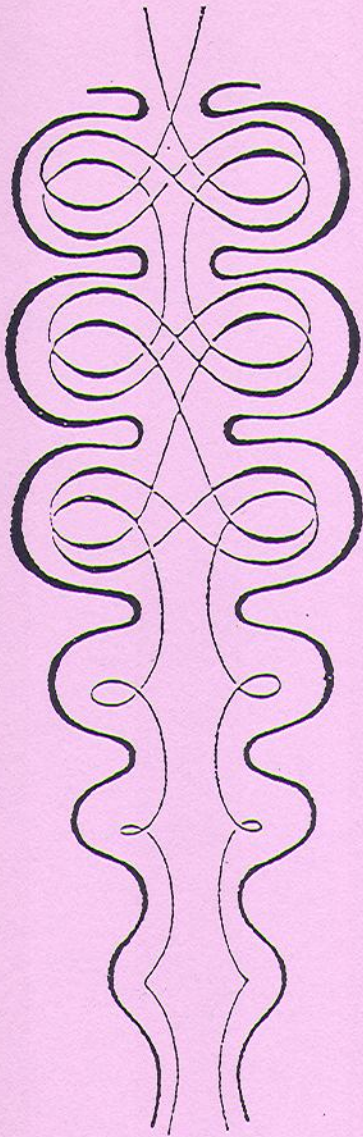




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# WALDORF

# SCIENCE

# NEWSLETTER

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## BOOK REVIEWS

Calling all projective geometers, I received the following announcement from Paul Courtney who has translated Louis Locher-Ernst's "Raum und Gegenraum" into English. Please address any responses to this posting to the address given below. Hawthorn Press are taking a cautious approach to the book's publication and are looking for advance orders. The closing date for these is currently 30th September 1997.

David Heaf Newsletter Editor,  
Science Group of AS in GB

### **SPACE AND COUNTER SPACE** by Louis Locher-Ernst

This book provides a mathematically rigorous treatment of three-dimensional projective geometry. At the same time it is a book about the art of thinking in which other ways of thinking --- qualitative, imaginative --- are exercised as well as the logical way.

The author's approach is synthetic, which means that the book is free from the equations and algebraic manipulation of more conventional approaches. Instead, the geometrical forms, constructions and theorems are built up from "fundamental phenomena" which are simple, self-evident propositions about geometrical relationships of mutual belonging (or incidence) and ordering. Mutual belonging and ordering, that is, of the basic elements from which projective geometry starts, namely point, line and plane.

The phenomenon of polarity is introduced, which in its broadest meaning is the theme of this book. At its simplest, this law says that starting with any construction or theorem we can simply replace each point by a plane, each plane by a point, and each line by another line, and (provided that mutual belonging is maintained) the resulting construction will still hold good. A simple operation, but with enormous consequences for our thinking and our consciousness.

Underlying what is presented in this book there is another polarity, which is the polarity between on the one hand logical thinking which is bound to sensory experience, and on the other thinking which is independent of the senses: pure thinking. Projective geometry provides a bridge between these two kinds of thinking.

The reader will often feel the urge to reach for pencil, paper and ruler to draw the constructions for him or herself, or simply to form the appropriate mental pictures. In addition each chapter concludes with a few elementary exercises and, as the author says, "everyone should be able to enjoy successfully accomplishing" these.

This book is for anyone who has come to the feeling that thinking has reached a sort of dead end, and wants to take up the challenge of transforming thinking, giving it direction and new life. It will have a particular appeal 1) for those with some acquaintance with projective geometry, say from having taken part in classes in the subject, who want to deepen their study, 2) for teachers in Waldorf or other progressive schools who need a source book.

Originally published in Switzerland by Verlag am Goetheanum as *{Raum und Gegenraum}*, this book was translated by Paul Courtney Ph.D. and will be published with a foreword by Ron Jarman.

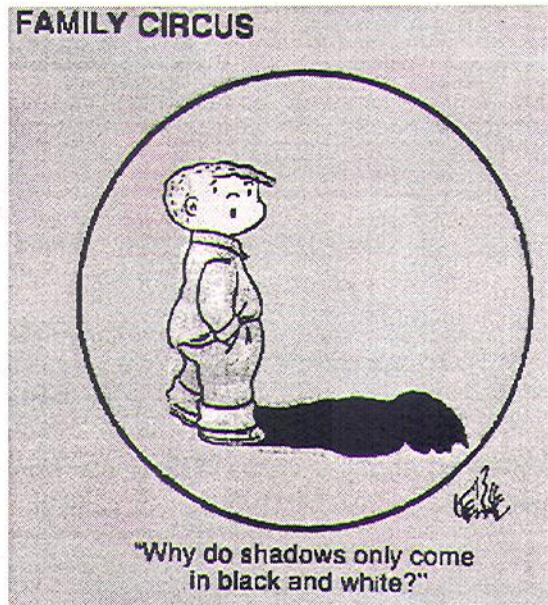
278pp; 205 figures; hardback; price 30 UK pounds post free worldwide (airmail 5 UK pounds extra).

Order now from: Hawthorn Press, 1 Lansdown Lane, Stroud, Glos. GL5 1BJ, UK Fax 01453 751138, Phone 01453 757040, WITHOUT SENDING ANY MONEY.

The book will be published when enough (-300) subscription orders have been received. You will then be invoiced.

Review via the internet by David Heaf

### **FAMILY CIRCUS**



### **NEW EYES FOR PLANTS**

*A workbook for observing and drawing plants.*

A unique approach to the learning and understanding of plant life evolved from the collaboration of Dr. Margaret Colquhoun, a leading holistic biologist and Axel Ewald, sculptor, artist and lecturer. Introducing fresh ways of seeing nature, the authors help the reader to embark on a journey of discovery.

A beautifully integrated publication, with inspiring illustrations and authoritative observations, text and image combine to produce a companion guide to plant growth the year round showing how science can be practiced as art and how art can help science.

"This book invites us to go on a journey, not simply of the imagination, but also of activity and transformation. The invitation is to reconnect with the living forms around us by looking and doing so that our eyes are opened to the nature of plant life."

Dr. Brian Goodwin, Dept. of Biology, O.U.

"Genuinely helpful ideas" *New Scientist*, 21st September 1996

"An outstanding introduction to Goethe's holistic approach to science, showing how the practice of drawing can enliven the scientist's perception of nature. Superb production, with many beautiful drawings, and we are all indebted to the authors and the publisher for such a magnificent volume" Henri Bortoft, Author of "The Wholeness of Nature"

- Contains over two hundred illustrations to inspire you
- Gives helpful exercises for observing and for drawing plants
- Shows how science can be practiced as an art
- Introduces the holistic approach of Goethean plant metamorphosis

Paperback, color cover, black and white illustrations, 208 pages, 270 x 210mm ISBN 1 869 890 85 X 14.95 UK pounds.

If you have difficulty ordering it from your bookseller contact: Hawthorn Press, Hawthorn House, 1 Lansdown Lane, Stroud, Glos, GL5 1BJ, ENGLAND

Review of *New Eyes for Plants* by Dr Isis Brook, author of *Goethean Science in Britain* Ph.D. Thesis, University of Lancaster, 1994

*New Eyes For Plants* is a workbook for observing and drawing plants. It is Goethean in perspective in that it emphasizes approaching the natural world with wonder, being diligent in observation and honoring the experiences of one's senses. The book takes the reader through the year and focuses on particular plants or phenomena that are emblematic in the way they reveal the workings of nature.

There are many beautiful illustrations which both inspire and possibly daunt the reader. Perhaps including a page of less accomplished work would help to demonstrate to the insecure reader that it is embarking on the process that is important.

The strengths of the book come from the skills of its contributors and the way it has developed out of a teaching situation: the Life Science Seminars. This mixture of expert knowledge and teaching experience means that the book, if used in the way intended, will provide an excellent practical introduction to Goethe's approach to science, to botany, to drawing and to approaching life with wonder.

The one failing of the book is as a replacement for participation in the courses which were its origin. But how could a book replace the communal experience of a guided entering into nature's mysteries? Although an interesting read and beautifully illustrated, to use the book to its fullest potential one must apply one's will and work through the book slowly and carefully completing each exercise, rather than skipping to one that looks more immediately enticing. This is a difficult task for people today who quite rightly question dogmatic adherence to instructions and can confuse impatience with a process with making independent choices. However, to extract the richness of this book, do try to work

through the whole, engage with the exercises fully and try to find others to accompany you on the journey.

– Isis Brook

Taken off the internet

\* \* \* \* \*

Novalis Verlag (Switzerland) have finally agreed to release for publication my translation of Heinrich Frieling's 'Der singende Busch (Novalis, 1986, ppl44, hbk, ISBN 3 7214 0555 2) - *The Singing Bush*'. English publishers did not consider it a worthwhile commercial proposition and so Novalis agreed that the translation could be released in photocopy form.

The book's subtitle is *The soul of the landscape in the voices and colors of its birds*. The following quotation from it best characterizes the author's approach:

"The strict order of meadow song is reminiscent of the rhythm of the nodes and stems, of the pointed and shimmering forms of the grass blades and their movement in the wind. But the birds don't simply imitate the sounds of their surroundings, even if they can. Instead their voices are born of the same laws from which originate meadow or any other landscape under consideration. They take on the soul of the landscape and give voice to it. Can a meadow only be understood as the sum of its grasses? Shouldn't we, like Plato, acknowledge 'meadowness' as its actual origin? The real causes of all occurrences do not lie in what the senses register. And just as the falling leaves are not the cause of autumn, neither is the sum of the sounds. Of all the meadow birds or the totality of the grasses an explanation of what meadow really is. In fact it is an idea, a spiritual reality like 'autumn' and we become aware of it only through the manifoldness of the sense world, just as its true individuality can only be grasped through our thinking." (p 124, German edition)

Frieling was inspired by Goethe's approach to understanding the natural world and has taken a leaf out of Goethe's book to the extent of careful observation and even of bringing a somewhat poetic style into his prose descriptions. One publisher described the prose, perhaps not unjustifiably in parts, as florid. However, there is a richness of observational material here which may appeal to the experienced bird watcher and listener who is interested in seeing how someone else has tried to apply a Goethean approach. It is certainly not a beginners guide and anyone outside Europe who is interested in it should bear in mind that it is mainly restricted to a hundred or so species which can be seen in Germany and surrounding countries.

The translation can be ordered from me in a choice of two formats: (1) A4, 32pp, 2 columns, price 5 UK pounds. (2) A5, 60pp, booklet format (A4 folded), 6 UK pounds. Postage and packing (in UK pounds): 0.50 UK; 1.00 Europe; 2.00 elsewhere. Please remember to state which format you prefer.

– David J. Heaf

## LETTERS TO THE EDITORS

I would like to make a brief comment on the reported opening words of a lecture by Hermann von Baravalle which were published in the Autumn 1996 edition of the *Waldorf Science Newsletter*.

Baravalle was somewhat optimistic in stating that "If one of the bigger buildings were to be erected on the moon, it might be visible in telescopes." Even with the latest earth-based telescopes today, the resolving power (ability to distinguish detail) amounts at best to about 0.6 arc seconds. This limit is ultimately determined by the density of the earth's atmosphere, and at the moon's distance corresponds to more than one kilometer.

This takes nothing away from the importance of Baravalle's pioneering work or the publishing of it. But teachers should be aware that any building observed on the moon through a telescope on earth would have to be a very large building indeed.

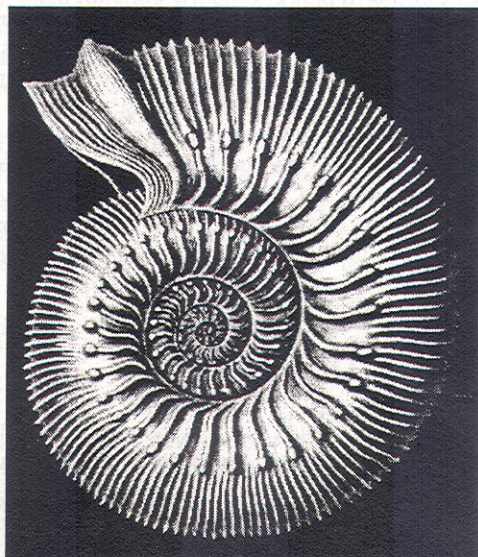
Norman Davidson  
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260 Hungry Hollow Road  
Spring Valley, NY 10977

\* \* \* \* \*

To all Waldorf biology teachers.

For study purposes I would love to see more articles about the What, Why and How of teaching human biology in the high school. I understand there is no written curriculum for these blocks. Craig Holdrege wrote an inspiring article for the Autumn 1995 Science Newsletter about teaching embryology in the eleventh grade. I would like to know how other teachers work with Steiner's indications.

