be occupied during the course of this summer [1922]".[21]

Practical results of the scientific research work (1920-1924)

It is well known that Rudolf Steiner referred on numerous occasions to the exemplary nature of Lili Kolisko's work and that he was completely satisfied with the progress of her research. That her paper on the spleen was quite literally boycotted by her colleagues provoked Rudolf Steiner to issue a stern reprimand on various occasions. Rudolf Maier's

laid side by side (Fig. 2) and compared. What seems different when only sense impressions are considered appears closely related with regard to the very mobile spiritual aspect. For example when looking at a plant we focus on something which directs our attention to the plant. Here it is the more specialised intuitive anticipation of 'leaf' through which we immerse ourselves more deeply in the plant as a process of formation. Looking at it in this way our perception is engaged not only in fixing the sensorial facts but also in the activity of fantasy which reaches beyond them and takes us into the process.

Something like this arises when we place Figure 1 on a slant (Fig. 3) and experience a discrepancy between the plant which we have already inwardly identified with (through intuitive anticipation) and the facts presented to the senses. In seeing how a plant is spatially oriented we are led in inner contemplation out of space by (exact) fantasy focused on the subject, i.e. in looking at it we half consciously create a picture of the way the plant grew.

Figure 2. Series of leaves from the main stem of nipplewort: left, cotyledon; right, last true leaf before the flower.

4.3 Developmental processes

4.3.1 Growing, vegetative plants

The spatial form presents us with something which is in the process of becoming and points us towards underlying effects. In following growth and transformational processes our sensorial observation is taken beyond spatial form. We are occupying ourselves with ideas or mental images of pictures of examples of a growing leaf. We immerse ourselves in the temporal sequence. We arrange the leaves side by side in order better to observe the transformation (Fig. 4). The situation we find ourselves in is similar to the one with a leaf series only our relationship to it is very different. With the leaf series (Fig. 2) we have various images of actual leaves existing at the same time side by side and there are no intermediate forms. But with the stages of growth (Fig. 4) there can be as many intermediate ones as we want. However, although in principle we can follow this process with the senses, we cannot do it with actual leaves. We can see only one stage at a time. We are dealing with two levels of reality which nevertheless to some extent interpenetrate. The following phases of development of a nipplewort leaf can be distinguished:

Figure 3. Fig. 1 on a slant.

1. Initial separating out of the leaf tip at the point of vegetative growth – *impulse*
2. Rhythmic segmentation of the basic form of the leaf – *plan*
3. Growth of the blade, lengthening of the petiole – *spreading*
4. Reaching the final form – *form*

This process happens in different ways to every leaf (Fig. 5). The plant as a whole undergoes a transformation. This can also be observed in the leaf series (the outer curve of Fig. 5 is a selection of Fig. 2). Firstly, the simple blade spreads from the plant. Then the leaf as it enlarges becomes more richly segmented. As the leaves become smaller they at first become more striking. Then the petiole and blade merge in that the latter spreads towards the base. Segmentation disappears again and the form gets increasingly pointed. The points on the leaf periphery become clearer too.

This process is expressed in the whole development of the plant. In the phase named 'spreading' by Goethe, the main shoot (in the series in Fig. 2 up to the largest leaf) remains on the ground. At the same time the roots reach downwards. In order clearly to see the formative potential of the growing, vegetative plant and its relationship to the environment it is necessary in this phase to compare examples grown under various conditions of soil and shade such as those for nipplewort shown in Figure 6. Under poor conditions the plant remains small and simple in form. With improving soil conditions the rosette leaves increase in size and become more segmented. The leaf segments become more separate and ultimately can occur as complete segmented leaves with their own petioles. If we look at the selection of central leaves going from 'poor' to 'lush', the transformation reminds us of a water vortex that is breaking up into many smaller vortices. The form becomes increasingly differentiated by repetition of the original form (on a smaller scale).

But the process is reversed: in water or another fluid medium the vortex is activated from without. The forms develop inwardly and as a rule look the same. With the plant the forms arise from within, move outwards and rigidify. Flow is from the inside to the outside, carrying the restrictions to form outward and through repetition of similarities a species-specific motif rendered visible. Whereas the water vortex finally disappears into itself, the

ond standard work on the etheric, pointed during the 60s to a central error in Wachsmuth's book, considered for decades to be the reference work on the etheric. According to Marti, Wachsmuth had failed to make a distinction between the 'general' etheric and the specific realm of the etheric formative forces.[15]

Researchers employed in Stuttgart

We know for certain that altogether between 9 and 11 co-workers were employed on a full-time basis in Stuttgart between 1920 and 1924, receiving their salary from Der Kommende Tag. 16 Those in leading positions were:

- the engineer Dr. Alexander Strakosch (1879-1958), administrative director of the scientific institute until replaced in this role at the latest in February 1923 by the medical researcher Dr. Eugen Kolisko, (1893-1939).
- Dr. Rudolf Ernst Maier (1886-1943), director of the Physical Section and for a time a member of the board of trustees of Der Kommende Tag.
- Lili Kolisko (1893-1976), director of the Biological Section – which developed out of the former 'Department for Contagious Diseases' – until 1923/4.

As assistants or co-workers, we find, in addition to P.E.Schiller:

- Dr. Hermann von Dechend (1883-1956),
- Dipl.Ing.* Wilhelm Pelikan, engineer, (1893-1981),
- Dipl.Ing Henri Smits, engineer, (? - 1969), who joined the fibres department of the Stuttgart Institute on 1st April 1921,
- Dr. Hans Theberath (1891-1971).

[* Dipl.Ing. corresponds to 'Dip.Eng', signifying an academically qualified engineer. Tr.]

Co-workers whose names do not appear in the Schiller File were:

- Karl Lehofer, engineer, (1897-1946), who joined the department of fibres in October 1921, Dr. Johann Simon Streicher (1887-1971), summoned to Stuttgart by Rudolf Steiner in c.1920 to work on the development of plant-based paints and dyes.

In addition there was:

- Hans Buchheim (1899-1987), assistant to R.E.Maier, at first in Stuttgart, then in Einsingen).

Also mentioned in the Schiller File is Dr. Walter Johannes Stein (1891-1957)[17], who kept a close eye on all the research work, as did Dr. Ernst Lehrs (1894-1979). [Please note also the boxed quotation from W.J.Stein on p 52.]

The departments and the rooms they occupied

It has not been possible to elicit with any certainty how exactly what was referred to in certain documents relating to the issuing of shares as 'Der Kommende Tag AG, Scientific Research Institute Stuttgart' was organised, or what the exact number and the structure of the individual departments was. Most documents refer to two departments – a Physics Department and a Biology Department – as, for example, in the only document to have been discovered so far in which the aims of the departments was spelled out in some detail.[18] Yet there were clearly other departments: a Chemistry Department and a Colour Department. The Fibres Department mentioned only in internal records was possibly part of the Chemistry Department. On the other hand, two records only[19] refer – and then by

On the other hand, in the spring of 1926, the young engineer Paul Eugen Schiller (1900-1992), who had joined the Stuttgart institute in 1923, was apparently able to move part of the equipment from Stuttgart to Dornach, where he founded a physics lab (the 'Physics Section of the Scientific Research Laboratory at the Goetheanum') in the two small corner towers of the so-called 'boiler house'.[10] However, it is not clear whether he initially worked alone or whether he already had one or more colleagues. We know for certain that others did join him later.[11] It would be even more important to discover to what extent there were at that time two parallel research institutes operating around the Goetheanum and in what way these collaborated. For it is certainly a fact that Dr. Günther Wachsmuth (1893-1963, director of the Scientific Section from 1924 on) and Dr. Ehrenfried Pfeiffer (1899-1961) had established their own improvised laboratory in Dornach at roughly the same time as the institute in Stuttgart and must be considered as the pioneers of the research into the formative forces and the significance of rhythmical processes.[12]

This part of the whole history in particular remains still to be written. At any rate, what has until now been the standard description of this time – Günther Wachsmuth's own account – refers exclusively to his own role and to the circumstances in Dornach and fails to mention by name a number of important researchers and intimate pupils of Rudolf Steiner.[13] Even more importantly, perhaps, there are in relation to Wachsmuth's own work (cf. his basic texts: 'The Etheric Formative Forces in Cosmos, Earth and Man' [Anthroposophical Publishing Co., 1932] and 'The Etheric World in Science, Art and Religion' [translation available only in typescript from Rudolf Steiner House library, London]) serious objections from two sources, which have unfortunately been given insufficient attention so far.

Firstly, in a letter Ehrenfried Pfeiffer wrote to Marie Steiner in 1948 we find him making the following corrections, in part biographical, in part substantial:

"Nonetheless, I had tried for a long time to support Wachsmuth. One of the reasons why I left Dornach and made no effort to return was that I knew that, had I done so, I would have had to resume the struggle with Wachsmuth. I was afraid of coming off worst and merely wearing myself down without achieving anything of value. The best I felt able to do under the circumstances was to adopt the same tactic you report that [Günther] Schubert employed: that of remaining silent; and, at least as regards the scientific work, of putting my own work and my own views to one side. There are serious differences of opinion between us, for example in relation to the [Wachsmuth's] book on the etheric formative forces, in which in my opinion Wachsmuth should have stated that Dr. Steiner's original indication as to the archetypal etheric forms (triangle – light ether; half moon – chemical ether etc) was in fact taken from the book by the Indian Râma Prasâd entitled 'Nature's Finer Forces', which Dr. Steiner, in my presence, had recommended Wachsmuth to study. Today Wachsmuth stands there as the creator of the theory of formative forces. What Wachsmuth wrote in the 'Lebensgang', or whatever the book about Dr. Steiner is called which appeared several years ago, is, in my opinion, misleading in many places, in particular regarding Dr. Steiner's scientific indications. These things, too, ought one day to be put right."[14]

Secondly, the Swiss doctor Ernst Marti (1903-1985), author of the sadly unfinished sec-

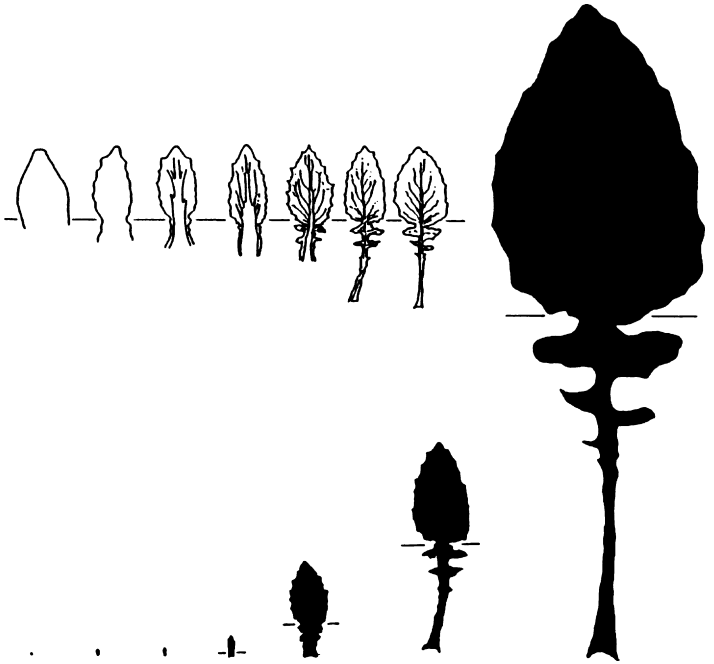


Figure 4. Developmental stages of a central leaf of nipplewort, *Lapsana communis L.* Upper row: leaf blades made all the same size. Lower row: relative natural sizes (see Bockemühl 1966, 1985)

plant forms more and more new, increasingly segmented forms which contribute to its changing shape (Fig. 7).

In the contraction phase a new dominant formative principle takes over: vertical lengthening of the shoots and stepwise transition to flowering. This flowering impulse is closely connected with the light conditions under which the plant is growing. Side shoots burst from the leaf axils. Lower down they are like whole plants but higher up rapidly make the transition to flowering and ultimately at the top are able only to develop flowers (see Fig. 1). The potential of the axils changes in parallel to the change in leaf form. This process also follows the transition to flowering.

