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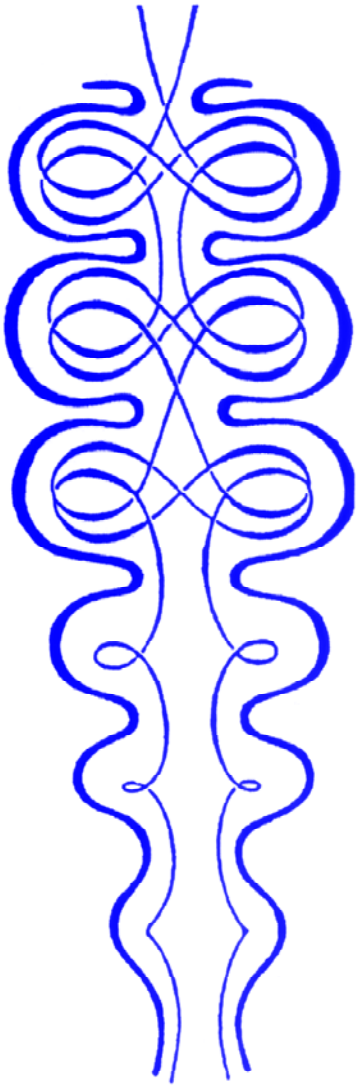

# WALDORF SCIENCE NEWSLETTER

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# Waldorf Science

## Explorations in Phenomenology as Practiced in Waldorf Schools

## A Science News Roundletter

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**VOL. 9, #17** **Autumn 2002**

## NOTE FROM THE EDITORS

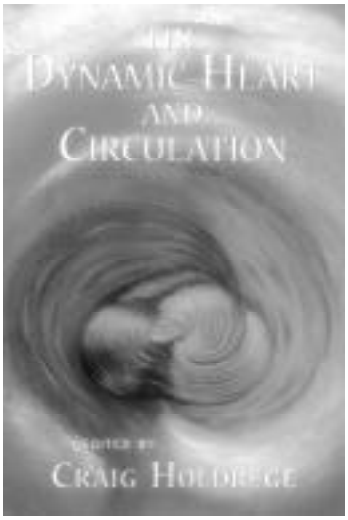
In this issue we are pleased to include several contributions toward deepening a "Goethean" approach to science. First, we include Part 1 of a major article by Dr. Wolfgang Schad, exploring in detail ways chemistry might be presented in Waldorf schools ("Towards A Sensible Kind of Chemistry"). It seems serendipity that just at this time, we found an article extensively discussing Goethe's method, and arguing that it is still important and less recognized today than it deserves (see review of "Exploratory Experimentation" in this issue), as well as some notes on Michael Faraday ("Faraday's Synthetic Investigation of Solenoids"). And, we refer readers to the publication of another major article by Dr. Schad "What is Goetheanism" by a counterpart science journal *Archetype* in the UK (see note on page 3, "New Translations from Great Britain"). With these, we have some rich food for thought on what this approach really entails.

At the AWSNA conference last June in Kimberton, a small group met to explore how to pursue further work on the unfinished questions that arose in the March 2000 Chemistry colloquium. We agreed to pursue another workshop with Manfred Mackensen, and also to invite colleagues to gather at the February Teacher's conference (sponsored by Rudolf Steiner College in Fair Oaks, CA), and participate in a continuing study-discussion on "What is a phenomenologically appropriate and scientifically-sophisticated conceptualization of atomic phenomena?" As reading material, we have suggested the first 4 chapters from Unger's *Forming Concepts in Physics* available from AWSNA Publications, Fair Oaks, CA. We hope many interested colleagues may be able to participate.

If you are not already aware of the On-line Waldorf Library (OWL) at >http://www.waldorflibrary.org< you should be advised to investigate it. Recent additions include eight lectures from last summer's AWSNA Annual Teachers Conference held at the Kimberton Waldorf School. There is a lot of food for thought in these lectures. The site also contains three chapters from *The Dynamic Heart and Circulation* edited by Craig Holdrege and commented on in this Newsletter on page 2.

—Editors

# Books of Note




THE DYNAMIC HEART AND CIRCULATION
by Craig Holdrege, ed.

This new book edited by Craig Holdrege contains six essays inspired by a Goethean view of the organism and of science. They are an attempt to "portray rather than explain." Some essays give precise descriptions of physiological processes, while others portray the heart and circulation within broader developmental and evolutionary contexts. The intricasies of the circulatory system and its place within the whole human being come into view.

Written by doctors, scientists, and teachers, the contributions in this book present a dynamic picture of the circulatory system that both balances and puts into perspective the prevailing one-sided mechanical explanations that dominante science and medical education. High school and medical students today don't usually learn "the heart has function that can be interpreted in terms of a pressure pump," rather, they learn "the heart is a pump," meaning that's all it is. When a metaphor is taken as a fact and becomes the sole lens through which one looks, the richness of reality recedes behind the sharp and narrow focus. One aim of this book is to transcend this narrow view and to begin to restore life to our understanding of the heart and circulation.

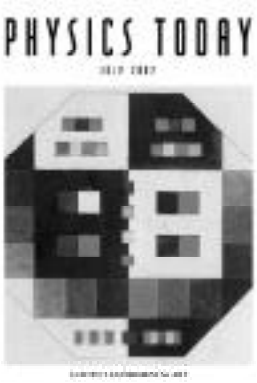
This book will fill a long-existing void in the literature. It will stimulate teachers, health professionals, scientists and lay people seeking a dynamic perspective on human physiology that is both detailed and comprehensive.

Chapters include:
"The Heart: A Pulsing and Perception Center" by Craig Holdrege
"The Polarity of Center and Periphery in the Circulatory System" by Heinrich Brettschneider
"The Physiology of Circulation: A Reappraisal" by Hermann Lauboeck
"A Dynamic Morphology of the Cardiovascular System" by Wolfgang Schad
"Patterns in the Evolution of the Heart and Circulatory System" by Christiane Liesche
"The Embryonic Development of the Cardiovascular System" by Matthias Woernle

Appendix — Heart Anatomy, The Hydraulic Ram

Paperback, 151 pages, $12.00
ISBN 1-888365-39-0

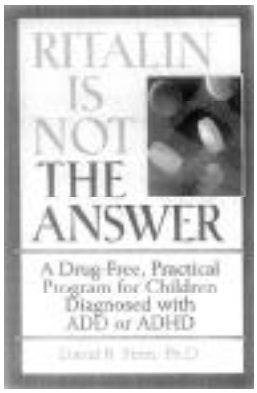
Available from AWSNA Publications. Phone: 916-961-0927




The editors would like to point out the July 2002 issue of "PHYSICS TODAY" focusing on Goethe's Experimental Art. In particular see the article by Neil Ribe and Friedrich Steinle reviewed in this newsletter.

Two new books have come out advising against the use of Ritalin.

— eds.




RITALIN IS NOT THE ANSWER
by David B. Stein. Ph.D.
A Drug-Free, Practical Program for Children Diagnosed with ADD or ADHD.

"At last! A book that views ADHD children as capable of learning. This book not only debunks the idea that ADHD children are diseased, but if gives parents a practical step-by-step program for helping these children to control their own thinking and behavior."

— Thomas G. Moeller,
professor of psychology,
Mary Washington College

Paperback, 224 pages, $15.00, ISBN 0-7879-4514-5


*THE RITALIN FACT BOOK: What Your Doctor Won't Tell You about ADHD and Stimulant Drugs,*
by Peter R. Breggin

A Harvard-trained psychiatrist who's been in private practice for 30 years, Breggin attacks the common practice of giving stimulants to children with attention-deficit hyperactivity disorder (ADHD). The author reports that nearly 6 million children take Ritalin, Dexedrine, Concerta, Adderall, and other stimulants. In most cases, he believes, ADHD diagnoses are in error and the drugs can't be justified. Moreover, Breggin argues that the drugs not only don't help children learn better or improve their scholastic performance, but also cause a host of physical and psychiatric problems on their own. Breggin is a noted crusader for his cause. Here he makes his case and offers nonmedicinal approaches to dealing with children who exhibit ADHD-like behaviors.

Paperback, 236 pages, $13.00
Perseus Press, 2002

# Acknowledgement from a Waldorf Parent

The Emerson Waldorf School recently held an open house. A parent attended who is also a medical doctor as well as a Professor of at Duke University. What follows is excerpted from a letter he felt compelled to write to the faculty following his observation of the students' work.

I want to thank you and the other Emerson Waldorf High School committee members for your efforts in putting together such a wonderful Open House. The presentations were excellent …

I did want to relay one observation that I hope you will share with your fellow committee members. The student workbooks were unbelievable! The one image I kept staring at, as I sat on the front row, was from a page entitled, "The Nephron." As a biologist and physician, who has spent countless hours studying the beastly nephron, I can tell you that this one beautifully drawn image captured the essential anatomical and physiological essence of this unit of function of the kidney. The attention to detail in the subtleties of the vascular interconnectivities could only have been made by someone who really "got it."

Also, I was drawn to the workbook entitled, "Botany." I was amazed by the attention to detail and the ability to capture the essential features of the plant or botanical process that was the subject of each page… The student who produced that workbook has already developed many of the skills required to be a scientist, including powers of observation, documentation, and interpretation. On top of this, there was an aesthetic sense in the works that I found particularly refreshing. I am a scientist, in part because I see beauty wherever I look in nature. Somehow I have managed to hang onto this sense of aesthetics despite years of rote and mind-numbing training that I have endured (fortunately, with a few memorable exceptions). Perhaps this is why I absolutely love to see students celebrating beauty in their studies of natural history!

… As I studied the workbooks, I became excited, thinking, "This is it—this is what's missing! If all of our students knew how to work in this manner, just think of the marvelous science we could do!" Thanks again for your work to make the high school happen.

— Dan Kenan, Ph.D.
Assistant Proffesor of Pathology
Duke University
Medical Center

# New Translations from Great Britain

David Heaf has just informed us that the Science Group of the Anthropsophical Society in Great Britain has published in *Archetype* an article by Wolfgang Shad entitled "What is Goetheanism?", and an article by Judyth Sassoon entitled, "Some thoughts on the oxalic acid/formic acid process." The ISSN # is 1462-8775 and the printing date is September 2002. It can be ordered by credit card at its web site

>http:www.anth.org.uk/Science/archetyp.htm<

— eds.

