

Microbial processes and plant life – a key to a chemistry of life, *Norbert Pfennig and Jochen Bockemühl*.

No. 10 (September 2004) 32pp. A5. £2.50

Mistletoe berry shapes and the zodiac, *Stephan Baumgartner, Heidi Flückiger and Hartmut Ramm*.

Experiments at Moon-Saturn conjunctions using the capillary dynamolysis method of Lili Kolisko, *Dirk Rohde*

No. 11 (September 2005) 64pp. A5. £4.00.

Moving pictures: the world of meaning of two meadow butterflies, *Daniel Kuster and Johannes Wirz*.

The marbled white butterfly (*Melanargia galathea*) in ecologically different farmland habitats, *Johannes Wirz and Daniel Kuster*.

The fortnightly tree bud rhythms of Lawrence Edwards, *Nick Kollerstrom*.

No. 12 (September 2006) 60pp. A5. £4.50

The buttercup family through the course of the year - interrelationships between plant phenology and basic questions in evolution, *Jürgen Momsen*.

The conifer type - steps in the development of an imaginative understanding of trees, *Jan Albert Rispen*.

The conifer cone, *Jan Albert Rispen*.

No. 13 (September 2007) 48pp. A5. £4.00

Integrity as identity, *Sylvie Pouteau*

Goetheanism – its methods and significance in the science of the living, *Ernst-Michael Kranich*

The 'T' and the reality of the atom, *Peter Gschwind*

Postage

The prices above are in UK pounds sterling and include UK postage. For other European destinations please add £0.50 per copy, elsewhere add £1.00 per copy

Possible payment methods

- 1) Cheque drawn on a UK bank;
- 2) Cheque in non-UK currency (including •);
- 3) International electronic transfer (please request our bank data and transfer codes). Buyer to pay wiring charges at sending *and receiving* bank.
- 4) UK coinage/banknotes or non-UK banknotes (sent at the buyer's risk).

Surcharge: if sending non-UK *banknotes* (including •), please add the equivalent of £3.00 (GB pounds) to cover our bank's exchange commission.

Cheques should be made payable to 'Science Group - AS in GB'

Bookshops

Trade discount terms: 33% on above prices plus actual postage costs.

Subscriptions

As the journal's size and thus cost varies there is no regular subscription arrangement. If you would like to receive notification of the publication of future issues please contact the editor at the address given on the back cover.

Networks, not building blocks The idea of the organism in genetics and epigenetics

Johannes Wirz

Introduction

Pablo Jensen (2001), science historian and quantum physicist at Claude-Bernard University, Lyon, masterfully describes the potentials and limitations of a quantum physical view of the macroscopic world.

'Rigorously explaining the properties of various materials with the help of atoms remains problematic and fragmentary. [...] Furthermore this relationship is loaded with approximations which could certainly not have been made without knowing the end results.'

If we replace 'materials' with 'organisms' and 'atoms' with 'genes', the sentence also appropriately describes the situation in molecular genetics. As with elementary particles, the existence of genes is rarely challenged. But the relationship between genetic information and its significance for the organism is so far largely unexplained. This assertion may seem absurd when set against the dizzy pace of progress in basic research in molecular genetics and its high profile in the media. Even so, justifying the assertion is the aim of this paper. It will first deal with the relationship between phenotype and molecular gene. Then suggestions for extending the central dogma that Watson and Crick formulated in the fifties of the last century will be presented based on recent research. And finally, against the background of Goethean work on organic nature, the 'idea of the organism' will be presented. This is a conception that solves the problem of genetic information and assigning significance and implies that the genetic program is actively interpreted and steered by the living organism itself.

This approach denies the possibility that living organisms are understandable exclusively as epiphenomena of molecular processes. It can therefore be described as anti-reductionistic or holistic, bringing together what modern science would like to keep strictly separated, namely knowledge and ethics. The reason for this is that Goethean research methods also assume a change in perspective from the third to the first person – the heart of nature can only be experienced by the inner being of man.

The gene in phenotypic and molecular genetics

Phenotypic genetics was founded by Mendel and has since very successfully investigated the processes of inheritance. About 5,000 human inherited diseases have so far been described (<http://www.ncbi.nlm.nih.gov/Omim/>), and in animal and plant breeding its potential has proved impressive. Knowledge and understanding of molecular genetic processes are not necessary for this. In contrast, since the sixties of the last century molecular genetics has identified the function of many genes and, based on the genome project, even claims to have produced a complete catalogue of all the genes of several organisms

including the human. Yet the relationship between phenotype and gene in most cases remains obscure, as the following example shows.

In 1995 Edward Lewis, Christine Nüsslein-Vollhard and Eric Wieschaus were jointly awarded the Nobel prize for medicine. With ingenious crossing experiments and phenotypic analysis Lewis studied the segment identity of *Drosophila* and, by inactivating a so-called homeotic gene (Ubx), produced a fly with four wings (Lewis 1978) (Fig 1.). Ubx may be regarded as the repressor of wing formation on the third thoracic segment. Ten years later, the developmental genes of the fruit fly were cloned and characterised. The first publication concerned Ubx (Bender et al. 1983) and showed that this gene coded for a transcription factor, an enzyme, that regulates the expression of other genes.

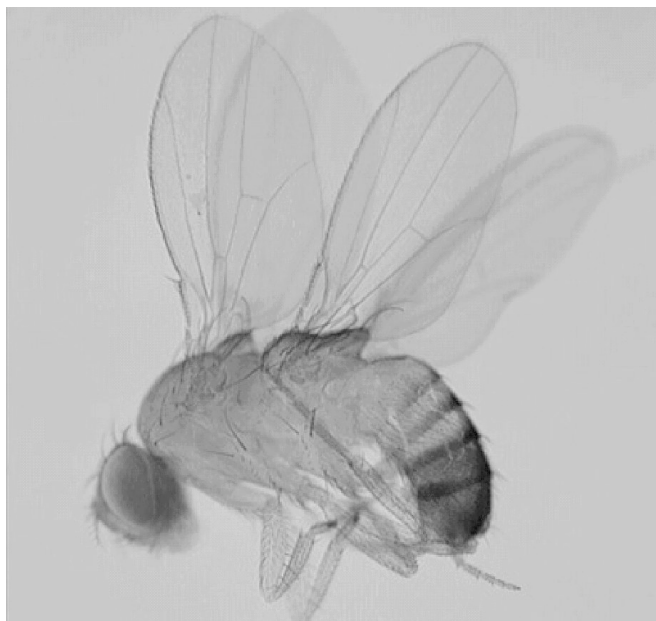


Fig. 1. Fruit fly with four wings. This phenotype arises from inactivation of the Ubx-gene.

Source: <http://pbs.org/wgbh/nova/genes/fate-nf.html>

The products of these genes were also transcription factors, responsible for the regulation of other genes – the picture of a cascade of gene activities appeared, and the project to understand the identity of segments at the molecular level was provisionally suspended. Whether the molecular *Bauplan*, i.e. the networking of all relevant gene sequences, which in *Drosophila* ultimately lead to head, thoracic and abdominal segments, will ever be deciphered is uncertain. Comparative studies with various organisms speak clearly against this, because these genes are also present in mouse and man with *Bauplans* totally different from those of *Drosophila* (Wirz 2000). Whilst genes are indeed indispensable in embryonic development, they are not sufficient for the explanation of ‘causal’ develop-

Back issues of *Archetype*

No. 1 (September 1995) 60pp. A5. £3.50.

A hypothesis-free science of inorganic nature, *Georg Maier*

Mathematics as a spiritual science, *Renatus Ziegler*

An overview of Goethe's geological writings, *Christine Ballivet*

What will mankind bring about by trying to gain control of heredity? – The fundamentals of a world outlook based on DNA, *Jaap van der Wal*

No. 2 (September 1996) 40pp. A5. £3.00.

Rethinking physics, *Nick Thomas*

Radioactivity in the history of the Earth, *Norman Grant*

Steiner's description of the Earth's history, *Norman Grant*

No. 3 (September 1997) 60pp. A5. £4.00.

Basic gestures of human embryological development, *Wolfgang Schad*

On the lemniscatory motion of sun and earth, *Louis Locher-Ernst*

Thermal expansion in counterspace, *P.P. Veugelers*

Mathematics and occultism, *Rudolf Steiner*

The polar relation between the human skull bones and limb bones, *Gordon Woolard* Letter re: article by N. Grant in issue No. 2, *Henry Goulden*.

No. 4 (September 1998) 56pp. A5. £4.00.

Elements of a differential and integral calculus in counterspace, *P. P. Veugelers*

Progress towards complementarity in genetics, *Johannes Wirz*

Between discordant eras, *Stephen L. Talbott*

Correspondence, *Ron Jarman, Norman Grant*

No. 5 (September 1999) 60pp. A5. £4.00.

The projective lemniscate, *Lou de Boer*

The fruitfulness of Goethe's approach to science at the present time, *Jochen Bockemühl*

Participation, cooperation and adaptive mutations: complementing ecological and evolutionary paradigms, *Johannes Wirz*

Foreword to 'The Natural Scientific Writings of Goethe' (edited by R. Steiner), *Karl Julius Schröer*

Karl Julius Schröer (1825 – 1900), teacher of Rudolf Steiner – A biographical Sketch, *David Wood*

Towards a history and sociology of the anthroposophical research institutes in the 1920s, *Christoph Podak*

No. 6 (September 2000) 56pp. A5. £4.00.

Geometric crystal morphology on a projective basis – towards the complementarity of morphology and structure theory, *Renatus Ziegler* (45pp)

Review article: capillary dynamolysis, *David Heaf*.

No. 7 (September 2001) 48pp. A5. £3.00.

The fourth dimension, *Rudolf Steiner* (Berlin, 24.3.05)

Large-scale reservoir projects – Examples of Faustian work, *Eduard Naudascher*.

Lilly Kolisko – life and work 1889-1976, *Gisbert Husemann*

No. 8 (September 2002) 40pp. A5 £3.00.

What is Goetheanism? *Wolfgang Schad* (32 pp)

Some thoughts on the oxalic acid/formic acid processes, *Judyth Sassoon*

No. 9 (September 2003) 44pp. A5 £3.50

Shape changes of ripening mistletoe berries, *Heidi Flückiger and Stephan Baumgartner*

Bovine spongiform encephalopathy and uric acid, *Judyth Sassoon*

Grundlagen von Goethes naturwissenschaftlichem Erkennen (Schieren 1998), gave equally little attention to the morphology of our time. That is justifiable, but it also means that those who are occupied with morphology are faced with a challenge that they cannot ignore. With the help of the references to the literature it is quickly possible to see whether an author only takes Goethe and Steiner into consideration, or has also studied authors who do not explicitly refer to Goethe, or even Steiner.

In my view, Goetheanism starts where we begin to observe our own thinking, tracing it and noticing what happens when we inwardly recreate the formative processes – precisely what Kranich was very concerned about (Kranich, 2007, pp. 12/13.). Do the images remain schematic? Does a change occur and do we notice during inwardly recreating the formative processes that what was schematic fades away and the quality of what is recreated becomes more vivid? Anyone engaged in plant morphology follows this path.

- Claßen-Bockhoff R. (2005) Aspekte, Typifikationsverfahren und Aussagen der Pflanzenmorphologie‘ in *Wert und Grenzen des Typus in der botanischen Morphologie* (ed. Harlan, V.) (Martina Galunder Verlag, Nümbrecht).
- Goebel, K. (1905) *Organography of Plants Especially of the Archegoniatae and Spermatophyta*. Volume 2: Special Organography. Oxford: Clarendon Press.
- Hagenmann, W (2005) Die typologische Methode: ein Schlüssel zu einer organismischen Botanik‘ in *Wert und Grenzen des Typus in der botanischen Morphologie* (ed. Harlan, V.) (Martina Galunder Verlag, Nümbrecht).
- Kranich, E-M. (2007) Goetheanism – its methods and significance in the science of living organisms. *Archetype* **13**, 12-24.
- Schieren, J. (1998) *Anschauende Urteilskraft – Methodosche und philosophische Grundlagen von Goethes naturwissenschaftlichem Erkennen*. Parerga Verlag GmbH, Düsseldorf and Bonn.
- Schilperoord, P. (2007) Metamorphose der Pflanze. *Elemente der Naturwissenschaft* **86**, 46-71.
- Steiner, R. (1889) *Grundlinien einer Erkenntnistheorie der Goetheschen Weltanschauung* 7th ed. (GA 2, Rudolf Steiner Verlag, Dornach, 1979); trans. *Theory of Knowledge Implicit in Goethe's World Conception* (Anthroposophic Press, N.Y., 1968).
- Steiner, R. (1985) *Goethe's World View*. Mercury Press, Spring Valley, NY. p. 90

Peer Schilperoord
Hauptstrasse 16
CH-7492 Alveneu
Switzerland

schilperoord@bluewin.ch

Translated by David Heaf from Schilperoord, P. (2008) Goetheanism – falsche Abgrenzungen. *Elemente der Naturwissenschaft* **88**, 66-69

mental processes. Even in animals such as butterflies there are surprises despite their being relatively close to the two winged species. Although Ubx likewise codes for a transcription factor, its organismic significance is diametrically opposite (Levine 2002, Ronshaugen et al. 2002). Wing formation in butterflies is not suppressed but stimulated by Ubx! The assignment of significance is dependent on the particular animal species. The genetic sequence is interpreted species-specifically – it is not a sufficient cause but a necessary condition for the realisation of developmental processes. The cause of the phenotypic expression is the living organism as a whole.

That no phenotypic features can be derived from the knowledge of molecular functions or base sequences in a gene, and that the assignment of significance lies not in the genes but in their carriers, is strikingly confirmed by research of other gene activities (see for example Moss 2005, who discusses this observation in depth; Wirz 1997). In modern genetics the substance of inheritance is often described as text and the human genome as the book of life. Therefore a simple example may clarify the matter under discussion. What is the significance of the letter sequence ‘hat’. In the German language it is a verb form. The English use it to describe a head covering and to Norwegians it means ‘hate’. The code is interpreted differently according to language. Any attempt to derive the meaning from the letters must fail.

The extension of the central dogma of genetics

Such considerations carry little weight in positivist science. It would with certain justification argue that to build a bridge between molecular and phenotypic genetics further building blocks are still missing, and, that after fifty years, only a beginning has been made in researching the molecular basis. A view of the central dogma of genetics (Watson 1968) and its development in recent years makes this bridge building questionable (Figs 2 & 3).

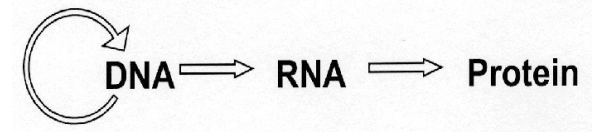


Fig. 2. The central dogma of genetics according to Watson and Crick. The circular arrow indicates semi-conservative replication; the straight arrows suggest the irreversibility of the flow of information.

The dogma contains two central statements that drive and constantly influence the research program of modern biology. The first says that there exists encoded in the DNA of an organism the entire information, i.e. the *Bauplan*, according to which its developmental processes are steered, its form developed, its metabolic processes produced and, in an animal, its neurological functions unfolded. The information flow follows a one-way street and cannot be influenced by the organism. Changes in the DNA are therefore always the result of accidental external influences such as cosmic rays, mutagenic substances etc. – evolution is a dice game without someone throwing the dice. Secondly, the

structure of DNA suggests a doubling that appears to be purely chemically determined as semi-conservative replication. If a double helix is melted into individual strands, the individual building blocks are situated on them in such a way that both daughter strands are identically constructed. The two central motifs that characterise life are, according to the dogma, clearly written in the properties of DNA: stability and constancy in inheritance, plasticity and chance variation as the drivers of evolution.