Marielle Levin  
2135 S. Emerson Str,  
Denver, CO 80210



## HISTORY AND NATURE OF SCIENCE

### Some Experiments of the Academia del Cimento

It is most useful, and indeed a necessary thing in the making of Natural Experiments, to be truly informed of all the Alterations the Air is incident to; for since it receives into it self, and as it were, embraces all things, leaning on them with its whole weight from a vast height, they must needs all bend under this Pressure; and as this violence which they suffer, is more or less, so are they more imprisoned or enlarged. Thus the Mercurial Standard either rises or falls, at the different height of the Atmosphere, or as some think, correspondent to the various Temperaments which the Air receives from the Sun, or from the Shade, from the Heat, or from the Cold, when open and free, or when shaded and apprest with Clouds when it either rarefies or condenses it self, and so gravitates more or less upon the Stagnant Mercury, by which, with different Pressures, it forces it higher or lower into the immersed Cane. It is therefore requisite (as well for that Experiment which we shall amply treat of in the first place, as for others, which in the sequel of this Discourse we shall handle) to be provided with such Instruments that we may be able to assure our selves, what is the true Measure, not only of the greatest changes of the Air; but if it be possible, the niceties of the smallest variation. We will therefore in the first place, describe those which have been serviceable to us, though they may have been already dispersed hence to several parts of Europe, so that they will want the pleasing dress of Novelty to recommend them: nevertheless, they will not be unacceptable to those that desire a more nice and particular Information (if not of their use, which is easily comprehended, yet) of the way and Artifice of making them.

Excerpt from Magalotti Lorenzo, *Saggi di Naturali Esperienza*, passim, translated by Richard Waller, London, 1684. From Guerlac, H. (Ed.), *Selected Readings from the History of Science*, Vol. 11. Ithaca: Hemy Guerlac, 1953.

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### Gas Volume and Temperature

The French physicist Guillaume Amontons (1663-1705) devised an air thermometer that was different from Galileo's, for it measured temperature by the change in gas pressure rather than by the change in gas volume. He used the thermometer to show that a liquid such as water always boiled at the same temperature. This made it possible to use the temperature at which water boiled as a standard reference. With his new thermometer, Amontons tested the volume of a fixed quantity of gas at different temperatures, and, in 1699, showed that the volume increased at a steady rate as the temperature went up and decreased at the same steady rate as the temperature went down. Much more important, he showed that for each gas

he studied, the volume change with temperature was the same. It seemed a property of all gases.

Excerpt from Asimov, Isaac, *Asimov's Chronology of Science and Discovery*, p. 177. New York: Harper & Row, 1989. Permission pending.

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## Boyle's Law

As Boyle experimented with vacuums, it was he who employed Robert Hooke to build an improved air pump.

The air pump got Boyle interested in gases, and in 1662 he discovered that air could be compressed. He did this by trapping some air in the short closed end of a J-shaped 17-foot-long glass tube into which he poured mercury to close off the bottom curve.

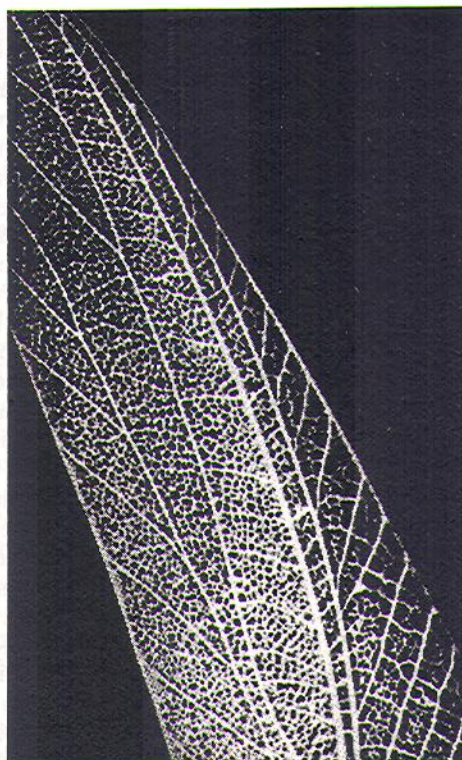
If he next added more mercury to the open end, the weight of the additional mercury squeezed the trapped air in the closed end more closely together, and its volume decreased. Indeed, Boyle found that the volume of the gas varied inversely with the pressure upon it. That is, if he doubled the weight of mercury upon it, the volume shrank to one-half the original; if he tripled the weight of mercury, the volume shrank to one third, and so on. This is called Boyle's Law.

The most important conclusion of this experiment was that air, and presumably other gases, was atomic in nature and that the atoms were widely spread apart. With pressure, the atoms were forced more closely together and the volume shrank.

Liquids and solids could not be compressed with the same ease that gases could be, but that did not necessarily mean they weren't composed of atoms. In their cases, the atoms might already be in contact.

The idea of atomism had not entirely died out since the time of Democritus (see 440 B.C.). There had always been a few from time to time who accepted atoms. Boyle's experiments, however, were the strongest evidence yet, and Boyle himself became a convinced atomist. It was to be a century and a half, however, before atomism won over entirely.

Excerpt from Asimov, Isaac, *Asimov's Chronology of Science and Discovery*, p. 155. New York: Harper & Row, 1989. Permission pending



Grasshopper wing

## PHYSICS AND CHEMISTRY AS EDUCATIONAL TOOLS IN THE 9TH & 10TH GRADE

by Hans Gebert

Social conditions are changing so rapidly that high school graduates are best prepared for life if they are able and willing to continue learning and to change their occupations in response to social need. A flexible and acute mind, an open heart for the conditions of others, a fine sensibility for the true and beautiful, and knowledge of the complexities of modern life are some of the most desirable results of education.

This is why subjects are taught not only for their intrinsic value but for their ability to:

1. develop such personal faculties as clear thinking, sensitive feelings, and strong will;
2. establish relations between students and their natural and social environment;
3. evoke appreciation for the complex currents and forces shaping our lives today.

Using two examples based on classroom experience, I want to show how physics and chemistry can be used as, what might be called, educational tools—to accomplish these purposes. Different subject matter could be used for the same ends; in fact, it is improbable that a

visitor to several schools would find exactly the same subject matter used in any two of them.

The work centers around the automobile. Part of each lesson is devoted to learning how the main systems of the car works. Starting with the engine, students learn in detail the cycle of operation in each cylinder: drawing in the mixture of vaporized gas and air, compressing and thereby heating it, causing it to explode by passing a spark through it, pushing out the combustion products. The valves in the engine and the distributor in the electrical system have to be synchronized so that the spark comes just at the right moment and the burned gases are eliminated in time for the intake of the next portion of mixture. Gradually it becomes clear how this is done, and how the engine, once started, recharges the battery for the next scare, and how it regenerates the voltage for producing sparks.

Next the class learns how the power of the engine is transmitted to the wheels. When starting, a great deal of force is necessary to get the car moving; when we are cruising on a level road, the driving force can be much less—it need only overcome road and air resistance. The students learn about the clever ways engineers have found of changing the driving force as required by driving conditions. Work like this makes demands on the intellectual understanding of the students. As they will be expected to make accurate drawings and to write lucid descriptions of the processes, their skill in drawing and writing and their thinking powers develop. At the same time they experience how human ingenuity is able to arrange valves, cogs, belts in such an ingenious way that an essentially destructive force, like the explosion of a gas-air mixture, is put to good use. To make the point vividly, the teacher might describe disasters caused by the explosion of similar mixtures accidentally ignited by sparks.

Understanding how such potentially explosive forces are controlled is especially relevant for students in the ninth grade. They are just at the height of puberty, experiencing new and potentially explosive forces arising in their own organism. They experience, too, that these inner forces often get them into trouble, much of which could often be avoided by a little thought. However, the right thoughts have an annoying habit of coming at the wrong time, and thinking does not yet seem to be quite strong enough to help in coping with the explosive puberty forces. The study of the automobile, showing as it does a result of the conquest of the heat forces in nature by the human intellect, gives courage to the students in their developmental predicament. The choice of this subject matter at the ninth-grade stage is an example of how the Waldorf teacher tries to further the development of the student by choice of subject matter.

While the working of the automobile is dealt with in one part of the lesson every day, the history of heat engines can be treated in another part of the lesson. The first heat engines were very crude pumping engines used in mines in England. The first major improvements were made by James Watt. These improvements were so important that many people are under the impression that Watt actually invented the steam engine. As a young man, Watt worked as a laboratory technician at the University of Glasgow, Scotland. The theoretical work on heat that Professor Joseph Black was carrying out at the university when Watt was there could well have inspired some of Watt's ideas for

improving the heat pump. While dealing with this section of history we have an opportunity to teach the fundamental laws of science discovered by Black. At the same time, we are showing an example of the interaction of pure science and technology.

Later in Watt's career his engines were manufactured by the firm of Boulton & Watt in Birmingham, England, and they were leased, not sold, to mine owners. The legal arrangements associated with these leases made it necessary to measure the work done by engines when using a certain amount of coal. This is a good starting point for talking about important concepts like energy, power, efficiency, and their measurement.

Both here and when describing Black's work, there is an opportunity for the students themselves to do some of the experiments connected with the measurement of heat and work. In this way they experience how scientific work is actually carried out. Before leaving high school they should have had this experience a few times—not to train them in experimental techniques but to let them take part in an activity that is important in our civilization.

The relation between Watt and his customers shows also how invention and science influence social conditions. The owners and managers were pleased that the new engines saved a lot of fuel in the mines. Soon, however, they were trying to find ways to avoid paying royalties to Boulton and Watt, and this may have been one of the incentives for the invention of the high-pressure steam engine that was necessary before locomotives could be built.

The consequent evolution of railways is another important chap in the history of technology. This is interesting from a technological point of view but even more so as an example of the way in which technological progress is often opposed by vested interest. In England the canal owners fought tooth and nail against the establishment of the railways. These battles were fought out on the floor of the Houses of Parliament and we have an opportunity to describe the parliamentary system at work in relation to quite a realistic problem. I have sometimes staged with classes the parliamentary debate about the licensing of the first proper railway in England from Manchester to Liverpool, giving the students a chance to deal with arguments for and against the establishment of railways.

We can also introduce two interesting and contrasting biographies. If any one man can be said to have invented the high-pressure steam engine, the man was Richard Trevithick. He was a prolific inventor and adapted the high-pressure steam engine to many uses, such as the propulsion of boats and ploughs. He also attempted to drill the first tunnel under the river Thames in London. He established pumping engines in the silver mines of Central America and lost all he had gained in that venture, when Bolivar drove out the Spaniards. In fact, all his projects were like the Thames tunnel: daring, imaginative, and ultimately unsuccessful; he died in poverty and hardly anyone knows of him nowadays.

George Stevenson's name is more familiar, but the widely held belief that he invented the locomotive is as unfounded as the belief that Watt invented the steam engine. Stevenson came from a very poor family in Yorkshire. With tenacity and perseverance he got an education for himself and for his son Robert. Together they built one locomotive

after another until they had the best engine that could be constructed at that time. Stevenson devoted all his energies to locomotives and to the many details needed to organize a railway system. He became famous and died a rich man. These two biographies, simply told, convey more profound lessons to the students than any amount of theorizing and moralizing.

I hope the rather detailed description of the various aspects that would together constitute a physics module in the ninth grade has shown how the developmental stage of the student is considered, how faculties are trained appropriate to that stage, how psychological confidence is created at the same time that knowledge is imparted, and how the pupils experience the interaction of science, technology, and social conditions.

## CHEMISTRY—NINTH THROUGH ELEVENTH GRADES

In this example we shall be more concerned with the development of subject matter and how this can be adapted to the intellectual development of the pupils. At the same time I hope to show how the students can be given an experience of their relation to nature on the one hand and of the way in which the thinking about nature changed gradually and is still changing. This can be done implicitly without theorizing about philosophy, leaving the students to formulate their own questions and conclusions. As described for the physics module, the teaching would at each stage include historical, experimental, and biographical aspects of the subject.

The sequence starts in the ninth grade with a discussion of photosynthesis. This is the basic chemical reaction for life on the earth; the plant manufactures sugars from the carbon dioxide of the air and the water taken up from the ground. Energy is supplied by light captured and suitably transformed by the green pigment chlorophyll; oxygen is released into the atmosphere. In grade school students will already have learned that oxygen is necessary for and is used up in burning and respiration, and photosynthesis appears now as the reaction that replaces the oxygen again.

The observable properties of sugars and the starch and cellulose developed from them are then discussed (not their formulas or structure—the concept of an element is introduced later). The characteristic smell of burning sugar and the stages of its combustion are observed, the beautiful color obtained when testing for the presence of sugar in a solution is shown, and the way in which sugar can liberate metals from their compounds and form metal mirrors is demonstrated; then we discuss the conversion of the other carbohydrates, cellulose and starch, into sugar. All this work is based on telling demonstration experiments in which powers of observation are trained and wonder is engendered.

Next the students meet fats and proteins, the other constituents of our food, and are shown where they arise in the organism of the plants. This leads on to a discussion of digestion, which will probably be a review of grade school work but which is now done in more detail and with more experiments. Other reactions will be discussed such as the formation of alcohol and vinegar and the formation of esters and ethers. Industrial processes are also introduced such as

the manufacture of soap, paper, and plastics, the dry distillation of wood and coal, the use of coal tar and petroleum in the manufacture of many objects in daily use. Time will, of course, permit a few such processes to be treated. The students get to know many different types of organic compounds such as amino and fatty acids, alcohols, esters, ethers, aldehydes, and ketones—all in relation to biological or industrial processes.