# Raising Money for Science

Every month I receive several inquiries about how money can be raised for science in our Waldorf schools. This column is an attempt to share the responses that I give and to ask readers to write me with other ideas that can be shared.

- If your school has a Development Director work in collaboration with him/her.
- Research all the large technical corporations in your area; ask them if they have a gifting program.
- Find a volunteer to visit the microfilsh files of the Foundation Center ask for a copy of COMSEARCH.
- Check with your Department of State for a listing of all private foundations, then write to them asking for a description of the range of applications they consider.
- Contact your state Science Teachers Association and ask them for leads.
- Assign someone to regularly scan the newspapers for school closings and auctions.
- Contact your state Department of Education and ask them about surplus equipment and school closings.
- Contact the local Archdioceses of the Catholic church and ask them about surplus equipment and school closings.
- Check with all your parents to see if the company where they work has company sponsored foundations.
- Make a "wish list" of equipment and make it visible through your school newsletter and bulletin board.
- Contact the federal government and ask for information from the National Science Foundation.
- Locate and visit your local state and federal surplus centers.
- Check out the chapter on "Fundraising and Grantwriting" in *Economic Explorations*.

Most all funding comes from local sources, this is where you should spend most of your energy. Good luck!

— David Mitchell

# The Twelve-Year-Old Child and Orpheus

## Some Thoughts on the Curriculum of Music

*by Christof-Andreas Lindenberg*

If you have ever stood in front of sixth graders and heard them sing and recite together, you know what breathing-in- common can come to mean: it comes closest perhaps to something heavenly, divine. The voices can be so unified as to have "breathed together" as one, each comma or pause is "spoken" or "sung" together: the emphasis on the right word or syllable, the phrase of the singing a little upwards or down, the speeding up, the slowing down, the taking a new breath—all is in harmony with something bigger that unites the children's utterances, like something hovering above them all. If one were able to transplant this power of Oneness into a jungle with wild animals, one could possibly experience an instant taming of the wild beasts!

This power is the descending Orpheus, the power of music *per se*. Now, at age 12, speech and song unite in the child, whose body shows a like harmony: not yet dragged down into the heaviness of puberty, yet having outgrown the higglety- pigglety limbs and body of the younger child. That is, it *should* be in this state of complete balance, though often we find there are more exceptions to the "rule" than would bear me out. But there *is* an archetype: Orpheus, the musical star-given proportions of the Astral body, the embodiment of music, is entering tenderly yet mightily, a promise of the ideal Man: here sounds (so we are told by Rudolf Steiner) the octave, or at least the promise of the octave.

It is not easy to understand the relationship of the octave to the 12-year-old child when you read this in the first of the music lectures from March 7, 1923 (Lecture V in *The Inner Nature of Music*, p. 58), as it seems to be clothed in a clause of improbablity: "As far as is possible *within the present-day limits* of music . . ." The reason for the hesitation is given in the next lecture (Ibid. p. 71): "Only in the future will man experience the octave's full musical significance."

Will the future also bring man to an understanding of the descending Orpheus, the true incorporation of the taming force that works without threat! Is it the higher Ego?

Talking to teachers, Rudolf Steiner, in several indications, leads us to solve the puzzle of the child in the twelfth and thirteenth year, the middle of childhood. Some two or more lectures devoted to that age group can he found in the course *Soul Economy and Waldorf Education*. The facts are indeed puzzling; we think by means of the bony skeleton—we do not, from the beginning, have a direct relationship to the bones—in the 9th, 10th and 11th years we live in the softer elements of the muscles. Then in the 12th year and onward we develop what, as tendons, connects the muscles to the hones; the 12-year-old moves his body out of the bone system, moves, thereby, out of the center of his body.

What is the skeleton? It is formed by our musical Astral body in the proportions of musical harmony; our skeleton is the the laws of music made visible. In 1924 Rudolf Steiner never tired in pointing out the relationship of the musical intervals to the skeletal structure (cf. *Eurythmy as Visible Music*, the *Pastoral Medical Course*, and the late *Courses for Teachers*). Thus we learn that at the moment in development when we connect to the bones, we in fact connect to a musical bone structure, with which we learn—for the first time—to *think*. So music and thought are linked.


Here we might remember the story of the great teacher in the North of Europe during the 3rd post-Atlantean epoch, who taught the wild tribes there to learn to think by playing his "ordering" music on the cantele. It is Vainemoinen (believed to be a former incarnation of Orpheus) who began his educational "taming" way back in unrecorded history. The later result, so Rudolf Steiner

said, was the pure thinking of Fichte, Schelling, and Hegel, philosophers whose thinking developed out of this northern, Teutonic thought training and not from the Greek schools. So we might assume that to learn to think is a *musical* process, and that Orpheus had something to do with it. (Of course, in Greece at the time of early philosophy, Orpheus was also doing his musical work to help this development).

The Astral body coming closer to the center of the physical: yes, here lies the basis of all musical understanding. Once Rudolf Steiner commented that breaking one's bones (in a fall, or otherwise) would result in becoming more musical! This was not just to comfort that he said this, hut obviously to point to the heightened activity of the Astral body in taking hold of the bone. The same thing happens in the growing-strong of the tendons, as our movement (that is, the activity of the Astral body) is conducted in direct connection with the bones. "The muscular system begins to serve the mechanics and dynamics of the bony system" (Lecture XI, Dornach, January 2, 1922).

The consequence is described subsequently (on the next page), "The incarnating human being first must penetrate the body before he/she can establish a relationship with the external world." What is the most potent means for establishing this relationship? It is through a new way of breathing, especially through language, through what connects us to others. Now we are led to understand (see next lecture in this cycle) that by the time the child reaches the age of twelve, he/she should develop a feeling for the beauty of language. So we see how another piece of the puzzle is added.

One of the really new subjects entering the curriculum in 6th grade is the first aspect of natural science. "Start with acoustics," we are told, "not with optics or mechanics." In acoustics the advice is: "Start by describing the larynx." When thinking begins to enter the child we take, from all the possible aspects of science, the one thing that in acoustics is alive as a subject—we bring in the speaking-singing organ of Man. That is central to where the 12-year-old orients from, not from the head or even the heart, but from the larynx.

Now the aspect of the approaching higher Ego—the octave entering in-makes sense when we see it all as a musical process of incarnating. The larynx is also derived from the bone structure, and here the new Orpheus fastens the Ego/Astral organization to the physical/etheric, in the place of word and song. Thus we come back to our beginning description of the reciting or singing 6th graders as a divine manifestation. One could put it in a diagram or simply enumerate the key words of the "happening." The picture is rounding: the child takes hold of the physical, hardened part of the body's structure, the skeleton—thereby the thought forms arise that take their processes from the musical proportions of the bones, through the tendons the movement is guided differently; and through the harmony of breathing achieved, the "middle" man can reach out. This manifests in language and song, and the three-part singing as an archetype of equal voice harmony. Above all, it is a superior element entering that makes the difference: the Octave Principle as a promise. "Finally, the feeling for the octave brings us to find our own self on a higher level." (March 7, 1923) This can be but a divining, yet with an early faculty of musical judgement (the earliest form of judgement to become manifest in the growing child) the higher self—the Orpheus above us—can enter. Orpheus enters in the waking, thinking consciousness, not yet fully in the feeling. (The heart as an organ for major and minor musical modes is only on the way and needs the full presence of the Astral body, incarnating around the age of 14, at puberty). This, then, is the special situation of the sixth graders: their whole being is promise and fulfillment at the same time.

Today, this brief state of seeing a God in a human form goes by unnoticed, as all the attacks are strongest in the prepuberty age. We are in danger of losing a most precious moment if we do not make use of the only tool able to counter the media onslaughts: through the true and unadulterated musical impulse. "Save Orpheus!" is the call at the present age: save him in our sixth graders.

# Report

Anthroposophical Initiative for Outdoor Education
Holds Fifth Gathering

In July, 2002, twelve individuals with an interest in outdoor education and Anthroposophy—six adults and six young adults under 24—hoisted backpacks and headed towards the Indian Peaks Wilderness in the Rocky Mountains of Colorado. We camped in a grove of aspen trees with a view of surrounding mountains, granite slabs, and a rushing river below. As outdoor enthusiasts, we hiked mountain trails, swam in icy lakes, and rejuvenated in the presence of the healing forces of nature. We also renewed old friendships and made new ones. Equally important, we explored the many ways that the Anthroposophical Initiative for Outdoor Education (AIOE) can be a meaningful organization to fulfill our mission statement:

> Working out of Anthroposophy, and the striving spirit of our times, we are committed to working together to further the development of a healing relationship between Wilderness, Nature, and the Human Being.

This was the fifth gathering of the initiative, which held its first gathering in the summer of 2000 (see Newsletter report of first two gatherings in summer issue, 2001). Since that report, there have been three more gatherings—a river trip on the Chama River in New Mexico, a winter camping trip in Algonquin Provincial Park in Canada, and the most recent backpacking trip in Colorado. At each gathering we welcome new members, and we are happy to see more young adults join us.

The questions we carried into the recent gathering were:

- Who is interested in or involved with wilderness work and Anthroposophy?
- How can we support one another and serve as a network?
- How can we be together on the land in a way that is healing for the earth?
- Are there initiatives, weaving these strands together, waiting to be created?

Additional questions that arose during our trip were:

- What is our group process?
- How do we want to make decisions? What form for meetings do we use?
- How can we better network and communicate when the group is apart?
- How can this group best serve the greater anthroposophical/Waldorf community?
- What is an appropriate way to recognize spirit in our meetings and in our work?
- What are our goals for the next 5-10 years?
- Are these gatherings only gatherings (a network, a support circle), or something more?
- AIOE leadership—How are we forming?

We met the morning of July 11 to pack group gear and drive to the trailhead. Once at our campsite, we set up tents and a kitchen site, and then met to go over basic logistics and safety issues, purifying water, etc. At our evening meeting it was clear that most participants were eager for more activity and a chance to explore our surroundings the next day.