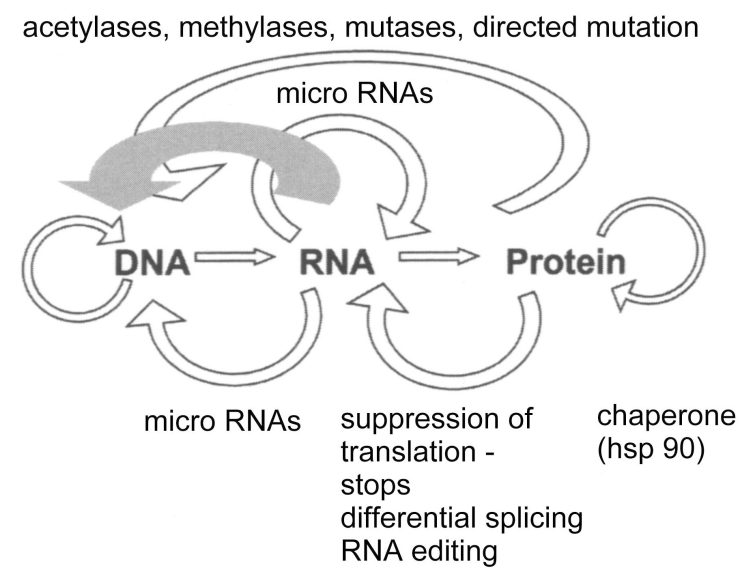


Fig 3. The extension of the central dogma. The DNA is part of a large molecular network with many feedback loops of RNA and protein; selected processes are described in the text ; the grey arrow indicates non-Mendelian processes of inheritance (without DNA), whose mode of action is still unclear.

This view matches reality only modestly. Correct replication of DNA requires more than chemical precision (Table 1). An error rate of 1 in 300 would simply not have been possible. In man, at each replication, i.e. at each cell division, about 10 million nucleotides would be incorrectly inserted.

Replication type	Error rate
Chemical/thermodynamic	3×10^{-2}
Enzymatic without correction	1×10^{-4}
Enzymatic with proofreading	1×10^{-7}
Proofreading & mismatch repair	1×10^{-10}

Table 1. The precision of replication of DNA. The poor precision of purely chemical replication is increasingly improved by polymerases. The highest precision is reached when after completion of the replication process enzymes correct false pairings (mismatch) in the double strand.

the model and the key² The definitions of the archetype of Claßen-Bockhoff and Hagemann relate only to the model. The keys are revealed in the way the various models are awakened to life by the authors. Kranich looked at the differentiating aspect of the definitions and thus overlooked what they had in common in their methods of working. He overlooked the commonality because he did not study the work of the authors referred to. Otherwise he would have been able to state that, for example, in Hagemann he had been able to find an exceptional ally in opposing the cell theory of Schleiden.

In morphology we work with various archetypes depending on whether we are considering a leaf, a flower or the whole plant. Claßen-Bockhoff indicated this when she wrote that the definition she gave expresses only the concept as she uses it in his paper. She summarises the essential thing she wants to say in all its brevity in the quotation from Hans Albert Froebe presented in this text: ‘In evolutionary morphology we observe the flow of phenomena and recognise that we need supports, i.e. archetypes, so we can keep ourselves steady in this flow’.

I can thoroughly recommend the book *Wert und Grenzen des Typus in der botanischen Morphologie* to anyone interested in morphology and the epistemological issues connected with it. The wealth of examples, various perspectives, theoretical explanations and, not to forget, the long list of references, are found almost nowhere else in such a compact form. That the authors are not all singing from the same hymn sheet makes it all the more exciting.

I have been observing developments in morphology for thirty years and I find it a big problem that too many papers are published without referring to the results of earlier generations, or even to those of contemporaries, and without people making themselves aware in what stream they are placed. Kranich is right to complain (p. 14.) that people are in the dark about the reasons for the comprehensive classification in families. But that does not mean that no work has been done on that, and still is being done. Approaches to this can be found in Goebel (1855-1932) and in his *Organography of Plants* which was published in its third German edition in 1933 (Goebel, 1905). A whole branch of science intensively concerned with evolution and ontogenesis is continuing to grow. If one wishes to publish in this subject one needs a lot of time to familiarise oneself with the history and present state of the discussion. In my view this is where the main problem lies for those wanting to make a contribution. If we make no or too little reference to what has already been achieved, we can of course get interesting results, but they cannot be integrated into or stand isolated in scientific space.

Whence comes this lack of attention regarding the history of morphology? I have considered this question for some time. I suspect that it is connected with the fact that, in his epistemological works on Goethe’s method, Rudolf Steiner had not engaged with the question as to what extent botanists and morphologists of the second half of the 19th century used Goethe’s methods. Hofmeister, Sachs, Hansen, and Goebel, to name but a few, were not mentioned in his epistemological writings. Steiner was not a morphologist and it was not his intention to comment on that subject. And the philosopher Jos Schieren, in his comprehensive book *Anschauende Urteilkraft – Methodosche und philosophische*

² There are several keys for each model; I assume that all the keys have not been found yet.

Goetheanism – false contrasts

Peer Schilperoord

‘In evolutionary morphology we observe the flow of phenomena and recognise that we need supports, i.e. archetypes, so that we can keep ourselves steady in this flow.’

Hans Albert Froebe

Shortly after the death of Ernst-Michel Kranich, a former lecturer at the Waldorf teacher-training seminar in Stuttgart, *Archetype* published his paper ‘Goetheanism – its methods and significance in the science of living organisms’. In it Kranich (2007) drew boundaries between Goethean botany and the kind of botany that remains stuck in ‘*Bauplan*-thinking’, or satisfies itself with exactly describing the phenomena. He mentioned only two morphologists by name, who, in his opinion, base their morphology ‘on an incomplete experience of reality’. Furthermore he asserted: ‘What is now designated as ‘type’ in modern botany is something different from Goethe’s vivid intuition (*lebendige Anschauung*) of a developing general plant being.’ (Kranich, 2007, p. 13.) As an example he named Prof. Regine Claßen-Bockhoff of Mainz University, a former pupil of Hans Albert Froebe (1932-2003), who had taught at Aachen University, and emeritus Prof. Wolfgang Hageman, a former pupil of Wilhelm Troll. As it happens, in the same issue of *Elemente der Naturwissenschaft* that contained the German original of Kranich’s paper, I expressed praise for the work of Hagemann (Schilperoord, p. 50). What is going on?

Morphology is a science of comparison. Comparing means putting in context; transforming one into another; recognising what is common and what is differentiating. Any morphologist uses these methodological approaches. So that we can avoid getting lost in the enormous diversity, we need systems of reference, models, schemata, bauplans, archetypes or whatever we like to call these simplifications. Goethe as the founder of morphology could not manage without models either. On 17 May 1787 he wrote to Herder in euphoric tones: ‘The archetypal plant will be the most wonderful creation in the world for which nature itself will envy me. With this *model* and the *key*¹ to it one can then go on inventing plants forever which must follow lawfully...’ (in Steiner 1985). Here Goethe writes of a model *and* a key. A model alone does not suffice. There has to be something in addition so we can inwardly set it in motion and thus arrive at the diversity. This is precisely what morphologists have done for 200 years. Steiner formulated it no differently too, as Kranich evidenced with a quotation from him (Kranich 2007, p. 15.): ‘... if we are to have a rational science, we must presuppose hypothetically determined forms in which the type takes shape. One must then show how these hypothetical forms can always be transformed to a definite form lying before our eyes.’ (Steiner 1889, p. 106; trans. p. 92). Those whom Kranich criticised, Claßen-Bockhoff (2005) and Hagemann (2005), did exactly this.

So why did Kranich criticise them? In his definition of the archetype is contained both

The error rate is considerably reduced by enzymes, the DNA polymerases. Enzymatically mediated replication increases the precision of the doubling. One error in 10,000 base pairs can be expected. This precision is sufficient in many viruses with small genomes, but would still be too high to guarantee the evolution and continued existence of single-celled and higher organisms. With proofreading, i.e. the correction of wrongly inserted nucleotides during the replication process, the error rate is further reduced and thus ensures the survival and evolution of many bacteria. Only by mismatch repair, i.e. replacement of wrongly inserted nucleotides after the completion of replication, is the survival of mammals and humans secured (one error per 10¹⁰ inserted nucleotides). Too many incorrectly inserted base pairs would not allow survival. Too great a precision would prevent evolution. In the first case we would have long since died out and in the second case we would still be bacteria! The linkage of mutation rate and the complexity of a living organism is subtle. If the error rate is reduced *before* a higher evolutionary stage of organisation is reached, then the possibility of higher development is minimal. If it occurs *after*, then continued existence is endangered. The situation is best described by an inner relationship of variability and constancy in the sense of an alternating causal relationship mediated by the living organism itself. This relationship of course has chemical-substantial prerequisites, but is the result of a genuine organismic function (see also Wirz 1998).

The last twenty years have made it necessary to revise the central dogma far beyond these considerations (Fig. 3). The DNA has lost its significance as a master switch and has become part of the molecular regulatory network. Furthermore, gene regulation, genetic stability and variability is closely connected with the cellular and outer environment of the particular organism – variation and selection are no longer two separated, independent realms, but form a continuum.

Thus it is now known that the precision of DNA replication of organisms is actively steered. Mutation rates are actively lowered or raised (Beaber et al. 2004, Björkman et al. 2000), a fact that under artificial laboratory conditions is frequently overlooked. Living organisms ensure that amongst their offspring a sufficiently large number of genetic and thus phenotypic variants are available to ensure the survival of the population. Although this discovery was made primarily with bacteria and yeasts, where, thanks to the short replication times, many generations can be investigated, we may conclude that active regulation of the mutation frequency also happens in plants and animals, which have DNA-polymerases and repair enzymes similar to those of microbes.

Under the title ‘Mice are not furry petri dishes’, Bull and Levin (2000) have emphasised a further aspect from the work of Björkman *et al.* (2000). In a bacterial strain, an antibiotic resistance gene that serves as a marker is differently inactivated according to whether the cells are raised in mice or on an artificial substrate (in petri dishes). Clones were isolated from mice which had lost all the resistance through exactly the same mutation *inside* the coding sequence of the gene. The loss of resistance in colonies in the petri dishes happened with mutations that occur *outside* the coding sequence. Obviously the bacteria are sensitive to their environment and react accordingly with different genetic adaptations.

But this by no means exhausts the capabilities for spontaneously regulating and forming the *Bauplan*. It seems that organisms creatively play with constancy and plasticity in

¹ italicisation by Schilperoord.

each process from reading DNA to producing protein. The first possibility concerns the structural organisation of the DNA and is called epigenetics. The chromosomes of all higher organisms are complex structures in which the DNA is wrapped in proteins, especially histones. The density of packing of both the DNA and the histones can be modified chemically (acetylation and methylation) (Jenuwein & Allis 2001). It is loosened and made accessible for transcription by the removal of methyl groups. It is enlarged when such groups are attached to the DNA or histones and this suppresses transcription. This structuring of the chromosomal landscape (Chakalova et al. 2005) with activation or inactivation of a multitude of gene sequences occurs not only in developmental processes and differentiation of various cell types but also with changes in the environmental conditions. Studies in monozygotic twins show that the pattern of epigenetic modification at the birth of both twins is still largely identical, but in later life is very different (source: <http://epigenome.eu/en/1,4,0>). Frequently such modifications are passed on to the next generation. Dutch research on children whose grandparents suffered extreme hunger during the Nazi embargo on food supplies showed a reduced body weight and an increase in various metabolic diseases (Pray 2004) which were caused not by mutations but by epigenetic changes. In *Arabidopsis thaliana* there are changes that arise from DNA modification and are stably inherited by the next generation, for example in the architecture of the flower (Lachner 2002). These processes are reminiscent not metaphorically but literally of Lamarckian inheritance of acquired characteristics (see also Jablonka and Lamb 2005).

Reports on the inheritance of characteristics that are not coded on DNA are puzzling. It was shown with *Arabidopsis* that a raised recombination frequency induced by stress in ancestors still manifests four generations later (Molinier et al. 2006) and that a phenotype (hothead) which shows fusion of the flower organs, reverts to the normal initial form even if the parents are homozygous for hothead (Lolle et al. 2005). Obviously the capacity to form a normal flower architecture without a change in DNA is inherited. The findings were announced as non-Mendelian inheritance of information and transgenerational memory of stress in order to characterise this new and still obscure form of inheritance.

All higher organisms can expand the spectrum of proteins far beyond the instructions coded in the cell nucleus. Although genome projects have shown that man, fly, mouse and *Arabidopsis* differ only a little in the number of genes, the differences at the level of proteins are enormous. How does this come about? Genes exist in the cell nucleus as coded sequences, the exons, separated by non-coding introns. From a single gene sequence, differential splicing permitted by the free combination of the exons produces thousands of different RNAs and thus proteins (Fox Keller 2000). Without this multiple usage (flexibility) it would never have been possible to arrive at the complexity of higher organisms. The information as to when and where a particular protein is produced cannot reside in the DNA-sequence. It is determined by the cellular, intracellular, developmental biological and environmental milieu.

Finally, all living organisms have a multitude of chaperones amongst which are the heat shock proteins (Hsp). In stress situations they maintain the functional fundamental structure of the proteins involved in metabolism. But the role of Hsp 90 goes far beyond this. In yeast, *Arabidopsis* and *Drosophila* it preserves potential phenotypic variants and thus

- (1980): *Lebenszusammenhänge*, Dornach.
- (1984): *Dying forests – a crisis in consciousness* (Hawthorn Press, 1984).
Translated from: *Sterbende Wälder – eine Bewusstseinsfrage*, Dornach.
- Bockemühl, J., Schad, W. & Suchantke, A. (1980): *Mensch und Landschaft Afrikas*, Verlag Freies Geistesleben, Stuttgart.
- Braun, U. (1979): *Untersuchung von Bodenverhältnissen im Goetheanumgelände*.
Unveröffentlichte Arbeit in der naturwissenschaftlichen Sektion am Goetheanum, Dornach, Switzerland.
- Ellenberger, H. (1982): *Vegetation Mitteleuropas mit den Alpen*, Eugen Ulmer Verlag, Stuttgart.
- Klapp, E. (1971): *Wiesen und Weiden*, 4th edition. P. Parey, Berlin & Hamburg
- Knoop, S. (1986): *Räumliche und zeitliche Verwandlung einer Wiese in ihren Pflanzengesellschaften*. Unveröffentlichte Arbeit in der naturwissenschaftlichen Sektion am Goetheanum, Dornach, Switzerland.
- Peters, E. (1979): *Entwicklung einiger Wiesenstandorte auf dem Goetheanumgelände*.
Unveröffentlichte Arbeit in der naturwissenschaftlichen Sektion am Goetheanum, Dornach, Switzerland.
- van der Ree L. & Verhaagen H. (1980): *Naturpflege auf dem Goetheanumgelände*.
Unveröffentlichte Arbeit in der naturwissenschaftlichen Sektion am Goetheanum, Dornach, Switzerland.
- Steiner, R. (1886): *A theory of knowledge implicit in Goethe's world conception*.
(Anthroposophic Press, N.Y., 1961) Translated from: *Grundlinien einer Erkenntnistheorie der Goetheschen Weltanschauung*, Rudolf Steiner Verlag, Dornach, Switzerland..
- Sukopp, H. (1969): Der Einfluss des Menschen auf die Vegetation, *Vegetatio* **17**: 360-371.
- (1972): Wandel von Flora und Vegetation in Mitteleuropa unter dem Einfluss des Menschen, *Br. Landwirtsch.* **50**, 112-139.
- Vahle, H. C. & Dertmar, J. (1988) 'Anschauende Urteilskraft' – ein Vorschlag für eine Alternative zur Digitalisierung der Vegetationskunde, *Tuexenia* **8** 407-415.