Science teachers may object to this work on the grounds that there is no proper chemistry in it if they are accustomed to start chemistry by discussing the difference between compounds and elements or between physical and chemical change. To this a Waldorf teacher would reply that, on the contrary, a great deal of very meaningful chemistry is indeed taught. We are dealing with chemical reactions basic to everything that happens on the earth. We begin the study at the very stage where it began historically: namely, with observable processes and their classification into different types. In addition we meet the needs and interest of the students at this age by emphasizing *how* things happen. Only later does the *why* interest them. Up to the ninth grade and the beginning of the tenth grade it is, therefore, good to use their interest in the *how* to learn a large body of facts. These can then later be used as examples when the more basic, theoretical principles are developed.

In tenth grade the transition takes place from the *how* to the *why* phase. It is good at this stage to systematize what has been learned in the grade school about acids, bases, and salts, and oxidation and reduction. From there the transition can easily be made to the idea of a chemical element in relation to the chemical processes with which we start. We find base-forming and acid-forming elements, we find metals and nonmetals, we meet elements that are easily oxidized and others that resist oxidation. We can now show how surprisingly few elements enter into the reactions described in the ninth grade, and we can relate the properties of carbohydrates, fats, and proteins to the proportion of these few elements in the compounds.

As an example of the way in which the properties of an element are related to the chemical processes in mineral, plant, and animal, we can choose nitrogen. It is interesting to see how nitrogen can form bases and acids. Ammonium nitrate, for instance, is a salt whose basic and acidic parts are both derived from nitrogen. Nitrogen is also characteristic of protein. The name of the breakdown products of protein, "amino acids," also shows the almost hermaphrodite nature of nitrogen "amino" reminds us of ammonia, a strong base, so "amino acid" is almost equivalent to "base-acid," a contradiction in terms! However, the life of man and animal is largely determined by polarities like pleasure-pain and courage-fear, polarities of soul experience that have to be able to swing from one extreme to the other rather easily. How interesting that the body of man and animal is also mainly made of protein with its nitrogen, swinging easily from base to acid and back! Plants do contain protein, of course, but only in small amounts. The main bulk of their bodies is made of carbohydrates containing no nitrogen. When we come to minerals constituting the stable crust of the earth, we must have salts with acidic and basic parts, each due to a different element. Or we have oxides of metals—calyxes, as the alchemists would have called them—indicating by this word

the loss of the shiny, sounding qualities of the metal through oxidation.

The tenth-grade chemistry module could culminate in a first, qualitative discussion of the periodic system of the elements.

When we get to the eleventh grade it is time to introduce the numerical laws of chemistry. We have now a great store of examples on which to draw—and can repeat suitable simple experiments quantitatively. Students will now be interested in a historical account of the way in which chemistry developed and in more philosophical questions. The history of the phlogiston theory of the eighteenth century and its gradual replacement by the oxygen theory of combustion shows scientists at work much in the same way in which they work today. The way in which the atomic theory was resuscitated by John Dalton at the beginning of the century, how it was accepted by some scientists and not by others, how there were periods in which the theory was rejected as fantastic and as too metaphysical by some of the most prominent chemists and physicists, makes a fascinating story. The reasons given for rejection or acceptance are instructive too. The module could culminate with a discussion of the discovery of radioactivity and the change in thinking it caused.

Such a treatment shows very well how scientific thought develops. It also raises profound questions about the nature of matter. The history can be continued in the physics and mathematics lessons and can show how the nature of space and time also came to be questioned. In fact, the students begin to experience the crisis in cognition of the turn of the century and are mature enough to face such fundamental questions. They also become aware how inadequate many apparently simple and neat solutions of problems can be.

I hope that these two examples show how physics and chemistry are used as "educational tools." Of course, they serve also as a foundation for future college courses. By no means all students need such college preparatory courses, and in some Waldorf high schools additional science programs are run as electives for those who need them. However, the range of electives is always kept to the necessary minimum and every student has to take the core courses both in the sciences and in the humanities.

Naturally the science lessons offer, above all, opportunities for developing logical, careful, and practical thinking. However, they also contribute to the development of a sense of responsibility toward our natural surroundings and toward society. They can awaken a feeling for the complex way in which scientific thought interacts with technology, philosophy, and social conditions. Teachers have the task of structuring the lessons so that science is taught truly humanely. They want to use the subject matter for developing human faculties at the right time. They want to convey some of the excitement that the human activity of scientific research affords its practitioners. They want to facilitate communication between the spheres of human endeavor and particularly between the sciences on the one hand and the arts on the other.

Reprinted from *Education as an Art* by Ekkehard Piening & Nick Lyons, with the kind permission of the College of Teachers at the Rudolf Steiner School, New York.

\* \* \* \* \*

If you were intrigued by Hans Gebert's article, showing how pedagogical principles work in the 9th and 10th grade science blocks, you will appreciate the fascinating chemical 'lore' collected in a major work by Frits Julius. He was the chemistry teacher at the Hague school in Holland for many years, and became a master showman as well as evangelist for a phenomena-based approach to chemistry. His short Book I, with very brief notes on 7th and 8th chemistry, has been available in English for many years. An excerpt from this Book II, introducing stoichiometric topics for 10th grade was published in the 2nd issue of *Waldorf Science Newsletter* (Spring 1995); the same issue also included a synopsis of the sequence of ideas introducing a "formula language" based on Julius' work (see his Chapter IV, "Guiding Principles for Didactics of a Chemical Formula-Language").

An excellent translation of Julius' Book II: *Foundations of a Phenomenological Chemistry*, has been completed by Diedric Ruarus of New Zealand, and will be published by Hawthorne Press in England.

Although I was unable to verify the availability date by our press time, perhaps by the time you read this, you can get it through your local Waldorf book distributor. Based on my earlier collaboration with Diedric, this should be a very useful book for high school teachers, as well as others interested in a phenomena-based, holistic approach to the mysteries of substance!

— John Petering



*Students doing a physics experiment*

## GOETHEAN SCIENTIFIC CREDITS

Goethe is credited with a number of scientific discoveries. Perhaps most notably the inter maxillary bone in humans. This bone is found in all mammals - forming the front part of the muzzle in the upper jaw. Contemporary nineteenth century anatomists believed that its absence in the human organism was a critical distinction between Man/Woman and the beasts. Goethe's conception of the unity of mammalian organization suggested that it be present in human anatomy - and Goethe found the vestige of it in the ear.

James Gleick in his book *Chaos* describes how Goethe's color theory influenced Feigenbaum in the formulation of Chaos theory:

'Feigenbaum persuaded himself that Goethe had been right about color. [...] But as Feigenbaum understood them, Goethe's ideas had more true science in them. They were hard and empirical. Over and over again, Goethe emphasized the repeatability of his experiments. It was the perception of color, to Goethe, which was universal and objective.'

[James Gleick, *Chaos*, London: William Heinemann, 1988, pp. 165-7]

And in the same book, he goes on to describe how Goethe's 'Metamorphosis of Plants' and Schwenk's 'sensible Chaos' influenced Libchaber.

Dr Brian Goodwin, who has been Professor of Biology at the Open University in England since 1983, is perhaps one of the best known exponents. In his book *How the Leopard Changed Its Spots* he argues for a qualitative approach to science along Goethean lines:

In other areas away from theoretical science, Goethean science is having a significant impact. Largely through the work of David Seamon, it has had an important influence on Environmental Theory. Goethe's science was also a major influence on Philosopher Ernst Cassirer and on all the later work of Wittgenstein.



Passion flower tendrils

## HUMOR

### How Different Professions Hunt Elephants

MATHEMATICIANS hunt elephants by going to Africa, throwing out everything that is not an elephant, and catching one of whatever is left.

EXPERIENCED MATHEMATICIANS will attempt to prove the existence of at least one unique elephant before proceeding to step 1 as a subordinate exercise.

PROFESSORS OF MATHEMATICS will prove the existence of at least one unique elephant and then leave the detection and capture of an actual elephant as an exercise for their graduate students.

COMPUTER SCIENTISTS hunt elephants by exercising Algorithm A:

1. Go to Africa
2. Start at the Cape of Good Hope.
3. Work northward in an orderly manner, traversing the continent alternately east and west.
4. During each traverse pass,
  - a. Catch each animal seen.
  - b. Compare each animal caught to a known elephant.
  - c. Stop when a match is detected.

EXPERIENCED COMPUTER PROGRAMMERS modify Algorithm A by placing a known elephant in Cairo to ensure that the algorithm will terminate.

ASSEMBLY LANGUAGE PROGRAMMERS prefer to execute Algorithm A on their hands and knees.

HARDWARE ENGINEERS hunt elephants by going to Africa, catching gray animals at random, and stopping when any one of them weighs within plus or minus 15 percent of any previously observed elephant.

ECONOMISTS don't hunt elephants, but they believe that if elephants are paid enough, they will hunt themselves.

STATISTICIANS hunt the first animal they see  $N$  times and call it an elephant.

CONSULTANTS don't hunt elephants, and many have never hunted anything at all, but they can be hired by the hour to advise those people who do.

OPERATIONS RESEARCH CONSULTANTS can also measure the correlation of hat size and bullet color to the efficiency of elephant-hunting strategies, if someone else will only identify the elephants.

POLITICIANS don't hunt elephants, but they will share the elephants you catch with the people who voted for them.

LAWYERS don't hunt elephants, but they do follow the herds around arguing about who owns the droppings.



## CHEMISTRY WORKSHOP

with Walter Lebendorfer,  
Director,  
Teacher Training,  
R.S. Seminarlat,  
Jarna, Sweden

by John Petering,

In many details, this workshop repeatedly echoed an important theme from the keynote lectures: "what new capacities should we be developing?"

If we take up chemistry in a "Goethean" sense, we find this is a realm of "in-between," of processes and relationships. It is a field where the "elective affinities" are the phenomena. Here, we have the challenge of learning to make a new connection with the world of matter, by really living into an extraordinary world of pictures, of potent soul experiences.

It is quite different whether one is involved with chemistry as science or technology, or else as a pedagogical tool for life. As technology, chemistry is a tool for controlling and utilizing the world for our purposes. But, this "objective" approach contains a danger: acting separately from nature, our lack of intimate knowledge or appreciation has already resulted in serious damage to the natural world. For the developmental aims of Waldorf pedagogy, the goal is to live into a wonderful world of pictures, soul experiences (a German word for this is "schliessen," making connections), to get "caught up" in nature, and put yourself experientially right into the process.

So, educationally, the goal is not so much to develop skills of remembering definitions, or even learning creative thinking; rather, to strengthen our capacity for evaluating and making judgments out of a detailed acquaintance with one or another realm of nature. As Manfred von Mackensen puts it in discussing his pedagogical rationale for building up a chemistry syllabus focused on chemical processes, we need a "morphological consideration of chemical phenomena"(1)

Dr. Lebendorfer began initially by urging us to live into the experience of the process of solution. This study of salts and solutions would be taken up in a grade ten main lesson of a Waldorf school. As Walter was fond of saying: "Not substantial thinking, but process thinking." We should observe the subtle variations in phenomena, which will reveal the characteristics of the various substances.

For example, salt crystallization from a saturated solution produces a wonderful variety of crystal forms, reminding one of various scenes and locales in nature. From sodium chloride (table salt), we can produce small,

glittering "icy" crystals. From a hot, saturated solution of Lead (II) chloride, as it cools, we get delicate, snowflake-like crystals, which settle slowly, like snow. The individual differences in the style of crystallization of the various salts can begin to instruct us in the individual character of each salt. We began the process of developing a typology of salts (see Mackensen's (2) Table of Salts).

Another example was our exploration of the variations in metal hydroxide precipitates; here, we also find a wonderful variety. We compared copper and iron hydroxide gels.

The addition of soda lye to a pale sky-blue copper sulfate solution, produces a deep blue, heavy, globular precipitate, which becomes even blacker with time. But, an amazing clearing happens as concentrated sulfuric acid is trickled in; the concentrated sulfuric acid rushes to the bottom of the dark blue-black "clouds" of copper hydroxide, lightening the solution, allowing light to burst forth from the bottom-lit beaker.

We compared this with how a delicate green Iron (II) sulfate solution produces pale yellowish-green "gel" when hot 2M soda lye (NaOH) was added slowly. When peroxide is added (oxidizing the Iron), a brilliant red layer appeared above, forming a triplet of red, pale green, darker yellowish-brown. The colors represent or symbolize the polarity of the active acids, the more earthy, insoluble alkalis, and the salt, balanced between them.

Here we see the challenge to develop a new way of thinking about chemical phenomena -- to develop a "picture thinking," and also to develop a new language, a subtle, qualitative terminology, which will promote correspondingly sensitive qualitative observational skills. But, we should enthusiastically explore and experiment with other arrangements. As Dr. Lebendorfer often said about alternatives: "You could do it! Why not!?" Walter also described how the fiery red-haired Dutch pioneer of Goethean chemistry, Frits Julius, took such joy in creating whole worlds in his chemical beakers. For him, chemistry was an exploration of an enchanted realm, not a process of analysis.

In grade eleven, the Waldorf chemistry curriculum focuses on exploring the unique individuality of important elemental substances, for example the dozen or so which comprise the human body. First, we took up sulfur, examining where it occurs in Nature, its characteristic reactions. Through the transformations which occur with various other substances (relationships), we find revealed the mystery of each substance. With sulfur, we find an extraordinarily profound connection with heat and warmth processes.