On Friday, two groups set out to hike. One hiked up to the Continental Divide for a 13 mile trek mostly above tree line, and the other hiked 8 miles to a high alpine lake for a swim in chilly waters. Well exercised, the group settled down to another evening meeting, which raised more questions than answers about group process and how to conduct these gatherings. We agreed to begin the next day with Spatial Dynamics at 7:30 am, breakfast at 8:00, and 1 hour meetings at 9:00am, 1:00pm, and 4:00pm. Before or during our meetings, individuals led fun games or activities to further community building and refresh energy.

On Saturday, after being guided on a blind-trust walk, we took on the question directly of how to work with group process. We challenged ourselves to balance the interest in doing (Where can we hike? How far can we go? How much can we accomplish?) with conscious attention to being ( What is the quality of our meeting one another? How do we create a space for encountering one another? How do we listen to the land?). We experimented with several forms for group work.

Saturday evening brought us a spectacular lightning and rain storm, followed by an exquisite double rainbow spreading over the valley before us. The storm hit as the Steering Committee, newly authorized from the day's meetings, was engaged in fiery discussion, prompting a new name, the Lightning Committee. Our evening council, like the cleansing rain and dramatic storm, brought fresh connections and heartfelt goodwill to the group, as we shared what inspires us in our lives and work. We sang songs for hours that night, a jubilant vocal celebration of human hearts connecting.

Included in our time together were reports about member projects: the Wilderness Explorations backpacking trip for youth, August, 2002; a Southwestern Outdoor Education Center initiative in Durango, CO; and the creation of a book on outdoor education from a Waldorf perspective, with submissions from AIOE members. Also, one participant shared through experiential activities her Masters thesis on outdoor play and play structures.

Our final meeting focused on core values held by the group, themes for future gatherings, and reflections on this gathering. We closed our circle affirming our time together, with gratitude for the land around us, and an eagerness to gather again in 6 months. We will continue to ask ourselves to be mindful of a healthy form for our work together, so that we might be guided in service to the earth, to young people, to the Waldorf movement, and to all who can benefit from a healing relationship to the wilderness.

Our gatherings are open to anyone interested in wilderness, outdoor education, and Anthroposophy. We especially encourage youth and young adults to join us. Please contact Jake Yeager at >jmyeager@lycos.com< to be on our mailing list or to be notified of our next gathering in February, 2003.

— Nancy Jane
For the Anthroposophical Initiative for Outdoor Education
Boulder, CO

# Towards a Sensible Kind of Chemistry

by
Wolfgang Schad
from the *Tycho de Brahe Yearbook for Goetheanism*
Autumn 2000
translated by Nina J. Kuettel

## Introduction

Chemistry has become a specter, at least for all too many of our contemporaries. For them it has become synonymous with being out of touch with life, an enemy of nature, with environmental pollution and utter materialism. Most everyone who buys a drink at the supermarket will look to see how many "chemicals" are in it: ascorbic acid, artificial coloring, emulsifiers, artificial flavorings, etc. This was not and still isn't always the case. In the chemistry classes of the Waldorf Middle Schools the children are still enthusiastic about chemistry. However, in the high schools where we deal with encountering the modern world in terms of science and industry/commerce, chemistry usually becomes a mere curiosity at best. Tell me how many Waldorf school students who, after leaving their beloved school days behind them, go on to study chemistry and become dedicated chemists or enthusiastic chemistry teachers? Where are they? Doesn't their absence also speak for the positive goodness of the Waldorf culture? This is the opinion of late: Today's chemistry is no honorable profession, but rather the work of the devil!

Seen from a historical perspective, it wasn't altogether their doing that the scientist and also the chemist have become extremely materialistic (namely in claiming a monopoly on the "real" explanation). Rather, according to Rudolf Steiner's analysis, it comes from the time of the Council of Constantinople, which had the effect on subsequent cultural development of Europe from 869 A.D. onward that the spiritual aspect of the human being was spoken of less and less. With all the turbulent, great discoveries made possible by the dawning natural sciences of the 16th Century, the representatives of the "spirit," the clergy, abandoned natural science. Fixed on their inflexible vocabulary of faith, not only did both churches generally fail to cope with the increasing ability to explain nature, but especially they also could not accept the capability of the world to transform and with it ideas of evolution. Since God is almighty then he must have created the world already perfect; why then must it develop itself out of an imperfect state? That cannot be. It was never suspected that living, working spirit never lives in the being but rather always in the becoming. Today, whoever still rejects thinking in terms of metamorphoses and thereby diverts evolution onto formal path descending from eternal "Types" (theologically: from God, philosophically: a finished World of Ideas) demonstrates his or her own remoteness from spirit. In 1870, the Vatican saw itself being saved only by the dogma of infallibility. The current leader was also recently beatified on September 3, 2000. In any case, natural scientists were left spiritually alone. Rigid representatives of the spirit effectively brought about materialism themselves without even recognizing it on their own horizon (Rudolf Steiner Collected Works GA 93a: 72; GA 293: 150). Then, as a result, the natural scientists themselves were often obstinate and the opposite position—the rejection of everything spiritual—was just as eas-

ily taken up by them. Steiner, however, preferred spirited materialists over spiritless spiritualists (Rudolf Steiner, 1917: 217). And the problem did not lie with the scientists themselves: "Not always the natural scientists, but the natural sciences are full of the good spirit" (Steiner). Please, let *us* also not fall into these mutually escalating opposing positions. When examined closer, the dueling know-it-alls on both sides are in the same business. This should serve as a forward to our topic; beyond misunderstanding and [mere] knowing, better to bring some "sense" into chemistry.

There are three views in all natural sciences. An inventory will always completely take in what can be found *now*. But we all want to understand how what we see now came about, how it arose out of its own becoming. Thus, we search retrospectively, with our questioning gaze turned to *the past*, for the cause. Still, that doesn't suffice. We also want to be able to follow world progression into the future. So, we likewise ask prospectively, what one can do with it *in the future*? We desire predictability and reproducibility, although that brings the danger that the future will only be understood in terms of the past just rolling along. Behold our technical civilization, which uses the causal laws in a final way and believes that that is simply all one can do. At any rate, it is clear that this form of scientific understanding certainly always has the advantage when it comes to expanding time in our relationship to the world rather than simply becoming completely absorbed by the moment, even if our perception of time remains, thereby, linear (that is, still only spatially visualized).

However, a fourth direction is an "integral temporalizing" which incorporates the present so fully that what comes before and after comes into the all-encompassing field of view, and sustainability and long-running tolerance is attained. There is nothing more practical than overcoming the temporal perspective of a frog and winning the time-integrated birds-eye-view. With this, we have arrived at a second starting-point for the following. Now, let's go on to our topic in a narrower sense.

Chemistry is existentially deeply intergrown with one's own human existence. It achieves its most outstanding performance in the domain of organs which lie furthest from our consciousness: protein building, hormone synthesis and disbursement, immune chemistry and muscular metabolism. Or, considering the highest form of body chemistry, the embryonic development, who knows how it happens, except by reading books?

Everything unconscious we experience holistically. In order to grasp it with consciousness, we have to detach it from the whole and analyze it. That is why in the past and also now, the runner-up to chemistry as a science has always been the "techniques of analysis." An elemental analysis discovered the chemical elements both qualitatively and quantitatively. Soon, the question was, "After one has sufficiently divided out, what remains to be done?" When the sheer profusion of elements caused one to lose track of them all, a counter-movement [for an overview] stepped forward. Which elements were closer together according to their chemistry—the metals or the non-metals, the bases or the acids? Goethe was highly interested in this subject. Already with his theory of color he ordered the poles of the chemical colors into the red-producing acids and the blue-producing bases. In the end, Heinrich W.F. Wackenroder (1798–1854) hoped to glean important information about the physiological chemistry of plant juices in the progressive sequence of leaf variations of individual flowering plants (in Wackenroder, January 21, 1832).

Goethe summoned Johann Wolfgang Doebereiner (1780–1849) to the University at Jena in 1810 with similar goals. Soon Doebereiner was showing him the process of turning starch into sugar and the catalytic effect of platinum as well as explaining the stoichiometric laws. Goethe promoted him however he could. "For many years I have seen quite a few excellent young men . . . on this path, but none that made me so happy or gave me so much hope based on my innermost convictions" (to F.A.G. von Ende, April 28, 1812).

Following Goethe's request in 1817 to analyze the Coelestin found in Dornberg, Doebereiner discovered the first elemental triad of calcium/strontium/barium in 1829 and with that laid the foundation for the discovery of his triad rule in the periodic table (Van Spronsen 1969: 1, Kraetz, 1992: 207). How happy Goethe would have been if he had known

about John A.R. Newlands' (1839–1889) rule of octaves, discovered in 1864: In every eighth element, the same chemical keynote sounds again.

Both of Doebereiner's discoveries—platinum catalysis and the element triads—were destined to have unsuspected implications. Without the concept of catalysts, the whole of biochemistry is unimaginable, material has an effect without being used up! The crowning glory of the triadic rule was the later discovery of the natural periodicity in the table of the elements; matter does indeed possess an inherent natural order. In philosophy, wonder stands at the beginning, as Plato and Aristotle saw it. Steiner recommends the opposite: "With teaching one must awaken a sense of awe at the end of a chapter . . . One must make them (the students) understand that it is something which would cause even a Novalis to fall to his knees before its greatness" (Steiner, GA 300/II: 42/43).

There are two sides to materialism. The one is warranted, it draws empirical attention to the world of matter and researches it with all the sense-bound resources of the natural sciences. The other is the universal proclamation that nothing exists except matter. This ideological claim is the same as every other totalitarian claim. Anthroposophists are always ready to clarify the second side in an authoritative manner. To explain the first side, one must still quote Rudolf Steiner himself:

> Can one say that materialists are correct in their assertions? Yes, about matter and its laws they may bring to light things which are extraordinarily useful and valuable (Steiner, GA 151, Jan. 21, 1914).

For him, materialism is one of twelve justified ways of considering the world.