Werner Schneider
Raingartenweg 2
CH-4143 Dornach
Switzerland

email: Werner.Schneider@bs.ch

Translated by Lynda Hepburn* from Schneider, W. (1991) Die Wiesen als Bild ihrer Umgebung, *Elemente der Naturwissenschaft* **54**(1), 10-44.

* <http://www.summittranslations.co.uk/>

<i>Galium mollugo</i> L.	x	.	1	1	+	+	
<i>Dactylis glomerata</i> L.	x	2	+	+	+	+	
<i>Lolium perenne</i> L.	x	2	1	1	+	.	
<i>Trisetum flavescens</i> L.	x	-	+	+	1	+	
<i>Ajuga reptans</i> L.	x	+	1	-	1	1	
<i>Trifolium pratense</i> L.	x	+	1	1	+	+	
<i>Plantago lanceolata</i> L.	x	1	1	1	1	+	
<i>Festuca pratensis</i> Huds.	x	.	+	+	1	.	
<i>Crepis biennis</i> L.	x	+	1	.	+	-	(missing in the dry meadow)
<i>Ranunculus acris</i> L.	x	1	+	.	1	+	
<i>Holcus lanatus</i> L.	x	+	+	.	1	-	
<i>Taraxacum officinale</i> Web.	x	3	.	r	1	-	
<i>Brachypodium silvaticum</i> P.B.	.	.	.	.	.	1	(Only shady north-facing meadow)
<i>Equisetum arvense</i> L.	.	.	.	.	.	1	
<i>Festuca altissima</i> All.	.	.	.	.	.	-
<i>Agrostis stolonifera</i> L.	.	.	.	.	.	-
<i>Lathyrus pratensis</i> L.	.	.	.	.	+	-	Differential species in the north-facing meadow
<i>Carex</i> sp.	.	.	.	.	-	-
<i>Luzula campestris</i> L.	.	.	.	.	-	.
<i>Festuca rubra</i> L.	.	.	.	.	1	.	
<i>Vicia sepium</i> L.	x	-	.	-	+	+	Species with varying distribution
<i>Avena pubescens</i> Huds.	.	.	1	+	.	-	
<i>Trifolium dubium</i> Sibth.	.	.	.	-	.	-	
<i>Anthoxanthum odoratum</i> L.	.	.	1	+	1	+	
<i>Veronica serpyllifolia</i> L.	x	.	.	-	-	.	
<i>Hypericum perforatum</i> L.	.	.	.	-	.	.	
<i>Medicago lupulina</i> L.	.	-	+	+	.	.	
<i>Bellis perennis</i> L.	.	+	+	-	.	.	
<i>Lysimachia nummularia</i> L.	x	.	.	r	+	.	
<i>Cynosurus cristatus</i> L.	.	.	-	.	+	.	
<i>Crepis capillaris</i> Wallr.	.	.	.	.	.	-
<i>Prunella vulgaris</i> L.	.	+	1	-	-	.	
<i>Carex sylvatica</i> Huds.	.	.	.	r	.	.	
<i>Cardamine pratensis</i> L.	x	-	.	.	-	.	
<i>Glechoma hederacea</i> L.	.	+	.	-	-	+	
<i>Cerastium caespitosa</i> Gilib.	.	+	.	-	+	.	
<i>Potentilla reptans</i> L.	x	.	-	-	.	.	
<i>Agropyron repens</i> P.B.	.	-	.	.	.	-	

References

- Bockemühl, J. *et al.* (1977): *Toward a Phenomenology of the Etheriv World. Investigations into the life of nature and man.* Anthroposophic Press. N.Y.
 (1985) Translated from Erscheinungsformen des Aetherischen. Beiträge zur Anthroposophie 1, Verlag Freies Geistesleben, Stuttgart

achieves at the level of proteins what the polymerases, which through modulation of replication allow the production of a multiplicity of different gene sequences, do at the level of DNA. If the synthesis of Hsp 90 is suppressed pharmacologically, this multiplicity manifests phenotypically (Queitsch *et al.* 2002, Rutherford & Lindquist 1998, Sangster *et al.* 2007). Descendants of a previously homogenous population show various morphological deviations from the parental type. These can be selected and after a few generations are stably inheritable independently of Hsp 90. Hsp 90 allows plants and animals to react quickly to changed environmental conditions by means of new phenotypes. Susan Lindquist has described these chaperones as a ‘capacitor’ of evolution (Rutherford & Lindquist 1998). Long term survival is impossible without them. If Hsp 90 is missing in baker’s yeast, the population dies out after a few generations under changing environmental conditions.

All the processes described point to a marked context-specific, highly differentiated reaction of organisms. They give rise to a picture of a continuum comprising organism and environment in which plants and animals use the possibilities according to their species and character and bestow meaning in a way similar to how languages use and interpret the sequence of letters ‘HAT’. Accordingly, the spontaneous capability exists not only in connection with the relationship of phenotype and molecular function, but also within the molecular network itself. This capability is effected both retrospectively – with epigenetic processes and inheritance without DNA – and prospectively – by the regulation of mutation frequencies and Hsp 90. In the first case one can speak of the inheritance of acquired characteristics, and in the second case terms such as ‘play’ and ‘chance’ are fitting, insofar as phenotypes are prepared and can be tested in possible though not foreseen environmental conditions.

This view should not be interpreted naively. Living organisms do not intervene at the molecular level in the course of their lives. Rather the processes have some resemblance to the neurological processes of Buddhist monks during meditation or to bodily reactions after consuming chocolate. In both cases the attention is directed at an activity and/or consumption. Examining cellular or molecular processes shows that meditative concentration leads to changes in brain activity which can be demonstrated using modern imaging processes, and that chocolate leads to an increase in the blood-sugar level and, through a complex cascade, stimulates the secretion of insulin which causes its reduction.

Goethe’s theory of the living world

The increasing number of possibilities for gene regulation, the production of a multitude of proteins and the control of genetic constancy or plasticity are the subject of molecular biological research whose end cannot be foreseen. It is reminiscent of an orchestra that is constantly growing as new instruments are discovered in it. But who is the conductor? The answer may at first seem trivial. It is the bacteria, plants, animals or man himself! However, to rediscover living organisms against the background of a physical-chemical picture of the world in biology is anything but simple, although there has long been a biological and philosophical tradition of understanding living organisms in their totality, i.e. not reducible to physics and chemistry (Brenner 2007). One representative of this

tradition is Goethe who transformed it into a scientific method. In his *Vorarbeiten zu einer Physiologie der Pflanzen* (Preliminary studies for a physiology of plants) he formulated the ‘double law’, according to which plants – and in my view all living organisms – are formed. In doing so he distinguished two aspects: the law of inner nature, according to which the organism is constituted, and the law of outer circumstances, according to which it is modified (Kranich 2007, Kuhn 1964, Steiner 1891, Wirz 2000).

To grasp the law of outer circumstances, seven supplementary sciences are named, including morphology ‘in the strict sense’ (Fig. 4). Here, Goethe anticipated modern science, as well as the synthetic theory of evolution (Mayr 1982). Today, the list needs to be extended to cover evolution, genetics and ecology, which, like all supplementary sciences, are involved in observations in the sense world. As Steiner (1891) indicated, inheritance is according to Goethe the result of a living organism appearing, not its cause. It guarantees the constancy of animal and plant forms in the sequence of generations. Plasticity, i.e. the potential to alter these forms during development and evolution, is a property of the inner nature, which is also described as the idea of the archetype (Steiner 1968). As experience shows, living organisms always react holistically, integrally according to changes in the external conditions. Against this background, the hypothesis may be put forward that living organisms, and plants in particular, react to interventions by means of molecular genetics in a way that is similar to how they react to changes of light, soil and nutrient supply (see below).

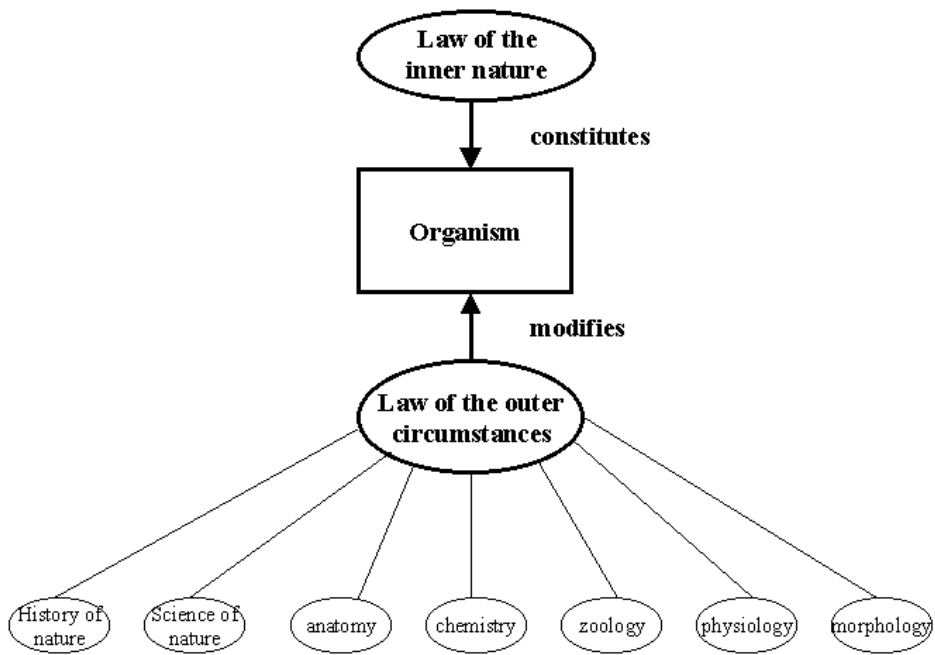


Fig. 4. The double law according to Goethe

Lesser Celandine	<i>Ranunculus ficaria</i> L.
Meadow Buttercup	<i>Ranunculus acris</i> L.
Meadow Clary	<i>Salvia pratensis</i> L.
Meadow Vetchling	<i>Lathyrus pratensis</i> L.
Ox-eye Daisy	<i>Chrysanthemum leucanthemum</i> L.
Red Clover	<i>Trifolium pratense</i> L.
Red Fescue	<i>Festuca rubra</i> L.
Ribwort Plantain	<i>Plantago lanceolata</i> L.
Rough Hawk's-beard	<i>Crepis biennis</i> L.
Rough Hawkbit	<i>Leontodon hispidus</i> L.
Salad Burnet	<i>Sanguisorba minor</i> Scop.
Slender Speedwell	<i>Veronica filiformis</i> Sm.
Upright Brome	<i>Bromus erectus</i> Huds.
White Clover	<i>Trifolium repens</i> L.
Wild Carrot	<i>Daucus carota</i> L.
Yarrow	<i>Achillea millefolium</i> L.

Species list for the six sites

	Da	H	F	Dr	o	s	
<i>Ranunculus ficaria</i> L.	X	Differential species in the hollow meadow and damp meadow
<i>Circium oleraceum</i> L.	X	.	.	.	.	.
<i>Heracleum sphondylium</i> L.	X	+	r	.	.	.	
<i>Rumex obtusifolius</i> L.	X	+	.	.	.	.
<i>Veronika filiformis</i> Sm.	X	+	.	.	r	.	
<i>Ranunculus repens</i> L.	X	1	.	.	.	r	Differential species in the less lush meadows
<i>Lotus corniculatus</i> L.	.	.	2	1	1	-	
<i>Leontodon hispidus</i> L.	.	.	1	-	1	+	
<i>Ranunculus bulbosus</i> L.	.	.	1	+	.	-	
<i>Sanguisorba minor</i> Scop.	.	.	r	+	2	.	
<i>Plantago media</i> L.	.	.	.	1	+	.	
<i>Bromus erectus</i> Huds.	.	.	+	4	1	-	Differential species in the flowery meadow
<i>Knautia arvensis</i> L.	.	.	1	+	.	-	
<i>Salvia pratensis</i> L.	.	.	+	-	.	.	
<i>Centaurea jacea</i> L.	.	.	1	.	.	.	
<i>Picrus hieracioides</i> L.	.	.	1	.	.	.	
<i>Chrysanthemum leucanthemum</i> L.	.	.	1	.	.	.	More abundant in the dry meadow
<i>Daucus carota</i> L.	.	.	-	+	.	.	
<i>Achillea millefolia</i> L.	.	.	-	+	.	.	
<i>Euphrasia rostkoviana</i> Hayne	.	.	-	-	.	.	Species with widespread distribution
<i>Trifolium repens</i> L.	r	+	-	+	1	.	
<i>Arrhenatherum elatius</i> L.	x	+	+	1	1	1	
<i>Poa trivialis</i> L.	x	1	1	-	-	1	
<i>Veronica chamaedrys</i> L.	.	+	.	-	+	1	
<i>Rumex acetosa</i> L.	x	1	+	-	-	.	

dent that the fodder quality of a meadow – in other words its usefulness for the animal kingdom – is primarily dependent on its species composition.

If we were to follow the same meadow through its changes during the course of the year, then we would have a view of the 'most essential plant nature'. (This only happened in passing in this study).

In all these three levels of meadow observation, we can discover a fourth element: the human being. The human being intervenes in the 'physical side' of a meadow through drainage, irrigation, manuring, mowing etc. and in the 'plant-like side' through the point in time at which these interventions occur. And by sowing and indirectly also through other measures, human beings influence the 'animal side' of meadows as well. The human being has a significant influence on whether a meadow is diverse and nutrient-poor or uniform, lush and productive. In this way the meadow becomes a picture of human intentions, of the human being's understanding of nature and of himself.

Returning to the Goetheanum grounds. As mentioned at the beginning of this study, the Goetheanum building is designed from the landscape forms of the *Tafeljura*. The orchards around the Goetheanum are also a part of this landscape. On the one hand they are part of the old local cultural landscape and on the other hand, in the subtle differences from one meadow to the next, reflect the main meadow types of the Jura landscape as a whole. What characterises the landscape on a large scale can be rediscovered on a small scale. Once discovered, this relationship can be deliberately fostered. A building and its surroundings can gradually become the highlight of a landscape and its being can appear more fully, in the form that human beings have understood it. This reveals the endeavour to introduce new things into the world, not as something completely foreign, but as developments from what already exists.

List of plant names

Broad-leaved Dock	<i>Rumex obtusifolius</i> L.
Brown Knapweed	<i>Centaurea jacea</i> L.
Bulbous Buttercup	<i>Ranunculus bulbosus</i> L.
Bush Vetch	<i>Vicia sepium</i> L.
Cock'sfoot	<i>Dactylis glomerata</i> L.
Common Birdsfoot-trefoil	<i>Lotus corniculatus</i> L.
Common Sorrel	<i>Rumex acetosa</i> L.
Creeping Buttercup	<i>Ranunculus repens</i> L.
Dandelion	<i>Taraxacum officinale</i> Web.
Eyebright	<i>Euphrasia officinale</i> L.
False Oat-grass	<i>Arrhenatherum elatius</i> L.
False-brome	<i>Brachypodium silvaticum</i> D.B.
Field Horsetail	<i>Equisetum arvense</i> L.
Field Scabious	<i>Knautia arvensis</i> L.
Field Woodrush	<i>Luzula campestris</i> L.
Goldilocks	<i>Ranunculus auricomus</i> L.
Hawkweed Ox-Tongue	<i>Picris hieracioides</i> L.
Hoary Plantain	<i>Plantago media</i> L.
Hogweed	<i>Heracleum sphondylium</i> L.