The hypothesis of an extraterrestrial cause (meteor bombardment) for the abrupt end of the Mesozoic age of dinosaurs is currently being debated (3-5). A moving image of how a shower of meteoric iron from the heavens possibly redeemed and transformed the sulfurous swamps of the dinosaur age was created by sprinkling powdered iron into a sulfur flame; the mysterious pale blue flame suddenly came alive with brilliant, meteor-like flashes, as the iron vehemently combined with the sulfur, forming the balanced, stable iron (II) sulfide. It is also interesting that we so commonly find large amounts of pyrite just in these iron-rich "red bed" sandstones, near the Cretaceous-Tertiary boundary.

Finally, we concluded with a consideration of the grade twelve syllabus. This realm presents a challenge for a Goethean approach to chemistry; the pioneer Frits Julius suggested developing a "chemistry on four planes" -- highlighting the characteristic phenomena in each of the four kingdoms of nature: mineral (conventional), biology (life); animal (sentience); human (individuality). Perhaps a chemistry of life involves a study of multiple, simultaneous homeostatic processes. What is characteristic of the animal realm? What does a chemistry of sentience mean, if not the study of the processes found in the nervous system and the substances which form a basis for sentience. And, most enigmatic, what is characteristic of the human realm? The individuality of the blood, the immune system as a sense organ in the metabolic realm, and the biochemistry of the brain were mentioned as possible topics for further research.

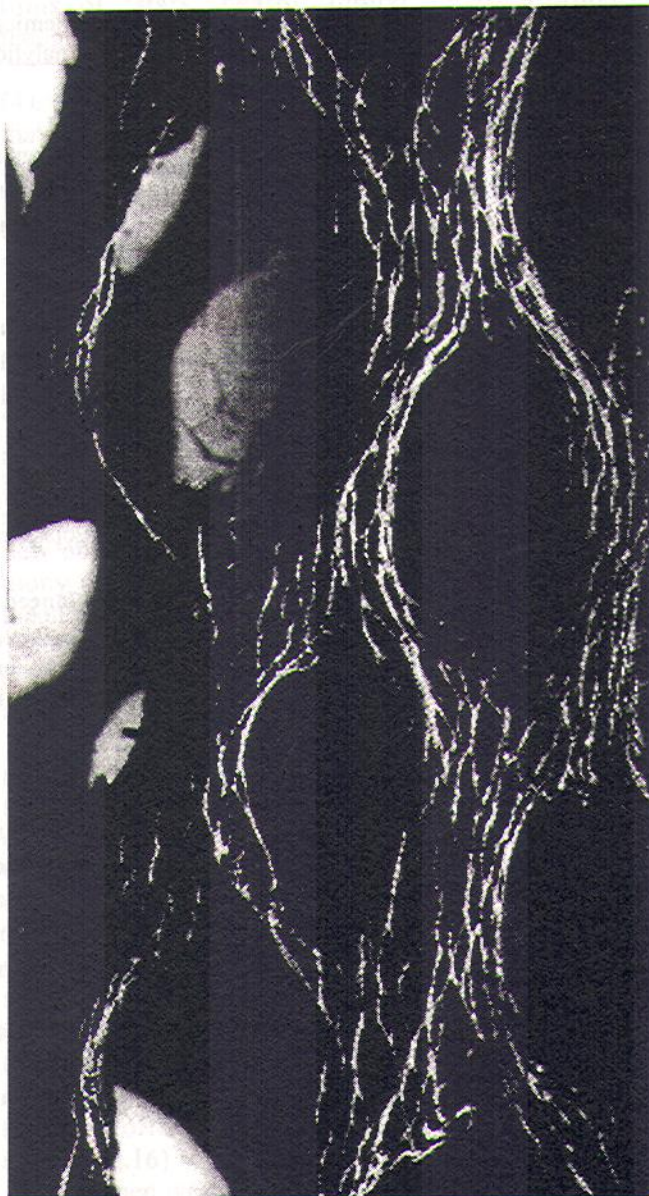
As Dr. Steiner indicates in the lecture "Michael and the Soul Forces of Man," a new faculty is needed, which he calls "gemüt" -- perhaps rendered as: intuition warmed by heart and active in full consciousness.

Two scenes stayed with me for some time afterwards. First, Dr. Georg Unger challenging the physicists to plunge back into their bodies and their senses, as they considered a forest pond: "what do you actually see?!" Second, Walter Lebendorfer welcoming the chemists to enter with their senses inside the colorful, amazing worlds created in their flasks and beakers, swim with the dancing metal precipitates, do geometry with the crystallizing salts, or really experience what Lao Tzu means, to give up your isolation and dissolve into a solvent, "Like a boat into the shores of heaven" (6).

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Skeleton of a cholla cactus

# The Important Salts

Gr 10 Chemistry  
Table of Naturally Occurring Salts

| <u>Common or Mineralogic name</u>              | <u>Chemical or Analytic name</u>     | <u>Formula</u>                                          |
|------------------------------------------------|--------------------------------------|---------------------------------------------------------|
| <b>Lithified salts (no taste)</b>              |                                      |                                                         |
| Barite                                         | Barium sulfate                       | Ba SO <sub>4</sub>                                      |
| Flourite                                       | Calcium difluoride                   | Ca F <sub>2</sub>                                       |
| Apatite                                        | Calcium hydroxy phosphate            | Ca <sub>5</sub> (PO <sub>4</sub> ) <sub>3</sub> (OH)    |
| <b>Semi-Lithified salts (only faint taste)</b> |                                      |                                                         |
| Gypsum                                         | Calcium sulfate dihydrate            | Ca SO <sub>4</sub> · 2H <sub>2</sub> O                  |
| Calcite, Selenite, Limestone                   | Calcium carbonate                    | Ca CO <sub>3</sub>                                      |
| Dolomite                                       | Calcium magnesium carbonate          | Ca Mg(CO <sub>3</sub> ) <sub>2</sub>                    |
| <b>Encrusting Salts (soapy &amp; bitter)</b>   |                                      |                                                         |
| Thenardite (Glauber's salt)                    | Sodium sulfate decahydrate           | Na <sub>2</sub> SO <sub>4</sub> · 10 H <sub>2</sub> O   |
| Arcanite                                       | Potassium sulfate                    | K <sub>2</sub> SO <sub>4</sub>                          |
| <b>Aromatic/spicy Salts</b>                    |                                      |                                                         |
| Table salt, Halite                             | blanced char., salty taste, aromatic | Na Cl                                                   |
| Sylvite, "diet salt"                           |                                      | K Cl                                                    |
| Ammonium alum                                  |                                      | NH <sub>4</sub> Cl                                      |
| 'sal ammoniac'                                 |                                      |                                                         |
| <b>Desert Salts</b>                            |                                      |                                                         |
| Potash                                         | Potassium carbonate                  | K <sub>2</sub> CO <sub>3</sub>                          |
| Soda ash (washing soda)                        | Sodium carbonate                     | Na <sub>2</sub> CO <sub>3</sub> · 10H <sub>2</sub> O    |
| Chile Saltpeter                                | Sodium nitrate                       | Na NO <sub>3</sub>                                      |
| Saltpeter                                      | Potassium nitrate                    | K NO <sub>3</sub>                                       |
| mason's saltpetre                              | calcium nitrate                      | Ca (NO <sub>3</sub> ) <sub>2</sub> · 6 H <sub>2</sub> O |
| or 'lime saltpeter'                            |                                      |                                                         |
| Argentite (phot. salts)                        | Silver nitrate                       | Ag NO <sub>2</sub>                                      |
| or Lunar caustic                               |                                      |                                                         |
| Cerargyrite                                    | Silver chloride                      | Ag Cl <sub>2</sub>                                      |
| <b>Bitter Salts</b>                            |                                      |                                                         |
| Epsom salts                                    | Magnesium sulfate                    | Mg SO <sub>4</sub> · 7H <sub>2</sub> O                  |
| Biscovite, magnesia chlor                      | Magnesium chloride                   | Mg <sub>2</sub> Cl <sub>2</sub> · 6H <sub>2</sub> O     |
| (ice melter)                                   | Calcium chloride                     | CaCl <sub>2</sub> · 6 H <sub>2</sub> O                  |
| <b>Corrosive Salts</b>                         |                                      |                                                         |
| Kalinite, Alum                                 | astringent, metallic                 | KAl(SO <sub>2</sub> ) · 12H <sub>2</sub> O              |
| Chalcanthite, blue vitriol                     |                                      | CuSO <sub>4</sub> · 5H <sub>2</sub> O                   |
| iron stone, green vitriol                      |                                      | FeSO <sub>4</sub> · 7H <sub>2</sub> O                   |
| --                                             |                                      | Al Cl <sub>3</sub>                                      |

# Goethe's Scientific Imagination

Notes from a lecture by Henri Bortoft  
March 1997

Henri's public lecture, done in connection with a major new publication of his essays (1), was a very lively, humorous affair, and this summary can only capture the bare bones of it. He began with several background points key to understanding Goethe's "way of science." First, he noted that it is often a surprise to people that Goethe produced a great deal of scientific work, and this may be due to the fact that it is not appreciated as 'real' science. This is doubly surprising, considering Goethe came to feel that it was just this scientific work which was of particular importance. Goethe was shocked that his color phenomena didn't convince people; so, he went deeper into investigating the nature of science, and actually arrived at very modern insights about the nature of natural science (see Merleau-Ponty and Kuhn in references 2, 3, below).

Perhaps the main reason Goethe is not widely appreciated today, is because we find it difficult to grasp his work as an *alternative kind* of science. From the prevailing empiricist (naive inductivist) view of science, we believe that knowledge arises from a direct experience of the world, as revealed to us through the senses. So, how could there be more than one true knowledge of the world? Surely only one can be true, and the rest must be counterfeit. So, as Bortoft said, "There can't be an alternative kind of science which can also claim to have its own kind of truths, as does our mainstream science. One of the greatest problems in understanding Goethe, or in understanding in general, is that it is not a matter of something you've got to *do*, but of something you've got to *stop doing* so that understanding can come in."

To really grasp Goethe, we have to become aware that we are making fundamental presuppositions about things. But this is quite difficult, because we are not aware that they are presuppositions; we believe that what we think is part of the fabric of reality. It is often said that in the enlightenment, people 'came to their senses,' quit speculating, and started looking at the world around them. Actually, it is more true to say that they 'took leave of their senses' developing ideas that contradicted their immediate sensory experience. This is an effect of what Bortoft calls an "organizing idea in science." As phenomenologists have explained, what we 'see' is deeply dependent upon what we expect to see (see Bortoft: "Knowing the World," p50 and "The Organizing Idea in Cognitive Perception," p124). Galileo's notebooks clearly show how he slowly came to 'make sense' of his observa-

tions of 'stars' nearby Jupiter in 1610, finally recognizing them as "moons".

Along with Thomas Kuhn (3), Morris Berman (4), and other historians of science, Bortoft suggests that this notion of objective truth, exemplified by Rene Descartes, is taken up with such enthusiasm because it fit into the cultural-historical currents of the 17th century. Goethe says "The history of science is science itself" and many 20th century philosophers of science such as Kuhn (3) and Popper (5) now agree that science is *intrinsically* historical. In his book, Bortoft details how Copernicus embodies neo-platonic ideas (Ref. 1, Part III "The Wholeness of Nature," "Copernicus and the Moving Earth" pg. 154 ff.), which are enthusiastically taken up by a small number of highly influential people, because they fit the historical times. Copernicus notes that although he has made *no* new observations, his system is *able* to show the harmony and symmetry of the whole, even if this may mean going against our naive experience of the senses. The challenge, as Galileo says, of "how to move the earth, without causing a thousand inconveniences" arises because our senses are illusory.

Then, with Descartes and then Galileo, the mathematical style of thinking (with logic, propositions, and proof) becomes *the* style of thinking, because it gave a sense of certainty. However, the fact that the world can seem mathematical (quantifiable) is due to the way we conceive the world: we "mathematize it" so then, naturally, we see it mathematically (Bortoft, pg. 172 ff.). Further, this mathematical approach strives to find the common property of many specific cases, or the "unity underlying multiplicity." Bortoft calls this the "extensive dimension of unity" which he characterizes as external, static. (see Bortoft's discussion of Bergson's 'logic of solids,' pg.16).

Then we come to Bortoft's main point: Goethe approaches things entirely differently. He *trusts* knowledge as it comes to him in partnership *through his senses*, especially as he pursues the processes of life. Goethe not only finds a way to perceive the unity (archetype) but also to perceive the multiplicity in the unity. Surprisingly, Bortoft said, in the light of the 'new' or 'post-empiricist' philosophies of science, we can now appreciate how modern Goethe's ideas about scientific method are.

I felt one of Bortoft's most interesting insights is his characterization of this approach as "multiplicity in unity – where each is the same One." Two examples of this way of recognizing things are: experiences with

ambiguous (or multi-valent) figures, and plant propagation. In ambiguous figures, we see the same percepts, but once we 'recognize' that the lines, for example, can form a duck or a rabbit, we can 'choose' to see either one or the other. The whole percept becomes completely one or the other image. Each are manifestations of the same One figure! Then, with propagating tomatoes, for example, the one plant becomes many, but each one is an actuality of the same One tomato. Thus Goethe practiced this mode of seeing plant organs, rising to a higher level, and seeing the archetypal plant 'type' in each individual plant. In this way we can experience in a participatory way the "dynamical unity of the coming-into-being of the plant." Bortoft characterizes this as dynamic, participatory mode, "the intensive dimension of the One" where the perceptions have intensive depth.