## The Order of Main-Groups [Columns] in the Periodic System

The above quote by Steiner certainly pertains to the Periodic Table of Elements, one of the most significant and fruitful discoveries in chemistry. A chemistry with sense and meaning could not exist without this order discovered there. When the question deals with predictability of the basic characteristics of elements, a look at the laws governing the Periodic Table will give every chemist an abundance of initial answers. Which valences, which transitional position between the three main kinds of bonds, what position between alkalinity and acidity, what phenomena of the chemical elements are possible? By 1869, Mendelejeff could very quickly predict a great deal as soon as he knew exactly what was what. The length of time required for chemical transformation (reaction rates) could also often be estimated. However, we don't want to merely point out what masterful knowledge can be derived, but rather, through the eyes of Goethe, experience the *qualitative* aspect of this system.

For instance, one can successfully ask of the Periodic system, "Which elements in which periods (rows) and groups (columns) are especially useful for life?" It can be observed that life always comes about in a tension of antagonists active over time, at the least maintaining energy-level differences that never become equalized so long as life remains. Chemically speaking, the clearest polar tension is that between alkali metals and the halogens, in main group I and group VII. Compounds of alkali elements form strong bases (as hydroxides), while the halogens form strong acids, which are life-threatening even at moderate concentrations. Life needs conditions that are tempered (harmonized), but never equalized. Strong bases and acids destroy it. In addition to that, within organisms, the lighter-weight elements from period 1 are more prevalent; it is not heavy but lightweight elements that are given preference. After zinc (element number 30 in the Table) there are very few elements necessary for life. It goes so far that in the most central biochemical process on Earth, photosynthesis, the lighter isotopic compound $^{12}CO_2$ is preferred over the heavier $^{13}CO_2$, opposing the natural ratio.

So, two things can be understood from the fundamental characteristics of life processes, namely that biochemical raw material for organic chemistry is to be found less in the extreme groups than in the middle main group IV and especially in their lightest representative—carbon.

Thus, organic chemistry became characterized as the chemistry of carbon compounds (even though all living cells are composed of far more water than carbon, at least as long as one doesn't interpret hydrophilic carbon compounds coordinated within the cell's hydrate sheath as being part of the system). Indeed, Eugen Kolisko saw Goethe's law of "intensification" between polarities, these "two driving forces of nature" at work in the placement of carbon down in the second period (row).

Silica, the next heaviest element after carbon within the same group (column), is also a substance often-used in physiology; from $H_2SiO_3$ it can easily become opal (amorphous $SiO_2$) and thereby follows all the modes of form within cell plasma. Consider alone just the silica framework of the silica sponges, radiolarian, silica flagellates, and especially the diatoms, or the opal integrated in the forming structure of all horsetails, the vascular bundle sheaths of bracken, grasses (leaf edges and awns), the stinging-hairs on sting nettle, and so forth.

The extent of the incidence of silicon is made clearer in the material processes of the earth crust. For the most part it consists of silicates such as all the plutonic rocks (granite, gneiss, gabbro) and is a significant constituent of the volcanic rocks, especially from compressive vulcanism. At the top of the list of abundance of elements found in the earth's crust (down to a depth of approx. 16 km or 10 miles) are oxygen (49.52%) and silicon (25.75%), bonded together for a total of 75.27%. Silicon—though always in oxidized form—is like a "carbon" in the constitution and metabolism of that part of the earth accessible to us. The old plutonite averages 3% carbon in the form of graphite. Therefore, more carbon is to be found in the earth's crust than in the entire biosphere within its organisms (Pflug 1984: 127). On the other hand, silicon dioxide is biogenetically present in all organisms, but in this case it is in trace amounts compared to carbon. As closely related to each other as both elements are, that is how complementary they stand facing each other as representatives of individual organisms as well as the Earth organism.

The alkalinity of the elements in the first main group *in*creases with lower atomic mass whereas the acidity of the seventh main group *de*creases, and francium and chlorine (hydrofluoric acid does not dissociate enough) are the major extremes in this respect. All the other main-group elements present stepwise transitional links between these extremes. This existing organization makes it evident that not only the vertically or horizontally neighboring elements exhibit chemical similarities, but also those that are diagonally related, like upper left to bottom right. That is what makes up the *universal* "*diagonal relationships.*" Since it virtually makes visible one of the Goethean "primal-phenomena," then it affectionately puts aside one of the still often argued barriers to understanding.

The chief reproach against a Goethean approach to the chemical elements is that most of them don't directly have to do with natural phenomena, but rather with manmade, technically created conditions of substances. Only a few of the elements appear pure in nature under normal conditions, such as carbon, nitrogen, oxygen, sulfur, copper, mercury and all the precious metals like gold, platinum, silver, etc. and the inert (or noble) gases. Yet, how rare these are compared to the majority of the 92 naturally-occurring elements! At this point, we don't want to immediately refer back to how deeply Rudolf Steiner took the concept of specific elements in questions about fertilizers and remedies used in agriculture and medicine. Instead, we will confine ourselves to Goethe's methodology:

> May each of us say on this occasion that *separation* and *attachment* are two inseparable acts of life … and the livelier these functions of spirit act together, like breathing in and out, the better it will be for science and the friends of science.
>
> — Goethe, HA 13:233

In order to present a front, Goethe was always unjustifiably placed as the great "biophilic Synthethist" in opposition to all analysts. Goethe's experience in practice as well as conviction was, never one against the other, but rather alternately pursue both. Even his zoological studies for the most part did not originate from observation of living animals but were rather mostly osteological (study of skeletons).

However, the skeleton is always a secondary phenomenon—frequently it first has to be produced by a person. Putting it back in the larger context (as a diminished object) will only work if one has separated it out from the larger context in the first place. For Goethe, both belonged together like inhaling and exhaling, “I had, after all, in my whole life, whether writing poetry or observing, proceeded synthetically and then again analytically. The systolic and diastolic of the human spirit was to me like taking a second breath, never separate, always pulsing.” (HA 13:27) We should no longer take part in fruitless polarization, but rather notice that *both* always take place. It can and shouldn’t be so difficult to come to an agreement about this. The fruitlessness of one-sidedness is surely warning enough. Pure analysis leads only to cemeteries of data or information, and mere synthesis to an overflight without a real sense of the facts. Our upper-grades students are severely allergic to both extremes. And that is often the best corrective for one-sidedly Goetheanistic teachers.

We approach the elements as they appear under normal circumstances and just this once pay attention only to their relationship to light, again focusing for now on the main groups. On the left and below, there is gathered a large domain of metals; they appear in shiny brilliance. That means, they reflect back most of the light largely unchanged and thereby remain dark on the inside. The non-metals are the polar opposite, with their dominance in the upper right region of the periodic table. There, the gases abound—frequently transparent and colorless—allowing light to stream through them nearly undiminished. If one takes a look at the second period (row) including lithium through fluorine, then the metallic luster begins to decrease stepwise, starting with beryllium through boron to carbon, and ends with the dull, lackluster black of carbon. However, carbon shows visibly subtle nuances depending upon its modifications: Amorphous as carbon-black or soot, it is blackest. The stronger mineralized graphite is gray-black. The recently discovered fullerene ($C_{60}$) appears red-violet when dissolved in toluene, and a pure diamond is completely colorless and transparent. The rest of the elements that follow, nitrogen and oxygen, are colorless gases, as are all the inert gases. At room temperature fluorine is only a very faint, yellowish green, nearly colorless gas.

A metallic sheen persists in the second period (row) from sodium, magnesium and aluminum up to silicon, even though this latter element exhibits predominately nonmetal characteristics in its chemistry. Like carbon, phosphorous can be black (diagonal relationship), realized as red and white phosphorous, likewise a color-transition that continues into the yellow tones of sulfur and chlorine.

In the third to the seventh periods (with increasing elemental weights), the emergence of dull black elements is shifted further to the right. Arsenic appears in a black and yellow modification and selenium in a black and dark red modification. Especially in the column of halogens (from F to heavier I), an increasingly intense hue is reached until iodine (already violet-colored as a gas) becomes a brilliant black. Astatine is not well-known enough to know its color(because it’s a short-lived radioactive element); however, it is predicted to be dark metallic. Then, along the diagonal between the dense metals, and the lightest, gaseous non-metals of the main groups, between full opaqueness and complete transparency, there shimmers a “colorful border” in which light is taken onto the surface and given off again in a modified form. These “transition elements” have at their disposal an increased activity in their association with light. As we have seen, pure carbon shows all three qualities: black, colorful, and colorless-transparent. In the following main-group periods the colorful appearing elements are written in bold-italic to highlight them.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| H | _ | _ | _ | _ | _ | _ | He |
| Li | Be | B | C | N | O | F | Ne |
| Na | Mg | Al | Si | ***P*** | ***S*** | ***Cl*** | Ar |
| K | Ca | Ga | Ge | ***As*** | ***Se*** | ***Br*** | Kr |
| Rb | Sr | In | Sn | Sb | Te | ***I*** | Xe |
| Cs | Ba | Tl | Pb | Bi | Po | At | Rn |
| Fr | Ra | | | | | | |

Just as light and dark does not only have to intermingle in gray tones, but rather the rising colors in between in countless phenomena which are clear to the Goethean view, so also is the colorful seam in the principle organization of the periodic table.

**The Iron Group**

The neighboring groups follow the above rule less and less. Sandwiching themselves in between the second and third main group, already with the fourth period, they are all metals. Since among themselves the periods are more similar to each other than the main groups are among themselves, the horizontal relationship plays a larger role in the metallic "transition elements" than either the vertical or diagonal patterns. What is striking by all these similarities is their "subtle arrangement." The first neighboring group is particularly highlighted because it contains essential trace elements. We are leaving out the first two elements (Sc, Ti) and the last (Zn) of the line-up in order to view the comparative morphology of the central group—vanadium, chromium, manganese, iron, cobalt, nickel and copper. In doing so it makes absolute sense to observe these metals not only in respect to their metal characteristics but also in respect to the coloring that they give their water soluble salt compounds. The divalent ferrous iron makes its appearance in subtle, delicate green, while trivalent iron in muted yellow, orange, and red-brown tones. It tends toward the passive colors when it is in a low-valence ferrous state, and in a higher-valence ferric state it tends toward the active colors of the spectrum. The first trait strengthens itself with cobalt. Cobalt's deep blue color (first a delicate pink as aqueous complex) is dominant with divalent compounds. With nickel, the divalent salt is grass-green as aqueous complex and the ammonia complex is blue in color. Bringing up the rear, copper is divalent and in many complexes almost azure. Depending upon water content, its carbonate-minerals azurite and malachite are deep blue or also lush dark green. Its ammonia complex is deep, dark blue.