But what is the law of inner nature? In the aforementioned text it seems somewhat cryptic when Goethe says that morphology, in a comprehensive sense, means understanding or recognising this law: 'Observing the organic whole through visualising all these considerations linking them together through the power of the spirit' (cf. Kuhn 1964). In other writings (Steiner 1985) it is clear that the heart of nature (*innere der Natur*) first and exclusively manifests as an idea in the inner being of man. It is this inner experience that enables us to grasp as a whole the multiplicity of species and environments; an experience that requires a change in perspective from observer (third person) to participant (first person). Goethe's biology of the archetype is 'idealistic', in that it enquires into the origins of life and its meaningfulness. It is 'materialistic' when it studies living organisms in their relation to the outer and cellular environment.

Non-target effects

As changes in the external conditions always show integral effects, it follows that a genetic modification should be visible in the whole plant. This was the working hypothesis for a research project with genetically modified plants that was carried out at the Goetheanum Research Institute. Such unintended effects, also called non-target effects, are of course described in publications here and there, but always regarded as mishaps of an otherwise successful technology. From a Goethean perspective they belong necessarily to the consequences of any genetic transformation that as 'external conditions' modify the plant's appearance. Unintended changes were studied in potatoes, tomatoes and spring wheat with a total of five different introduced foreign genes. They affected developmental dynamics, shape, leaf architecture and organisation of the inflorescence and infructescence and could be observed in all the GM plants investigated. Many of the qualitative observations could be statistically verified with the help of a randomised block design and sufficient replicates.

Trials were undertaken at the Swiss Research Centre at Changins to insert a resistance to blight (*Phytophthora infestans*) in potato (the variety Bintje) by means of two strategies. In the first case plants were transformed with the viscotoxin-1 gene from mistletoe, whose gene product shows antifungal properties. In the second case the gene for aminolevulinate synthase was inserted. This enzyme leads to an accumulation of a cytotoxic substance which is expected to kill cells that have become infected. Both strategies failed. In contrast, disturbances in the developmental dynamics, an alteration in the shape of the plant and marked differences in leaf shapes were observed (Fig. 5) (Richter 2002, Richter *et al.* submitted). The differences in the leaf shapes in comparison to the non-manipulated control plants were as pronounced as those between different commercial varieties.

Equally clear non-target effects could be demonstrated in tomatoes (Schätzl 2007). Figure 6 shows a summary of all changes that were documented in a graduate research project. The comparison was between non-manipulated control plants GCR 161, an inbred line of the commercial variety Moneymaker, with plants that were modified with the GUS gene from *E. coli* in the laboratory of Michel Haring at the University of Amsterdam. This gene codes for a glucuronidase and is often used as a marker to trace gene

activities. As the substrate (glucuronic acid) is lacking in tomatoes, no non-target effects were expected. However, as Figure 6 shows, the spectrum of changes was broad, involving the plant's developmental dynamics and all its organs.

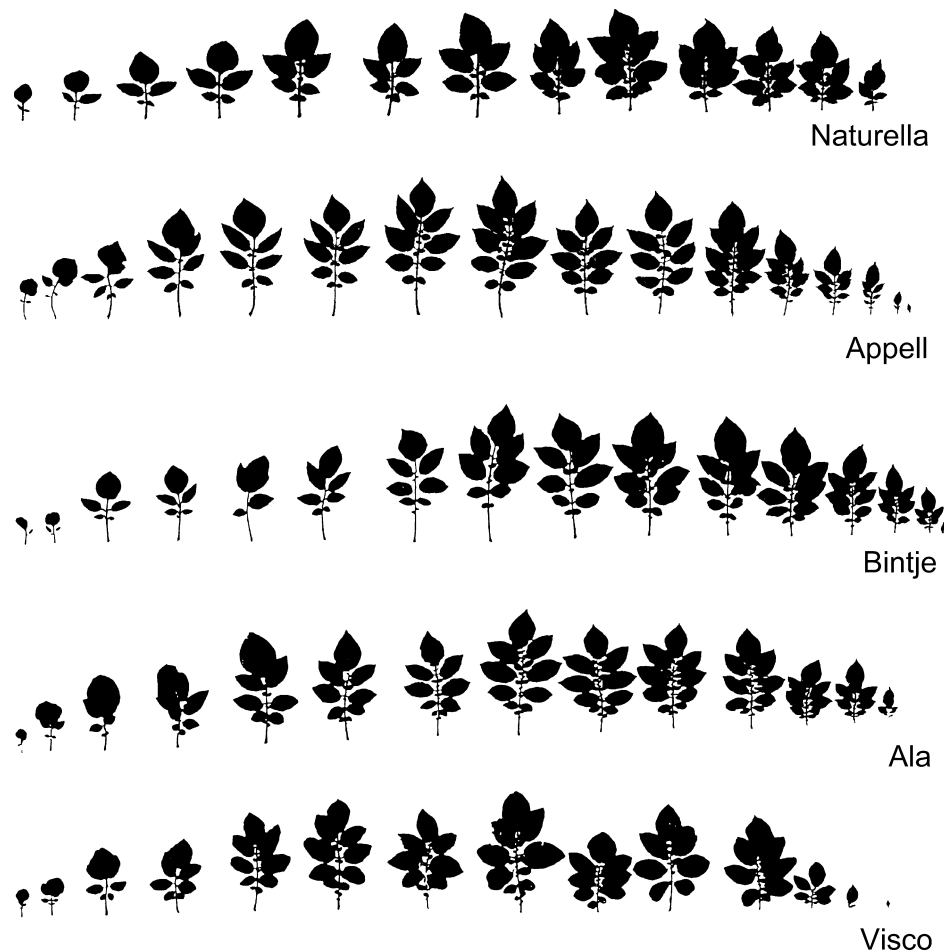


Fig. 5. Leaf series of potatoes. The first three series come from the commercially cultivated varieties Naturella, Appell and Bintje; the last two from GM plants with a gene for aminolevulinate synthase and viscotoxin-1 from mistletoe. Visco shows great irregularities in metamorphosis, small leaves with rounded leaflets. With Ala the irregularity in the series is less pronounced, the leaflets are narrower than with Bintje, the leaves have a greater number of intermediary leaflets.

7. The dry meadow

The dry meadow has not been dealt with separately here. This is because it has not developed fully in the Goetheanum grounds and its individual character only emerges slightly. The dry meadow is too localised to be able to stand out from the other meadows through a group of independent species. (Only the frequent occurrence of the wild carrot, the yarrow and the eyebright indicate a group of this kind). But its appearance is so characteristic, that it can be distinguished from all the other meadows.

Conclusion and outlook

This work has attempted to characterise six different meadows according to their vegetation. The aim was to guide the reader to an understanding of what is typical for each, to grasp the 'meadow type'. The attempt was made to uncover what was typical about the meadows a step at a time by looking at them in three different ways. First we took a look at the 'meadow structure as a whole' and at the particularly noticeable and most frequent growth forms of the individual plants. We tried to see them as a picture of their whole environment, of their surroundings.

Next we looked at the different family groups which are particularly characteristic of the individual meadows and in so doing, discovered something of the typical nature of the meadows.

Last we investigated individual plants and plant groups which are so typical of their particular meadow that they do not grow in the others at all. The growth forms of these plants correspond especially clearly to each of the environments. Indeed, these growth forms are not simply adapted depending on the environment, they are fundamentally formed to fit their preferred environment. This is known as the life form or the life form type. (This became especially clear in the case of the buttercup species). This third type of meadow investigation forms a link between the first and the second.

We could now pursue a further question of a practical nature: which kind of meadow produces which kind of hay? (It is not out of place in a vegetation study of this kind to pay some attention to the cows – without cows our meadows would not exist at all!) We can only offer a few provisional thoughts, a few preliminary remarks on this here.

To do this we need to consider the different ways of looking at the meadows more generally.

The form of a meadow expresses the qualities of the environment. This can be studied in the greatest of detail. (We did this in our first method of studying the meadows). This characterises the relationship of the meadows in particular to their physical environments. If we now look at the species composition of a meadow, we are then considering something which cannot merely be understood on the basis of the direct environment. A clary/false-oat grass meadow is for instance not just a dry, rather nutrient-poor variety of false-oat grass meadows, but it is also something special with a characteristic nature of its own. Ellenberger apparently considered them so outstanding and unique that he shared the opinion that they are one of the most beautiful plant communities in Central Europe (Ellenberger 1982, p 737). The development of characteristic individual forms is something we are familiar with in particular from the animal kingdom. It is therefore no acci-

6. The group of differential species in the north-facing meadows (Figure 18)

Lastly, we still need to look at the differential species in the north-facing meadows. In the shady north-facing meadow these are primarily the false-brome and field horsetail, in the open north-facing meadow primarily the meadow vetchling, field woodrush and red fescue. Amongst these five plants there is only one with conspicuous colourful flowers, the others have inconspicuous colouring and a grass-like linear form.

The false-brome has broad soft drooping leaves, corresponding to the shaded woodland edge situation.

The field woodrush produces a basal rosette with rather stiff leaves from which the dark nodular condensed inflorescence stands out clearly.

The hair-like leaves of the red fescue form delicate rosettes which produce stolons with which it can push through between the other plants.

At first glance, the meadow vetchling has little in common with the other plants. However it has a special position within the group of clover-type plants. Like the bush vetch it clings onto neighbouring plants with its leaf tendrils. However, its leaves are narrower, so in this respect, amongst the plants which are related to the clovers, it is the most similar to the grasses. The inflorescence is very clearly separated from the leaf realm. Both things are characteristic of our open north-facing meadow, which is in general characterised by grasses and in which the flower and leaf regions are clearly separated from one another.

The entire group of differential species – including the field horsetail – displays a 'grass habit'.



Fig. 18. North meadow

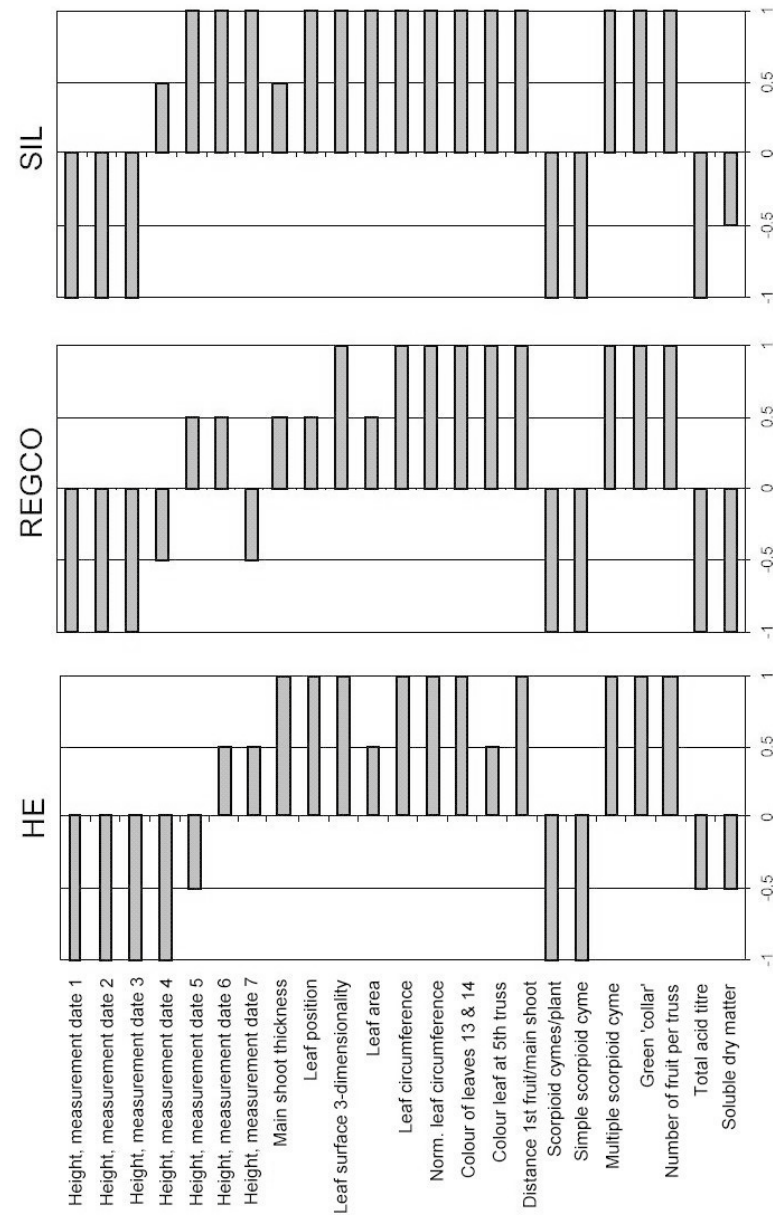


Fig. 6: Summary of non-target effects in GM tomatoes. The bars show deviations in comparison with the non GM variety GCR 161. Bars to the right denote larger values, to the left smaller values than control. ± 1 shows statistically significant differences. ± 0.5 shows tendencies. HE is a GM line with higher GUS expression. REGCO is a GM line that has lost the GUS gene again through out-crossing. SIL denotes a GM line without GUS expression; the activity of the transgene is suppressed by gene silencing. From the first column it is clear that the genetic transformation leads to changes in developmental dynamics, leaf features, stem thickness, geometry of the infructescence, the number of fruit per truss and composition.

The results show that despite the minute genetic change plants react integrally to it. If one compares the size of the introduced sequence (ca. 10,000 bp) with the size of the genomes of both plants (850 Mbp for potato, 950 Mbp for tomato) then the change corresponds to the insertion of a single word in a book of two hundred pages. The new interpretation of the genetic text by the plant itself confirms Goethe's idea of the organism. The hypothesis is supported that against the background of this idea non-target effects should be expected. From this perspective, the commercial cultivation of more than 100 million hectares of GM crop plants in 2007 (<http://www.isaaa.org>) is a real disaster and yet it was only possible under the false premiss that GM crops are substantially equivalent to the untransformed plants used as starting material.

Conclusion

Modern biology is on its way to rediscovering meaningfulness and significance in the living world besides the biological and molecular functions. These qualities determine living organisms ideally, as inner nature. The examples from the project on unintended effects show that, on the basis of the idea of the organism, testable predictions can be deduced. In experiments, wholeness and context should not be disregarded. Qualitative, aesthetic phenomena in plants and animals should be taken just as seriously with regard to their expressive capacity and knowledge value as quantitatively measurable traits.

This paper is also intended to encourage people to read results from the literature of current biological research in a critical-constructive way, questioning what lies behind assumptions and to investigate in applied research whether some of the findings presented such as epigenetic structuring of the chromosomal landscape or fixing of a morphological and physiological spectrum through chaperones could be used in breeding research. A consequence of the above would be projects that aim to re-test the concept of acquired characteristics.

Not least can Goethe's approach help us to become aware of the fact that people and living organisms are existentially interconnected as regards their inner natures. Only through a respectful attitude towards plants and animals can respect and dignity be guaranteed for man. Perhaps in future a maxim of Goethe will be on the agenda: 'If a student of nature wants to claim his right to free contemplation and observation, he will make it his duty to ensure the rights of nature; only where she is free, will he be free, where she is bound by human rules, he will be bound too'.

Acknowledgements

I very warmly thank Ruth Richter, Barbara Schmocker and Florian Leiber for their valuable comments and corrections.