It was interesting how, building on the ideas of Georg K hlew nd (6) and Friedeman Schwartzkopf (7), Bortoft describes the relationship of sensory and imaginative seeing as the "belonging together," or the "twofold" way of conceiving. As Barfield (8) put it: "Imagination [in this sense], in fact, presupposes "double" vision and not simply the substitution of one kind of single vision for another. It requires a sober ability to have the thing both ways at once." So, rather than imagination being used to form novel hypotheses to test experimentally, imagination in Goethe's sense "leads to an experience of the wholeness of the phenomena, something which is part of them and not added on to it by the mind" (Bortoft, pg. 307).

Finally, Bortoft described how Goethe's way can transcend the objective-subjective dualism, and points to a potential for expanding science. In a surprising turn of thought, Bortoft shows how we can finally realize Goethe's way can never compete with a causal, quantitative way of science. "The science of quantity and the science of wholeness are both true, but nature is revealed differently in each of them. ... They appear as alternatives when taken in the numerical, quantitative sense, which corresponds to the world of solid bodies. But if we can leave this restricted case behind, we discover the higher possibility of the diversity which is within unity itself. Then we can see how truth can be neither singular nor plural, but One truth which is multiple. This is a higher perspective which has the effect of turning the one and the many inside out. ... From this transformed perspective, we can recognize how the so-called problem of objectivism and relativism arises from the way that the external perspective, corresponding to the logic of solid bodies, influences the form of our thinking. When we become free from this constraint, we can recognize that Goethe's organic perspective of "multiplicity within unity" can *itself become the means* by which Goethe's style of science can be seen to be justified in its claim to be scientifically true. Furthermore, it does so in a

way which expands our understanding of scientific truth" (Bortoft p326).

It is very difficult to actually leave behind our pervasive habits of "object thinking" and fully practice organic, metamorphic thinking (see Holdredge's discussion of modern molecular biology, Ref. 9). And, it is characteristic of this 'organic' approach that it cannot be 'learned' from the outside, by reading about it; it must be experienced, lived through. In this connection, it was very appropriate that Bortoft offered an extensive workshop experience of Goethe's method the next day.

## Workshop on 'Goethe's Method'

In the workshop, we explored basic experiments in color optics. But, on the basis of a deeper understanding of Goethe's method, we could now appreciate more subtle aspects of *how* we were approaching the subject. We explored four important stages of this process, which we might designate: attending to the phenomena, exact imagination, metamorphosis of the series, and the jump to seeing the wholeness. I feel this workshop gave one of the clearest examples of Goethe's method I have experienced.

First, we must embark on encountering the phenomena via "*active seeing*" instead of the passive reception of visual impressions. This entails putting intention into seeing, plunging into seeing the qualities of the colors. ... this takes attention away from the verbal-intellectual mind and promotes de-automatization from the analytical mode of consciousness." (Bortoft, pg. 42, 66). Two details which I felt were crucial to promoting this step of active seeing, are finding 'enhanced' phenomena, and looking in outdoor settings. If possible, we should produce experimental phenomena under conditions which are 'enhanced' or sufficiently large-scale, so that the beauty and majesty of the phenomena can manifest powerfully and clearly. As another Goetheanist says, it is like the difference between observing a cloud from a distance, surveying it in a detached way, and on the other hand, walking into it and "getting soaked in the thunderstorm" (von Mackensen, 10) It is often useful, once we have discovered a new phenomena, to seek out the corresponding phenomena out in nature and soak it in there, in its richness. We may find how the initial phenomena are quite complex, and so then we begin to produce them under related, but simpler conditions.

As we explored initial experiments in prismatic color phenomena, Bortoft pointed out how the context and what issues motivated the research will color the findings; Newton was trying to eliminate color aberrations from his telescope lenses, while Goethe wanted to understand the lawfulness of color in order to be a painter.

In the second stage, which Goethe termed *exact sensorial imagination* ("exakte sinnliche Phantasie"), we are challenged to re-imagine the phenomena inwardly, seeing them with an inner eye. This gives our thinking more the quality of perception and sensory observation more the quality of thinking (Bortoft, pg. 42). Also, we discover how well we really observed all the details. Then, going beyond a mere tallying of the facts, we enter into the qualities too, noticing any feelings as we examine each detail. Goethe felt that here, the lawfulness of nature is active within the researcher, instinctively, as a 'mimesis' not just rote copying. Interesting how again the artist is a dominant figure in these metaphors, and also how this echoes the sequence of presentation indicated by Steiner for a main lesson in science.

Third, we should combine the experiments into an "*extensive series of experiments ... working out every possible aspect and modification of every bit of empirical evidence*" Goethe termed this *manifolding* (Vermannigfaltigung) (Goethe, "*Experiment as Mediator...*" Ref. 11.) Here, we begin to find the essentials; with prismatic colors, how two sets of colors arise, but only at boundaries, transition zones.

Lastly, as we explore back and forth along this 'rainbow of perception' we can have the experience of coming to a new "comprehension as ... a *form of seeing* embedded in the fullness of the phenomena. This seeing which *lets* the phenomenon show itself fully, lets it appear is the theory for Goethe. The theory is an *experience of insight* in which what is seen is the intrinsic necessity, and hence the intelligibility, of the phenomenon." (Bortoft pg. 228). This kind of seeing is actively receptive where the "organizing principle (which is the necessity) of the phenomenon itself which can come to expression in the researcher's thinking" (Bortoft pg. 242).

This is a new way of thinking which is achieved through a new organ of perception, and thus requires the experimenter to undergo a transformation also, along with his experiments. This experience of 'multiplicity in unity' where the One plant now manifests in the prepared imagination, is a complementary form of the reality of the plant. The human being now completes the circle and this "delicate empiricism" now "allows a higher product of nature to appear, which is only possible through a human being's conscious participation (devotion) in the processes of nature." (Bortoft pg. 274). By exploring the "belongingness of the phenomena" into focus, we overcome the isolation of the single observation. This comprehensive way of seeing fosters *understanding* the phenomena; and this stands in contrast to the hypothetical model of science, which seeks a theory as a basis for *explaining* something (pg. 291).

This step is quite delicate, and requires a lot of patience. We normally tend to jump to ideas too soon, and forget the 'beginners mind' we had at the outset.

With Goethe's way, imagination is active in the seeing *in the immediate present*; not in the past (testing hypotheses already formed), nor in the future (leading to forming theories for explanation). Once we begin to sense a certain lawfulness, we can look for instances of this in nature's rich phenomena, what Goethe called "an instance worth a thousand" or an "archetypal phenomenon."

In the end, Bortoft points out, this approach leads to meaningfulness. There is nothing inherently intelligible about why a light 'wave' 'vibrating' with a 'wavelength of 540 mm' should appear with the quality 'green.' However, with Goethe, the quality of green as one middle color between interacting warm and cool colors does seem to have a certain sense in it. And, like most allegorical or symbolic things, it partakes in the larger relatedness we see in the interaction of cool colors of earth and soil, and the warm sunlit air and sky, with the green mantle of the biosphere between.

Henri Bortoft is clearly both a thorough student of the epistemology and philosophy of science underlying both Goethe's and Newton's approaches, as well as a skilled and careful researcher in practice. It seemed unfortunate to me that his book "The Wholeness of Nature" while very thorough, cannot convey much of the context: the lively, dry British humor of the author, as well as his devotion to actively applying this little-known approach to understanding Nature.

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# $\pi$ and Trigonometry

A Tenth Grade Main Lesson Block

by

Martin Levin, Shining Mountain Waldorf School

In the August 1994 issue of this newsletter there appeared an article by David Mitchell describing how students could be asked to find the value of  $\pi$  by measuring. That was intended for use in the middle school. We will describe here a corresponding treatment of the topic for the high school.

I will begin with a bit of personal background. In the mid 1970's Hans Gebert described briefly to me a high school mathematics curriculum which he had received from Ernst Bindel and which with some modifications he had used himself. It included a block in the tenth grade in which the students calculated  $\pi$  by Archimedes' method of calculating perimeters of circumscribed and inscribed regular polygons. He said that doubling the number of sides of the polygons would give new polygons whose perimeters were found from the previous one's by taking first the geometric and then the harmonic means. A few years later I switched from college to high school teaching. For my very first main lesson block I found myself in front of a tenth grade class trying to develop those few sentences into an interesting course. It was a disaster. However, after a few years experience with high school teaching and after reworking the course several times, it eventually developed into a very successful block which is now my favorite one to teach.

We begin with a review of similarity and the calculation of arithmetic and geometric means. The ratio of circumference to diameter is the same in all circles because of similarity. This ratio is called  $\pi$ . Although they may have been told before what its value is (e.g. 3.14 or  $22/7$ ), they only knew that because an authority said so, but now they need only believe what they see or

reason through for themselves. So, we will try to discover the value of  $\pi$ .

The students draw circles with compasses, cut them out and measure them. Contrary to what was said in the August 1994 article in this newsletter, I have always found that the students do not get the same values, and therein lies the crux of this whole main lesson block. We spend the better part of a main lesson period discussing the matter, after which it becomes clear that  $\pi$  is the same for all ideal circles, but not physical ones. The ideal circle which lives in the realm of thought, and is what we use to recognize a circle, is what we strive for when we make a circle. Physical circles are always imperfect. So, the value of  $\pi$  has to be found through thinking. Archimedes was the first to do this. The biography of Archimedes is told, including the dramatic story of his death. The withered old man of brilliant intellect in deep concentration slain by the proud brawny soldier is a poignant picture of the passing of power from Greek to Rome and also of those conflicting forces in the adolescent.

As a university professor I heard many students wonder why it was necessary to prove things in mathematics, but I have never heard a student who has experienced this main lesson block make that complaint.

Then the class studies Archimedes' method for calculating  $\pi$ . He approximated circles with regular polygons. By keeping the perimeter fixed and doubling the number of sides the in-radius and circum-radius make better and better approximations to the reciprocal of  $\pi$ . Archimedes showed that when the number of sides is doubled the new radii can be found from

the old ones by taking arithmetic and geometric means. The development of these ideas entails some challenging work in both algebra and geometry. It is first rate mathematics. I have then always asked the students to carry out the calculations, requiring several pages of calculation, without a calculator, to finally arrive at an upper and lower bound for  $\pi$ . The difficulty of this whole calculation, both theory and arithmetic, gives an appreciation for the special quality of the number  $\pi$ . The limiting process used here gives a good preparation for the later study of calculus.

One can then go on show how to use a trigonometric table to solve right triangles and then show how Archimedes' calculations of the polygon radii were used by Ptolemy to help calculate the first trigonometry tables.

I'll mention here just one of the changes that I made. In the first few years of teaching the block I kept the radius of the polygons fixed and calculated the *new perimeters* when the number of

sides doubled. This was the way that secondary sources said that Archimedes had done it. I thought that it would be simpler for both the proofs and calculations to instead turn it around, keep the perimeters of the polygons fixed and calculate how the *radius changed* when the number of sides was doubled. However, I did not do it that way, because I wanted to remain true to Archimedes' original method. Then one day I took the trouble to look up a translation of Archimedes' original work. Lo and behold! He had done it the other way also. The secondary sources were wrong! I followed that method thereafter.

This block has a unity and sophistication of thought which I have found to be very satisfying for students and teacher alike. I would hope that no one would try to just mimic what I have described here, but that it might provide some useful ideas to draw upon.

## TO INFINITY AND BACK IN CLASS ELEVEN

by Norman Davidson

"The science of pure mathematics, in its modern developments, may claim to be the most original creation of the human spirit."

A.N. Whitehead,

English philosopher and mathematician, 1861-1947

Why did Aristotle consider that a circle was more perfect than a straight line? He saw the circle as a form which could be completed, and the line as one which could not – therefore the incomplete form was the least perfect of the two. The line could be extended on and on infinitely without end.

What has modern thinking to say about this? A revolution has taken place in concepts concerning space which is as great as was the change from an earth-centered to a sun-centered universe. The modern mind has reached out into infinite space and placed the concept of an "ideal" point as it is sometimes called or a "point at infinity" on a line if extended infinitely far. To then step beyond this point means to return back along the line from the opposite direction! In modern thinking a straight line is as continuous and complete a form as a circle and reaches a perfection of its own which the ancient Greeks never dreamed of.

Such a thought process as outlined above is introduced into the Michael Hall curriculum in Class Eleven. Clarity and elevation of thought along with rigorous logical discipline meets the needs of the 17-year-old at this stage through a study of Projective Geometry as a main lesson. It takes its place alongside other lessons at this age which likewise touch on aspects of life which respond to universal questions within the human being.