Besides the frequent Fe(II) and Fe(III) compounds, one can, as opposed to Co, Ni, and Cu, with a little chemical force, oxidize iron in the six-valence to the violet-red ferrates. Such high valences are much more the normal case with the lighter siblings of iron. Manganese can easily be run through all the valences from two to seven whereby almost all the colors of the spectrum can appear depending on valence, complex and grain size. The most stable compounds tend toward the red side of the spectrum as in the natural minerals of rhodochrosite (manganese carbonate), Thulite, a manganese Zoisite, or the deep red-violet of the well-known potassium permanganate. In spite of the myriad of colors, they are still cautious and muted, similar to iron.

With the chromium salts (hence the name of the element) the colors take on a downright striking luminosity, especially once again in the high-order compounds such as the hexavalent chromates and bichromates. Even the bivalent chrome-alum gives the element peach-blossom red coloration. The trivalent chromium peroxide becomes a luminous blue if poured into ether. The bulk of the tourmaline's coloration can be attributed to the beauty of chromium's colors in their varying valences through the rainbow spectrum.

Chromium stands very close to vanadium, which also tends to the higher-valence vanadantes, and as vanadium pentoxide $V_2O_5$ is especially stabile. The dominant colors of vanadium ores are yellow to red, when the lab salts also accept all the other colors.

Spreading out the color wheel of the seven iron-related elements with their ions and complexes before an eleventh grade class is an aesthetic achievement. It shows how much nuanced wealth of color exists in the otherwise completely colorless solid metals (with the exception of copper and gold). Besides that, even with all the color variations, every one of the seven still has its own individual note of color intensity that is very characteristic and yet difficult to qualitatively describe. How subdued are most of the colors of iron compounds, and how garish are most of the colors of chromium compounds! That is where the respective individualities of the metals are shown.

The question of the metallic qualities of these elements remains. Their appearanch ranges from the blunt steel gray of pure vanadium to the warm dark red of copper. Iron alloys have diametrically opposing characteristics. Vanadium/Chromium/Manganese steel

is especially hard but tends to be brittle. Cobalt/nickel/copper iron alloys on the other hand are markedly elastic. In the first case one has a good chisel and in the second case good ball bearings. Now, in light of these images of phenomena, the chemical characteristics can be adequately organized.

| | **V** | **Cr** | **Mn** | **Fe** | **Co** | **Ni** | **Cu** | |
|---|---|---|---|---|---|---|---|---|
| Gray | ← | | | Bright/Luminous | | | → | Reddish |
| Hard | ← | | | Steel alloy | | | → | Elastic |
| Tendency to reds and yellows | ← | | | In salt and complex compounds | | | → | Tendency to greens and blues |
| High | ← | | | Valence | | | → | Low |
| Brittle | ← | | | Iron alloys | | | → | Elastic |

The occurrence of these metals in biochemistry is likewise very instructive. They all have biocatalytic functions. Cobalt is in the all-important vitamin B-12. Vanadium, iron and copper play an especially meaningful role as respiration complexes. Iron is known to be of central importance in the Heme of red hemoglobin (here only bivalent! The red color is already produced by iron-free Heme, or Protoporphyrin). Copper is the corresponding respiratory-metal in the Haemocyanin in the blood of most mollusks (snails, mussels, and octopus), where the oxygenate blood is blue from the copper (II) ion, and colorless from the reduced ion. Vanadium is intrinsically enriched in the blood of the sea cucumber (Holothuridians = sea animals related to the sea urchin and starfish and likewise of a five-ray body type). It's worthwhile to compare a Holothuridian, a vertebrate, and an edible snail.

The central place of iron first comes to full expression when compared to its sister elements. It is the center between the extremes and is present practically everywhere. This central position becomes stronger when one looks at the whole periodic table according to the constancy of the elements. All of the convictions of durability of the elements that have been handed down to us from antiquity have been made dynamic in modern times. Nikolaus von Cusa knew already in 1440 that the Earth didn't stand still but rather turned on its axis and traveled around the sun. Johannes Kepler concluded from the measurements of Tycho de Brahe that the planets didn't move in uniform orbits but rather in elliptical orbits at varying speeds. In 1698 Leibniz postulated the idea of mutation of organism species. Astronomers Edmond Halley (1718) and Johann Tobias Mayer (1760) were the first to discover that even the fixed stars did not remain fixed in relationship to each other, but rather moved ("proper motion"). The discovery of radioactivity in 1896 by Henri Becquerel soon initiated the notion of the mutability of the elements themselves.

The heaviest elements above bismuth don't have completely stabile isotopes and they change into lighter elements, quickly or slowly, through nuclear disintegration and often becoming a noble gas such as the lighter technetium and promethium. On the other hand, the lightest elements can become more stabile through nuclear fusion. Every time, whether from nuclear fission or fusion, nuclear energy is released at the polar ends of the entire periodic table and the remaining elements are more stabile than the initial elements. If one calculates the respective energy potential, then it decreases towards the center of the periodic table. In this sense, iron has proven itself to be the most stabile element and for

this reason in terms of nucleus energy it is the most central element of all in the periodic table.

**The Organization of the Periodic Table**

At one time, the science of chemistry hoped that through chemical analysis and reducing the immeasurable wealth of substances to their constituent elements, that a compendium and overview of the whole could be achieved. Today, when we count the 109 elements, then it has certainly become an unexpected richness that, as a next step, one wants to steer back into the three elementary particles (proton, neutron, and electron). However, even at this level, the riches of discovery do not fail to materialize. Students experience it as a great success of insight when one mathematically shows them the inherent organization of the periodic table. We include in that the number of elements in all seven periods together.

| | |
|---|---|
| I | 2 |
| II | 8 |
| III | 8 |
| IV | 18 |
| V | 18 |
| VI | 32 |
| VII | 19 + x |

One sees that the second and third as well as the fourth and fifth periods contain the same amounts. If we think of the seventh period in its complete form (32), then one sees that it likewise makes a same-size double period with the sixth. We then come to the numerical series of 2/8/8/18/18/32/32. This row of numbers already satisfies our desire for order, symmetry and regularity and that satisfaction increases when it is shown that there is an underlying conformity to law within them.

$$\left.\begin{aligned} 2 &= 2 \times 1^2 \\ 8 &= 2 \times 2^2 \\ 18 &= 2 \times 3^2 \\ 32 &= 2 \times 4^2 \end{aligned}\right\} 2 \times n^2 \quad (n = 1, 2, 3, 4)$$

Matter is then not merely chaos. It has a mathematical organization which will amaze 10th or 11th grade high school students. It pays to allow the students to sleep over such a result and then seize yet another approach the next morning.

The organization of the number series 2 x $n^2$ is impressive, but still it isn't completely factual. The last period ends with last natural element 92, uranium, and it extends artificially today to element 109, Meitnerium (Mt). Nine elements are still missing and must end with an noble gas with the atomic number 118. However, they are not known and the radioactivity of all elements beyond bismuth allows them to disintegrate into lighter elements.

Not only at the end, but also at the beginning, the periodic table is not complete but breaks off. Then, just as n = 2, 3 and 4 takes two periods every time, n = 1 must also take two periods for reasons of symmetry. In spite of all the universal conformity to laws, the periodic table is not complete, but rather it is open at the beginning and the end. The material world is not a complete, closed world, perfect-within-itself. When I have laid this problem before a 10th or 11th grade, then every time they pulled out of themselves this significant conclusion, the material world is not finished, but in development. Just as an unfolding plant no longer carries its first leaves, but also hasn't yet produced its future

shoots, so also with the material cosmos. With that one has given a 17-year-old, for instance, verifiable knowledge with which he or she can free themselves from the dogma of materialistic determinism because matter itself is not complete. The idea alone of such an infusion of dynamism into the physical-chemical worldview makes all the effort worthwhile. Everyone in the class can make good use of just such overlapping relationships, regardless of their level of ability, because this is the age in which the youthful consciousness begins to tentatively build its own worldview.

The appended theme of evolution within the periodic table was already pursued in the 1950's by an anthroposophic physicist and an anthroposophic mathematician, Arnold Blickle and Ernst Bindel. Because of its competence of subject matter, the article is still a worthwhile read. They also brought out the connection that element numbers per period (2/8/18/32) were in stages of four and part of a total seven-stage development just as are the many outcomes of the previous four post-Atlantean epochs Rudolf Steiner depicted in 1913 in the four materializations of the planetary cosmos. Hence the four kingdoms of nature, the four Greek elements and the four life bodies of human beings. Blickle and Bindel read the periodic table in the sense of Proust's theory that hydrogen is the oldest of all the elements. The deliberations of today's astrophysicists on cosmogony are very similar. According to them, 99% of all cosmic material is hydrogen. But if one looks at today's astrophysical cosmos as one of four previous materializations of the same, then the reading becomes much more dynamic. The eighth and seventh periods are then the last disintegrated leftovers from the age-old earliest epoch (Old Saturn) in which they were certainly still seminal, that is, lightweight. In our epoch of Earth development it is hydrogen and helium that are the most seminal of known elements and which as the sun, gives the planetary cosmos its life energy. In between are the various substance structures at different levels of development. Herein resides a meaningful beginning for a future chemistry.

(to be continued)

This is the first part of a two-part article. The concluding section will appear in the Spring 2003 edition of the *Waldorf Science Newsletter*.

— eds.

# Exploratory Experimentation Goethe, Land, and Faraday

Review of a noteworthy, contemporary article in the July 2002 issue of "Physics Today" by Neil Ribe and Friedrich Steinle.