References

Baars, T *et al.* (eds.) (2008) *Forschung am Lebendigen. Wissenschaftsphilosophische Hintergründe, Wissenschaftsergebnisse und Forschungsansätze der*

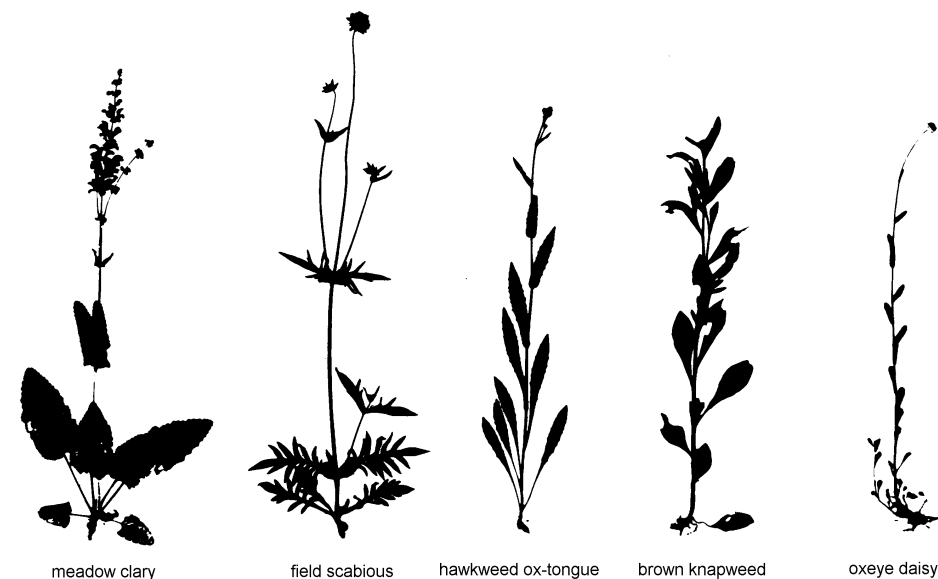


Fig. 17. Flowery meadow

the daisy family. Each plant produces several of these flowering structures which are carried on the branching flowering shoot.

The other three plants are all members of the daisy family. The brown knapweed and the hawkweed ox-tongue grow from individual rosettes. The hawkweed ox-tongue forms a denser flowering head, the brown knapweed a looser one.

The ox-eye daisy produces vigorous stolons with small new rosettes at their ends which each form a single, mostly unbranched flowering shoot. The blossom sits on a tall stem and is a large and impressive composite flower.

The five plants described express what is typical in the flowery meadow very well. The leaf realm starts with a rosette on the ground, but is then drawn upwards by the vigorous stem growth. Right at the top is the bright glowing blossom. The flowers and leaves are therefore equally developed. This contrasts with the luxuriant meadows on the one hand where flowering is lost in the vegetative realm and the dry meadow on the other, where life is condensed, flowering is strictly separate from the vegetative realm and is also sparser. The flowery meadow can therefore be viewed as lying between the polar tendencies. It is like an enhancement of the two polarities – no other meadow is able to flower so vigorously. It therefore combines the lushness, which is otherwise a feature of the vegetative realm, with the differentiated creative power of the reproductive realm.

It is no surprise that composite species – the scabious included – are amongst its most typical representatives. The members of the daisy family have, on account of their special structure, i.e. a multiplicity of flowers and concentration into a single head, also achieved an intensification of flowering.

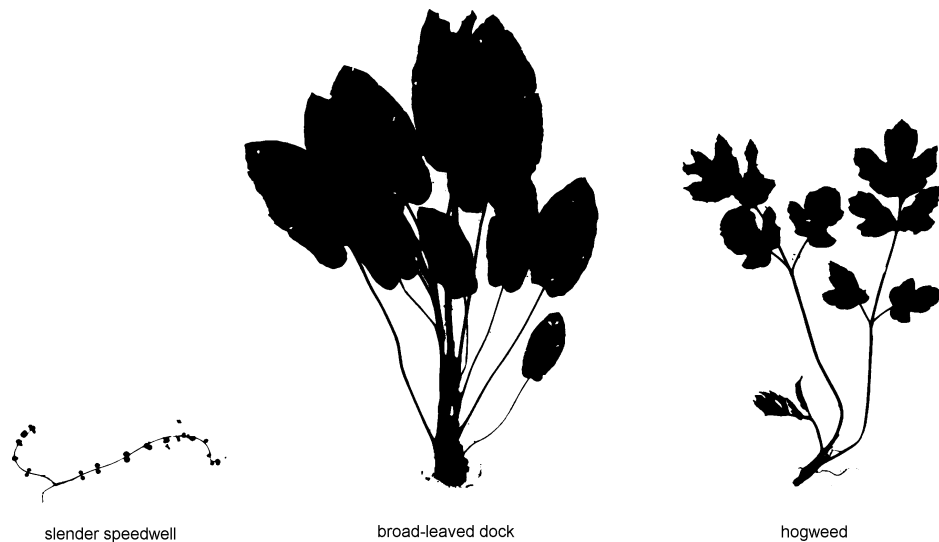


Fig. 16. Hollow meadow

leaves directly above the soil surface. So they do in fact resemble the dock and hogweed a little, which in summer likewise form extensive green layers with their large leaves further from the ground. The creeping buttercup combines the two growth habits. On the one hand it creeps along the ground like a root and on the other its leaves are relatively broad and raised up on long stems.

So far we have compared two meadow groups with each other: the damp meadow and hollow meadow with the less nutrient-rich flowery meadow, dry meadow and north-facing meadow. We now wish to differentiate further within the nutrient-poor meadow group. First we shall look at the particularly striking flowery meadow.

5. The group of differential species in the flowery meadow (Figure 17)

The meadow clary, brown knapweed, hawkweed ox-tongue and ox-eye daisy only grow in the flowery meadow and so constitute its differential group. (The field scabious is very close to this differential group, although it also occurs in the shady north-facing meadow.) They are all conspicuous plants which lend the flowery meadow a marked character.

With its large simple leaves and simple tapering flowering shoot, the clary is reminiscent of the dock which has already been described – but the two plants are nevertheless very different.

The leaves of the clary are tough and have only a short stalk. The stem is square, rigid and, instead of the small greenish inconspicuous wind-pollinated flowers of the dock, supports large dark blue, mysteriously shaped flowers which are pollinated by bumble bees.

The field scabious produces a strong basal rosette. Some of its leaves are subdivided, some simple. The small flowers are arranged in composite lilac heads like the plants in

biologisch-dynamischen Land wirtschaft, Darmstadt (in press).

- Beaber, J. W., Hochhut, B. & Waldor, M. K. (2004) SOS response promotes horizontal dissemination of antibiotic resistance genes. *Nature* **427**, 72-74.
- Bender, W. *et al.* (1983) Molecular genetics of the bithorax complex in *Drosophila melanogaster*. *Science* **221**, 23-29.
- Bjorkman, J. *et al.* (2000) Effects of environment on compensatory mutations to ameliorate costs of antibiotic resistance. *Science* **287**(5) 1479-1482.
- Brenner, A. (2007) *Leben. Eine philosophische Untersuchung*. Published by EKAH, Bern; as free PDF at www.ekah.ch.
- Bull, J. & Levin, B. (2000) Mice are not furry petri dishes. *Science* **287**, 1409- 1410.
- Chakalova, L. *et al.* (2005) Replication and transcription: Shaping the landscape of the genome. *Nature Reviews Genetics* **6**, 669-677.
- Fox Keller, E. (2000) *The century of the gene*. Harvard University Press, Cambridge, Ma.
- Jablonka, E. & Lamb, M. J. (2005) *Evolution in Four Dimensions – Genetic, Epigenetic, Behavioral and Symbolic*. MIT Press, Cambridge, Ma.
- Jensen, P (2001) *Entrer en matière: Les atomes expliquent-ils le monde?* Seuil, Paris.
- Jenuwein, T. & Allis, C. D. (2001) Translating the histone code. *Science* **293**, 1074-1080.
- Kranich, E.-M. (2007) Goetheanismus – seine Methode und Bedeutung in der Wissenschaft des Lebendigen. *Elemente der Naturwissenschaft* **86**, 31-45.
- Kuhn, D. (1964) *Goethe, die Schriften zur Naturwissenschaft*. Vol. 10: Aufsätze, Fragmente, Studien zur Morphologie. Leopoldina, Weimar.
- Lachner, M. (2002) Epigenetics: SUPERMAN dresses up. *Current Biology* **12**, 434-436.
- Levine, M. (2002) Evolutionary biology. How insects lose their limbs. *Nature* **415**, 848-849.
- Lewis, E. B. (1978) A gene complex controlling segmentation in *Drosophila*. *Nature* **276**, 5 65-570.
- Lolle, S. J. *et al.* (2005) Genome-wide non-mendelian inheritance of extra-genomic information in *Arabidopsis*. *Nature* **434**, 505-509.
- Mayr, F. (1982) *The Growth of Biological Thought* Harvard University Press, Cambridge, Ma.
- Molinier, J. *et al.* (2006) Transgeneration memory of stress in plants. *Nature* **442**, 1046-1049.
- Moss, L. (2005) Darwinism, dualism and biological agency. In: Hösle, V. & Illies, C. (eds.) *Darwinism & Philosophy*. Notre Dame, Indiana.
- Pray, L. A. (2004) Epigenetics: Genome, meet your environment. As the evidence accumulates for epigenetics, researchers reacquire a taste for Lamarckism. *The Scientist* **18**, at www.the-scientist.com.
- Queitsch, C., Sangster, T A. & Lindquist, S. (2002) Hsp90 as a capacitor of phenotypic variation. *Nature* **417**, 618-624.
- Richter, R. (2002) Phenomenological studies on transgenic potatoes: genetic modifica-

tions add more than intended traits. In: Heaf, D., Wirz, J. (eds.) *Genetic engineering and the intrinsic value and integrity of animals and plants. Proceedings of a workshop at the royal botanic garden, Edinburgh*. International Forum for Genetic Engineering, Llanystumdwy.

- Richter, R., van Damme, J. & Wirz, J. (submitted) Unintended effects of single gene insertions in potatoes – assessing developmental dynamics and leaf morphology.
- Ronshaugen, M., McGinnis, N. & McGinnis, W. (2002) Hox protein mutation and macroevolution of the insect body plan. *Nature* **415**, 914-917.
- Rutherford, L. & Lindquist, S. (1998) Hsp90 as a capacitor for morphological evolution. *Nature* **396**, 336-342
- Sangster, T A. *et al.* (2007) Phenotypic diversity and altered environmental plasticity in *Arabidopsis thaliana* with reduced Hsp90 levels. *PLoS ONE* **2**: e648.
- Schätzl, A. (2007) Nicht beabsichtigte Effekte von gentechnischen Veränderungen bei Tomaten (*Lycopersicum esculentum* Mill.). *Untersuchungen der Entwicklungsdynamik, des Habitus und ausgewählter Fruchtmerkmale*. Diplomarbeit an der Fachhochschule Weihenstephan.
- Steiner, R. (1968) *Theory of knowledge implicit in Goethe's world conception*. Anthroposophic Press, Spring Valley, NY., GA 2.
- Steiner, R. (1891) Über den Gewinn unserer Anschauungen von Goethes naturwissenschaftlichen Arbeiten durch die Publikation des Goethe-Archivs. In: *Methodische Grundlagen der Anthroposophie*. Dornach 1989, GA 30.
- Steiner, R. (1985) *Goethe's world view*. Mercury Press, Spring Valley, NY., GA 6.
- Watson, J. D. (1968) *The double helix*. Simon & Schuster, NY.
- Wirz, J. (1996) Progress towards complementarity in genetics. *Archetype* **4**, 21-36
- Wirz, J. (1997) DNA at the edge of contextual biology. In: Wirz, J. & Lammerts van Bueren, E. (eds.) *The Future of DNA*, Kluwer Academic, Dordrecht, Boston, London.
- Wirz, J. (2000) Typusidee und Genetik. In: Heusser, P. (ed.) *Goethes Beitrag zur Erneuerung der Naturwissenschaften*, Paul Haupt, Bern.

Johannes Wirz
Forschungsinstitut am Goetheanum
Hügelweg 59
CH-4143 Dornach
Switzerland

johannes.wirz@goetheanum.ch

Translated by David Heaf from Wirz, J. (2008) *Nicht Baukasten, sondern Netzwerk – die Idee des Organismus in Genetik und Epigenetik* (preprint from Baars *et al.* 2008), *Elemente der Naturwissenschaft* **88**(2), 5-21.

to the flowery meadow, there are signs of what then emerges as a basic growth principle in a characteristic form in the bulbous and creeping buttercups. In the flowery meadow the meadow buttercup assumes some of the character of the bulbous buttercup, in the damp meadow some of the character of the creeping buttercup.

Conversely, in the flowery meadow the bulbous buttercup shows parallels to the meadow buttercup (*Figure 14*), whereas it develops in its more typical form in the dry meadow (*Figure 12*).

There is yet another species of buttercup, the goldilocks, which grows in the grounds of the Goetheanum under old trees close to the north-facing meadow. The leaves are round, soft and simply formed: in its upright structure it resembles the meadow buttercup, but in its succulent texture it is similar to the lesser celandine. The goldilocks and lesser celandine are primarily woodland plants. The goldilocks belongs in lush temperate beech woods and oak-hornbeam woods, the lesser celandine in riverside woodland. When they occur in meadows, they evoke the qualities of these woodland sites. The lesser celandine occurs in the damp meadow which is related to the riverine woodland and the goldilocks beneath the shade of fruit trees. Something similar can be seen in the case of the creeping buttercup which we are familiar with as a rampant weed in fields and gardens. It occurs in meadows if they tend to rampant lush growth, which is the case in the hollow meadow and damp meadow.

4. *The differential species in the hollow meadow and damp meadow (Figure 16)*

The creeping growth which we have seen in two buttercup species (lesser celandine and creeping buttercup) is particularly typical for the hollow meadow and damp meadow. It occurs here in another plant, the slender speedwell, which is no relation of the buttercup family. The creeping buttercup and slender speedwell are characteristic of the hollow meadow and damp meadow, the lesser celandine only of the damp meadow. All three plants are absent from the flowery meadow and dry meadow. (However the slender speedwell can occur in the somewhat more vigorous north-facing meadows).

Clearly these two meadows are not just 'negatively' differentiated from the other meadows i.e. by the absence of specific plants, but also 'positively' i.e. they have their own group of differential species. In addition to the species mentioned already, these include the hogweed and the broad-leaved dock. The hogweed and dock are both vigorous plants with leaves which stretch far away from the stem. The dock is soft and succulent, the hogweed more clearly shaped. The hogweed flowers are correspondingly highly differentiated while the dock is scarcely able to separate its flowers from the luxuriant vegetative realm. In the group of differential species in the damp meadow and hollow meadow, two different growth habits are visible: the hogweed and dock, with their formless, relatively large leaves which stretch out into space, belong to one of these. The lesser celandine and slender speedwell, both small plants which creep along the moist ground like roots, belong to the other. It may at first be surprising to find that within the same differential group the growth habits are so different. However, they are less different if we look at the lesser celandine and speedwell in spring during their main growth period. They then spread out over a wide area and, still more or less unshaded, form extensive carpets of

of the bulbous buttercup are a somewhat stronger and deeper yellow than the meadow buttercup, its sepals are distinctively reflexed. The bulbous buttercup accentuates its more compact form with a perfectly round tuber. The meadow buttercup has an elongated tap root.

We find that both species of buttercup show distributions which correspond well to their growth form: the meadow buttercup in all the meadows except for the dry meadow and the bulbous buttercup only on the drier and more nutrient-poor meadows.

So we have succeeded in dividing the less vigorous, nutrient-poorer meadows from the more luxuriant meadows by characterising the differential species. This has given us a clearer understanding of what nutrient-poorness actually implies. We have also discovered a common developmental style in the growth forms of the very different kinds of plants in the groups of differential species.