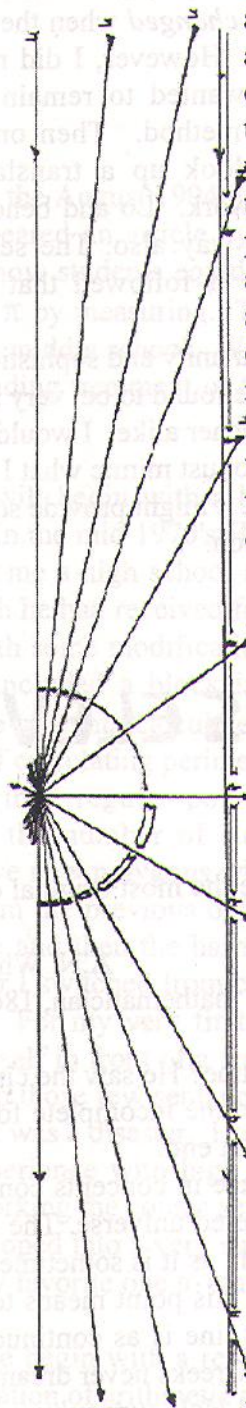


Fig 1

The example given above with an appropriate drawing was introduced early in the Projective Geometry main lesson given this year. The great mathematician and astronomer Kepler seems to have been the first to formalize the concept of a point at infinity being shared by two parallel lines. The drawings which accompany this article are reproduced from the recent work of a pupil, Hans Kaspar Wehrli. Figure 1 shows the relationship between a point and line. A specific line through the point above gives rise to a specific point on the line below. This is called a one-to-one correspondence. For any one line through the point there is only one corresponding point on the line. If we start with a perpendicular line through the point and rotate it clockwise, this moves the corresponding points to the left along the line. When the line through the point becomes parallel to the line below we then say the corresponding point is at infinity. Move the line further clockwise and the point reappears on the right side of the line and returns whence it started. When the lines were parallel there can only be one point at infinity and this is found in either direction, left or right, along the line. The one-to-one correspondence is maintained, and every line has one point at infinity. The consequence of this, which is then worked with as a basis throughout the rest of the projective geometry course, is that there is one straight line at infinity in any plane and that these lines make up one and only one plane at infinity – the archetype.

Such concepts unite, in a precise yet livingly imaginative way, all the elements of space both finite and infinitely distant. There is the picture of a universal wholeness within which one freely builds, step by step without calculation or measurement but simply through pure pictorial thought. This is called the synthetic approach as opposed to the analytic or algebraic.

Such a synthetic, visual foundation of modern geometry was, in fact, born historically at the same time as the abstract one and both confirm the same phenomena of space - they are complementary activities. The algebraic basis was founded by the French philosopher Descartes (1596-1659) and the synthetic or projective method formulated by the French architect and engineer Girard Desargues (1593-1662). Historically the qualitative projective approach to the same questions of space was obscured by the popularity of the quantitative analytic approach, the former only to be resurrected later (19th century) for further development in its own right. This is also what happens with the pupil around the age of seventeen when intellectual thinking comes into its own, becomes legitimately "popular"; then out of this can be reborn the qualitative synthetic thinking which frees our ideas of space and brings balance to counteract rigid concepts. A space in which extension pushes out from a material center point is met by a space within which elements at the infinite periphery (points, lines and plane) can work inwards, bearing new laws arising out of the polarity between point and plane and between line and line. New spaces are created. We can say with the French philosopher and mathematician Pascal that "It is not from space that I get my dignity, but from the control of my thought ... By space the universe embraces me and swallows me up like an atom, by thought I embrace the universe..."

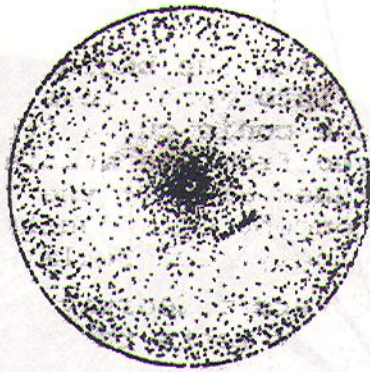
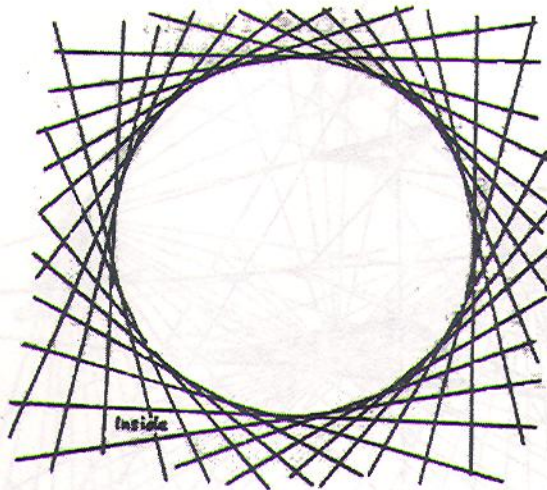


Fig 2



An example of the aforementioned polarity is shown in figure 2 where a circle can either be formed of points developing outwards, so to speak, from a center point, or of lines growing "inwards" from the infinite periphery. The center of the first circle is the point in the finite center, whilst the center of the second circle is the line at infinity. Thus every figure has its polar opposite construction and this lays the basis for the metamorphosis of forms.

Fig 3

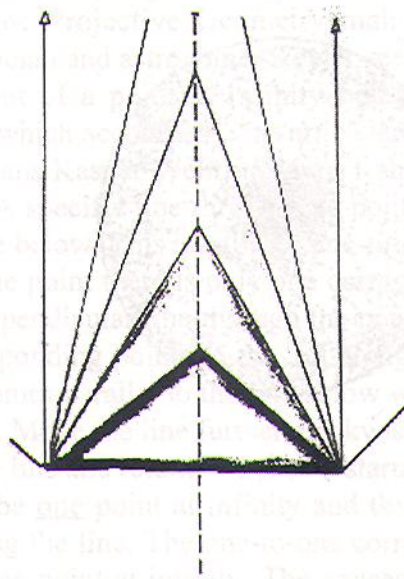


Figure 3 shows a triangle whose apex is extended along a line to infinity, then taken beyond infinity to return and form a triangle whose sides now extend over infinity.

Fig 4

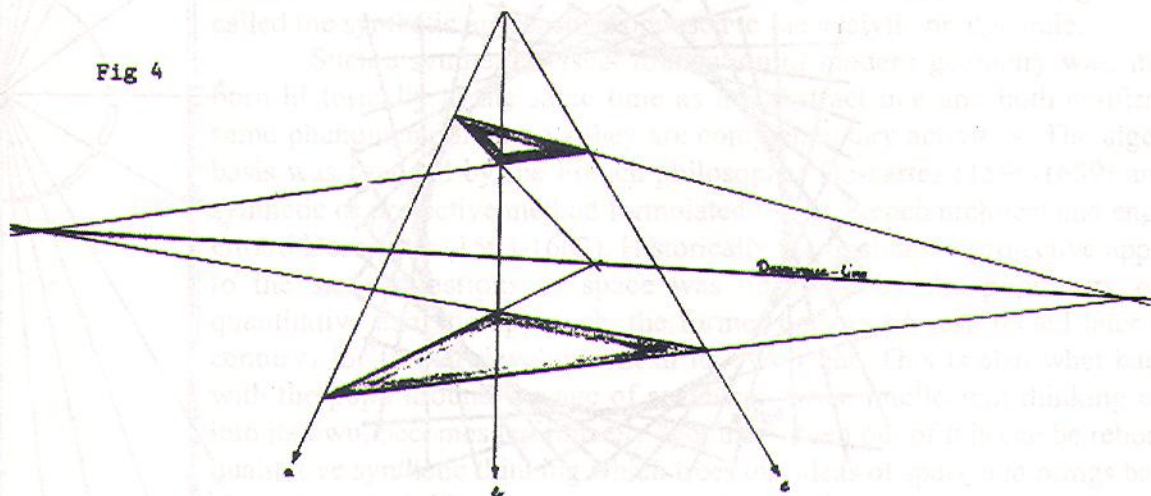


Figure 4 illustrates the famous triangle theorem of Desargues where it is shown that if two triangles have corresponding corners perspective to a point, then corresponding sides intersect on a line. Figure 5 demonstrates the elegant synthetic proof of this in three dimensions – it being self-evident that any five planes intersect in the lines and points of the Desargues configuration when the lines and points are projected onto the plane of the paper.

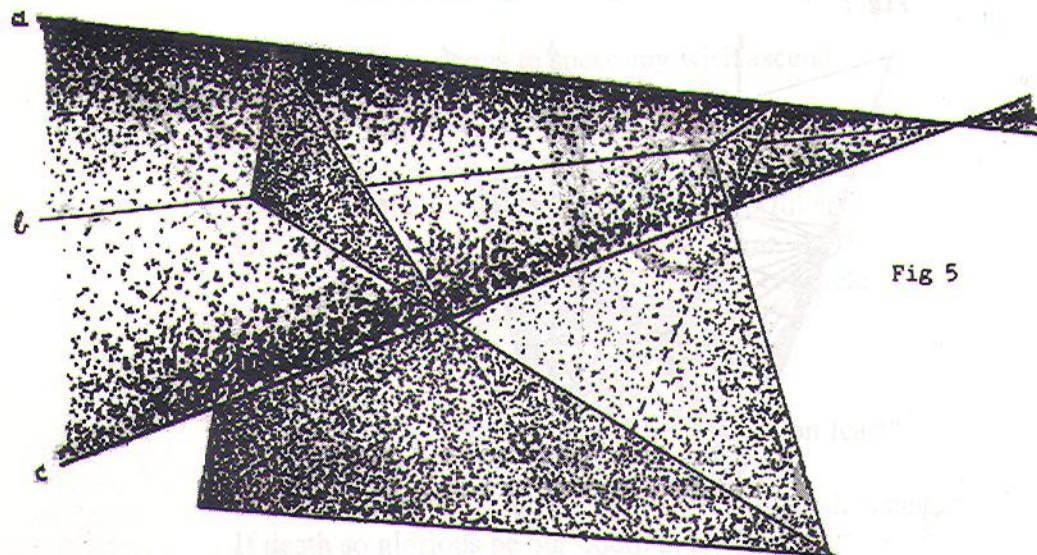


Fig 5

Figures 6, 7 and 8 show how projections in the plane from any five elements (here three points and two lines) form conic curves - ellipse, parabola and hyperbola.

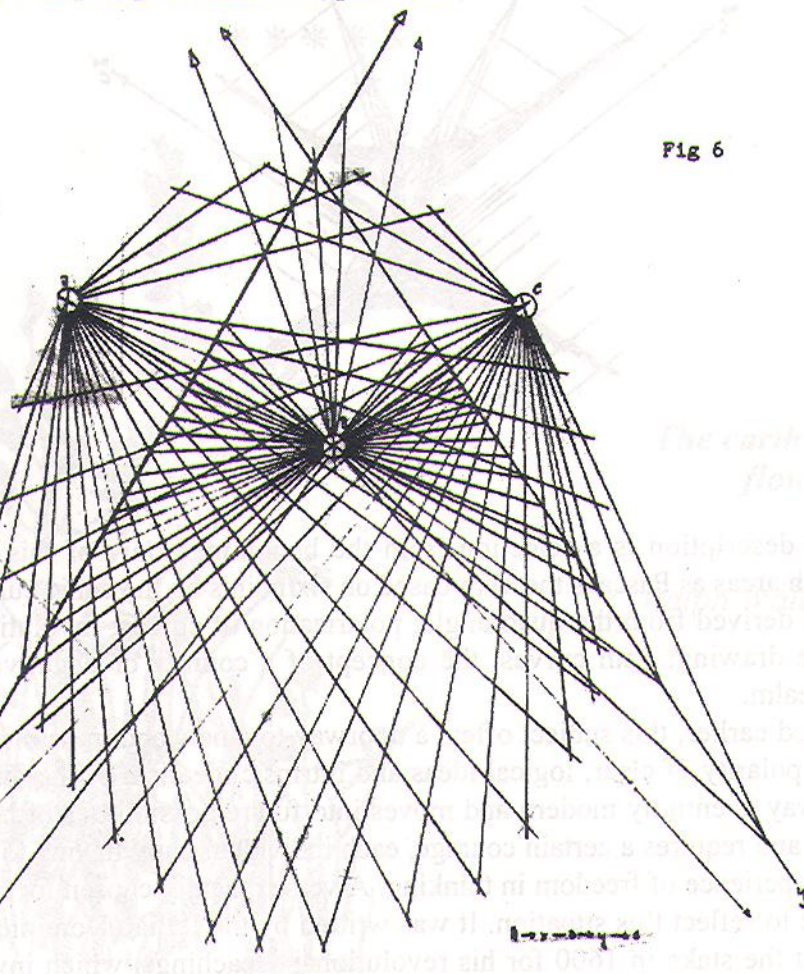


Fig 6

Fig 7

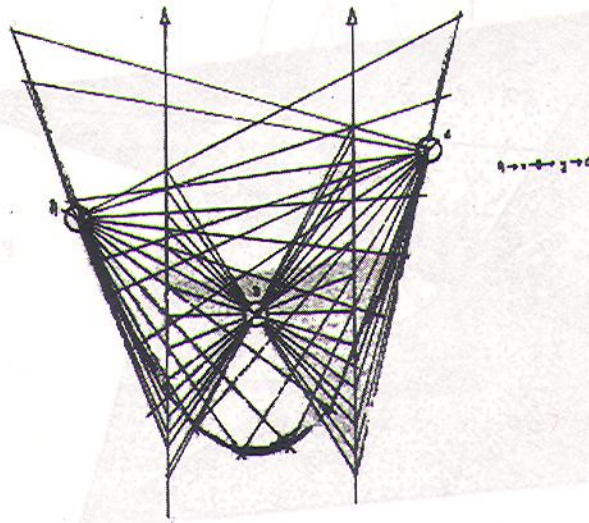
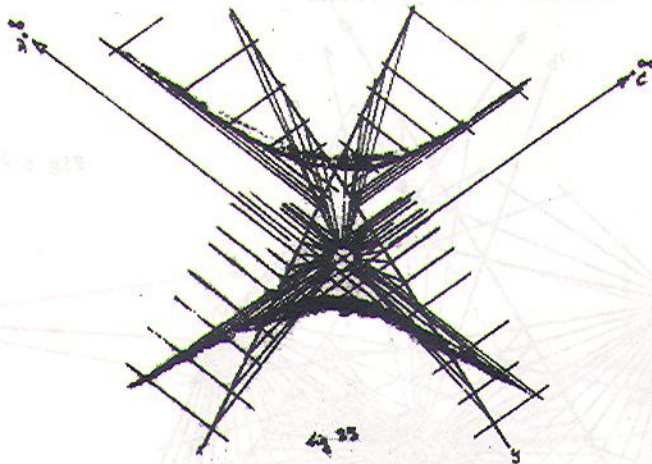


Fig 8



The above description is a selection from the beginnings only of this study which can then be developed into such areas as Pascal's theorem based on six points on the conic curve (the mystic hexagram); laws of harmonics derived from the quadrangle; polarization of curves; involution (Desargues again); the laws of free curve drawing; path curves; the concept of a counter or negative space - a flight into an increasingly rich realm.