4.3.2 Flowering

On the whole flowering appears as a totally new formative principle (Fig. 8). It is usually more characteristic, more impressive than that of the leaves, but it loses the latter's mobile relationship to the environment. The capacity of transformation attributable to light and soil is given up in favour of an integral form comprising shapes and colours (and often scent) which governs the individual organs. There are no axils or axillary shoots. But even in flowers there occurs, like in leaves, repetition of the same pattern (Fig. 2), e.g. when

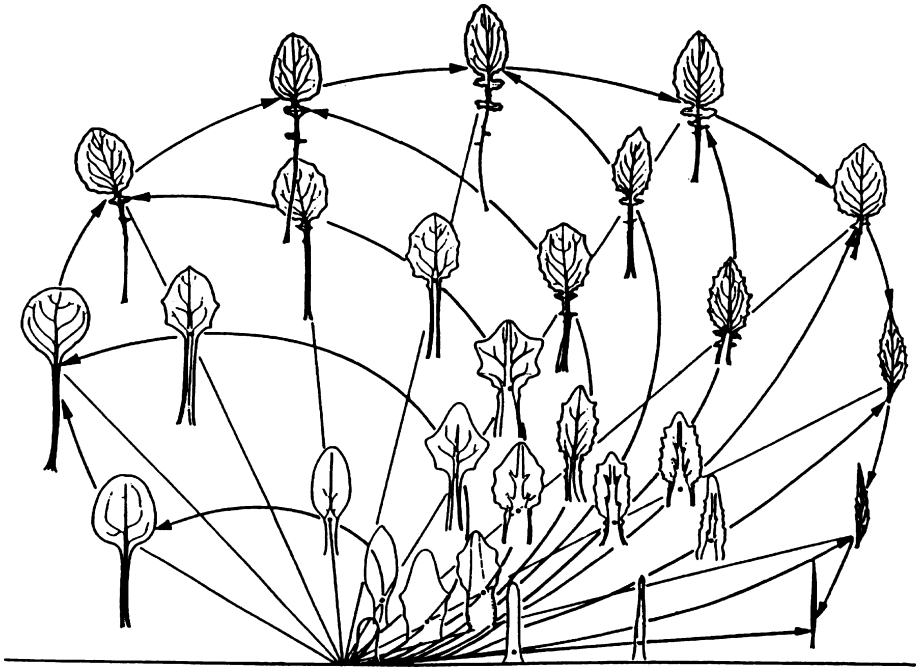


Figure 5. Relationship between the growth of individual leaves (raying out from the centre) and a leaf form series of fully grown leaves (outer curves) of nipplewort.

several flowers, such as with nipplewort, form a 'composite flower' (*'Überblüte'*, Schad 1985) or, for instance with edelweiss, where individual flowers are subordinate to the structure of the little flower heads which in turn are grouped as a whole flower, i.e. a 'composite-composite-flower' (*'Über-über-blüte,* cf. compound umbel (*Tr.*)).

Such structures occur not through better fertility, as we saw with leaves, but as a structural principle. Here, increasing the fertility can have exactly the opposite effect by dissolving the complex form again. Because of this, one would hardly recognise an edelweiss grown in the luxuriant conditions of a lowland garden (Fig. 9). In this comparison there is a reversal: what was expressed as multiplying outwardly in the leaves as in Fig. 6, becomes, in the composite flowers, a formative principle determined from within.

4.3.3 Fruiting

Whereas with flower formation the tendency is towards greatest complexity and concentration in formation, in fruit and seed formation the formative process takes on an inward tendency in that the complexity of the seed can only be grasped with thinking as a *formative potential.*

what can so far be stated with certainty i.e. what has been thoroughly researched so far. At some later date it might then be possible to shed a more wide-ranging and revealing light on those times and to venture a more comprehensive interpretation based thereon. [3] This will inevitably require a partial revision of the views which have so far been held or emphasized in the relevant literature, and of what later commentators have often merely copied from one another without a concern for overall consistency between the available records. This essay aims to provide some indications for such a revision and also to at least suggest some of the fundamental questions which are necessary to establish specific connections to the present situation.

Two contemporaneous research institutes

The 'Akten des Stuttgarter Forschungsinstitutes', (the records of the research institute in Stuttgart, referred to on page 2 of the Schiller File), have not been found and are sadly missed. Were these extant, they would most probably offer decisive information on who exactly was working in the various departments, at what times and on what projects. The scanty and still unpublished records relating to this institute which are so far in the possession of the 'Rudolf Steiner Nachlassverwaltung' (the official administrator of Steiner's estate) and of the Goetheanum Archive reveal nothing fundamentally new, in fact scarcely anything which cannot in principle be found elsewhere.[4]

Nonetheless, it is possible to state, on the evidence currently available, that the Stuttgart Institute came about as a result of the initiative of the scientists themselves and that it was founded in about mid-March 1920 in connection with Rudolf Steiner's second scientific course (GA321) and was most probably deliberately timed to coincide with the formation of the enterprise of Der Kommende Tag AG.[5] However, its existence was a brief one, ending abruptly in the course of 1924, when, on 24th July of that year and in the light of the apparently inescapable financial situation, the general shareholders' meeting voted in favour of the plan for a gradual liquidation of the institute, including a splitting up of the various research areas.

The Biological Section under the direction of Lili Kolisko had already, at Rudolf Steiner's request, been contractually attached to the Goetheanum under the new name of the 'Biological Institute at the Goetheanum, Stuttgart'.[6] In the face of this move, it became impossible for the other sections to continue, especially as an appeal to Dornach for a similar take-over fell on deaf ears.[7] The argument has therefore been advanced that the decisive factor for the sudden liquidation was not so much – as has been often stated – the devastating inflation and the inability of the Company to continue to finance its thus far unprofitable institutes and employees, as rather a lack of interest on the part of the majority of the members of the Anthroposophical Society in such exoteric goings-on, in this so-called 'new way'.[8]

It seems that very few of the employees were able to continue working independently. Only Rudolf E. Maier and Hans Buchheim were able to find in Einsingen[9] a suitable place to work, where they could carry on their particular studies in an intensive manner. We also know of Hermann von Dechend that he continued working alone for a while in the rooms at Kanonenweg 44/2 in Stuttgart.

Towards a History and Sociology of the Anthroposophical Research Institutes in the 1920s

Christoph Podak

This article first appeared in the monthly journal Der Europäer (3, 9/10, July/August 1999) and was originally intended as part of volume 122 of Beiträge zur Rudolf Steiner Gesamtausgabe – Aufgabenstellungen für naturwissenschaftliche Forschungen - Äußerungen von Rudolf Steiner über: Die vier Ätherarten / Elektrizität / Veredelung von Torffasern / Radio (Articles for Rudolf Steiner's Complete Works – Suggested topics for scientific research work – Comments from Rudolf Steiner on the ethers, electricity, refining peat fibres, radio. Rudolf Steiner Verlag, Dornach. Publication expected 1999), but was not included. Rudolf Steiner gave many indications and suggestions for scientific research, often including experimental details. Many of these were during his lectures, which are now largely published, but many more were given in personal conversation with scientists. Paul Eugen Schiller (1900-1992), former director of the physics laboratory at the Goetheanum, Dornach, Switzerland collected together these suggestions so as to make them available as research material for the Science Section of the Goetheanum School of Spiritual Science. This collection, often referred to as the 'Schiller File', is included in volume 122 together with a commentary and relevant references (mostly of German works).

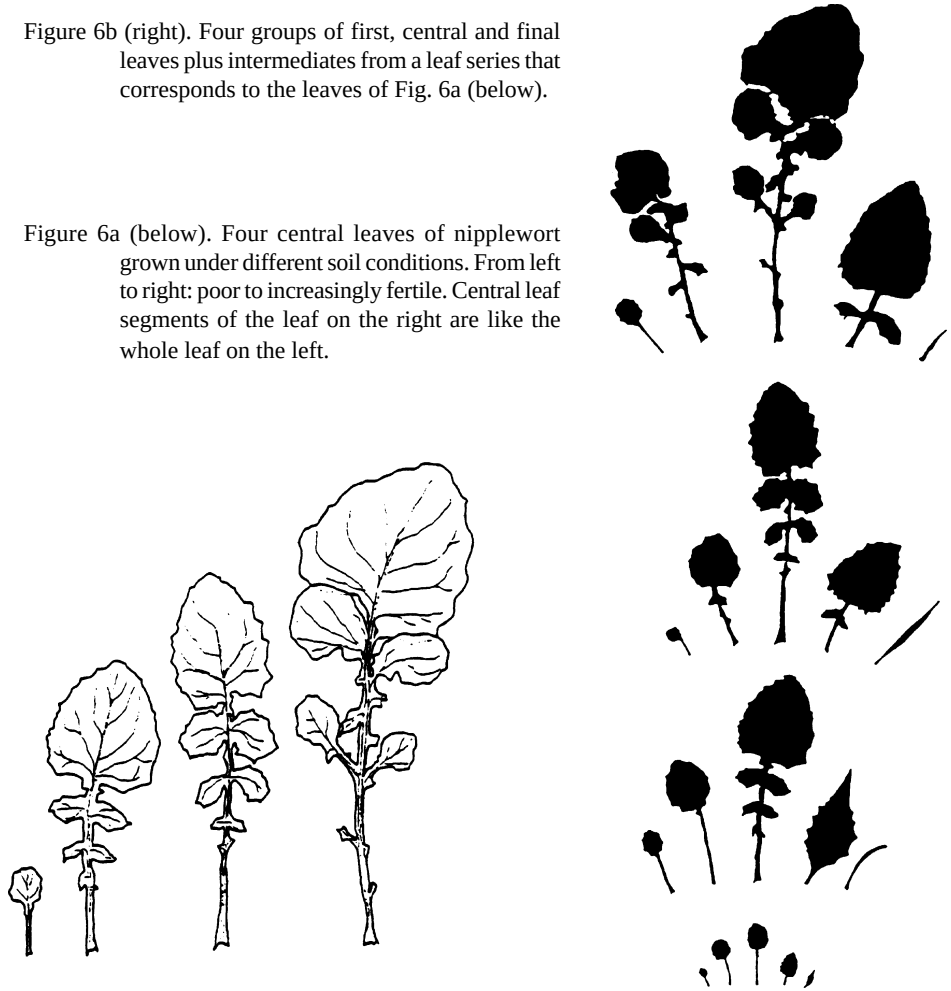
"Two tasks:
To personalize the machine;
to personalize science."
Simone Weil

The history of the 'Schiller-File' reflects at once the history of the research institutes of the 'Der Kommende Tag' Company in Stuttgart and of the laboratories at the Goetheanum in Dornach, as well as of those still continuing efforts to do justice to Rudolf Steiner's intended programme for the development of an 'etheric technology'. A further aspect is that these initiatives are closely connected with the history of the anthroposophical movement itself. The task is to sketch these connections and their historical-institutional context or at least to describe these in a concise way. [1] But because part of this story concerns what those individuals involved wished to achieve and actually achieved, a report on the main milestones and results of these efforts must include an attempt to reconstruct a 'sociology of the circle around Steiner'.[2] This in turn means an unavoidable confrontation with the problems surrounding attempts at anthroposophical community-building, so that a History and Sociology of the Anthroposophical Research Institutes in the Twenties and of their leading personalities has a single aim, seen in the one case more from the simple facts, in the other more from the point of view of the motives, the interpersonal relations and the effectiveness of the research in the outer world.

In view of the still inadequate state of the source material, I shall first attempt to describe

Figure 6b (right). Four groups of first, central and final leaves plus intermediates from a leaf series that corresponds to the leaves of Fig. 6a (below).

Figure 6a (below). Four central leaves of nipplewort grown under different soil conditions. From left to right: poor to increasingly fertile. Central leaf segments of the leaf on the right are like the whole leaf on the left.