The full article is presently available online at:
http://www.physicstoday.org/vol-55/iss-7/p43.html

As some readers of our newsletter may know, the subject of color theory is sometimes taken up with the study of optics in the physics *main lesson* block in grade 12. In it, the subject of Goethe's color theory, and perhaps also a discussion of how it was mostly ignored by physicists and yet appreciated by others who studied color may come up for discussion. It might be interesting to have students read other contributions to this debate, and a recent essay seems to be a worthwhile addition to the literature on this (along with the work of Edwin Land– inventor of polarizing film and Polaroid instant film).

The authors begin by pointing out the fascinating puzzle posed by Goethe's ideas:

> Helmholtz, Werner Heisenberg, Walter Heitler, and Carl Friedrich von Weizsäcker are among those who have written substantial essays on Goethe. More recently, chaos theorist Mitchell Feigenbaum consulted Goethe's work and was surprised to find that "Goethe had actually performed an extraordinary set of experiments in his investigation of colors." Not only that, Feigenbaum persuaded himself that "Goethe had been right about color!"

Then, they summarize nicely the contrast between Newton and Goethe's understanding of color and the methodology implicit in their experiments.

> Newton's and Goethe's respective approaches to color illustrate two very different approaches to experimental research. We call them theory-oriented and exploratory experimentation. Theory-oriented experimentation is often regarded as the only relevant kind: It corresponds roughly to the 'standard' view in the philosophy of science that experiments are designed with previously formulated theories in mind and serve primarily to test or demonstrate them.

So, Newton's ideas have come to dominate most textbook discussion of color, even though:

> [Newton] left unclear, though, how the relative 'number of rays' of each of the component colors was to be defined, and … admitted that he was unable to generate white from two colors, although his scheme predicted that possibility. But those failures did not worry him: Such color-mixing problems, he remarked, were "Curiosities of little or no moment to understanding the Phaenomena of Nature."

The synthetic stage of Goethe's investigation is illustrated by his experiments on the colored fringes that appear when gray and colored images on various backgrounds are viewed through a prism. Figure 3 shows how part of one of Goethe's diagrams (see the cover of the issue), from *Theory of Colors*, looks through a prism with its refracting angle held downward.

By contrast, exploratory experimentation has been relatively neglected by historians and philosophers of science. Its defining characteristic is the systematic and extensive variation of experimental conditions to discover which of them influence or are necessary to the phenomena under study. The focus is less on the connection between isolated experiments and an overarching theory, and more on the links among related experiments. Exploratory experimentation aims to open up the full variety and complexity of a field, and simultaneously to develop new concepts and categories that allow a basic ordering of that multiplicity. Exploratory experimentation typically comes to the fore in situations in which no well-formed conceptual framework for the phenomena being investigated is yet available; instead, experiments and concepts co-develop, reinforcing or weakening each other in concert.

Then, Ribe and Steinle examine the findings of Edwin Land, a recent, well-recognized researcher in color vision. The following experiment is credited to Land in the catalogue of experiments maintained at UC-Berkeley "lecture demonstrations" web page, Book E: Optics of Color Perception:

(http://www.mip.berkeley.edu/physics/E+05+45.html)

Land began with two black-and-white transparencies of the same colored scene. One, the "long record," was taken through a reddish filter. The second, the "short record," was taken with a more bluish filter. The two B&W slides differ only in lightness or darkness. But, when projected in aligned onto a screen, using a red filter for the "long record" slide, and unfiltered incandescent light for the "short record" slide, the observer sees, an image brilliantly and diversely colored, almost like the original scene. Yet, according to the conventional three-color theory (based on the ideas of Newton, Maxwell, and von Helmholtz), the image on the screen could only be some shade of pink.

Lastly, in the print version of the article (unfortunately not in the on-line version) they point out how Michael Faraday also utilized each of the two modes of investigation, as indicated in his notebooks. When he began his investigation of electromagnetism in 1821, Faraday realized the traditional language of attraction and repulsion was not adequate to capture the observed behavior of a magnetic needle near a vertical wire.

> Faraday analyzed the relation by establishing a chain of closely linked effects (see figure) that made clear how the solenoid effect could be obtained by successive variation of the simple case of a pole rotating around a

wire. His analysis nicely illustrates his general approach to a whole range of phenomena, including the motions of wires or wire loops toward a nearby magnet, the rotation of a free vertical loop toward an East-West orientation, and the rotation of a cylindrical magnet around its axis when traversed by a current.

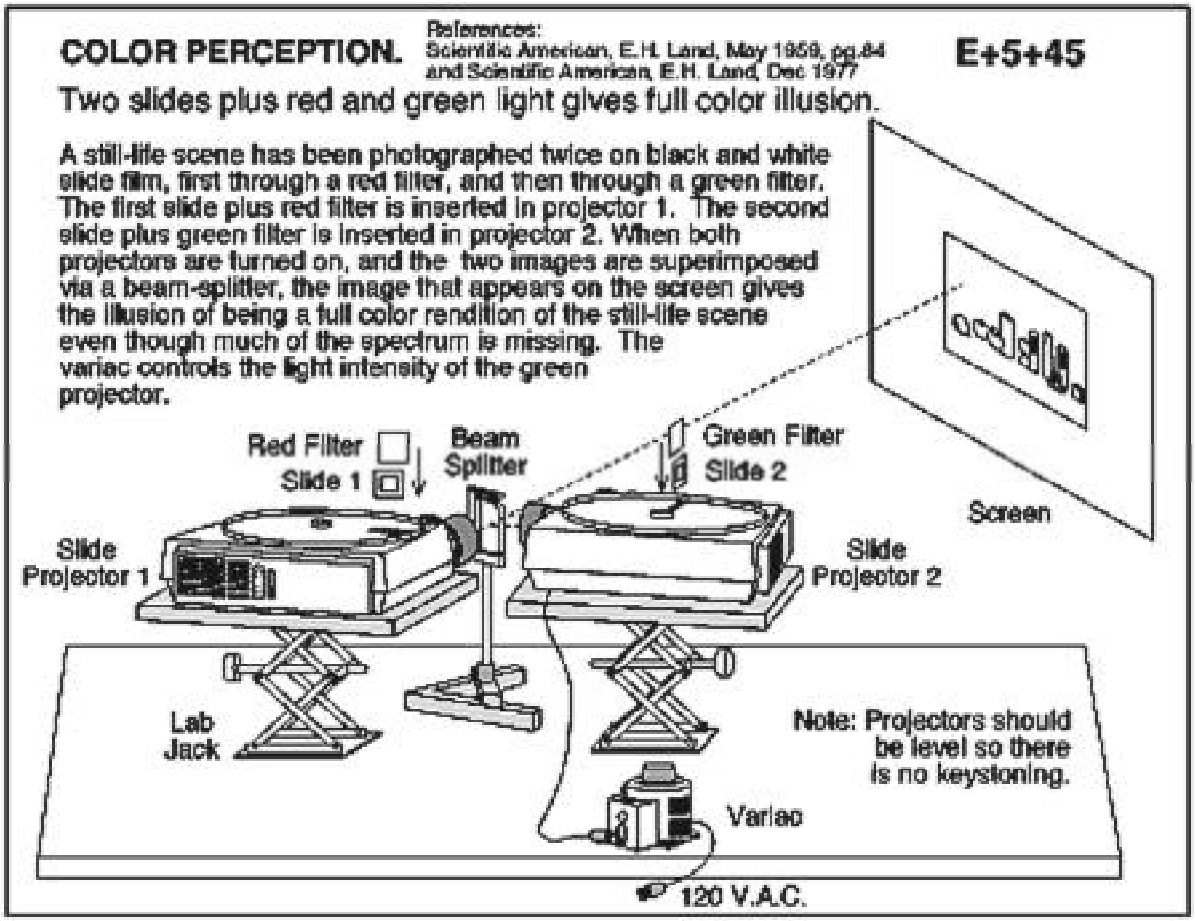
Faraday later undertook synthetic investigations in an attempt to deduce other induction effects from the law of electromagnetic induction. In general, synthetic and analytic methods were interwoven in Faraday's work, corroborating, and occasionally conflicting with each other.

Faraday shared with Goethe more than merely an experimental approach. Just as Goethe had made no attempt to theorize about the 'hidden' nature of light, so Faraday declined to speculate about the 'real' nature of electric currents and magnets. Instead, they both aimed to develop appropriate concepts for formulating phenomenological regularities and, in the process, emphasized the establishment of experimental links between simple and complex phenomena. These methodological similarities were noted by Hermann von Helmholtz in an 1881 lecture on Faraday, in which he stressed that Faraday's aim to express only 'observable and observed facts, most carefully avoiding any interference of hypothetical elements' and explicitly noted the similarity between Faraday's and Goethe's approaches.

In conclusion, the authors take a very synthetic approach in placing the various methodologies they have discussed (perhaps a rather "Goethean" way):

> Theory-oriented and exploratory experimentation are not exclusive categories, but rather members of a spectrum of experimental research strategies. Which is more productive in a given context depends on many factors, including a field's state of development, the sort of knowledge (for example, underlying mechanisms versus phenomenal regularities) sought by the physicist, and the complexity of the system being studied. Our aim in emphasizing the exploratory path has been to bring to light an experimental style that has played an important, but hitherto underrecognized, role in the history of physics.

— John Petering



# Faraday's Synthetic Investigation of Solenoids

July 2002, *Physics Today*, p. 48
Special comments on Faraday by Neil Ribe and Friedrich Steinle
http://www.physicstoday.org

Exploratory experimentation has proved successful not only in optics, but also in other fields of physics. In the field of electricity and magnetism, for example, we note the work of Alexander von Humboldt, Johann W. Ritter, and Christoph H. Pfaff in reaction to Luigi Galvani's discovery of animal electricity in the 1790s; Andre-Marie Ampere's early electromagnetic research in 1820; Julius Plucker's research on discharge in rarefied gases in the mid-1800s; and Wilhelm Roentgens first investigations of x rays in 1895. A particularly striking case is the work of Goethe's contemporary, Michael Faraday.