3. Additional species of buttercups and their distribution

The buttercup genus lends itself to other comparisons. The different species can be nicely arranged in a sequence according to their growth forms (*Figures 14 and 15*). We are already familiar with the bulbous buttercup in the flowery meadow, dry meadow and north-facing meadow and the meadow buttercup which grows everywhere except for the dry meadow. Another species of buttercup, the creeping buttercup, occurs in the hollow meadow and damp meadow. As already revealed by its name, the shoots creep across the ground. It then sends up leaves on long thin stems, the flowers appearing somewhat above the layer of leaves. Another buttercup species, the lesser celandine, grows in the damp meadow. Everything is very simply formed in this species: it has a shallow root system in the upper soil layers and in early spring puts out rather round, undivided soft and succulent leaves from its bunches of small oblong root tubers. The shoot creeps along flat over the ground.

The following metamorphosis sequence can be seen: the bulbous buttercup in the more nutrient-poor meadows with its contracted detailed form is replaced in the more luxuriant meadows by the more succulent meadow buttercup which spreads vigorously upwards. The creeping buttercup is added in the moist hollow and damp meadows, a species which looks like a meadow buttercup which has collapsed. The trend towards more undefined structure proceeds even further in the lesser celandine. Appropriately, it occurs in the more luxuriant, moister and more shady damp meadow. The buttercups are therefore distributed as follows (north-facing meadow excluded):

meadow type:	damp	hollow	flowery	dry
bulbous buttercup			*	*
meadow buttercup	*	*	*	
creeping buttercup	*	*		
lesser celandine	*			

So each species of buttercup belongs in particular meadows. On closer inspection it appears that, e.g. in the metamorphosis of the meadow buttercup from the damp meadow

Meadows as a picture of their environment

Werner Schneider

Summary

The relation between the different varieties of the false-oat-grass (*Arrhenatherum elatius*) meadow and their respective environments is investigated in a study comprising the following methodical steps:

- The integral impression of a chosen variety is described and illustrated.
- Specimens of such plant species found on all the varieties of meadows are compared.
- Typical forms of growth typical for each meadow are selected and those species are viewed which characterise the respective varieties.

The reader should be stimulated to grasp the concept of this type of meadow in such a lively way that he will be able to derive its various forms from their respective environmental conditions.

Introduction

Meadows and pastures form an important part of Europe’s cultural landscape. They surround human settlements and cover large areas where there is no arable agriculture. They even appear in the form of lawns in modern city and suburban landscapes.

These meadows, pastures and lawns are not uniform but extremely variable, and it is primarily the environment which creates this diversity. How easy it is in the damp mild climate of Britain to produce a uniform green lawn and how difficult this is under the summer sun of Italy! Nevertheless, the English lawn has become a 'green dream' which people all over Europe try to attain. Every landscape therefore expresses something of the forces of nature at work and also something of the intentions of the people who have created it.

Such creation can be done in very different ways: unthinkingly, accidentally or according to very strict plans, or alternatively from an empathetic understanding of nature.

Rudolf Steiner has provided an example of creation from an empathetic understanding of nature, in this case for a building. The second Goetheanum in Dornach takes up the landscape theme of the *Tafeljura* and makes it visible in a new way (see J. Bockemühl 1980). The Goetheanum is not just set in a magnificent park, but in an orchard.

This study is devoted to these meadows with their fruit trees. It aims to investigate the particular qualities of the meadows and thus show that this way of working with nature can be far superior to a magnificent park.

In addition, this study addresses the matter of introducing methods on how to reach a comprehensive understanding of meadows, following the work of J. Bockemühl (1988 etc.).

Choosing the six meadow sites

The orchards mentioned above have been carefully tended for many years and are therefore healthy and fruitful to this day. This makes them particularly well suited for study and much research has already been done on them on a variety of topics. *Lieke van der Ree* and *Hyc Verhaagen* carried out research in relation to cultivation methods, focussing in particular on the distribution of selected species (1980). *Enno Peters* looked at the seasonal progression of individual meadow sites (1979). The most recent major work was produced by *S. Knoop* (1986). Our subsequent meadow studies are based on their work. *H. Grüllmeier*, *H. Vereyken* and *M. Wolter* helped with further research on the meadows within the framework of the first study weeks of the Goetheanum Natural Science Section in 1988. *P. Restle* and *Ch. Karutz* assisted with preparation of our research material. I wish to thank all these people, and in particular my wife for correcting the manuscript and *Jochen Bockemühl* for conceptual and financial support.

Fig. 1 shows the meadows selected for detailed study. All the meadows belong to the false oat grass community (*Arrhenatherum elatius* community, *W. Koch* 26). As an aid to communication, we wish to give our meadows the following names: ‘hollow meadow’ (H), ‘flowery meadow’ (F), ‘damp meadow’ (Da), ‘dry meadow’ (Dr), ‘open north-facing meadow’ (ON), ‘shaded north-facing meadow’ (SN).

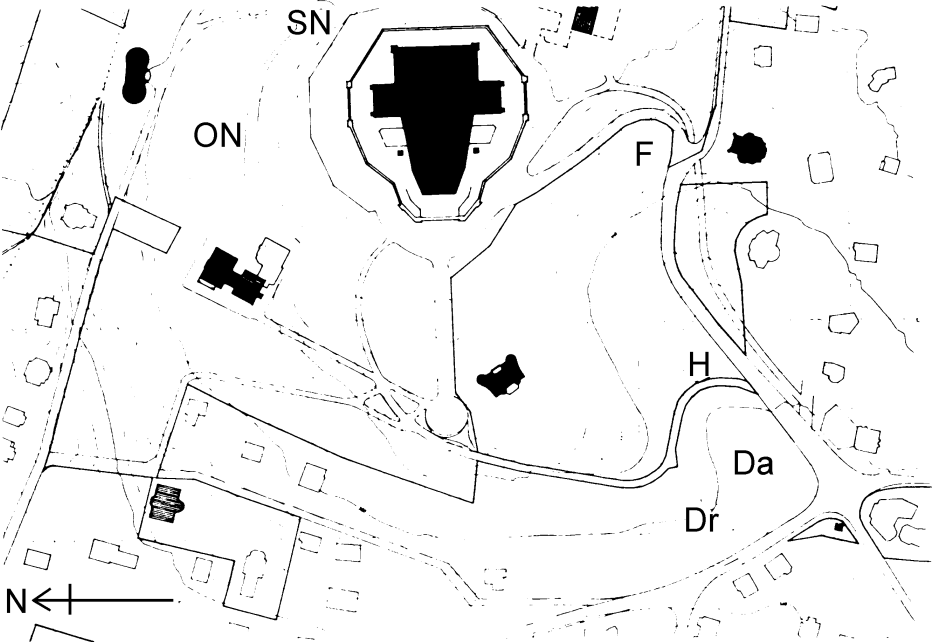
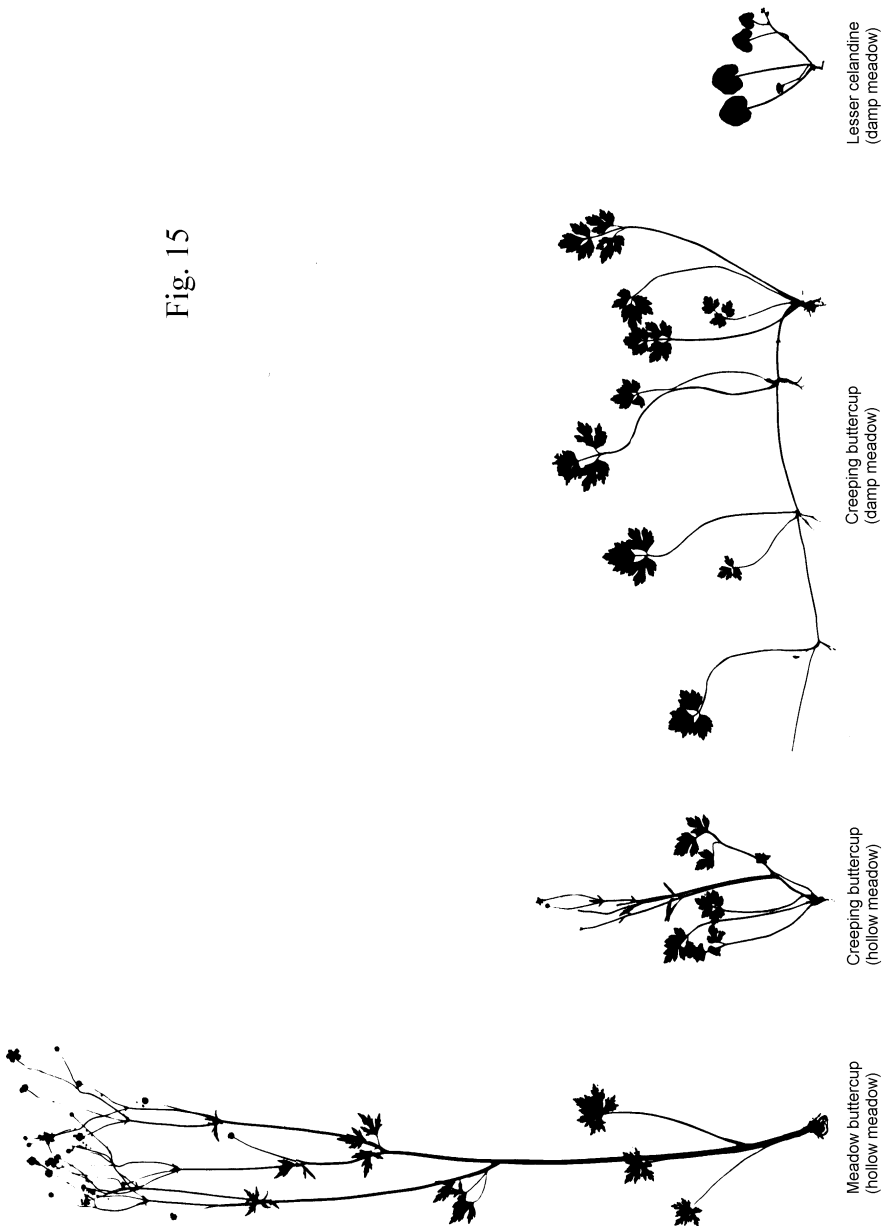


Fig. 1: Goetheanum with meadow sites

Fig. 15



cately formed with narrow leaves which appear dry on account of their dull grey-green colour. The delicate appearance of the brome is emphasised by the single long soft hairs on the leaf margins.

Once again it appears that the distribution pattern corresponds to the growth form of the two grasses.

We wish to compare the bulbous buttercup with the meadow buttercup which is widely distributed and – as will be shown – typically is only missing from the dry meadow (Figure 14).

Both plants share the same growth principle: both start their life as seedlings on a particular spot and spread out spherically from there, first in the leaf realm and later in the flower realm. A self-contained round leafing sphere is formed, with a round flowering sphere above. The two plants can only be distinguished if you start to look at details. The stem and leaves of the bulbous buttercup are relatively solid, those of the meadow buttercup are softer and more watery. The leaf form is more self-contained in the case of the bulbous buttercup and more ragged and 'indefinite' in the meadow buttercup. The flowers



Fig. 14. Flowery meadow

By the end of May all the meadows have developed fully and the differences between the various types of meadow can then be seen most clearly. This early summer stage was therefore chosen for our research.

We shall first describe and compare the six meadows step by step. Our aim is to point out the relationships amongst the great diversity of the six meadows. We shall first consider the 'hollow meadow' and the 'flowery meadow':

Description and comparison of the meadows in early summer before the first cut

1. The hollow meadow (Figure 2)

An orchard sloping towards the southwest ends in a small hollow. We stand at the edge of this hollow. Behind us are tall spruce trees which keep off the afternoon sun. The south and east horizons are also raised, even if scarcely any shadow falls on the small patch of meadow from there.

Our hollow area is usually somewhat damp. At the end of May the vegetation is dense and high, the green shady and dark. The scene is characterised by a few yellow spots of buttercups, here and there some lush leaves of dock and hogweed and blades of grass extending above the green.

The transect diagram illustrates the situation: the leaves of the herbs and grasses stand tall and dense and are tangled together. This makes the ground beneath very shaded. It is covered by a few small creeping plants. The grass panicles only overtop the leafing realm by a small amount.



Fig. 2. The hollow meadow

2. The flowery meadow (Figure 3)

Further up the same slope the ground is less sunken. Nothing prevents the afternoon sun from streaming in here. Only towards the east and north is the horizon somewhat raised by trees. On sunny days in late May you are surrounded here by the warm scent of hedge bedstraw. Insects hum and visit the numerous heads of the oxeye daisies. Deep blue clusters of cleary and the purple composite heads of field scabious add to the colourful splendour. The grass is not dense and waves in the wind.

Transect diagram: the leaves have developed less luxuriantly and the plants stand less close together. The light can penetrate further into the vegetation. There are scarcely any continuous shaded areas on the ground. Many plants are in flower.

In comparison with the 'hollow meadow', the rampant lush leafy green is less developed. The plants are sturdier, the green is more mat, the magnificent display of flowers and therefore the scent and the insect fauna are richer.

The hollow meadow and the flowery meadow can be experienced as polar opposites. However, they are not so very different from one another. We could find meadows which are considerably more extreme polar opposites when looked at from the same viewpoint. We now wish to seek out two such meadows.

If the difference from the 'hollow meadow' to the 'flowery meadow' is increased, then we come to the 'dry meadow'.



Fig. 3. The flowery meadow

3. The dry meadow (Figure 4)

Our dry meadow is situated beneath the Goetheanum on a very open shoulder of the hill sloping towards the southwest.

Here the upright brome stands in rank and file, holding its blades straight and erect like an army of tin soldiers. The ears also sit upright on the stalks high above the leafy clumps



Fig. 13. open North meadow

In order to be better able to understand our hoary plantain, we want to compare it with the widely distributed ribwort plantain. Both plants have a simple form: the leaves are entire with parallel veins, the flowers are inconspicuous and sit like ears on a long stem. Like grasses they are wind pollinated. The largest difference between the two plants is in the shape of the leaf: the leaves of the hoary plantain are wide and arise with almost no stem from a rhizome, forming a tight basal rosette. The leaves of the ribwort plantain narrow gradually towards the leaf base, the blade is generally elongated, the leaves point upwards and fit in directly with the upright grasses.

This striving away from the ground is a basic gesture of the more luxuriant meadows. The ribwort plantain can participate in this on account of its manner of growth whereas the hoary plantain cannot. It is therefore no surprise that the ribwort plantain also grows on the more luxuriant meadows where, in accordance with its contracted growth form, the hoary plantain cannot fit in.

The salad burnet has no close relatives in our six meadows, so there is no plant with which to compare it.

The upright brome is a very characteristic grass. As there is no closely related plant to compare it with in our meadows, we wish to compare it with a plant from another genus, the cocksfoot.

Both are tussock-forming grasses, but are nevertheless very different. The cocksfoot is strong with a thick sturdy stem and broad rough leaves. The brome is much more deli-

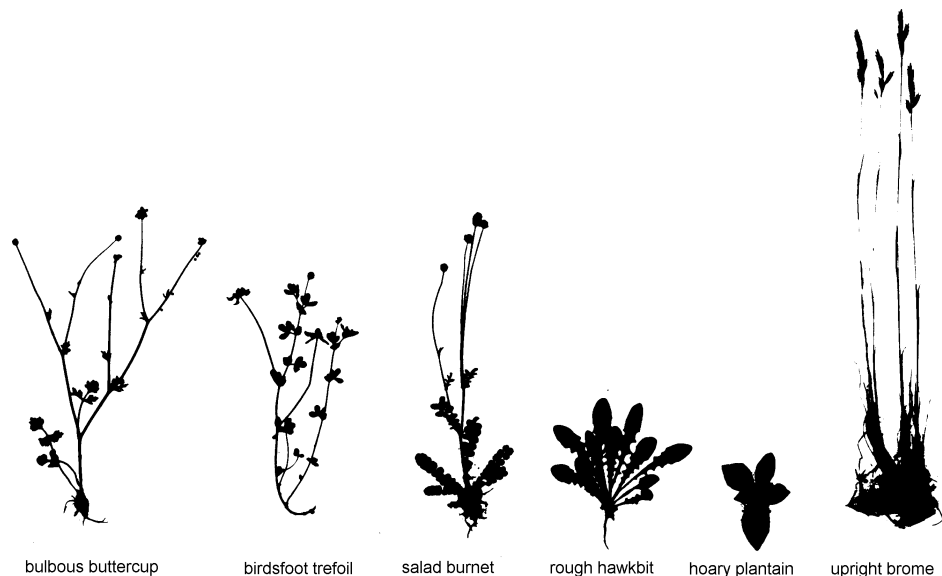


Fig. 12. Dry meadow

Figure 12 again. First we wish to compare the plants within the group of differential species with each other.