5. Tendencies and limits experienced in traversing the formative stages of plants

What we experience in this approach as the relative wholeness of the plant changes in the course of its life:

– the *seed* awakens in us the expectation of a growing plant. We must place it in certain conditions which correspond to it;
– the *growing*, *vegetative* plant gives us a picture of the invisible light and soil conditions;
– the *flowers* present an integral complex form which becomes independent of the vegetative plant which, whilst it appears together with it as its easily recognisable 'gesture',

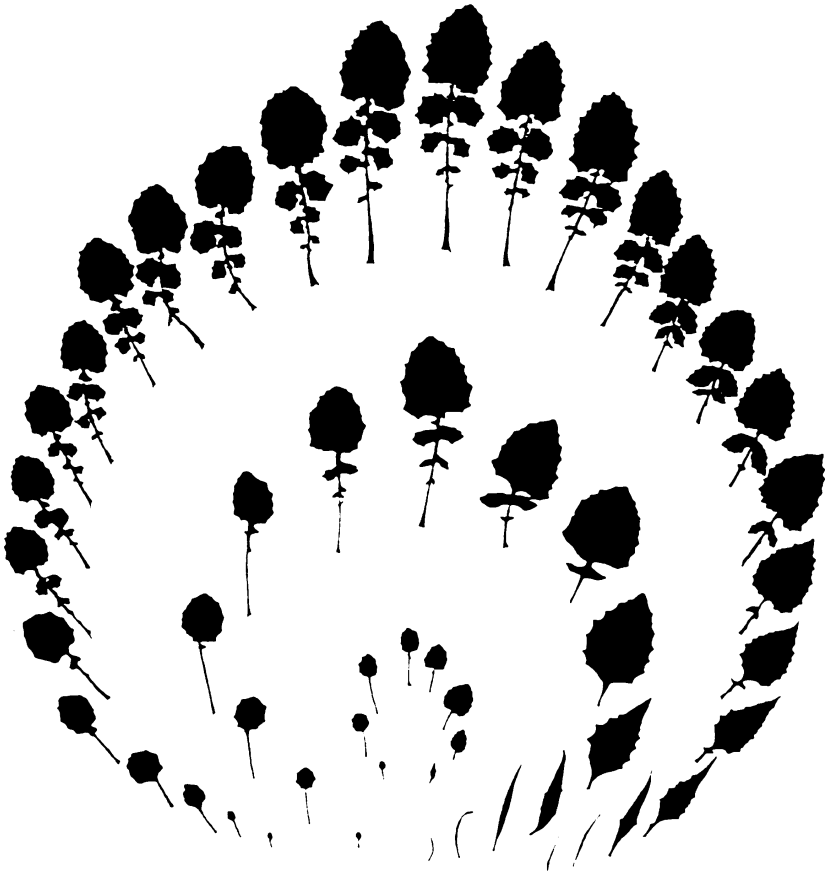


Figure 7. Complete leaf series which corresponds to the first three leaves of Fig. 6 (see Bockemühl 1992).

cannot be deduced from it;
– as we proceed from observing the flower we come once again to the *seed*, the most comprehensive representative of the living plant. When we look at it inwardly, what we hold in consciousness as formative potential has a real connection with the little grain which we can once again sow in the ground.

Between these stages are transformations which are basically no longer describable in terms of 'spreading and contracting' and 'refining of the saps' in Goethe's sense. The tendencies and transformations of this process of development result from the following stages:
– becoming aware of transformation;
– finding in it the traces of thinking;

Karl Julius Schröer (1825-1900) – Teacher of Rudolf Steiner
A Biographical Sketch

David Wood

While August of this year marks the 250th anniversary of Goethe´s birth, the year 2000 marks the hundredth anniversary of the death of the great Goethe scholar Karl Julius Schröer, the "dear teacher and fatherly friend" of Rudolf Steiner. Born in Preßburg (now Bratislava) on the 11th Jan. 1825, Schröer attended the universities of Halle, Leipzig, and Berlin, where he studied philosophy, theology, philology and the history of German literature. Early on he was attracted to Germanic folk dialects and customs, becoming well-known for his publications on the Oberufer Christmas plays. In 1849 Schröer was called to the chair of German Literature at the University of Budapest. He transferred back to Preßburg in 1852, and then to Vienna in 1861, where he was made director of the city's evangelical schools. The fruit of all this educational work was the small volume Unterrichtsfragen (Questions of Education), a book which Steiner believed "should be counted among the pearls of pedagogical literature" (cf. Steiner´s autobiography, and especially the book The Riddle of Man). From 1866 to 1895 Schröer taught at the Technical College of Vienna, where he was Professor of the History of German Language and Literature. It was here in 1879 that Schröer and Steiner first met, when the latter became a student at the college. Schröer dedicated the second half of his life almost exclusively to Goethe. The Vienna Goethe-Verein (Association), was largely founded as a result of his initiative (in 1878); while the first eight years of its literary organ – the Chronik – owed its originality and vitality to Schröer´s countless Goethe studies. The 1881 publication of his edition of Goethe´s Faust only served to reaffirm Schröer´s position as one of the leading Goethe scholars of the time. With an extended commentary, and detailed historical introductions, it was a model of inspired Goethe scholarship. Not long after Schröer was called upon to participate in the renowned Kürschner edition of Goethe´s works. – And indeed, it was Schröer himself who recommended the 21 year old Rudolf Steiner to Joseph Kürschner for the task of editing Goethe´s scientific writings (in June 1882). In addition to writing the above foreword to Goethe´s scientific writings (which introduces Steiner to the scientific and literary world), Schröer also edited all of Goethe´s dramas. – His commentaries and introductions to these dramas form some of his most extraordinary and brilliant work. In 1884 Schröer published what is perhaps his most beautiful literary and spiritual legacy – the little volume: Goethe and Love (to be published in Autumn 1999 by Mercury Press). This small book wonderfully illustrates two of the most important aspects of Schröer´s unique personality – his sublime philosophical Idealism, and his lofty conception of love. Karl Julius Schröer passed away in Vienna on the 16th December 1900, aged seventy-five years.

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His scientific writings exhibit the deep background of his spiritual life, and his poetic works arouse an interest in these researches. He has already powerfully worked upon our culture for an entire century, while our understanding of his work increases daily; and thus in the future his influence will be still greater, especially that of his scientific writings.

Then at last we shall recognize, that the originality and depth of the German spirit consists in the fact that our greatest poets, Schiller and Goethe, are also our greatest thinkers.

Föherezeglak, Hungary, 28th August, 1883. K. J. Schröer.

Translated from the original German by David Wood

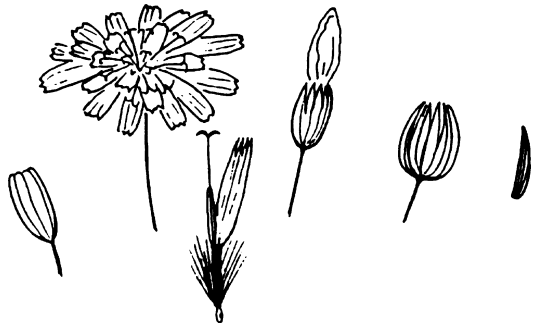

Figure 8. Flower bud, flower head, single flower, closing flower, seed head and seed of nipplewort, *Lapsana communis L.*

– taking these further through pure thinking in order to experience limits, changes of direction etc. as with a process of geometric deduction;
– bringing the mode of observation developed out of the facts of the sensory phenomenon once again to the phenomenon, so as to encounter the unmistakable 'gesture' of nipplewort through which again and again we can recognise it.

Any botanist knows this last stage of being so familiar with particular plants observed in the field that they seem as if part of oneself. But this experience of identification is by and large not made sufficiently conscious or pondered with discrimination.

In what I have described it is only a matter of form insofar as it points to a process of substance transformation which is to be grasped as a formatively mobile tendency. I am referring to transformation as an aspect of giving substance to something and as seeing plant chemistry as a context of transformation. In trying to grasp inwardly the formative tendency of each stage, one experiences inner limits each time in that one notices how, in the consequences inherent in the transformation, the plant would have to give up existing if a change of direction were not to intervene:

– the green leaf as it continues to multiply would dissolve into its environment like a water vortex (Fig. 6);
– the flower would come to its limit in the continued increase in complexity of its formative principle towards the composite flower and composite composite flower (Figs. 8 & 9);
– the increasingly universal formative potential of the seeds would bring the plant close to its archetype thereby no longer being able to manifest to the senses;
– therefore, in the germination and growth, the plant once again gradually forfeits its universality.

In the transition from the leaves to the flowers and from the flowers to the fruit and seeds we can thus discover inversions (*Ümstulpungen*) which cannot even occur hypothetically

Figure 9. Edelweiss *Leontopodium alpinum Cass.* Left: Example from the Alps with a composite composite flower comprising several flower heads (cf. compound umbel). Right: Example from a lowland garden showing how the fertile growth breaks up the composite composite flower into a disordered flower of isolated flower heads (drawing by Silvia Briner).

in what is presented to the senses.

To think such a process in such a way that one's experiencing of it proceeds without a sensory support is possible with the help of projective geometry (Locher 1937, Adams & Whicher 1979). It provides a kind of guide enabling the qualitative transformations to become inwardly perceptible.

The way which has been sketched out here is based on observations of form. It can be enhanced through appropriate mobile attentiveness to other observable characteristics which cannot be discussed here such as colour, composition, scent and taste.

In the 'chemistry' of this inward process of transformation two things become directly observable when the concepts about the areas under study are, as described in the introduction, kept open to the extent that their language which expresses the qualities of life of a place can be read or 'heard' (Bockemühl 1978 & 1982). One is the 'effects' of the light

not perhaps advisable for everyone. Thus here the divinatory nature of his spirit certainly comes into play, correctly leading and guiding him. And if one moreover takes into account the serious and conscientious manner of his approach, then the designation of his endeavours as dilettantism can hardly be justified. He shuns no effort, neither in the collecting and examining of materials, nor in the impartial pursuit of every consequence.

Regarding method, he seeks to present the facts in such a fashion that they themselves become audible as it were. He approaches the object selflessly, ever on guard against self-deception.

It seems to me without a shadow of a doubt that the divine sparks of genius are just as recognizable in Goethe's scientific writings as they are in his works of poetry. The gifts of genius are ever precious. Science has workers galore, yet few spirits bearing new impulses. Had Goethe worked as an academic teacher, educating students to penetrate ever more intimately into his perceptions, then his school would have certainly attained great renown, even if only by virtue of its connection with the whole development of the scientific and spiritual life in Germany, out of which Goethe's endeavours grew.

However it goes without saying that the matter stands thus – those who wish to intercede for Goethe have to swim against the tide.

We have started to understand and explain Goethe's poetry from out of the whole of his nature, out of the totality of his writings. Yet his writings on natural science have not received a treatment in like manner.

It is thus with pleasure that I greet the undertaking of the editor of these natural scientific writings of Goethe.

Proceeding from the study of natural science, I have seen him drawn to Goethe's personality. He has applied himself to the study of these writings with devoted enthusiasm. He has reached the conclusion that they are only to be judged in connection with the whole of Goethe's being. He believes that the key to Goethe's entire thinking is to be sought in the spiritual life of his age. Although Goethe is not assumed to be a philosopher, it yet appears that he was stimulated by contemporary philosophical streams, as well as also influencing them. In this regard the editor does not omit to quote from the direct sources, and to strive for clear historical conceptions.

Although I do not permit myself to enter the province of the natural sciences, I cannot but concede that the self-harmonizing conclusions that I daily perceive among all these endeavours, must be a guarantee that the comments and explanations which accompany these natural scientific writings of Goethe will also of necessity be a furtherance to their understanding – something we have not previously had, and an assistance for which the attentive reader will undoubtedly thank the editor, despite perhaps not agreeing with him in every detail.

I believe myself justified in saying this as the first volume now lies before me in manuscript. I feel confident in expressing the hope that this will also be the case for the following two volumes. May this undertaking be a considerable contribution to the appreciation of Goethe's position with respect to science!

Goethe has not only worked upon our folk in a rejuvenating manner by means of his poetic works of art; it was also granted him to have an influence upon scientific currents.

endowed spirit.

Yet poetically, he isn't then inclined to follow empty formations of the imagination. Does he himself not especially mock those opponents when they demand that one see, what in truth one did not see.

If we were afraid of arousing antagonism with the preceding words, then we will certainly not help our case further by saying: we particularly protest against the commonly held misconception that Goethe's scientific endeavours are only to be considered as an amusement he enjoyed in his spare time, after the diminution of his poetic powers had occurred.

Such an opinion is simply not historically tenable. His entire tendency in this direction was already evident in his youth, simultaneously developing in him with the inclination towards poetry, with which it thoroughly harmonized, and from which it cannot be separated.

Goethe's scientific works are the deeds of genius, rooted in the observations of his early youth, harmoniously developed throughout his life, and standing in complete harmony with his entire being.

I freely admit that I myself have only gradually worked my way through to this view. However since that time Goethe's scientific writings have appeared to me in a completely new light, and I have studied them with great profit. With every passing day I perceive ever more clearly their connection to the whole of Goethe's being, and to me this naturally increases their value.