*Figure 1*

Faraday began his electromagnetic investigations in 1821, just a year after Hans Christian Oersted's remarkable discovery of the interaction between the current of a voltaic battery and magnetic needles. Initially, Faraday focused on the behavior of a horizontal magnetic needle suspended near a vertical wire (Figure 1), a problem that Ampere had studied briefly but left unsolved. Faraday found that the traditional language of attraction and repulsion was not adequate to capture the observed behavior of the needle, but that the concept of circular motion-of the wire around a magnetic pole or vice versa—did better. After many attempts, he realized each of the two kinds of rotation experimentally, and later displayed both simultaneously with the device shown above." It remained unclear, however, just how the circular motion was related to other electromagnetic phenomena, such as the well-known magnetic effects of "wire helices," or solenoids. Faraday analyzed the relation by establishing a chain of closely linked effects (see figure at left) that made clear how the solenoidal effect could be obtained by successive variation of the simple case of a pole rotating around a wire. His analysis nicely illustrates his general approach to a whole range of phenomena, including the motions of wires or wire loops toward a nearby magnet, the rotation of a free vertical loop toward an east-west orientation, and the rotation of a cylindrical magnet around its axis when traversed by a current.

Faraday began by varying the conditions of the simple experiment (a) in Figure 2, in which a magnetic pole rotates around a wire. Using two parallel wires with variable separation and currents in the same direction (b), he found that the speed of rotation was increased, but that the effect was not fundamentally altered. If, however, the currents were in opposite directions (c), something resembling attraction and repulsion occurred in the symmetry plane between the wires. Faraday recognized that this new effect could be understood simply as a combination of circular motions. The attractive and repulsive effects were intensified when the straight wires were replaced by a loop (d). Further intensification was achieved by forming a spiral, whose cross section is shown in (e), or a cylindrical helix (f), effectively combining the intensifying effects of a doubled wire and a ring. Combining a spiral and a helix finally led to a configuration (g) whose behavior resembled that of a bar magnet. At the end of this series of experiments, Faraday concluded, "Thus the phenomena of a helix, or a solid cylinder, are reduced to the simple rotation of the magnetic pole round the connecting wire of the battery . . . ."

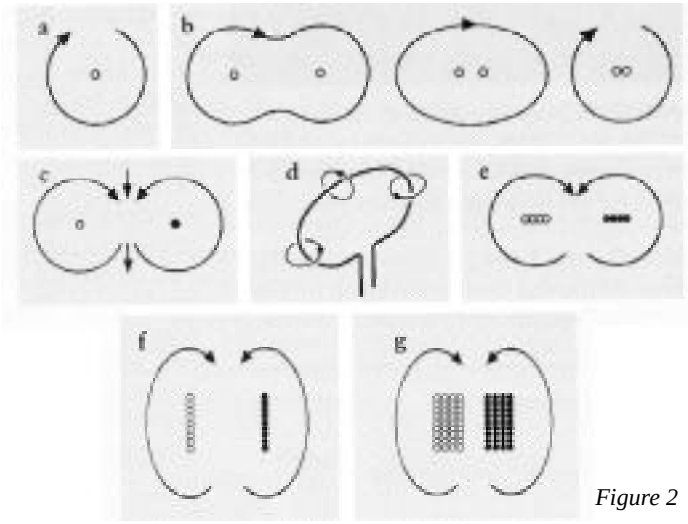



*Figure 2*

# Faraday's Analytic Investigation of Induction

July 2002, *Physics Today*, p. 48
Special comments on Faraday by Neil Ribe and Friedrich Steinle
http://www.physicstoday.org

0n returning to electromagnetic research in 1811 after a nine-year hiatus, Michael Faraday focused on electromagnetic induction, an effect that had been sought in vain since Hans Christian Oersted's discovery that magnetic needles interact with currents. Faraday quickly succeeded in realizing induction in his laboratory, using a soft iron ring with one set of coils connected to a battery and another to a galvanometer, as illustrated in his sketch at left below. But the effect raised many questions. Was the induced current in one coil caused by a magnetism of the ring, a magnetism caused by the current of the second coil, or was there some direct influence between the two coils? And why was induction observed only when the current was switched on or off, and not when the current was steady? Instead of publishing his discovery immediately, Faraday kept it secret and undertook several months of exploratory experimental work. In analyzing the induction of currents by magnets (as opposed to by currents), he varied the magnets' shape and strength, the shape and thickness of the wires, and the overall configuration. Quickly realizing that the relative motion of wire and magnet was in essential factor, he varied both its direction and speed, but the underlying principle still proved elusive. In particular, it was not clear just what features of the apparatus should be used to describe the motion. Faraday tried the magnetic poles, the directions of the wire and the magnet, the compass directions, and even André-Marie Ampère's hypothetical circular currents within the magnet—but in no case could he formulate a regularity consistent with the experimental results. Finally, he tried the set of "magnetic curves" described by iron filings around a magnet (see Faraday's sketches shown on the bottom), which had long been known but never considered more than a curiosity. Success was immediate: All the experimental results could now be comprehended under a single principle, the "law of electromagnetic induction," which stated that currents were induced when the magnetic curves were "cut by the wire."

Faraday later undertook synthetic investigations in an attempt to deduce other induction effects from the law of electromagrietic induction. In general, synthetic and analytic method, were interwoven in Faraday's work, corroborating, and occasionally conflicting with, each other.

Faraday shared with Goethe more than merely an experimental approach. Just as Goethe made no attempt to theorize about the "hidden" nature of light, so Faraday declined to speculate about the "real" nature of electric currents and magnets. Instead, they both aimed to develop appropriate concepts for formulating phenomenological regularities and, in the process, emphasized the establishment of experimental links between simple and complex phenomena. These methodological similarities were noted by Hermann von Helmholtz in an 1881 lecture on Faraday in which he stressed Faraday's aim to express Only "observable and observed facts, most carefully avoiding any interference of hypothetical elements," and explicitly noted the similarity between Faraday's and Goethe's approaches.

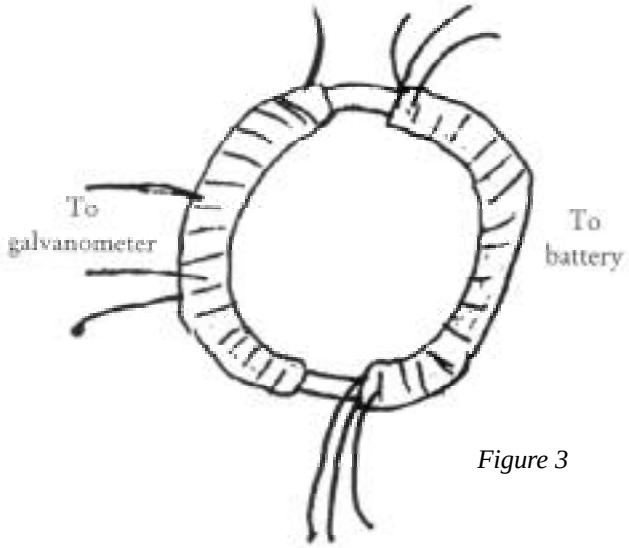



*Figure 3*

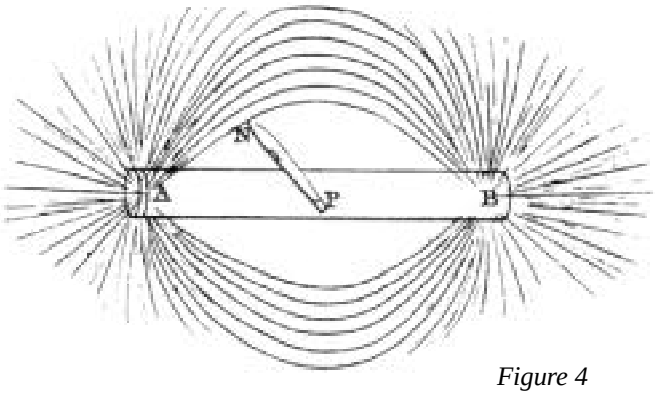


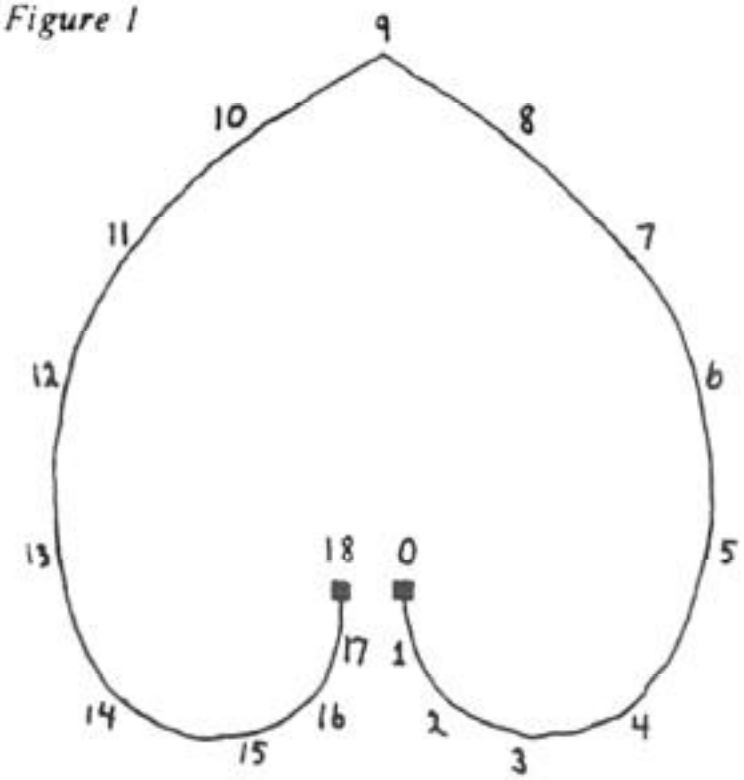

*Figure 4*

# Geometric Addition Table: A Curious Configuration

by

Earl Ogletree

*Figure 1*




The addition facts are always the same, but a new perspective adds exploration and discovery to learning math basics

Most children are familiar with the conventional rectangular addition table. It displays the addition facts up to nine in a neat, orderly way. But this is only one form of organizing the addition facts. Another form is the geometric addition table pictured above.

The geometric table offers no additional information, and it's actually more difficult to read. So why risk confusing students with this unfamiliar, odd-looking configuration?