All our six plants have little bulk and are finely formed. The birdsfoot trefoil and bulbous buttercup both tend strongly towards the production of flowers and both produce a counterweight in the root zone. The birdsfoot trefoil has a strong tap root, the buttercup a tuber. Going from the burnet to the hawkbit, then to the plantain and finally the brome, the plants show increasing tendencies to form rosettes and have simple forms.

As it happens, in our group of differential species we have representatives from all three major meadow plant groups: herbs (most typically the bulbous buttercup), a grass (brome) and a clover plant (birdsfoot trefoil).

In order to take the next step in describing our group of differential species, we now need to draw on plants outside this group for comparison. We shall choose closely related plants which also occur in the other meadows, i.e. in the hollow meadow and the damp meadow (we already applied this procedure with the birdsfoot trefoil when we compared it with the red clover). We can learn more about the rough hawkbit by comparing it with the dandelion.

The rough hawkbit is a summer and autumn plant: in May it is still very inconspicuous. The dandelion, in contrast, clearly belongs to the time of year with the most vigorous growth, i.e. spring. The dandelion is also to be found everywhere in the grounds where growth is vigorous or it is damp (damp meadow, hollow meadow, north-facing meadow). Its growth is correspondingly luxuriant, soft and succulent. The rough hawkbit is drier, 'more contained' and more finely formed. It reflects the more contained, restrained growth in summer on the poorer sites (*Figure 13*).

which, for their part, stand neatly next to each other. Isolated little herbs grow between the clumps of brome. Flowering is restrained. However, here and there a spot of colour gleams out from amongst the dry green of the brome leaves.

Transect picture: the leaves are very finely formed. They are held back near the ground in tufts and rosettes. The plants stand singly and bare earth can be seen. The flowers and ears distinctly overtop the leaf realm. A layering has occurred in the leaf and flowering areas. At the other pole of our sequence, the more extreme 'damp meadow' can follow on from the 'hollow meadow'.



Fig. 4. The dry meadow

4. The damp meadow

Descending further down the slope from the 'hollow meadow', the ground becomes softer and damper. A few fruit trees give light shade. The meadow here is open in character, but nevertheless with vigorous upward-shooting growth. Everything is lush and bountiful, the leaves are soft and dominate the rather sparse flowers. (There was no transect set up here). From the flowery meadow to the dry meadow the plants become more compact, more contracted. The flowering realm stands out more clearly from the leaf realm, is sparser in general although not less diverse. Going from the 'hollow' to the 'damp meadow', expansion increases. The greenness grows upwards more vigorously, the flowers drown visibly in the sea of leaves. There is more shade due to the fruit trees and the plants are less densely interwoven with one another.

Digging into the soil a little in the dry meadow reveals a densely entangled root system from which the earth can trickle as though through a sieve. In the damp meadow root penetration is looser and the earth hangs in big clods on individual root strands.

Damp meadow	luxuriant vegetation with broad-lobed leaf shapes.
Hollow meadow	flowers disappear in the vegetative realm. The root system is open.
Flowery meadow	more upright densely-formed vegetation with profuse flowering. The leaf and flower zones interpenetrate.
Dry meadow	more contracted vegetation with gaps. Less colourful flowers which are separate from the vegetative realm. The root system is dense.

Now we wish to incorporate the two final meadows – the north-facing ones – into our discussion. They will illustrate that there are further developmental sequences amongst meadows to be discovered.

5. *The open north-facing meadow (Figure 5)*

This meadow lies on the north-facing slope below the Goetheanum and descends to a road. The sun glances flat across it even in summer. It is usually a bit damp and hardly ever dries out. It has also received practically no manuring for several years.

A low carpet of grasses covers the slope. The grass heads stand out from this distinctly. The predominant flower colour is yellow but in general the green impression remains the decisive one as flowering tends to be sparse. Despite this uniformity, the number of different species of plants is not lower here, but actually somewhat higher than in all the locations described so far. The various different species of grasses are particularly noticeable here. The transect shows a low, almost lawn-like growth, a rather unassuming flowering, the clear distinction between leaf and flower regions and an above average contribution of grasses to the meadow as a whole.



Fig. 5. The open north-facing meadow



Fig. 11. Flowery meadow

flowering shoots with tiny leaves grows directly from the tap root. Only further up do the stems become stronger, the leaves larger. These leaves look very different to those of the red clover. The leaf base is marked by strong green stipules which look similar to the three parts of the leaf blade. The leaf base with stipules, the petiole and the three leaflets together create a distinct unified form, i.e. the whole unit changes in size, but not the individual parts on their own, as is the case in the petiole of the red clover, for instance.

The birdsfoot trefoil therefore develops more distinctly and rigidly as a whole than does the red clover. It could also be said that the whole plant is more strongly flower-like. The red clover, in contrast, remains more vegetative with less distinct form. Its growth form only approaches that of the birdsfoot trefoil in the dry meadow. The birdsfoot trefoil's character therefore belongs in all those meadows which are vegetatively suppressed and which produce distinct forms. It reflects its growth form in its pattern of distribution.

2. *The differential species in the less vigorous meadows*

It now appears that a whole series of plants belong alongside the birdsfoot trefoil, all plants which have a similar distribution pattern to it. They are the following: the bulbous buttercup, the salad burnet and rough hawkbit, the hoary plantain and upright brome (see Figure 12).

In plant sociology this kind of group of plants which only occur in very specific meadows and not in others is called a differential species group.

What interests us is whether a group of differential species is simply a number of plants which have been randomly thrown together, or whether there is an inner similarity amongst these plants?

In order to investigate this, we shall turn to our special group of differential species in

The grasses display unifying tendencies with their linear leaves and uniform inflorescences. They form the basic structure of the meadow.

The herbs influence the general growth of the meadows in spring in particular. Then they come into full flower, make a fleeting show of colour and give variety. As summer progresses they become inconspicuous and some disappear almost completely.

The clover plants again form a rather general leafy carpet of small rounded surfaces. Vegetative growth, flowering and fruiting take place continuously and almost simultaneously. The different relationships of these three groups of plants to each other influence the basic character of each meadow.

Now we wish to proceed in another direction.

Groups of plants which only grow in particular meadows

Particular species of plants can be typical of specific meadows and be totally absent from other places, so that plant sociology speaks of what are called 'differential species' or 'diagnostic species'.

We have already established that our six meadows differ in their species composition. As previously mentioned, we now wish to look for characteristic species or groups of species in our six meadows. This means that we wish to discover species which only appear in particular meadows and not in others.

We shall first survey the group of clover plants:

1. Red clover and birdsfoot trefoil (Figure 11)

Birdsfoot trefoil is not equally distributed through all the meadows as is the red clover, for example, which we have found in all our six meadows. This is particularly obvious in summer, when the birdsfoot trefoil flowers show yellow against the green. The areas with birdsfoot trefoil are then clearly distinguished from the other areas which tend to display the dull red of the red clover.

If you investigate the distribution of the two plant species more closely, then the following appears: the red clover occurs everywhere, but particularly abundantly where the birdsfoot trefoil gradually disappears. Birdsfoot trefoil grows in our flowery meadow, in the dry meadow and in the open north-facing meadow. There is no birdsfoot trefoil whatsoever in the hollow meadow and the damp meadow.

What kind of character do the birdsfoot trefoil and red clover have? Might it be possible to understand the distribution pattern of the birdsfoot trefoil by comparing the characteristics of these two species? We shall attempt this.

The red clover produces a really long tap root with a short rhizome at the top from which sprouts a rosette of long-stemmed leaves and numerous flowering shoots.

The leaf bases are inconspicuous and pale and carry small, sometimes red-tinged stipules. The petiole is sometimes longer, sometimes shorter, depending on the nature of the surroundings. The leaf blade is tripartite. The flowering heads are carmine red, spherical and stalkless and sit inside the leaf region. The fruits are small and inconspicuous and are concealed in the brown wilting flower heads.

The birdsfoot trefoil also produces a tap root, but no proper rosette. A pair of thin weak

6. The shady north-facing meadow (Figure 6)

A little further up the slope rises to the terrace of the Goetheanum. It becomes steeper and is also shaded by spruce trees. The sun scarcely ever shines directly in here. The meadow is open and the ground between the herbs covered with soft cushions of moss. Here and there a creeping herb winds its way in between, but most herbs occur as solitary plants. They have grown tall and leggy. The transect shows the open situation, the sometimes very tall individual plants and a leaf region which is only slightly separated from the flowering one.

The two north-facing meadows can best be linked to our familiar hollow meadow. The three meadows can be arranged in the following sequence: hollow meadow – open north-facing meadow – shady north-facing meadow.

A uniform green characterises both the hollow meadow and the two north-facing meadows and the colours of flowers tend to be sparse and quite monotonous, mostly yellow. The carpet of grass is closed in both the hollow meadow and the open north-facing meadow. But in the open north-facing meadow the vegetative realm withdraws towards the ground, so becoming separate from the flowering realm. The carpet of grass in the shady north-facing meadow tends to be open, the ground visible. But this occurs in a completely different manner than in the dry meadow: the plants grow singly, as though they had fallen apart and are not condensed in rosettes. We would like to set up another comparative table:

Hollow meadow	luxuriant species-poor vegetation with lobed leaf shapes. The flowers disappear in the vegetative realm.
open North-facing meadow	compact vegetation with distinct shapes, a lawn-like growth, species-rich despite the uniform appearance.
shady North-facing meadow	sparse grassy carpet, tall leggy single herbs, abundant moss.



Fig. 6. The shady north-facing meadow

We have now placed our 6 meadows in two sequences:

-- open north-facing meadow – shady north-facing meadow
damp meadow – hollow meadow --
-- flowery meadow – dry meadow

The question now arises as to why one sequence emerges as opposed to another? Or, more generally, why does one of these meadows grow in its particular way and not differently?

The most common answer from scientists would probably be: each meadow grows in the way it does on account of its environment, because of different environmental factors such as the 'moisture content', 'light intensity', 'nutrient content', etc. But this leads to the important question as to whether such a causal relationship is admissible in the first place. We must consider how we arrived at the concepts of 'meadow' and 'environment'. We wish to place ourselves for once in a meadow in the most unbiased way possible.

We are surrounded by colours, scents and sounds and sense the warmth and light conditions. The objects and the more general situation of the place are not yet perceived separately, but interweave with one another in a relatively undefined whole. We experience the situation as a unity.

If we now wish to obtain more clarity, we must break up this unity. We take details out of the unity and ourselves confront these details. Our meadow now consists of numerous individual plants and the environment has also fragmented into separate factors.

Next, we could try to find our way back to the unity i.e. we wish to discover relationships between the single objects.

A first stage in relationships consists in the fact that each single object can, as an object, have an effect on others, or each environmental quality can affect the objects according to certain laws (e.g. heat results in expansion in volume). These are outer relationships.

In the plant realm a second inner stage of relationships is added. Here, for example, the meadow and environment – or, in a more extreme form, the individual plant and particular environmental factors – are juxtaposed with one another. These are connected in a non 'outer causal' relationship. The environmental factors can only be grasped in connection with the plants. In other words, only the plants can tell us which factor in a general environmental situation are significant for them. Conversely, it is not possible to tell from looking at isolated plants which environment they like growing in best. What are known as 'indicator values' which are allocated to plants in botany can only be defined when the plants are able to grow in their environment.

'Indicator value' and 'environmental factor' are therefore concepts which are mutually dependent. To postulate an outer causative relationship between them would therefore be a case of 'circular reasoning'. Strictly speaking it is incorrect to say that a meadow grows in the way it does because its environment determines this.

Does this mean that it is impossible to answer our initial question as to why one meadow grows in its particular way and the other one grows differently? Is it only possible to ascertain that one kind of meadow grows here and another there?

If a simple causative answer is expected to the question, then disappointment is in store. However, we can definitely gain a different and more appropriate understanding of the

leaves are different. Even within one plant, the shape of the leaves changes from the bottom to the top. The herbs bring variation and diversity to the appearance of a meadow. They are also the prime contributors to the changing face of the meadow during the course of the year. Our very diverse flowery meadow is primarily a herb meadow.

3. *The Clovers*

The clover-type plants also create a 'world in itself'. It is true that they resemble the other herbs in some ways. For example, they flower profusely and can also produce large primary roots. However, we can also find numerous striking differences. There is often no central flowering shoot: in a similar way to grasses, many clover-type plants branch right at the base. Like the grasses, they also display scarcely any leaf metamorphosis. In addition, the flowers are mostly not terminal but enclosed in the leaf zone unlike the two other groups. The leaf realm and flower/fruit realm penetrate each other. Fruiting plants are also able to continue producing leaves.

Clovers also have a different annual rhythm to grasses and herbs. In spring they are not very noticeable in our meadows, while in the second growth in summer birdsfoot-trefoil and red clover, for example, are easily visible. They then flower again and in far greater abundance, defining the appearance of the summer meadows to a large extent.

The clover's lifecycle does not only run according to its own, otherwise unusual rhythm within the same year, but also within a longer period of time. *E. Klapp* (1971) describes how clover species are subject to fluctuations in numbers which are not directly dependent on outer conditions (we were not able to ascertain anything of this in our meadows on account of the observation period being too short). Clover plants create the beginnings of something like their own rhythm.

This fits well with other special characteristics: clover flowers possess a very individual sculpted form. Due to nitrogen fixation clover species can be partially dissociated from the general soil conditions. They therefore display a certain independence. It is justified to place them in a separate third group beside the grasses and the herbs.

4. *Connections*

Naturally our three groups are not as strictly uniform as our description may suggest. All groups have deviations, intermediate forms which approach another group in certain ways. So, for example, there are herbs which are close to the grass type (e.g. ribwort plantain). Or there are clover species which incline towards the herbs in their simple flowering rhythm (e.g. bush vetch) or towards the grasses on account of their narrow leaves (e.g. meadow vetchling). There are also grasses which show a relationship to herbs: those which form very strong rosettes or tufts like herbs (e.g. upright brome) or others which spend themselves so much in flowering as though they were herbs (e.g. false oat-grass).

We have described our meadows in two ways so far. First we looked at the 'general growth form' of the meadows, in particular the relationship between the leaf, flower and root realms (we distinguished flower-rich meadows from more vegetative ones). Next we looked at the relationships between grasses, herbs and clover plants, first using selected examples and then more generally. In summary this gave the following:

species. But despite this the overall impression is uniform, because the different grasses have a similar form. In contrast, in the flowery meadow a range of profusely flowering herbs are to be found and grasses are less common.

Each meadow contains its own plant species which belong to it (this is a long-standing fundamental finding in the science of plant sociology). What interests us now – just as with the plant forms looked at previously – is whether we can find an inner connection between the type of meadow and the species composition. This is the question we shall explore next.

It has already been mentioned that meadow plants can be classified into three main groups, i.e. the grasses, the herbs and the clovers. (This classification, by the way, originates from the official grassland literature [see *Klapp* 1971]). We have discovered that there are meadows which are 'grass meadows' (open north-facing meadow) and others which we could call 'herb meadows' (flowery meadow).