When dealing with genius it is not so much a question of right or wrong, as one of understanding! – If one realizes this, then one can find consistency and harmony in his manner of thinking. The mistakes and ludicrous errors that are so often attributed to Goethe are simply impossible for the disposition of such a towering spirit.

To be sure, no-one is infallible, and Goethe is also not. In some of his judgements he constantly changed his opinion, hence he must have been repeatedly in error. Such an error can always be understood within a larger context, so that a point of view must be found in which he is also correct. If one is able to demonstrate such an error of this kind, then one may clearly see which presuppositions led him to it; and from this vantage-point we shall be content, and continue to behold his mighty spirit with exaltation. We recall a number of such cases – thus for instance: in his early youth he deeply and profoundly recognized the significance of Gothic architecture long before any of his contemporaries; it then disappeared from his horizon so that he no longer appreciated it, until he finally drew near to it again, becoming captivated afresh!

If one can point out a Goethean error – indeed perhaps not in such a comprehensible fashion – then it is probably appropriate to reflect upon this before taking a matter less seriously than he himself did. Above all it is worth noting here that empiricism was never a contradiction for Goethe; for this is where he begins, and he observes very precisely. What was contradictory however, were theories he could very easily comprehend, yet he failed to accept them if they could not be empirically proved.

If one historically follows Goethe's scientific studies then they have without question a somewhat unschooled character; and he openly proceeds to the object in a manner that is

and soil etc. and the other is that the relationship we have attained of the plant to an aspect of our own being creates an organ of perception for healing it. Only in such circumstances does the knowledge of conventional chemistry take on a concrete significance in the totality of the plant.

6. Conclusion

As Schiller followed the work of his friend Goethe on the metamorphosis of plants he came to recognise the significance of the connection between the life of the plants and the human being and composed the following verse:

Do you seek the highest, the greatest?
The plant can teach it to you.
What it is passively, let yourself be it willingly – that's how it is!

In the preceding discussion an attempt has been made to transform methodologically what the poet saw into a realistic relationship so that on the one hand in observing and contemplating plant formation we become aware through our own activity of the experiences of limits and, on the other hand, so that in such contemplation a real capacity for perception develops that can be applied practically (e.g. in ecological issues or medicine).

The Goethean approach to science can give a direction in other areas in that when dealing with a concrete problem it allows the development of the inner capacity for observing the gestures of one's own activity in the context in question.

Notes

1. This article is the text of a lecture given on 22 May 1994 at the conference *Goethe scienciato* in Milan.
2. For the approach I have taken in this article I acknowledge the work of Goethe, Steiner and many others whom I cannot mention all by name here. Georg Maier has been especially helpful to me with his approach to forming concepts in physics and his involvement with aesthetics. However, here I am concerned with understanding what has been shown and not whether somebody or other has already said it. (see also *Amrine* 1987).
3. Goethe, J. W. von (1793) *Der Versuch als Vermittler von Objekt und Subject* (Goethe, edited by Steiner, II, 10-21) originally published in *Natural Science in General: Morphology in Particular,* Vol II, No. 1 (1823), translated by Bertha Mueller in *Goethe's Botanical Writings,* University of Hawaii Press, 1952, *The Objective and Subjective Reconciled by means of the Experiment,* pp 220-227.
4. Goethe, J. W. von (1810) *Zur Farbenlehre.* (Goethe, edited by Steiner, III, 71-528). For an English translation see for instance Charles Lock Eastlake's translation, John Murray, 1840, republished by MIT press in facsimile, 1970.

5. Goethe, J. W. von. (1790) *Metamorphose der Pflanzen* (Goethe, edited by Steiner, II, 17-60) For a complete English translation see *Goethe's Botanical Writings*, Bertha Mueller, University of Hawaii Press, 1952, *The Metamorphosis of Plants.*
6. Goethe, J. W. von (1807) *Zur Morphologie: Die Absicht Eingeleitet.* (Goethe, edited by Steiner, I, 8). *Goethe's Botanical Writings*, Bertha Mueller, University of Hawaii Press, 1952, *On Morphology: Our objective is stated.*

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Translated by David Heaf from *Elemente der Naturwissenschaft* **61**(2), 1994, 52-69.

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causality, despite the fact it follows a different kind of lawfulness. But it is true, one must indeed designate it as physical or physiological if one would explain how out of the known causes the life of an organism could originate from the combined working of the motors. However, as long as we are unable to do this, yet still continue to use those means by which we normally explain the physical realm, then we will be forever adhering to particulars, forever only having the parts in our hand, but unfortunately lacking the spiritual band. Goethe therefore directed his sight upon the whole, upon the necessary, the typus, and it was this that led him to his great discoveries. One can divest him of these discoveries, and say that others came across them independently. However, their significance does not consist in their what, rather it lies in the relation they have to Goethe's entire view of nature, from whence they have sprung.

The reproach of mysticism leveled against Goethe's view really does not say much. He cannot help but consider one object as more unveiled, another as more concealed. Whoever fails to notice this will not be able to enlighten us any better, and we certainly do not gain anything by simply setting the nearest machine with all its machinations on the same par as the substance-transforming life of the organic realm.

However we should fully bear in mind what really transpires when using this abbreviated method of explication. It thus allows the vast fullness of the life-conditions of millions of beings in all their diversity to appear analogous to the meager productions of the human wit, thereby naturally appeasing itself to the great satisfaction of mediocre minds. Opposed to this, Goethe´s conceptions also seek to apprehend the vast richness of the phenomenal world, yet he does not accept the derivation of the living organism from out of the lifeless, as long as the latter only exhibits laws of such a kind as do not appear to be active in the organic world. Goethe certainly took upon himself a difficult problem with his studies on the laws prevailing in the organic realm, proposing higher tasks for research, going in search of more complete truths. And if he is accused of mysticism, then it should be noted that in the face of all ecclesiastic tradition he remained true to his heretical views from early youth, indeed right up until the end of his life; not deviating for an instance, and never becoming involved in hypocrisy. That he was able to perceive in a vivid and wondrous manner those things in the sense and moral worlds which astound us without us being able to explain them; that he likewise venerated the mysterious in them in accordance with a higher purposefulness, nay looked upon it in adoring admiration, is indeed proof for us of the depth and soundness of his spirit. – How he conceived the most sublime of all mysteries, the unified principle of the universe, its causes and continued existence, and even God Himself – he was only able to express in poetic and allegorical discourses: "I have no name for it. Emotion is everything; names are but sound and smoke." – Compare the poems entitled God and World: Proömium, World-Soul etc. Wherever the hasty and rash intellect is satisfied with an incomplete and pretended knowledge, and perceives a void in those things which represent the richly prescient forms of faith among humanity, we find in Goethe an abundance of thoughts and feelings, and the demand for a higher truth, one that presupposes a mightier light, corresponding to the fullness of his rich spirit. Thus he sympathizes with every devoted and elevated kind of faith, as opposed to the sterile nature of nihilism; every faith is related to his positive, creative and rationally

world with fresh new senses. We recall how Fichte recognized the German spirit to be an unmixed, original folk, standing in opposition to what is unoriginal, and hence also to a faith based upon Roman authority. He too perceived the archetypal spirit therein, and just as it organically arose, so this spirit is also directed toward a knowledge of the organic. French materialism conceives the domain of the living to have originated out of inorganic nature, apprehending it as a mechanism, without recognizing its inherent lawfulness. We find something similar to Fichte's conceptions in Schelling. The stream of cause and effect is suspended through organization; cause and effect cease to be purely physical in the organism; they receive a character determined by means of a principle belonging to life itself.

Yet these are only views introduced prior to Fichte and Schelling by Goethe himself.

Indeed, this idea concerning organic life had already formatively appeared to Goethe in his Leipzig student days. In a song from this period called: Die Freude (Joy), he gazes at an iridescent dragon-fly, which suddenly appears unattractive when robbed of its freedom of movement, leading him to cry out: "Thus it is so with you, dissector of your joy!" This then resulted in his attention being directed upon the idea of organic life, and we see how he became captivated by this conception and sought to develop it further. On the 14th July 1770, concerning the attempt to capture beauty "as one captures a butterfly," he wrote: "The corpse is not the whole animal; something else also belongs to it, life itself, the spirit, that endows everything with its beauty. – Forget this killjoy passion for the empirical, that exterminates our summer birds and anatomizes our flowers." – And if we here rejoin that well known passage from the first part of Faust, (1582 ff.) then we are no longer in any doubt – that what is demanded here is indeed a spiritual comprehension of the organic world:

> Who wishes the living to know and describe,
> Seeks first the spirit thence to drive,
> Then all the parts he has in his hand,
> Lacks only, alas! the spiritual band!
> Chemistry calls it encheiresin naturae,
> Mocking itself, unbeknownest.
>
> *Trans. Olin. D. Wannamaker*

Chemistry calls that which it is unable to fathom, the manipulation of nature. And by means of this expression therefore derides its own powerlessness without even realizing it. And we do not need to emphasize that Goethe knew how to value chemistry and anatomy in their rightful place.

It is striking how the aptness of the above verse is immediately convincing, is upon everyone's lips, and yet the science that seeks to understand the living organism proceeds in this same condemnable manner.

Goethe certainly did not reveal the final secrets of life itself, as little as his opponents were able to. He simply proceeded straight to the phenomenon of the organic in its totality, and sought to apprehend it, while other researchers looked for it in mechanical-physical

Participation, Co-operation and Adaptive Mutations: Complementing Ecological and Evolutionary Paradigms

Johannes Wirz

Introduction

Ecology, genetics and evolution face major transformations. The current foundations of evolutionary biology, i.e. *random variation*, *competition* and *selection* (for a review see Ford 1964), do not fully account for the description of evolutionary processes. In particular, one of the supports of Darwinian evolutionary theory – the peppered moth (*Biston betularia*) and industrial melanism - has provoked renewed questioning (Coyne 1998, Majerus 1998, Holdrege 1999). The shift from light colored to melanistic forms of the moth is said to be the result of darkening of the tree trunks in heavily polluted areas and of subsequent selective removal of the conspicuous forms by predaceous birds. This is untrue for several reasons. Firstly, the moths do not rest on trunks (in 40 years not more than two moths have been observed in such positions). Secondly, the resurgence of the light forms occurred well before the tree trunks had been recolonized by (white) lichens. Thirdly, the moths show no tendency to choose matching backgrounds. The conclusions are clear. The story of the peppered moth shows evolution in action, but does not support Darwinian interpretations of random variation and selection.

Besides these critical arguments against the classical foundations, a number of new observations in genetics and ecology await integration into the evolutionary paradigm. Recent studies have revealed additional principles shaping biological processes, the form of organisms and their interactions with the environment: *directed* or *guided variation* and *co-operation.*

These principles challenge the reductionist paradigm, which considers biological processes and organismic form to be the result of complex molecular interactions ("bottom to top view"), since they suggest qualities like intelligence, insight and wisdom which are normally attributed to conscious beings. This lies at the heart of the ongoing transformations, because it requires not only enlarging the methodological and conceptual tools for studying ecology, genetics and evolution, but asks for a radical new conception of life and life processes ("top to bottom view").

Some 200 years ago, J.W. Goethe anticipated such a transformation by introducing the *idea of the archetype* (*Typusidee*) as a basic concept to the science of organic nature. As will be shown, his theory does not conflict with modern biological paradigms. On the contrary, it integrates them into a holistic view. What distinguishes Goethe's conception is the acknowledgment of the spiritual quality (*Geist*) of nature. It was his deeply rooted authentic experience that the inanimate, as well as the organic world reveal their nature or essence by means of sense perception and thinking process. Accordingly, the discrimination between sense perceptible world and idea is not inherent in nature itself but effectuated by man (Eckermann 1830, Steiner 1897). Thus, in doing science man *participates* in nature's material, as well as ideal productivity.

In the present paper, Goethe's epistemology of organic nature will be outlined. The

methodological concept of *participation*, and the significance of *co-operation* and *directed* or *adaptive mutations* for ecological, genetic and evolutionary processes will be shown. These new views, including investigations from the Science Research Institute at the Goetheanum will be put in relation to Goethe's conception of organic nature. Finally, some pertinent consequences will be discussed.

Goethe's conception of organic nature

In the work published after his death (cited in Kuhn 1964) Goethe outlined a general conception of his theory of organic nature. The appearance of living beings is governed by two laws: the *law of inner nature*, which reveals the constituting idea of life, and the *law of outer circumstances***,** which provides insight into the spectrum of modifying forces.