As suggested earlier, this subject offers a doorway to a new and transformed way of thought which directly meets the polarity of clear, logical ideas and intrinsic idealism of the maturing teenager. The step through this doorway is entirely modern and moves into future possibilities of human consciousness. This step is a challenge and requires a certain courage, each individual pupil having to take it independently as it rests on an inner experience of freedom in thinking. A verse recently chosen for recitation by the class each morning attempted to reflect this situation. It was written by the Italian Dominican monk Giordano Bruno who was burned at the stake in 1600 for his revolutionary teachings, which involved new notions of the universe and infinity. To grasp new concepts requires a flight, a dying to old ideas, plus courage. The poem runs thus:

## The Philosophic Flight

Now that these wings to speed my wish ascend,  
The more I feel vast air beneath my feet,  
The more toward boundless air on pinions fleet,  
Spurning the earth, soaring to heaven, I tend:  
Nor makes them stoop their flight the direful end  
Of Daedal's son; but upward still they beat.  
What life the while with this death could compete,  
If dead to earth at last I must ascend?  
My own heart's voice in the void air I hear.  
"Where wilt thou bear me, O rash man!  
Recall thy daring will! This boldness waits on fear!"  
"Dread not," I answer, "that tremendous fall:  
Strike through the clouds, and smile when death is near,  
If death so glorious be our doom at all!"

This article was first printed in the Michael Hall Newsletter when the Norman Davidson was a high school teacher. It is printed with his permission.

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*The earth laughs in  
flowers.*

*Ralph Waldo Emerson*

# A Note On Pascal's Triangle

by Martin Levin,  
Shining Mountain Waldorf School

Pascal's triangle of numbers with its many remarkable patterns has been much studied and written about. However, this note will describe yet another one of its property, which this author has not found mentioned elsewhere.

Define the alternating product of two n-tuples,  $(x_1, x_2, \dots, x_n), (y_1, y_2, \dots, y_n)$ , to be

$$\sum_i (-1)^i x_i y_i.$$

For example:  $(2, 5, 1, 0, 6) (3, 8, 7, 4, 10) = -2*3 + 5*8 - 1*7 + 0*4 - 6*10 = -33$ .

It turns out that the alternating product of the n-th row of Pascal's triangle with any n+1 consecutive numbers in the k-th diagonal of the triangle with  $k < n$  is always 0.

A diagram of Pascal's Triangle with 10 rows. The rows are numbered 0 to 9 from top to bottom. The diagonals are numbered 0 to 9 from left to right. Arrows point to the right for each row number and to the left for each diagonal number. The numbers in the triangle are:

|   |   |    |    |     |     |    |    |   |   |
|---|---|----|----|-----|-----|----|----|---|---|
|   |   |    |    |     |     |    |    |   |   |
|   |   |    |    |     |     |    |    |   | 1 |
|   |   |    |    |     |     |    |    | 1 | 1 |
|   |   |    |    |     |     |    | 1  | 2 | 1 |
|   |   |    |    |     | 1   | 3  | 3  | 1 |   |
|   |   |    | 1  | 4   | 6   | 4  | 1  |   |   |
|   |   | 1  | 5  | 10  | 10  | 5  | 1  |   |   |
|   | 1 | 6  | 15 | 20  | 15  | 6  | 1  |   |   |
| 1 | 7 | 21 | 35 | 35  | 21  | 7  | 1  |   |   |
| 1 | 8 | 28 | 56 | 70  | 56  | 28 | 8  | 1 |   |
| 1 | 9 | 36 | 84 | 126 | 126 | 84 | 36 | 9 | 1 |

It is convenient to begin numbering the rows and diagonals with zero. For instance, the 4th row is  $(1, 4, 6, 4, 1)$ . In the 3rd diagonal are the 5 consecutive numbers  $(4, 10, 20, 35, 56)$ .

$$(1, 4, 6, 4, 1) (4, 10, 20, 35, 56) = -1*4 + 4*10 - 6*20 + 4*35 - 1*56 = 0.$$

Likewise in the first diagonal are the 5 consecutive numbers  $(5, 6, 7, 8, 9)$  and

$$(1, 4, 6, 4, 1) (5, 6, 7, 8, 9) = -5 + 24 - 42 + 32 - 9 = 0.$$

The author puts as a challenge problem to the reader to prove that this alternating product is always zero. Moreover, if anyone has seen this property of the Pascal triangle mentioned elsewhere, the author would be pleased to receive the reference.

# Science in the Waldorf Kindergarten

## THE SEEDS OF SCIENCE

by Margret de Ris

Before planning how we may bring an experience of science to preschool children, we must have a clear picture of the way in which this age group behaves. When we observe four-year-olds at play the most outstanding characteristic is first, their constant activity, and it is in this "always doing" that the small child orientates himself to the physical world and experiments with the physical world. To satisfy this urge we must supply the children with material which they can handle, explore, and shape to their needs. Second, there is their tremendous enthusiasm and interest in everything about them. There isn't anything too trivial to merit their attention or too far above to escape the eternal question "why?" The four-year-old has the true spirit of the scientist and philosopher. He is open-minded, without prejudice, and questions the "why" of everything. Third, the preschool child approaches life in a subjective way. He identifies himself with the world about him and in his play shapes and makes things over to suit his imagination. It is the period of "make believe" and we must be extremely careful not to burden the small child with a lot of factual knowledge, but supply experiences which make him wonder and think about the world and give him a chance to work out his own curiosity. The most delicate role of the teacher is to watch for these seeds of curiosity and then nurture them with appropriate experiences that will satisfy this curiosity.

The desired objectives in bringing an experience of science to children are first, to help the child adjust himself to the world in which he is to live; second, to eliminate superstitions and unscientific ideas as well as unreasonable fears; third, to foster in him an attitude of questioning and experimentation; and fourth, to lead him ever more deeply into a feeling of kinship with nature.

Our school is fortunate in its location just half a block from Central Park and our daily excursions to the park provide excellent opportunity for experimentation and investigation. The children become keenly aware both of the changes in weather and also of changes in season. They observe how their beloved late summer flowers gradually disappear and the leaves fall to the ground. As winter passes and ice and snow gradually disappear, the children wait with eager interest for the

approaching signs of spring. They observe that the ground changes. It is no longer hard and frozen, but becomes soft and moist. Gradually, here and there the grass shows signs of green and small buds appear on trees. In the fall the children are given full freedom to play with the leaves, rake them in piles, collect them, and discover differences. We take with us our baskets and look for nuts under some of the trees, acorns under others, and long beans under still others. Back in school we empty our treasures onto special shelves and the children hunt eagerly through the pages of our big tree book for pictures of these same fruits. Before long they know the names of several of the trees and it becomes a game to see how many of the trees they can identify. We also observe the squirrels busily collecting acorns and learn that they are preparing for the winter. We notice that most of our song birds have disappeared and learn that they have gone farther south where there is no hard winter and where they will find the food they need. This leads to an interesting discussion as to the type of birds, what foods they eat, and how they travel. There are quite a number of charming stories which make this whole subject very much alive. The children also miss some of our little friends, like the chipmunk, and learn that they have gone to sleep for the winter.

The children show tremendous interest in every phase of nature. What we adults have come to take for granted to the small child still holds the greatest wonder and delight—the wind pushing and carrying him, to watch the clouds chasing through the sky, to listen to the sound of the rain, the deep silence of the falling snow—all these experiences are full of newness and fascination for him. It is up to us as teachers to foster and nurture this closeness the child has with nature.

Central Park with its multitude of experiences is our outdoor laboratory. Here we can combine vigorous play with quiet individual observation. While climbing the big rocks we also become aware of the special crystals contained in some of the rocks and the mica glistening in the sun. We come to handle some of the rocks and observe that some stones are very hard while others crumble to dust. Whenever we discover something particularly interesting we take it back to our science corner where we can all study it

together. In digging in the ground we observe that there are places where there is pure sand which has been washed down the hill after the pouring rain while in other sections the earth is black and heavy. We spent some time in a secluded section of the park making miniature gardens. The children collected flowers and small branches and, using these for trees, created charming little enclosures framed by stones which they had laboriously collected. The most important educational feature resulting from this play came the next day when the children returned and found the rain had completely washed away the earth, leaving deep gullies where their gardens had been. The children were amazed by the force of the rain. Another rather illuminating outdoor experience was a trip to a nearby small truck garden. We took a few children at a time and they had their first glimpse, among other things, into the building up of a compost pile. They observed how nothing was wasted but everything added to this pile, from kitchen garbage to leaf mold. The children were allowed to help load the wheelbarrow and empty it onto the compost pile. They were much impressed to see what had happened to the garbage of the preceding year and how it had been miraculously transformed into black earth.

Within our classroom we have tried to give the children as many different experiences of nature as possible. Our old sandbox has been turned into an indoor garden where we experiment with all sorts of seeds. The most satisfactory has been just ordinary canary seed, which shows almost immediate results. We have also a section where we try carrot greens, sweet potatoes, etc. The children thoroughly enjoy watching for signs of the seeds, and the area is big enough so they can use the watering can to their heart's content. We also try experiments with bulbs, placing them first into a dark closet, and when they have started to sprout, bringing them into the light. The children take real interest in observing the shoots change to green when they are brought into the light. They also observe how the blossoms turn towards the sun.

We have a large-sized terrarium with different colorful plants. The children soon ask why the plants in the terrarium do not need watering and are interested when they raise the cover to see drops of moisture. This gives them a slight intimation of the meaning of rain. In the terrarium we have a few red newts, a tiny snake, and two turtles. These little creatures are a great attraction and the children particularly enjoy watching the turtle and are fascinated by the way in which the legs, head, and tail completely disappear in the shell. We also have an aquarium with two goldfish—very colorful ones with large tails, a few snails, and tadpoles. The tadpoles are specially interesting and the children watch with eager interest for the little feet to appear and the gradual transition to the frog stage.

We were very fortunate last spring in discovering a large cocoon in the park which we kept in our classroom. One morning when almost all the children were present one youngster noticed a slight movement in the cocoon, and after about an hour's struggle there emerged the most beautiful moth, much to the delight and almost startling surprise of the children. They were trembling with excitement and it was an experience which most of them will remember for many years to come.

We have tried to give the children experiences with a variety of small animals suitable to the classroom. The most successful were a pair of white rats which were very friendly and could be relied on not to bite. It was a good experience for some of the children to actually hold a small animal. The timid child would more easily forget his own fear and in identifying himself with the animal would feel bigger and stronger himself. It is also a very important experience for small children to learn how to hold and handle an animal without hurting it. The children learned to realize that these little creatures just didn't like noise and confusion and would stay in their house until the excitement died down. We have had the visit of a kitten which one of the children brought in, a pair of hamsters lent by Hunter College laboratory, a variety of turtles and frogs, and a pair of guinea pigs. We didn't keep any of these animals, with the exception of the rats, more than a week, partly to retain the children's lively interest, but also to make the children aware that it isn't kind to keep these little visitors too long in captivity. The children learned a great deal from their intimate contact with these animals. They helped to feed them, to clean them, and also took part in the responsibility of keeping cages properly closed to save them from the cat.

An important factor in the children's relationship to plant and animal life in the classroom is the element of repetition. We try to have our experiences with nature as much as possible at the same hour every day and cover much the same ground. Each child or group of children has a special task—to water plants, loosen earth around plants, give water and food to animal visitors, collect leftover foods for them, help clean cages, etc. In talking about animals we try to develop an understanding of the relationship of different animals to wildlife—as dog to wolf; cat to lion—also of what we mean by the word animal as differentiated from plant and stone the different types of animals birds and fish.