Before we can continue discussing our six special meadows, we must first address the general question of what the characteristics of grasses, herbs and clover plants actually are?

1. *The grasses*

It is due to the grasses that in our climate meadows appear green for almost the entire year. This is why it is considered ideal to allow only grasses to grow in English lawns. Most grasses can even regrow immediately every time they are cut.

They also have the characteristic that their flowering shoots grow from the basal leaves, in fact each shoot grows singly from the rootstock without branching. The roots also follow this growth pattern, with no main root which branches, but countless equally important roots (adventitious rooting).

The roots are thus wide-spreading and densely interwoven with one another. They are a major factor in creating a closed sward. The leaves have simple shapes and show little change. The flowers are very inconspicuous.

The grasses are therefore characterised by a strongly vegetative and uniform life. Meadows where grasses dominate are as a result uniform (open north-facing meadow).

2. *The herbs*

Herbs are very different in nature: most meadow herbs grow out of a rosette and most produce a single main shoot with side shoots from its axils. During this process the rosette leaves die off. The leaves on the stem usually display a distinct metamorphosis of form from the bottom towards the top and the flowers are often coloured and impressive. After the first cut, some of these herbs repeat this growth process (oxeye daisy) while others are hard to find again over the summer (bulbous buttercup and, to a certain extent, meadow buttercup, common sorrel). Towards autumn a rosette is formed which then waits for the next spring. This basic pattern is adapted in many different ways. For this reason, even small children can easily distinguish one herb from another – e.g. an ox-eye daisy from a buttercup – whilst the grasses are all lumped together because they are so similar. In the case of herbs both the flowers and the type of branching and shape of the

relationship between meadows and their environment. Indeed, in that case we may not think in a linear causative way, as can actually only be done for strictly separable quantities, but we need to try to 'find one thing in the other' as is appropriate for quantities which have arisen from a whole.

We now wish to apply this other kind of thinking – it could perhaps be called 'pictorial thinking' or 'unifying thinking' – to our Goetheanum meadows. Let us first look at the hollow meadow. We know this meadow well from the earlier description. It still remains for us to describe the environment as vividly as possible if we wish to discover how the two are related.

The hollow meadow is always rather cool and damp. We can learn about this dampness by noticing that the dew lies here longer than in other places and wets our trousers and shoes. The ground is always soft and if we sit down, we feel what close contact we have with it and how the damp cold penetrates us.

Let us now compare the environment in the dry meadow. Here the soil dries out a short time after a shower and is then cracked and hard and trickles through our fingers if we rub it. We can sit down without getting dirty or feeling cold.

The comparison shows us that dampness creates connection, dryness separation. This is exactly what we noticed before when we were studying the growth form of the two meadows. In the hollow meadow the leaf, stem and flowering realms are soft and lobed and in general closely interwoven with one another. In the dry meadow, in contrast, separation predominates. The plants stand singly beside one another in rosettes and the leaf and flower realms are detached from each other. Do we now have an accurate picture of dampness and dryness? Shortcomings will immediately be evident if we look at another meadow, the open north-facing meadow, which is likewise damp but whose style of growth is totally different from the hollow meadow.

In the open north-facing meadow the ground is also soft and slippery, and the sun rarely ever dries the soil out completely. But there is no sign of large-lobed, soft delicate plants with a clearly separated leaf and flowering realm. How can we still find a characteristic damp trait in this very different style of growth? We can indeed discover a constant connecting theme, this time in the leaf region. It is densely intertwined, lawn-like and uniform. Nevertheless, the considerable difference between the hollow meadow and the open north-facing meadow remains unexplained, above all because not only the moisture but also other environmental qualities which can be experienced directly such as light and temperature conditions are very similar.

This gives rise to the speculation that a further environmental factor which is not directly accessible for human beings is involved here, namely the soil. The soil processes must be very different in the two meadows. The soil beneath the hollow meadow must be much more strongly permeated by life, which would fit well with the rampant vegetative growth there. The much more inert soil processes under the north-facing meadow would be reflected in the suppressed meadow growth. This brings us to the pair of qualities nutrient-rich – nutrient-poor.

Another important pair of qualities for our meadows is the contrast between light – shade which can be seen in the comparison of the damp meadow and the shady meadow

which have already been discussed.

The quality of 'light' gives us the following experience: everything appears in a clear defined form. Excessive brightness is blinding so we must protect ourselves from it. The quality of 'shady' makes the forms appear less distinct. The subdued light makes us relaxed and open. We can stretch out, expand. But if it gets completely dark, then we lose our bearings

The meadows dealt with so far are entirely open to the light: the damp meadow and the shady north-facing meadow on the other hand are in half shadow. As expected, the last two meadows have indeed grown more loosely, their plants are less distinctly formed and have fewer flowers. The differences between the damp meadow and the shady north-facing meadow again indicate the differing soil qualities.

We have now been able to find relationships between meadow growth and environmental conditions: we have tried to understand the one from the other. We have consciously reconstructed the vaguely perceived unity in our naïve experience, even if only in a rudimentary way. Details have acquired a meaning within the whole. It is therefore worth paying more attention to these details. We should not fear losing the whole but shall rather obtain a richer and more precise picture of it.

Four individual plants which are present in all six meadows

First we shall proceed as follows: we choose four plant species which grow in all six meadows and turn our attention to the differences in the growth forms which the same species take on in the different meadows.

1. Cocksfoot grass (Figure 7)

The first of our four selected plants is a grass, the cocksfoot. Grasses naturally make up the basic structure of meadows. They form the more or less closed turf and fill the soil with a dense mat of roots.

The strong, wide-leaved, grey-blue-green cocksfoot is noticeable amongst the grasses. It grows in tufts with strong stem bases and has thickset, conglomerate flower heads.

We now need to find cocksfoot grass which has grown in a typical way for each piece of meadow. This means that we cannot simply pick a random piece of cocksfoot. Rather, we must first become familiar with the whole range of forms and then select an 'average representative' specimen. *Figure 7* shows plants selected in this way.

We want to describe them:

- In the damp meadow the cocksfoot grasses are 'drowned' i.e. they are overgrown by the other vegetation. They have thin stems, the leaves are soft and very long.
- In the hollow meadow are to be found the most robust specimens with thick stems and broad leaves. The stems are tough and can scarcely be broken, the flower clusters are large and fat.
- In the flowery meadow the cocksfoot once again has less abundant fullness. The plants are more finely formed, with the top leaf distinctly shorter, the flowers are tighter and smaller.

In the growth form of the common sorrel and hawk's-beard we have by and large discovered the general meadow growth types again, however the detailed relationships are more complicated. The hawk's-beard in the north-facing meadow is a surprise: it is very robust, in total contrast to the common sorrel and clover. In the open north-facing meadow it occurs singly and stands distinctly above the general level of the vegetation. Each of the four individual plants looked at so far – cocksfoot, red clover, common sorrel and hawk's-beard – reflect the environmental conditions which affect them. But each plant reacts in a slightly different 'individual' way. We need to investigate this more closely.

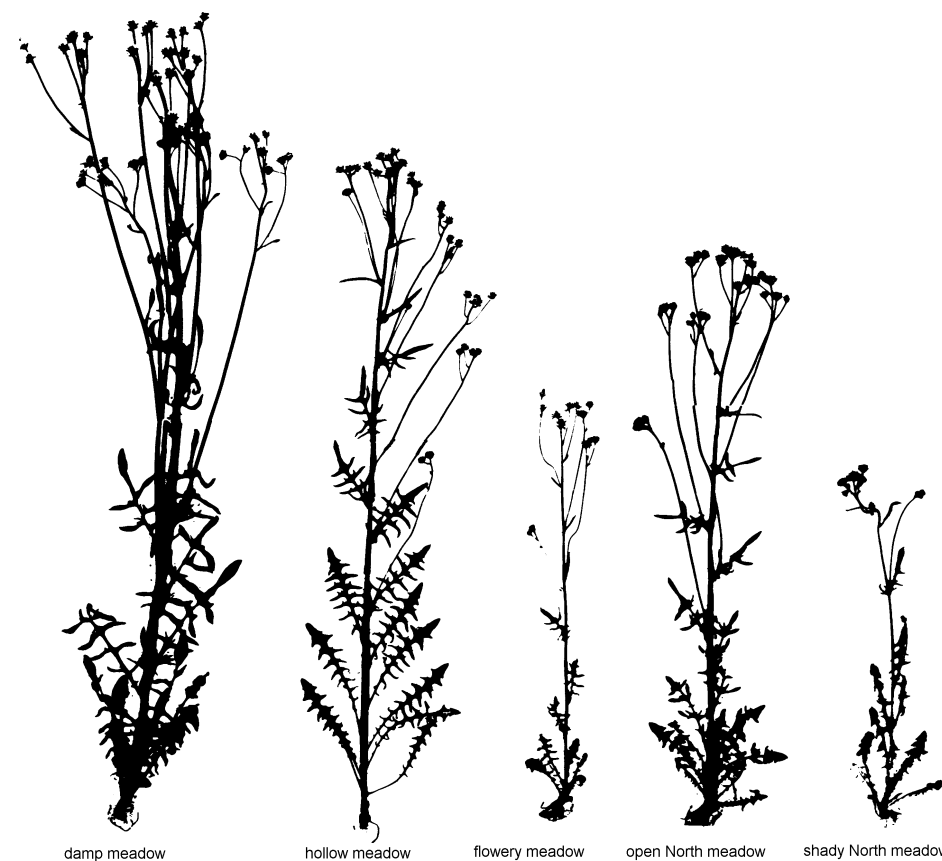


Fig 10. Rough hawk's-beard

Meadow type and species composition

We have also discovered something else as a result of our studies of the meadows: the species composition of the six meadows is quite different. The contrast between the flowery meadow and the open north-facing meadow is particularly noticeable.

The north-facing meadow is dominated by grasses, and with a surprising variety of

3. Common sorrel and rough hawk's-beard (Figures 9 and 10)

After the grasses and the clovers, we shall turn to the herbs in a narrower sense, another large group of meadow plants. This time we shall choose two representatives, the common sorrel and rough hawk's-beard.

Both plants grow from basal rosettes. In the case of the common sorrel, the rosettes wither soon after the stem has elongated, which is why they are missing in our illustrations.

Again we shall observe the changes in the two species of plants throughout the six meadows:

The sorrel has grown very robustly in the hollow meadow and the damp meadow. The flower heads are large but loosely formed. The plants are significantly smaller in the flowery meadow and the dry meadow. In the dry meadow they have developed a very tight flowering head with a strong seed set. On the north-facing meadow the sorrel plants are thin-stemmed and small.

In the hollow meadow and damp meadow, the hawk's-beard has grown luxuriantly tall. Strong stems support profuse flower heads. In the somewhat more open damp meadow the rosette leaves are even better preserved. In the flowery meadow the hawk's-beard plants are small and delicate. There they are completely intertwined amongst the other vegetation which they have risen above in the other meadows. The hawk's-beard is missing from the dry meadow.

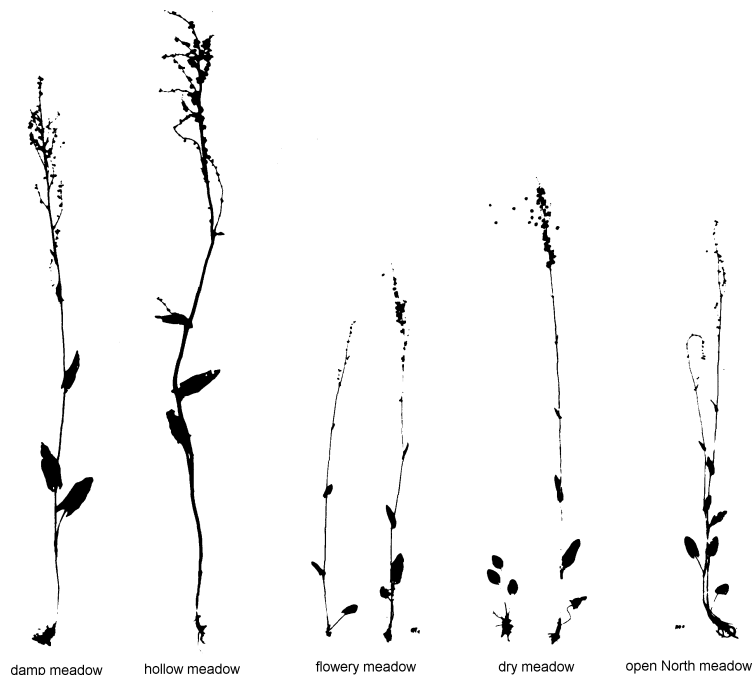


Fig. 9. Common sorrel



Fig. 7. Cocksfoot grass

- These traits are further enhanced in the dry meadow: the plants produce little leaf area, the top leaf is even shorter, the flowers strongly contracted. The plants can be broken off easily here, meaning that their stems are brittle.
- In the open north-facing meadow the cocksfoot is stronger and forms quite large flower heads. The leaves are somewhat longer and thin.
- In the shady north-facing meadow the cocksfoot is thin-stemmed with long, almost thread-like leaves and narrow flower heads.

We can therefore see that the growth forms of the cocksfoot grass show the same on a 'small scale' as we already established as the general growth habits of the meadows.

Only in the damp meadow does the cocksfoot fail to follow the general growth pattern. It is not more luxuriant than the plants in the hollow meadow, but more delicate. This signals a gradual shift in the species composition of the meadows: the cocksfoot is less abundant and grows more poorly. (Fig. 7)

2. Red clover (Figure 8)

Grasses and clover grow next to one another in almost every meadow but they nevertheless show large contrasts in form. Grasses are simply constructed linear plants which when flowering distribute their pollen all around them. Clovers, on the other hand, produce broad leaf surfaces, the flowers are strongly sculpted and form small internal spaces. They are pollinated by insects.

We shall choose the common red clover as a representative of this group and again observe typical plants from each of our six meadows:

- In the damp meadow the red clover is thick-stemmed and bulky. The leaves show little transformation, only decreasing a little in size towards the top. Even the leaves directly beside the flowers are still quite large.
- In the hollow meadow the red clover has grown more in length (only one single shoot of a whole red clover plant is illustrated). The flower scarcely rises above the leaf realm. The leaves also increase in size from the base towards the top.
- The red clover in the flowery meadow is distinctly smaller. The leaf realm is closer to the ground. The leaves do not become larger towards the top. The leaf accompanying the flowering head is small and inconspicuous. The flower rises distinctly above the leaf zone.
- In the dry meadow the red clover has an erect form. The flowers are even more distinctly separate from the leaf zone. The leaves are short-stalked with strong red-coloured stipules and become smaller towards the top.

The direction of transformation taken by the red clover is closely related to that of the cocksfoot. In both cases the plants become gradually smaller from the hollow meadow to the dry meadow. The relationship between the leaf realm and flower realm changes and the forms become stiffer, more clear-cut and tougher.

Now let us consider the red clover plants in the two north-facing meadows:

- In the open north-facing meadow the red clover produces a delicate open form. The flowers scarcely stand out from the leaf region.
- In the shady north-facing meadow the above tendencies are even stronger. The plants here are very thin-stemmed and the small flowers lie within the leaf region.

This suggests a contrast between the open north-facing meadow and the damp meadow. In the open north-facing meadow the cocksfoot grass displays strong growth, the red clover weak growth, whereas in the damp meadow the red clover is stronger and the cocksfoot weaker. This tendency also exists on a large scale. The north-facing meadow tends to be generally a meadow of fine-leaved grasses, the damp meadow has a much stronger tendency towards broad-leaved growth as shown by the red clover.

Fig. 8. Red clover