In his manuscript "*Preliminary studies towards a plant physiology"* (*Vorarbeiten zu einer Physiologie der Pflanzen,* cited in Kuhn 1964, Steiner 1891) these two laws are further differentiated. The law of outer circumstances can be derived on the basis of seven auxiliary sciences – systematics, physics, anatomy, chemistry, life history, physiology and morphology, in the sense proper to "*Gestaltlehre*". These auxiliary sciences deal with distinct observable aspects of living beings (today, additional disciplines like genetics, ecology etc. would have to be included, as well). Integration and synthesis of descriptions, laws and conclusions obtained in the seven sciences by the power of the mind result in *morphology in the expanded sense*, the discipline for approaching the law of inner nature. Goethe advocates calling *morphology in the expanded sense,* 'theory of processes' (*Verwandlungslehre*).

The science of organic nature follows two branches which are intimately connected to each other. Both benefit from the existence of the other. In a first step, the law of inner nature provides the inner orientation for investigating life and life processes, often by mere intuitive feeling. A different set of questions and categories is used, dependent on whether plants or animals are studied. Next, the law of outer circumstances with its seven disciplines helps to model, to shape and to redefine (to "modify") the former. A more developed form of the law of inner nature, in turn, allows for focusing more precisely and specifically on aspects related to the modifications of the object studied.

The circularity of the scientific process reveals the potential of development and growth of concepts and ideas. In spite of the interdependence of the two laws one should, however, not be mistaken about their hierarchical order: the constituting law (*law of inner nature*) is on a higher level than the modifying one (*law of outer circumstances*)! The iterative scientific process transforms the knowledge about the spiritual quality of nature, which was experienced "instinctively" by Goethe, into a more conscious, more concise and more accessible tool.

In the course of the last 200 years the science for substantiating the law of inner nature has suffered from severe atrophy, whereas the sciences for finding the laws of outer circumstances have experienced a tremendous growth. But evidently, without the former, the latter risks losing sight of the object of its investigation, namely the living organism.

"It was impossible to fix the creation that now bubbled forth, on the other hand I could make it last for as long as I desired, it neither diminished, nor intensified." To this he added the following: "It is at this point that we can immediately begin with the higher study of the fine arts; and one then realizes ever more clearly what it means to say that the poet and every true artist must really be born. Thus their inner productive powers must especially be able freely to bring forth those after-images, without preconception or desire, those idoles which have remained behind in the organ. They must unfold, grow, extend and draw themselves together, so that from out of these fleeting schema they may truly become objective beings." He then compares the confident drawings of Raphael and Michelangelo with the tentative sketches of other artists, and hence one can see how the most fruitful studies may also be derived from every kind of art, and made upon those things which already exist, as well as upon those in the process of becoming.

With these requirements for the creative spirit a sharp dividing-line is drawn between spirit-borne research and the work of a handy-man. – It is not as though it occurred to Goethe to belittle any kind of serious striving; for he was certainly the first to acknowledge the industry of the collector, the sorter, and every purposeful activity of the worker. Everyone, however, who is touched by his spirit, will recognize that we should direct our gaze upon the creative activity of true scientific research. It is precisely because of this that we desire that the totality of his spirit comes to be acknowledged in the widest circles.

The disparaging judgements occasionally made about poets and poetry by a somewhat narrow conception whenever mention is made of Goethe's scientific endeavours, should not prevent us from recognizing that the spirit in these scientific writings is the very same one that pulsates in his poems and entire personality, elevating the researcher and protecting him against superficiality. The comment made by Schelling in 1802 about the Faust fragment is still valid: "Goethe's poetry," remarked the brilliant thinker, "has opened up a fresh source of inspiration, which alone suffices to rejuvenate the science of our time, diffusing over it a breath of new life. Whosoever wishes to penetrate into the inner sanctuary of nature nourish yourself with this music of a higher world, draw this power within you in early youth, a power that radiates outwards from this poem in dense rays of light, setting the inner being of the world into motion."

Such enthusiastic words may sound affected to our prosaic age, but they contain a healthy kernel of truth which will be recognized more by a future age than by our present one.

The greatest events in the classical age of our literature should not remain unknown to us – an age in which the spirit of towering individuals felt themselves to be as one, and imbued with a common historical impulse of evolution.

Thus when under the influence of the attractive theories of Stuart Mill and Buckle we should not continue to neglect our own philosophers and historians, or when faced with the remarkable discoveries of the natural sciences in other countries, forget the earth–shattering spirit of Goethe and his age.

We see how he exercised an influence upon Schiller, Fichte, Schelling and Hegel, how his spirit unconsciously worked hand in hand with the philosophers, and how they too worked reciprocally upon him. This spiritual life is a continuation of the spirit of ancient Greece, confronting our aging epoch as something new, allowing us to apprehend the

though not true in itself, is yet true for all normally constituted men."

"Goethe's significance lies within formal domains, and it is only in regard to his epistemological and methodological directions that no doubts, no disputes can arise. The formal domain alone marks out those rules of conduct which are present in the unified nature of Goethe. Every single work of this man proceeds so naturally out of the direction of his spirit, that this principle can also convey to us the unified fundamental direction in all of his works. Thus here too is the solution to the problem: whether or not Goethe's researches are of scientific value." (Harpf, pp. 34, 39.)

Now, we would also especially like to emphasize the significance of the subject itself for the quality of research in Goethe's principle of knowledge. We recall one of his sayings:

> If the eye were not of sun-like nature,
> It could never gaze upon the sun;
> If the power of God did not lie within us,
> How could we be so enchanted by the Divine?

Naturally we are not therefore saying that what we know is coloured by a subjective tinge, rather that the spirit of the researcher must be imbued with creative forces which enable him to recreate the created within.

If we recognize a high-point of humanity in Goethe, then it is not really surprising to see particularly clearly marked in his character those features which destinguish the Indo-Germanic race of people from the rest of humanity. That the creative spirit of the Aryan, and the engendering being of nature are livingly created as it were in the original-words of his language – not united in mechanical fashion but endowed with an inner force of life; that he therefore also characteristically enlivened his root-words by conferring a gender upon them; and in his Mythologies deified the whole of nature, making the Gods human once again – all of this did indeed entirely spring from his spirit, out of the spirit of Goethe. For his attention is directed towards life itself, towards the realm of the living. We shall now only put forward one example, as opposed to many. Was he not thoroughly delighted by the appearance of some poems in Germanic dialects from J. P. Hebel, and why was he so pleased? He delighted in the joyous talents of the poet, with which he was able to transform forest and field, sun, moon and stars, indeed the whole of nature into a German country people, and "in the most simple and charming fashion make the universe thoroughly rustic." With Hebel, he delighted in the creativity, the creative acquisition.

He traced the creativity in man right back to elements in the senses. It is a power to bring forth that which manifests itself independently of the will, just as flowers bloom.

Attractive and instructive as a proof of these views are Goethe's remarks on Purkinje's book: *On Sight* with regard to its Subjectivity (1819). Here Goethe argued that "recollection and the power of the imagination are themselves active within our sense organs, and every sense has its own inherent memory and power of imagination." He relates: "I had the ability, that if I closed my eyes and lowered my head, and reflected upon a flower in the centre of my organ of vision, it did not thus remain for a moment in its original form, but separated apart; and from out of its centre unfolded once again into a new flower.

Participation

The first example helps to illustrate what is meant by *participation*, and what happens in the course of a shift from a first person to a third person perspective. As a student, I had to bleed rabbits in order to obtain antibodies against the proteins they had been immunized with. The first time I did this I spent hours with the animals, trying to push a needle into their ear veins. I experienced strong feelings of clumsiness, empathy, pain and sorrow, but also gratitude. A couple of months later, and with much more experience, the same procedure with the same number of animals took only a small fraction of the time I spent in the beginning. I just wanted to get the blood as quickly as possible, in order to pursue my experiments. Preparing a publication, it came as a shock to read my own writing, saying that I had produced antibodies in rabbits... The original, unconscious participation had been replaced by the distant position of a detached observer. In this process, the animals turned from sensitive beings into apparatuses for antibody production.

This is what almost all students experience in some way or the other, sooner or later. Empathy, passion and emotions which lead people to science are quickly transformed for the sake of objectifying. The example shows that participation plays a key role for a sense of qualities and for questions related to ethics, intrinsic values etc. In the mode of the external observer these questions become obsolete, not because of conscious exclusion but because of personal or scientific presuppositions. An historical analysis of the problem of presuppositions in biological thinking is given by Mayr (1982). More recently, Rehmann-Sutter (1996) has shown to what extent they are shaped, often unconsciously, by the basis of scientific and social traditions, methodological and conceptual approaches in biology and, as a consequence, results thereof. Since, according to Rehmann-Sutter, presuppositions are made or chosen before scientific work starts, they are selected by *pre-theoretical* decisions.

How can participation become an instrument in Goethean science? A wonderful example is given by Holdrege (1998a), describing biology and life of the sloth. With many details, a picture of this strange animal is drawn and a path opened to grasp it as a "coherent whole".

An additional example - a brief outline of the development of the brown grass frog *Rana temporaria* - will help to find some essential aspects of participation as a scientific tool (for details see Wirz 1990).

Figure 1 shows a small pond in Dornach, Switzerland, in the beginning of March. Like an open eye, in which the blue sky is mirrored during sunny days, the pond lies in surroundings that show the traces of the past winter. The pale vegetation has not withstood the snowfall and haphazardly covers the ground. But here and there, the rosettes of the first herbaceous plants and the fertile shoots of the giant *Equisetum* can be discovered. Close to the pond, water lilies and marsh-marigolds have formed their first new dark-green leaves. Clumps of a gelatinous mass float in the water. Within it, hundreds of small black dots, the fertilized eggs of *R. temporaria*, can be detected. Closer inspection shows early developmental stages (Fig. 2). Vegetation and animals reveal the first outline of what is to come in the future. Expectation characterizes the mood of the observer.

One month later, the scenery has changed dramatically (Fig. 3). The green color is

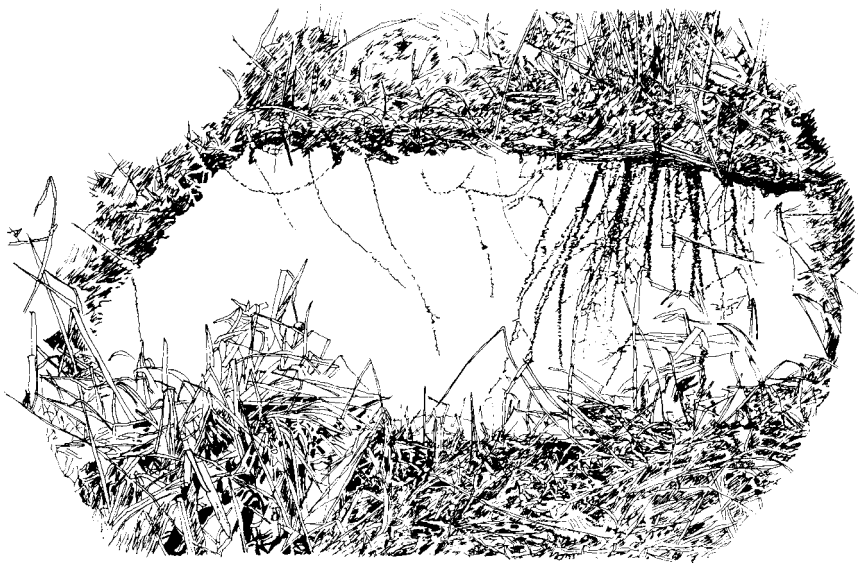


Fig. 1 (above): A small pond at spawning time.

Fig. 2 (left): The development of the embryo of the brown grass frog. Noticeable developmental stages are shown in sequence clockwise: after the first cell division; gastrulation, leading to rotation of the embryo; neural tube formation; embryo prior to hatching with clearly visible gill clefts, eye and somites.

preponderant all over the place. From above, buds of shrubs and trees are breaking open and freeing bright greenish leaves. The ground is entirely covered by a large variety of different plants. Patches of white, yellow and pink flowers are dispersed like splotches on a palette. The dynamics of growth of the vegetation can hardly be followed. The tadpoles have hatched and grow rapidly (Fig. 4). Rhythm is the most characteristic property during these developmental stages; rhythmic movement of the larvae, rhythmic patterns in grazing and digestion. During this period the first outline is brought into appearance. Breathless activity catches the attention.

consistent and rigorous in his methodology. The latter was the most thorough imaginable. He never proceeded from an idea, a preconceived notion, rather in each case experience was the source of knowledge for him.