Water with all its tremendous possibilities is one of the best materials for experimentation. A rubber tube with which the child can siphon water from a higher container to a lower one gives endless opportunity for scientific discovery—so does any variety of water play. The main thing is to allow the child as much freedom as possible without the feeling of hurry or the worry about clothes for instance.

A sieve allows for any number of experiments with water as well as sand. Water colors also lead to a

variety of interesting experiences with color which the child can bring about at will.

In regard to all approaches to science with preschool children we try to avoid ever burdening them with facts and information. Information is only given when the child asks for it and then to the extent that it really holds his interest. The small child's relation to science is an entirely different one from that of the older child or adult. The four- and five-year olds are still close to the baby stage where experiences are closely connected with bodily sensations such as tasting touching and handling. Our analytical approach does not satisfy them nor are they satisfied by merely watching but they must take an active part. I found that it is most valuable for this age to have the satisfaction of personal discovery and the possibility of applying this discovery to their dramatic play.

In our music period we have made use of any number of ways of producing sound from improvised drums to wires strung across two nails.

The possibilities for scientific experiences in preschool are practically limitless and the important point to me has been to supply the children with an atmosphere which is conducive to quiet experimentation. Our duty is to help the child clarify his ideas and in this way avoid many later fears and superstitions. The small child has had little experience and will identify himself with everything he hears and sees. For example during one of our experiences with seeds a little boy was much troubled when he saw some beans sprout. Inquiring into it we found the child had formed the erroneous conclusion that some beans he had consumed the night previous for dinner would sprout in his stomach. This led to a rather interesting experiment where we cooked different seeds and then planted them.

We have also experimented with ice and the effect of ice on glass jars. The children were much surprised to see that ice floats in water and that liquids expand when freezing. We had a graphic illustration of this when our milk was left outside the building one extremely cold morning and we found tall white caps on the tops of the bottles.

This led to a series of experiments with freezing. Then there is of course the endless fun of breaking ice puddles and of lying on the ice on the pond when it is thick and like glass and peering down into the clear water below and seeing life. This makes a deep impression on every child.

There is little the small child busies himself with that doesn't in some way enter the field of science—from the use of cylindrical blocks for moving heavy boxes to experimenting with equilibrium on the seesaw or with friction by rubbing two stones together. The most important thing is not so much which experience we emphasize but that we develop human beings who will not be afraid to try things who

will be explorative and have confidence in themselves.

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*Passion Flower Stock*

# EXPERIMENT

## A Visible Adder Unit From Old Telephone Relays

by Jim Steil & Peter Glasby, Adelaide South Australia

Using an article by Peter Wenger (Kassel Germany), I have constructed an 8-bit adder as part of what we call down here "afternoon practical lessons" with 10th graders. What the project amounts to is that the student each make a 4-relay module with 4 mm. banana socket inputs and outputs, so various configurations of modules can be assembled – the final one being the configuration required for a "half-adder" circuit. These are then connected in pairs to become a "full-adder," and finally, the adder circuits placed into a series of trays (old painting board racks), interconnected, and routed to a display panel, to function as a full 8-bit Adder Unit. This is very understandable and very overseeable for the students. The project can be done from scratch quite easily by two groups of students (10-15 each), in about 20 long periods (1-hour-15 min.). That includes making up your own leads, boards, mounting sockets on plywood or Plexiglas, building the units, and also 6-8 lessons for theory, as well as practice using the boards. In successive years, just this time would be required, or you could (as I have done) make "extras" to improve on the design or enrich the practice.

The entire project cost us only \$900 plus soldering irons, with the added requirement of 64 old telephone relays. If one had to buy these (or their equivalent) that puts the price up a fair bit, so I wonder, in either case, if anyone is interested in this project.

would be happy to make the translated article available along with details of how we have made it up down here (Wenger's plan lacks specific details). We plan to further extend this project into 11th and 12th grades to build up a more comprehensive overview of the field of electronics and computers, but I feel it stands well, and "fits" the grade 10 curriculum pedagogically quite well on its own.

Send requests to:

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5251 Australia

# EXPERIMENT

## Sodium Sulfate Crystallization Demonstration Experiment

Gr. 10 Chemistry of Salts, Acids, Bases  
by Jim Steil, Adelaide South Australia

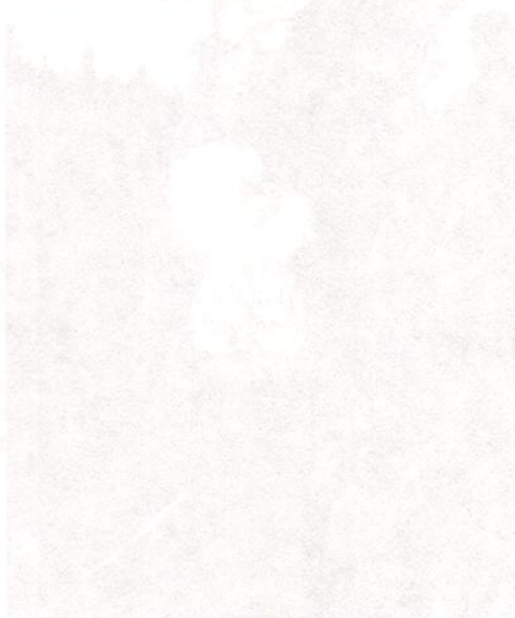
The following is a refinement of a chemistry demonstration first presented by Walter Lebendorfer at the Science Conference in Spring Valley NY in July 1990. I came across the following description of a demonstration in an old book (1867) while reading up on heat of crystallization a few months ago:

"...This may be shown by pouring a boiling saturated solution of sulfate of soda into a flask, and securing the mouth by tying it over with a piece of moistened bladder (dialysis membrane?). When cold, the solution will retain its liquid state without presenting any appearance of crystallization, until a hole is made in the bladder, when in an instant, crystals will begin to shoot, the fluid will become nearly solid, and so much heat will be evolved, that the vessel will feel sensibly warm to the hand."

It works beautifully (no false starts), using a specific gravity cylinder, closed with a rubber stopper, with a tube and clamp attached. You can slowly let the air in and, depending upon how much salt you have in it, the liquid may crystallize by itself, or with a seed crystal. One time (when I knew it was very close to going) I struck the rim with my finger and *ping!* the solution 'froze' (began to crystallize) from the top down.

Also, when re-heating your solution, you keep the temperature below 70°C, beautiful needle-like crystals will grow like crystal sea-urchins, suspended beautifully, rather than the fast-growing feather-like forms that otherwise arise.

See the Chapter 7 "The Human Being & Salt" in Cloos, "The Living Earth" which gives some interesting thoughts on crystallization, which I found fit in very well with this particular way of doing this crystal demonstration.



# EXPERIMENT

## Simple Blast-Furnace – Gr. 7/11 Chemistry, Smelting

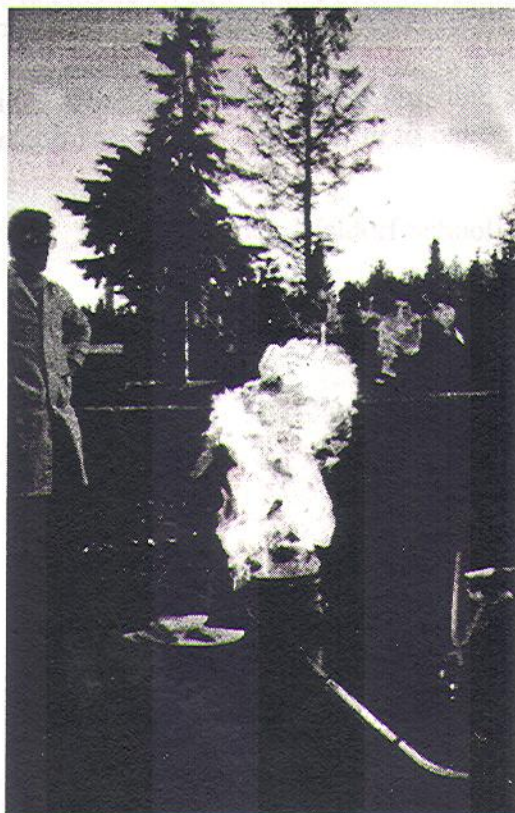
by Jim Steil, Adelaide South Australia

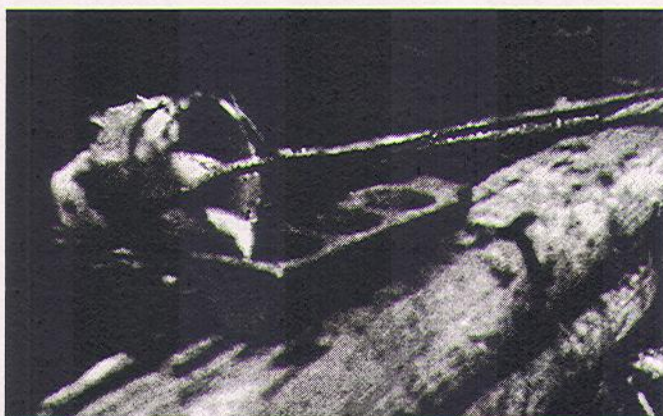
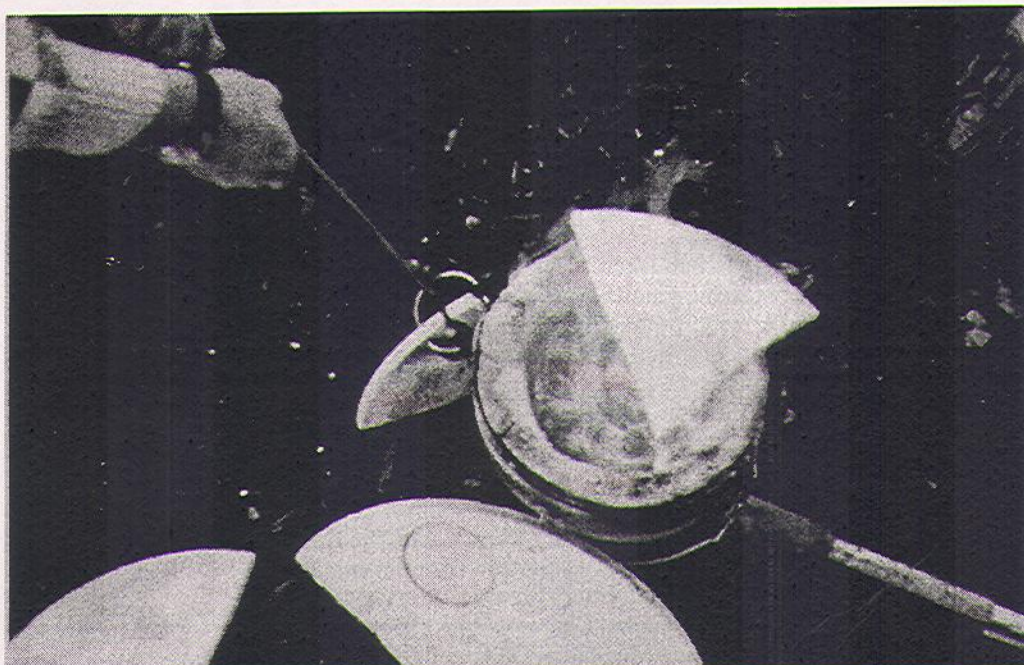
I would like to pass along the following description of a chemistry project with my encouragement! I have built a puddling furnace (not really a 'blast furnace' but it runs up a pretty good flame, anyway), for my grade 11 morning lesson "History of Chemistry, Introduction to the Elements; Alchemy." The furnace was quite easy to build; I obtained ground-up, separated ore from a local mining company, and used lots of help from the local assayer at the local smelter too, who really wanted to help (to improve their image I suppose). The copper was smelted from copper sulfide ore. The charcoal-fired furnace was built from a plan given in the book described below; and I'd be happy to help as well as hear from others who go ahead using it, or have done similar projects. Total cost should be under \$100, as long as you can find a parent to make you some tongs (or make them yourself) to lift the crucible out of the furnace.

Maybe I'll learn how to cast metal next, and make a profit on this project. I highly recommend writing them and asking for a set of catalogs. They have lots of old and offbeat science books, how-to manuals, and excellent reference books!

See the book:

"The Charcoal Foundry" by Dave Gingery  
from Lindsay Publications, Inc.,  
Bradley, Illinois, USA, 60915;  
Tel (815) 935-5353 or (815) 935-5479 FAX






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Note from Editors,

This project is described in a general way by von Mackensen, in "Fire, Lime, Metals" Workbook for Gr. 7 and 8 chemistry. Jim Steil's basic design uses a 5-gallon metal 'bucket' lined with kiln firebricks, sawed and fitted like barrel staves, around the inside periphery of the bucket. Alternatively, you could line the bucket with very effective ceramic insulation, available from any ceramics supply firm (ex., AMACO Ceramics in Indianapolis, IN, USA), making a simple sort of raku kiln. The furnace needs a flame from propane, and air supply from the bottom, powered by a medium blower. Also, you will need to purchase a cast iron 'plumbers pot' from a large hardware or plumbing supply house, or from a blacksmith supply firm (Centaur Forge, 117 N Spring St., Burlington, WI, USA, 800- 666-9175, and 414-763-9175).