And he also warned against too hastily drawing conclusions from an experiment. He demanded the most diverse experimentation, and the utmost possible certainty in relation to the correctness of each empirical observation. He does not seem to have forgotten – and there appears to be a truth underlying this which is only accessible to a few – that human cognition is bound by certain limitations. ”With nature, we may observe, measure, calculate, weigh etc. howsoever we desire, yet it is only our measurement and weight, for man is the measure of all things.”

If by accepting the proposition of Protagoras: man is the measure of all things, Goethe also seems to be emphasizing the subjective aspect in his critique of knowledge, then we should not label him less objective than those, who when studying an object trust their perceptions without taking into account the possibility of self-deception or even subjective conditioning.

Thus Goethe’s position with respect to Newton seems to me to lie in this direction.

Already in his earliest years Goethe surprises us with the view: Our vision cannot penetrate to final truths. Our knowledge is merely a reflection of the entire light. (Cf. my edition of the second part of Faust for further references of Goethe regarding this view.) Later in his Pandora he says, man is ”appointed to see illuminated things, but never the light!”

This wisdom, modest in itself, does not prevent him from researching, from striving forward as far as possible in a manner wholly free of all prejudice.

Hence his knowledge was a limited one, and he himself was conscious of these limitations. We recall the words of Faust (I, 235):

> Yes, what one thus designates as knowledge!
> Who may call a child by its rightful name?

The small volume by Harpf mentioned above deals with Goethe’s principle of knowledge. We heartily agree with all its main points – There it is said that a certain ‘relativism’ lies at the basis of Goethe’s cognition. This can even be seen in the writings from his younger years, indeed as far back as the period of his boyhood. (see my Introduction to the Mitschuldigen, Goethe’s Dramas, Volume I, p. 37.) ”Love and hate cloud our vision.” – ”That you people must immediately utter: That is silly, that is clever, that is good, that is bad!” – Herein, however, I wish to differ from Harpf, for I do not designate Goethe an eclectic. We do not meet with an assortment of other people’s opinions in Goethe, rather every opinion is tested in a truly objective manner by means of the conditions upon which the object depends; and moreover he also submits the subjective limitations of his own views to examination. Consider his treatise: The Experiment as Mediator between Object and Subject. Experience lies at the basis of his knowledge; he seeks to understand what is experienced out of its own conditions, and does not tire of safeguarding himself from error by repeated experimentation. ”Hence this is to mediate a generally valid truth, which

penetrated far ahead of his time, directed everywhere upon the whole. The proof of isolated mechanical causalities was mostly only a conformation for him of those things he had already foreseen.

Growing up in the spiritual life of Germany during the epoch of its highest impetus, the age worked upon him thus – just as he too worked upon the age – and this is also true of his scientific writings, despite for ages not receiving the recognition they deserve; they bear, just like his poetry, the mark of immortal classicism.

Although I do not feel competent to enter into their technical merits, I may perhaps be allowed to draw attention to the most crucial aspect of Goethe's work.

With his simplicity and depth he was forever striving to rise above the commonplace nature of the above mentioned intellectual knowledge.

Reason is directed upon that which is in the process of becoming, the intellect upon that which already exists. – So runs one of his maxims, which reminds us of the words of Homunculus (Faust II, 2380): "Reflect not upon the What, rather more upon the How."

So at first he set great store upon reason without being aware of it.

Thus if we now view the entire range of Goethe's thought not only in harmony with his being but also with his poetry, then we are in a position to judge the shallowness of those views which only wish to praise him as a poet while casting doubt upon his abilities as a researcher and thinker. There only arises out of this latter view a caricature of the whole personality of the poet against which we cannot protest strongly enough.

One attributes a certain amount of dilettantism to him, which was apparently nothing more than the strivings of vain powerlessness; however, this can only be ascribed to him by those who have never come into contact with the entire range of his originality, with the moral greatness of his mighty spirit.

And we do not need to elaborate how the significance of his poetry is diminished by such views, nor how destructive such doctrines are for our education when proclaimed from our university chairs. Thus it will not do to consider Goethe as a poet separate from the whole of his being; and hence his scientific writings too are only to be understood in connection with his poetry.

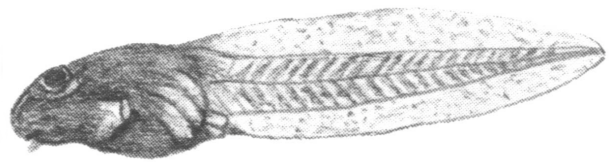
Expert opinions on Goethe's scientific writings have been passed; it is only regrettable that those who have so far interceded for him believed his merit lay more in the results of his researches than in his methods and magnificent conceptions. Hence it is apt that a recently published book remarks: "The dispute which has recently flared up between two of the most important natural scientists in Germany pro and contra Goethe, shows once again how unfruitful it is to examine and value Goethe's researches solely according to their content." – i.e. as to their what. (A. Harpf, Goethes Erkenntnisprincip, Bonn 1883, p.38.) Goethe thought about this 'what' very modestly, and in his modesty we may also see a sign of his superiority, in contrast to those who are so joyous regarding the thought: "we have progressed so incredibly far!"

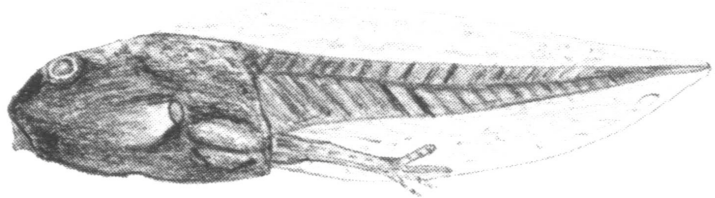
To view the organic realm as a mechanism, as is nowadays so often the case, to skip over and casually accept the unexplained depths that we are unable to fathom – all this is supposed to count as liberalism!

Goethe was never superficial; was extremely humble in regard to his achievements,

Fig. 3 (above): The same pond as Fig. 1, at hatching time.

Fig. 4 (right & below): Larval development: the small tadpoles lengthen after hatching. Changes in relative sizes of head and body are noticeable; limb buds and the spiral intestine appear.





At the beginning of June, the height of the vegetation has reached its climax. The pond is completely hidden. A rich variety of flowers will persist until the end of summer. The leaf canopy has closed completely by now. Sun and shade create the familiar atmosphere of a moist and dusky place (Fig. 5). The frog larvae stop feeding, the tail is reabsorbed, the

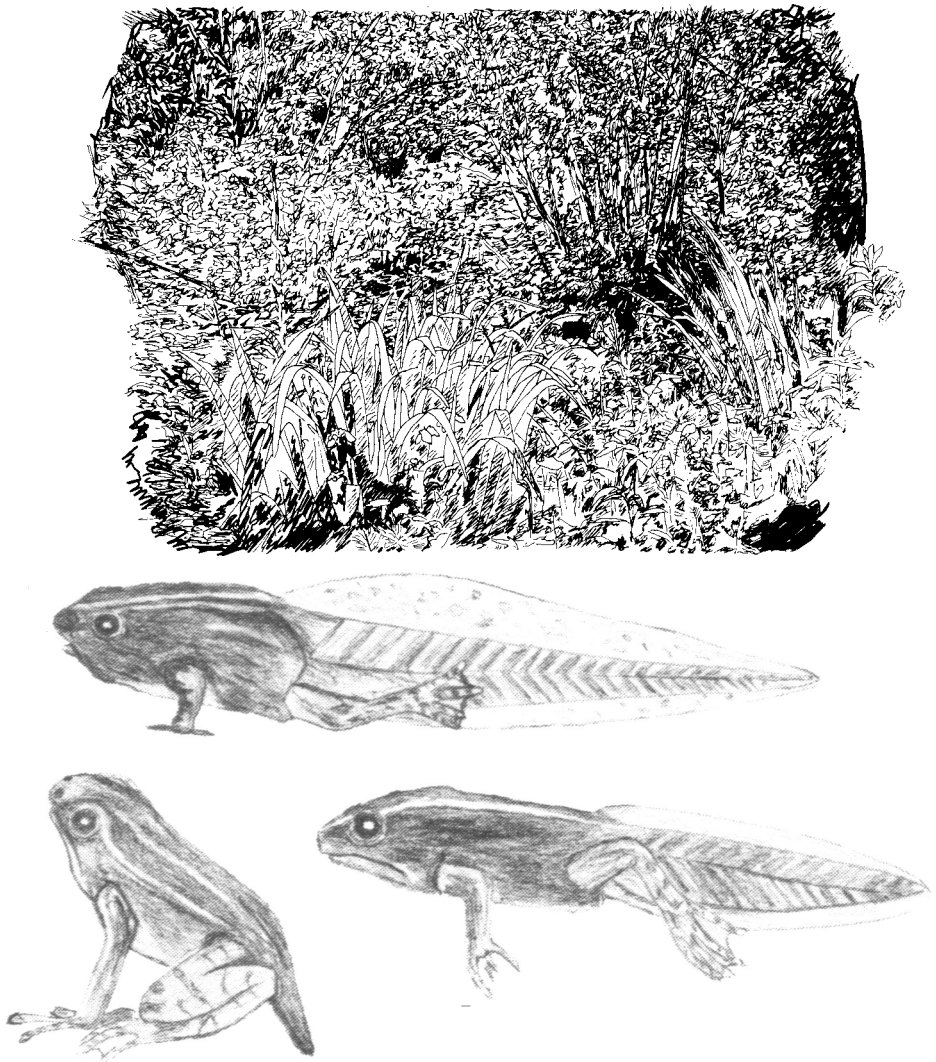


Fig. 5 (top): The pond during the period of metamorphosis of tadpole to frog.
Fig. 6: Three stages of metamorphosis of tadpole to frog. Reduction of the size of the intestine leads to emphasis of the head; forelimbs appear; the tail shortens.

hind legs of the animals start moving and transform the rhythmic swimming of the larval stages into a straight forward movement. Soon, the forelegs break through the skin (Fig. 6) – The fully metamorphosed frogs leave the pond and disappear in the twilight of the surroundings. Only by serendipity can they be observed later on. As in a daydream, the

refuge in feeling.

Our modern view is nothing more than an intellectual knowledge of the finite, unable to see the eternal therein, and thus falls into an infertile and eternal-emptiness, recoiling before the void and fleeing with all thought into the life of feeling.

In both cases the intellect comes to a halt because it can proceed no further.

To be sure, there have been exceedingly great advances in the natural sciences in our time. For instance, such a work as Helmholz's theory of sound sensation is simply remarkable. Yet one does not then say that all philosophizing about music is now worthless. Helmholz himself says in his conclusion that he did not enter the realm of musical aesthetics at all, for in this domain he felt himself to be too much of a dilettante; this must be left for others to do. – However, where are these others?

Here the physicist arrives at a boundary, where a world begins that is not his own. We will soon see that even the organic world – just like art – is determined by a lawfulness to which the physicist has not yet found the key.

Kant rejected the notion that our intellect had the ability to know a whole as a whole, and to pass with this knowledge from the whole to the parts. For in art and nature this was only possible for a so to speak, 'divinely created intellect'; in contrast to one like our own, which can hold the parts in its hand, but alas, does not possess the spiritual band. Such an intellectus archetypus is to be found in Goethe's method of perception. And thus we naturally find that Goethe was entirely surprised and challenged by these words of Kant. He says (in the small essay Perceptive Judgement): It may well be the case that "through perception of an ever creative nature we make ourselves worthy of participating spiritually in her productions. And since I had after all ceaselessly pressed on, at first unconsciously and out of an inner urge, toward that primal archetypal element, and had even succeeded in building up a presentation of this that was in accordance with nature, then nothing more could hinder me from boldly undertaking the adventure of reason, as the old man of Königsberg himself calls it."

It is well known that Schiller described Goethe's spirit as intuitive, in contrast to his own which he called speculative. For Schiller was the first person to understand this particular aspect of Goethe's spirit, an aspect most people failed to see. It was he who drew Goethe's attention to the fact – something which Goethe himself did not realize – that his archetypal plant (Urpflanze) was no experience, but rather an idea! In the sublime unconsciousness of his nature Goethe had already successfully negotiated the adventure of reason without even being aware of it.

Such a spirit directed toward the necessary elements of the empirical world certainly seemed destined for scientific research.

For if the true scientific method consists in the researcher not admitting anything except that which the object itself yields, and which knows nothing at all of speculation and theory, then Goethe's intuitive method is certainly a scientific one. For within this domain it really all does depend upon method. That the natural sciences would have attained their current level without Goethe remains a side issue, a totally open question. One can only say that even if Goethe himself had experienced all these advances, he certainly would have appreciated them, yet still scarcely perceived anything very unexpected. His gaze

Those who completed their education in Germany before 1848 well remember the age in which the study of philosophy dominated all circles, reverberating through all the sciences – the age of Idealism.

It was the time in which our nation was completed with a mighty uplift. The whole of humanity pressed forward to the new culture, which with rejuvenated senses continued the ancient world within Germany. Philologists, philosophers, and poets all worked together out of a unified spirit – a spirit which permeated all the sciences and challenged every realm of knowledge to find a connection to the ruling ideas of the time.

The centripetal force of philosophical thinking took hold of all circles, making mighty demands upon scientific exactness. The collecting and ordering of experiences no longer sufficed. Every single thing had to be recognized as part of a unified whole, no science was allowed to restrict itself as though it could exist independently of the rest; each one had to be conscious of its relation to the others. One scoffed at this notion of deducing all things "out of the Idea" which was commonplace within the leading philosophical schools. However it was nothing more than the demand for thoroughness through which German science has gained its imposing record; and which is so deeply grounded and widely practiced that one must look no further than to it when seeking a standard for scientific exactness.

In the meantime a current entered under the banners of France and England in which the Natural Sciences took over the leading position once occupied by philosophy. The more elderly among us who completed their education prior to the appearance of this current now stand face to face with a world in which scarcely a trace of that Idealism is to be seen, and where one looks down upon that former age as though one had forgotten all of its mighty impulses, and would rather do without all of its preparatory work. Deeper thinking natural scientists lament that predominating superficiality which only sees the task of science to consist in descriptions of the single phenomena, and which renounces any explanation of interrelationships. (cf. Haeckel, General Morphology II, 162.)

The ludicrous errors of those great philosophers are often recounted; however the world no longer knows the breadth of their thoughts.

We see no continued development at all in this fact, but only a break from the past – and this can certainly call forth many misgivings.

According to archaeology, the educational heights achieved in Germany while it was still oblivious to all politics allowed our folk to attain its position in the world long before its victory with the sword.

The exemplariness of our schools and colleges, the exactness of our scientific methods, the disciplined nature of our thinking on account of which our standard of education is lauded – still stand in plain view.

In such circumstances one must be allowed to ask: can it be viewed as an advance for us when we have to drag in tow those who are not at all acquainted with our thinkers; or again, are we right in breaking with the well-established structure of our educational system to follow unfamiliar stars?

Hegel once said in his polemic against the so-called 'sentient theology': Because the intellect has shown cognition to be of a purely finite nature, our deeper needs have sought

alertness of the observer is lowered.

On the basis of these short descriptions several points can be made: Firstly, animals, developmental processes and specific environment are the expression of one and the same entity. Secondly, the idea of the "brown grass frog" grows with each single observation; it provides the context to embrace all of them. Thirdly, the observer's inner experiences are related to the outer ones and thus become an integrative part of the overall description. Repeated observation and practice show that this interrelation can be more and more developed. The insecurity and the doubt about "subjectivity" of feelings recede from evidence. The participatory approach reveals that organic processes appear to be connected to one another not only in functional but also in qualitative terms. Thus, it is the methodological tool for the development of a science of qualities.

Portmann (1973), an eminent holistic biologist from Switzerland, summarized results derived from the first (participatory) and third person (external observer) perspectives in a metaphor: the play of life can be observed in two different ways. From behind the curtain, the whole technical apparatus – the functions of life necessary for staging the play – comes into view. In the auditorium, the drama itself – the meaning and the values of life – can be experienced.

Goethean science connects the two perspectives. It presupposes participation, as well as the position of the external observer and thus, recombines quality with quantity.

Co-operation

The interrelation reveals *co-operation* (sometimes called *mutualism*) among these processes. Co-operation is given some credit in the analysis of ecosystem functions, but seems not to be attributed with a role in evolutionary processes (Maynard Smith 1989), which, according to this author are basically driven by competition. From the perspective of Goethean science, however, the search for functional, as well as qualitative co-operation seems mandatory. Goethe (cited in Kuhn 1964) has suggested an expanded definition: "'The fish exists for the water', seems to me to say far less than 'the fish exists in the water and by means of the water'. The latter expresses more clearly what is obscured in the former; i.e. the existence of a creature we call 'fish' is only possible under the condition of an element we call 'water', so that the creature not only exists in that element, but may also evolve here" (English translation cited from Holdrege 1998b). According to Goethe, this view takes into account that animals show characters which are expedient with respect to their inner organization, as well as to their perfect adaptation to their environment. Furthermore, Goethe's view suggests that we should look for "integral co-operative processes" in ecology, as well as in evolution.

Literature is starting to accumulate showing that co-operation promotes diversity and sustains ecological stability. Co-operation between fungi and plants results in higher productivity and provides alleviation of problems like CO_2 enrichment (Read 1998, van der Heyden et al. 1998). Animals feeding on fruits support the plant's reproductive success by depositing the seeds via excretion far away from the mother plants, and thus help to stabilize and expand the plant populations (Moore 1997). Cross feeding of Douglas fir to birch seedlings via mycorrhizal connections ensure growth and development of the latter

(Read 1997, Simard et al.1997). Moreover, sugar transfer only takes place if the ambient light conditions do not allow for sufficient photosynthesis within the seedlings.

By myopia of paradigm, evolutionary biology and ecology have long overlooked the concept of cooperation or they have tried to reintegrate it into that of competition.

Competition has gained wide recognition, both in theory and practice. It is, for example, one of the basic principles in conventional agriculture. Arable crops are supposed to require weed control if they are not to be out competed by the natural flora. Pest management has to be applied for the reduction of damage by insects and plant parasites. The measures taken, herbicides and pesticides, destroy undesired plants and animals with the resulting well known deleterious effects of resistance formation by both weeds and pests. Often enough, effective and sustainable control could be exerted, if less competitive and more co-operative measures were chosen, for example crop rotation and promotion of predatory insects by tracts of fallow land. The principle of co-operation is worth developing as an instrument for ecological practice.

As part of a project aimed at an understanding the concept of the *ensoulment of landscape* (*Beseelung der Landschaft*) introduced by R. Steiner (1924) – a participatory approach to assessing the meaning of animals beyond ecological functions (Kuster and Wirz 1996) – the principle of co-operation has been integrated into ecological restoration work. Compared with similar places in the nearby Jura mountains, the grassland around the Goetheanum showed deficits, both with respect to species abundance and population densities of insects. A major reason for this deficit was found in the intensive grassland management. Based on bio-dynamic farming practice, meadows were integrally cut three to four times a year, removing in totality important habitat qualities in a very short period of time. This management imposes a strong competition, since it favors plants that are able to cope with repeated cuttings.

In the Jura, however, grasslands of similar quality to that exhibited by the meadows at the Goetheanum, were traditionally used as pasture with a low number of cattle, which created differentiated habitats; sometimes they were cut late in summer. The small size of the plots and different times of mowing, resulted in a highly differentiated patchwork of vegetation structures.

To improve the living conditions for the insect fauna, the traditional situation was mimicked by a differentiated mowing system (Kuster and Wirz 1998, 1999), applying a spatial and temporal mosaic cut. As a result, the meadows exhibited a pronounced aesthetic appearance with a variety of developmental stages and vegetation structures throughout the year. In addition, an extraordinary increase in species diversity of butterflies and grasshoppers could be observed. The two groups had been chosen to monitor the quality of flowers and vegetation structure, respectively. Table I indicates that, during the project period since 1995, the species diversity of butterflies has increased by some 35%. Frequent species exhibited an increase in population density up to twenty fold (see Table II).

Foreword to The Natural Scientific Writings of Goethe from Kürschner's Deutsche National-Litteratur, Goethes Werke

(Volume 33, 1884, pp. I – XIV, Edited by Rudolf Steiner)

Karl Julius Schröer

It was in Königsberg, in the Summer of 1876 that I visited Karl Rosenkranz, that brilliant disciple of Hegel, whom I also greatly admired on account of his book about Goethe. At that time one could certainly call him the Nestor of the university.

A completely blind old man stood before me. His features were somewhat rigid. However, as soon as he began to speak about philosophical issues concerning Goethe's relationship to science – he then became thoroughly animated!

So much of what he touched upon I had experienced, so many things to which he drew attention, I too had also considered – only it all received so much more emphasis through him.

He recalled the sovereignty of philosophy in the 1840's and then its later disappearance from view. – There passed an unforgettable hour which did not fail to make a very deep impression upon me.

I cannot recall all the details of the discussion – yet I know he recommended F. Grävell's book to me: Goethe im Recht gegen Newton. – And I can still feel the invigorating power that this visit left in me; it was especially good to see Goethe's position with respect to science explained in a somewhat different manner than it is usually conceived, particularly in relation to the whole development of the spiritual life of Germany in our time.

It was in the 18th century that the fruits of Humanism ripened in Germany, the spirit broke forth to direct perception of antiquity, and discovered the source of that inspiring world within its own being; a spirit which now worked with rejuvenated senses in a rejuvenating manner upon humanity.

This course of development is represented by Goethe and embodied within his own life; he also describes it in his Faust. He was unconsciously driven by ideas which the contemporary philosophers in Germany were wrestling to clarify. Goethe exerted a fruitful influence on the younger philosophers: Schiller, Fichte, Schelling and Hegel, and they too worked in a reciprocal manner upon him. His spirit lives as a unified whole in his poetry and other writings and thus outlasts the systems of the philosophers, because he continually works in an enlivening manner; he is a cultural source who also influences those other civilized nations not accessible to our philosophers.

In that hour it was as if all these facts were embodied before my eyes. Rosenkranz had indeed preserved an animated freshness within his thoughts as no other disciple of Hegel before him. And we are certainly aware how for many people philosophy has become ossified; they perceive nothing but emptiness and eccentricity, hidden behind an obscure manner of expression! – Nevertheless, the change that has taken place in men's minds since that time, i.e. since about 1848, can hardly be viewed as an advance by those who still possess recollections of that period. I felt this very intensely in the presence of that elderly man as he carried me back to that former age.

members of the Goetheanum Research Institute for colleagueship and continuous support. This work has been made possible by grants from the Rudolf Steiner Fonds für Wissenschaftliche Forschung, the Evidenz-Gesellschaft and the Goetheanum, Freie Hochschule für Geisteswissenschaft, Dornach.

This is the text of a presentation given at a conference entitled *Goethean Science in Holistic Perspective* from 20th to 22nd May 1999, at Teachers College, Columbia University, NYC, organised by Douglas Sloan.

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Table I. Butterfly and two day-flying moth species 1995-1998 (nomenclature according to SBN (1991)). ** indicates species observed after implementation of the differentiated management. Numbers in the right hand column indicate species on the red list (Duelli 1994): 1, close to extinction; 2, severely endangered; 3, endangered; 4, potentially endangered.

Schwalbenschwanz (swallowtail)	Papilio machaon	
Zitronenfalter (brimstone)	Gonepteryx rhamni	
Postillon (clouded yellow)	Colias crocea	
Heufalter (pale clouded yellow)	Colias hyale/alfacariensis	
Grosser Kohlweissling (large white)	Pieris brassicae	
Kleiner Kohlweissling (small white)	Pieris rapae	
Rapsweissling (green-veined white)	Pieris napi	
Senfweissling** (wood white)	Leptidea sinapis	
Aurorafalter (orange tip)	Anthocharis cardamines	
Tagpfauenauge (peacock)	Inachis Io	
Trauermantel (Camberwell beauty)	Nymphalia antiopa	
Admiral (red admiral)	Vanessa atalanta	
Distelfalter	Cynthia cardui	
Kleiner Fuchs (small tortoiseshell)	Aglais urticae	
C-Falter (comma)	Polygonia c-album	
Kaisermantel (silver-washed fritillary)	Argynnis paphia	
Kleiner Perlmutterfalter	Issoria lathonia	
Mittelwegerichfalter** (heath fritillary)	Mellicta athalia	
Weisser Waldportier**	Brintesia circe	2
Schachbrett** (marbled white)	Melanargia galathea	
Grosses Ochsenauge (meadow brown)	Maniola jurtina	
Brauner Waldvogel (ringlet)	Aphantopus hyperantus	
Kleines Wiesenvögelchen (small heath)	Coenonympha pamphilus	
Waldbrettspiel (speckled wood)	Pararge aegeria	
Mauerfuchs** (wall brown)	Lasiommata megera	
Birkenzipfelfalter (brown hairstreak)	Thecla betulae	
Blauer Eichenzipfelfalter** (purple hairstreak)	Quercusia quercus	
Pflaumenzipfelfalter**	Fixsenia pruni	1
Kleiner Feuerfalter** (small copper)	Lycaena phlaeas	
Brauner Feuerfalter	Lycaena tityrus	
Faulbaumbläuling** (holly blue)	Celastrina argiolus	
Dunkelbrauner Bläuling (brown argus)	Aricia agestis	3
Violetter Waldbläuling (mazarine blue)	Cyaniris semiargus	
Hauhechelbläuling (common blue)	Polyommatus icarus	
Himmelblauer Bläuling (adonis blue)	Lysandra bellargus	
Braunkolbiger Braundickkopf (small skipper)	Thymelicus sylvestris	
Braunstrich Dickkopf (large skipper)	Ochlodes venatus	
Dunkler Dickkopffalter** (dingy skipper)	Erynnis tages	
Kleiner nördl. Dickkopffalter** (grizzled skipper)	Pyrgus malvae	3
Zweibrütiger Dickkopffalter**	Pyrgus armoricanus	2
Roter Würfelfalter**	Spialia sertorius	
Veränderliches Widderchen**	Zygaena ephialtes	
Gewöhnliches Widderchen (six-spot burnet)	Zygaena filipendulae	

Table II. Population Dynamics of Selected Butterfly and One Moth Species

	Index			
	1995	1996	1997	1998*
Wood white, Leptidea sinapis	0	6	5	4
Pale clouded yellow, Colias hyale	0	9.5	16	18
Meadow brown, Maniola jurtina	116	258	278.5	266
Ringlet, Aphantopus hyperantus	10	22.5	37	34
Small heath, Coenonympha pamphilus	5	34.5	49	61.5
Wall brown, Lasiommata megera	2	0	2	12
Dunkler Feuerfalter, Lycaena tityrus	3	2	7	13
Mazarine blue, Cyaniris semiargus	3	28	61.5	70
Common blue, Polyommatus icarus	64	111	105.5	73
Six-spot burnet Zygaena filipendulae	28.5	124.5	106	340.5

*The numbers of butterflies were assessed according to Hall (1981); for all the species listed, the meadow represents a holo-habitat, i.e. it fulfills the needs for all developmental stages: eggs, larvae, pupae and butterflies. *last census, August 28.*

These results cannot solely be attributed to the existence of different vegetational structures, but appear to be the consequence of their simultaneous presence. The effect of boundaries between different developmental stages of the vegetation in the meadow could be directly observed. Grasshoppers concentrated along the border lines between areas which had been cut and parts with a well developed high vegetation structure. Butterflies like *P. icarus* or *A. agestis* showed preferences for high vegetation structures for rest and preferred areas with shorter structures for egg deposition and nectar feeding.

Restoration practices which adapt co-operative natural principles can maintain or even enhance the ecological performance of a site. Furthermore, they open the way to developing tools for assessing the relation between esthetical experience and ecological values.

Adaptive mutations

The concept of co-operation has little impact in evolutionary biology because the main source for variation, which selection acts upon, has been attributed to random mutation and random hybridisation by sexual reproduction. Other means of generating variation, for example by inheritance of acquired characters, have been dismissed for various reasons (see below).

This was not the case in the early days of modern evolutionary theory. Lamarck (1809) favored genetic processes involving the inheritance of acquired characters. Darwin (1859) put forward two hereditary principles: spontaneous and directed variation (use and non-use of organs). And Haeckel (1866), the strongest proponent of Darwinism in continental Europe at the end of the 19th century, clearly favoured the inheritance of acquired characters, which he judged to be a consequence of the biogenetic law.

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been scrutinized and complemented:

Third person perspective	⇔	Participation
Competition	⇔	Co-operation
Random mutation	⇔	Adaptive mutation

It cannot be overlooked to what extent the concepts of the onlooker mentality, competition and random processes have governed, and still do, the current ideas in the life sciences, but also in society, economy and philosophy. I believe that the complementing principles might help to redefine values and processes in all these areas and disciplines.

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The ambiguity was quickly abandoned after the description of spontaneous mutations in bacteria (Luria and Delbrück 1943) and the successful synthesis of genetics and evolution into the neo-Darwinian theory (Mayr and Provine 1980).

In 1988, however, the resurrection of the genetics of acquired characters was heralded (Cairns 1988). Experiments in bacterial genetics revealed that mutations favorable for metabolism of certain sugars occurred at higher frequencies than expected on the basis of spontaneous mutations. Moreover, these genetic changes could only be detected if the sugars were present in the nutritional medium. This new type of mutation was called *adaptive mutation*, *directed mutation* or *selection induced mutation* (for a review see Foster 1993, Wirz 1998). Table III shows under what conditions adaptive mutations arise. Interestingly enough, there exists a complete polarity with respect to the prerequisites of spontaneous mutations.

Table III. Conditions promoting spontaneous and adaptive mutations in bacteria

spontaneous mutations	**adaptive mutations**
independent of life history	dependent on life history
undirected	directed
exponential growth	growth arrest
replication dependent	replication independent
selection after mutation	selection induced mutation

The differences should have strongly supported arguments for the occurrence of adaptive mutations in bacteria. Instead, the controversy about adaptive mutations continues. Strong criticisms are put forward for several reasons: some of the experiments proved not to be conclusive enough or allowed for "classical" interpretations. Despite great efforts, adaptive mutations cannot be described by molecular genetic mechanisms, in contrast to spontaneous mutations, for which detailed molecular knowledge exists. Finally, there exists an important ideological reason. Adaptive mutations challenge the basic dogma of modern genetics and evolution. They imply that genetic changes are not the cause of variation but the consequence of the organism's interaction with its environment. The occurrence of adaptive mutations presupposes an entity that uses and directs its genetic repertoire. The principles of participation and co-operation seem to supply organisms with the property of changing their genetic setup on the basis of (inner) interaction. They transform acquired faculties into a form that can be passed over to the next generation. This transformation occurs according a precise "communication" with the environment.

If these properties belong to a universal way of life and evolution, they should be detectable in other than unicellular organisms as well. Since, to our knowledge, nobody has looked for adaptive mutations in higher organisms, we decided to investigate directed mutational changes in *Drosophila melanogaster*.

In the first series of experiments, the variation of quantitative traits was investigated; such traits are believed to be under the control of more than one gene. In a second series

the enhanced reversion of a well characterized mutation under inducing conditions was analyzed. Here, the genetic change to be observed is under control of a single gene.

In both cases, the precondition of stationary phase required for adaptive mutations in bacteria, was mimicked by separation of virgin males and females right after eclosion, thus arresting reproduction. Flies were subjected to inducing conditions for some ten days and, subsequently, allowed to mate. Offspring were reintroduced into a next breeding cycle under the same conditions, and a small number of flies was tested for altered phenotypes.

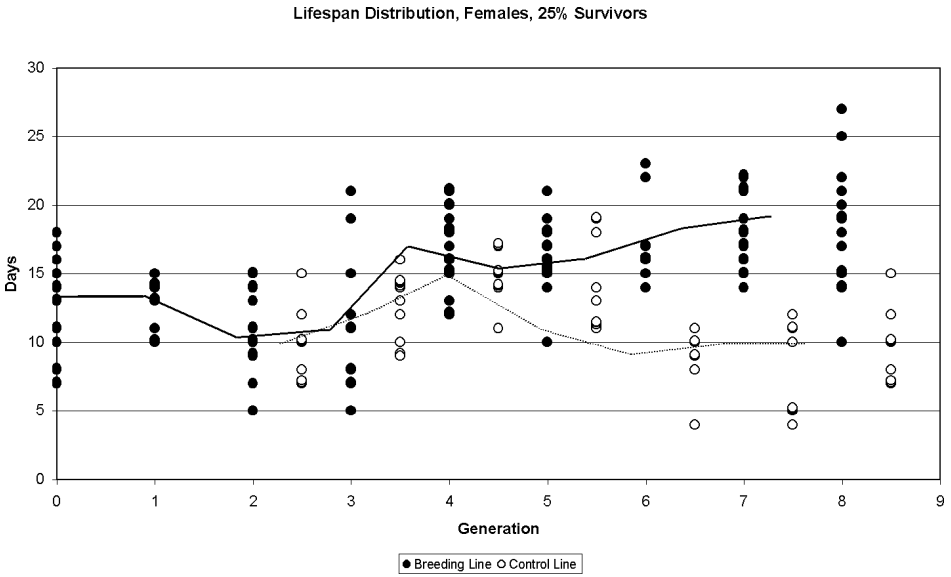

Figure 7

As a quantitative trait, the change in life span under new nutritional conditions was investigated. Flies that had been inbred for many generations on cornmeal medium were exposed to a novel food source based on animal sugar, fat and protein, i.e. curd medium. In each generation, the life span of virgin females and males was monitored; a variable number of vials containing twenty flies each, were prepared, and the surviving flies were counted every day. Fig. 7 shows a summary of the life span distribution of succeeding breeding generations. The median values of 25% survivors increase from 10 to 13 days (generations 0-3) to 18.5 days (generation 8). As a control, flies from the same original stock were kept on the same curd medium, but bred without reproductive arrest. The median values of 25% survivors fluctuated around 10 days from generation 2 to generation 8. Statistical analysis (U-test) showed that the life span of flies from late breeding generations differ significantly from that of the controls or early breeding generations (data not shown).

The occurrence of spontaneous mutations seems improbable for the following reasons.

First, the low genetic variability of the highly inbred fly stocks does not allow for selection of new characters (Maynard-Smith 1989); thus, flies should not adapt to new environmental conditions. Second, the difference in life span between breeding and control strains indicate that the exposure of adult flies to new nutritional sources is essential for the effect shown by the offspring. The preliminary results indicate the occurrence of directed adaptation for quantitative traits in *Drosophila*.

In the second series of experiments, single gene adaptive reversions were investigated with flies exhibiting a Dominant Temperature Sensitive (DTS-4) phenotype (Holden and Suzuki 1973). Adult animals survive at the restrictive temperature of 29 degrees, whereas embryonic, larval or pupal development is abolished. Recent experiments (Smyth and Belote 1999) have shown that DTS-genes encode proteins that belong to a family of enzymes, so called proteasomes. These enzymes are involved in growth control, metabolic regulation, embryonic development and directed cell death, i.e. apoptosis.

Virgin males and females from a fly stock carrying the DTS-4 mutation were collected and exposed to a heat shock treatment at 29 degrees for some ten days. They were mated and their offspring were reared at the permissive temperature of 20 degrees. After eclosion, the flies were subjected to the same heat shock treatment. For each breeding generation, some 50 to 100 embryos were transferred to 29 degrees and development was monitored. After three to four breeding cycles, revertants started to appear (Table IV). In two cases, crossings with the original mutant stocks were possible and revealed that the directed reversions were the result of a double crossing-over event, or that they had taken place on the same chromosome where the original mutation had been located.

These experiments strongly suggest that adaptive mutations occur for defined genetic loci, if, and only if, the flies are subjected to the “inducing” environment. On the basis of the small numbers of embryos tested, the observed reversion rate is orders of magnitude higher than that which would be expected for random reversional events. Spontaneous reversions from mutant flies that had never been exposed to the restrictive temperature, could not be observed.

Our results suggest that adaptive mutations, indeed, are a complementary principle to random mutations throughout the bacterial, animal and possibly the plant kingdoms. Hereditary and evolutionary processes are not driven unidirectionally from genes and DNA to organisms, but also by the life history of living beings themselves, i.e. from organisms back to DNA.

Perspectives and outlook

In the present paper I have made an attempt to introduce Goethe’s conception of organic nature. The main consequence of his theory is the recognition of the spiritual quality of nature. This recognition calls for a shift of the scientific approach from mere function to meaning and value of life. Although such a conclusion could also have been derived on epistemological grounds, it has been shown that results of contemporary biology itself call for such a widening of the concepts of nature and life. The time seems to be due for a complementation of current views and paradigms.

Three principles concerning scientific methodology, ecology, genetics and evolution have