Its main advantage is motivation. Besides helping students learn and practice the basic addition facts, the geometric table provides them with the opportunity to view the facts from an entirely different and intriguing perspective. With this more visually oriented table, students enjoy learning number patterns and relationships through exploration and discovery.

Studying the various number relationships involves the students in inductive reasoning. They discover particular facts and from them make generalizations, For example, after children have been working with the addition facts $3 + 1 = 4$, $4 + 1 = 5$, etc., they can generalize that the sum of one and any other natural number equals the number that follows- a pattern that is basic to the formation of tables.

The geometric table provides faster carriers ample opportunity to explore and learn by discovery; yet slower learners continue to be interested and motivated. It can be used as a game, puzzle, and learning tool in any elementary grade.

**How to Make It**

To construct the geometric addition table for the facts up to nine, draw an inverted heart shape similar to the one shown in Figure 1. The right-hand fan on this outer shell is the 0 table; the left side is the 9 table. Number the shape from zero to 18, spacing the numbers as shown in the diagram. Note that pairs of numbers (1, 17; 2, 16; etc.) line up horizontally.

Since this particular table includes the addition facts up to nine, nine appears at the top point of the diagram. A table could be constructed for the facts up to five or 37 or any number. In each case. that number appears at the top.

Next, draw the 1 table inside the 0 table, roughly parallel to it, starting at one and ending at 10 (see Figure 2, next page). Then draw the 2 table inside and roughly parallel to the 1 table able. ending at 11 (see Figure 3). Note that the table for each number ends at that number added to nine. 1 + 9 = 10, 2 + 9 = 11, etc.

Insert the number three where the 1 and 2 tables intersect to indicate the sum of the two tables (1 + 2 = 3). Then insert a square on the 1 table (as shown in Figure 3) and label it "2" to represent one added to itself. Since each table is represented by only one line, a number added to itself is indicated by a numerated square rather than an intersection.

Draw in the 3 table (see Figure 4), filling in sums at the intersections. Then insert a numerated square for the 2 table. Draw in the 4, 5, 6, 7, and 8 tables, labeling all intersections and squares. Use a different color for each table to make the completed diagram easier to read.

Your finished table should resemble the one shown. Note that each fine intersects all other lines, but only once, and that each line has a mirror image—tables 1 and 8, 2 and 7, 3 and 6, and 4 and 5 have he same shape on opposite sides. Also, if the lines are drawn correctly, the intersections with the same sum fall in a straight line.

**How to Use It**

To use the table for addition, locate a problem's given addends in the outer shell. Then trace he tables originating at these points until they cross. The number at the intersection is their sum. For example, the problem 2 + 0 = ? is solved by tracing the 2 and 6 tables to their intersection, 8 (see Figure 5). The table can easily be converted to higher place values.

Since subtraction is the inverse of addition, the table can also be used for subtraction problems. To solve 12 - 5 = ? trace the table of the known addend, 5, to the intersection where the sum 12 appears and then trace the intersecting table back to the outer shell to find the unknown addend, 7 (see Figure 6). In both addition and subtraction problems, it is important that the students trace tile lines carefully.

You can introduce the table to your students in several ways:

1. Make a 0.9 meter by 1.5 meter (3 foot by 5 foot) wall chart of the table with flaps that cover the sums and use it like flash cards. Children can go to the chart and trace addends to find their sums. Or, draw the table on the chalkboard without the sums and have the children write them in.

2. Have students work with the table at their desks. Make copies of the table on a duplicating master, leaving out the sums. The children trace the addends and fill in each sum.

3. Older children can draw their own geometric table using the one you made as a model. Use of a variety of colors.

*Figure 1*

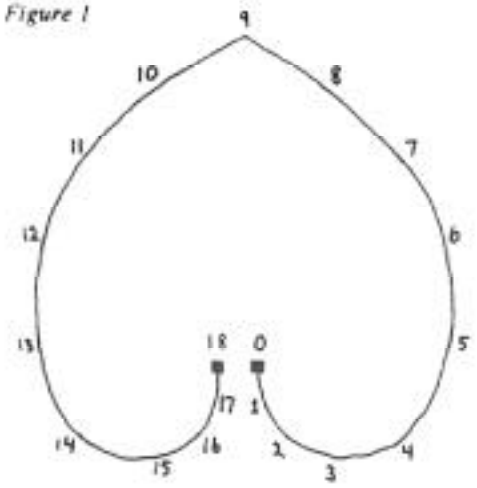



*Figure 2*

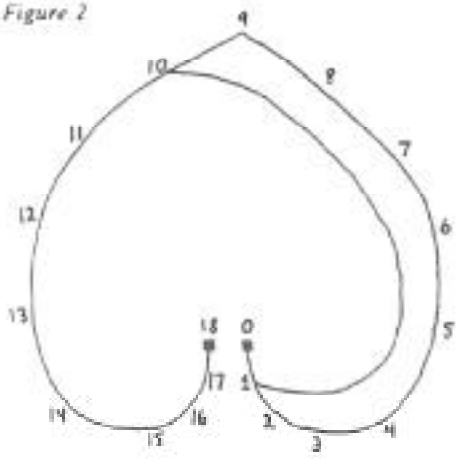



*Figure 3*

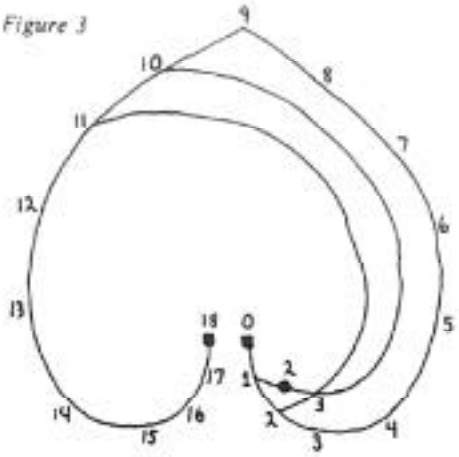



*Figure 4*

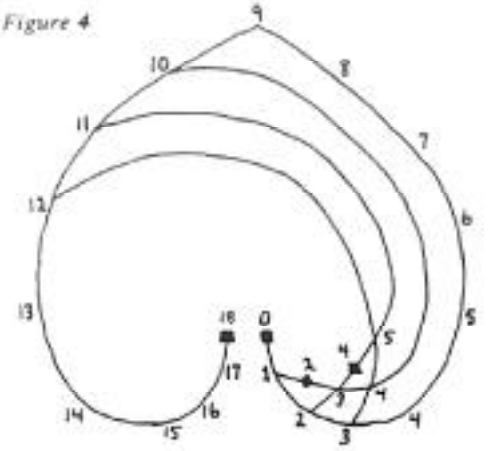



*Figure 5*

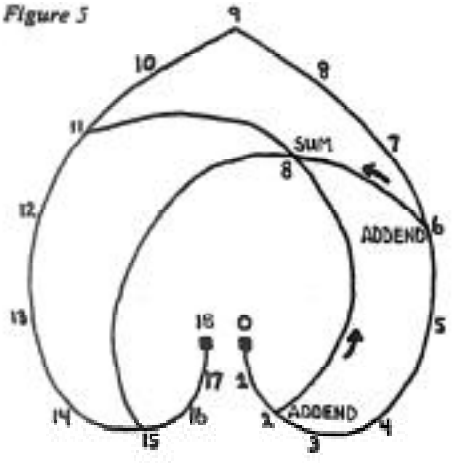
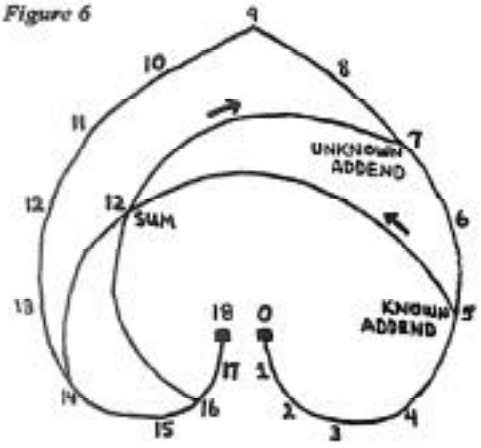



*Figure 6*



# Ladybugs

by

Betty Debnam

Have you ever watched a little red ladybug walk across a leaf or fly to your hand? Some people think it's good luck if a ladybug lands on you.

This superstition probably arose because ladybugs, or lady beetles, are such helpful insects. They eat pests such as aphids, spider mites, and mealybugs that destroy crops and garden plants. An adult ladybug may eat 100 aphids a day.

It is such a helpful insect that several states have made it their state insect. These include Delaware, Massachusetts, New Hampshire, Ohio and Tennessee.

**Legendary ladybugs**

The legend is that the ladybug got its name when swarms of insects were eating the crops. The farmers prayed to the Virgin Mary to save them.

When ladybugs flew in and ate the insect pests, the grateful farmers started calling them "the beetles of Our Lady." This was shortened to lady beetles, or ladybugs.

There are about 5,000 different types, or species, of ladybugs in the world. These helpful insects are so small, many can fit on a penny.

**Spots of a different color**

Most ladybugs have spots on their backs. Different species of ladybugs can be red, pink, white, orange or yellow. Some are black with red spots. Some have no spots.

Newly formed adults acquire color and spots as their wings harden and darken.

**Life cycle**

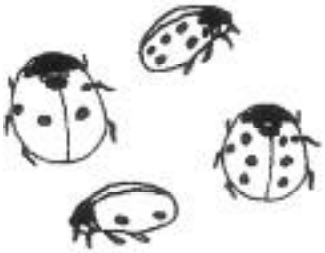
The female may lay hundreds of eggs on a leaf where there are aphids.

After two to five days, the eggs hatch and larvae crawl out. They start eating the aphids right away. After a larva has eaten 300 to 400 aphids, and after it has shed its shell three times, it forms a pupa. This is stuck to a leaf.

After about a week, the adult ladybug comes out of the pupa

Adult ladybugs gather together in large numbers and hibernate during the winter. Some people collect these hibernating ladybugs to sell to gardeners. People buy ladybugs to control the pests in their gardens.

The bright colors and patterns of the ladybug warn predators such as birds that they taste bad. If they are attacked, an awful-smelling yellow liquid shoots out of their leg joints. The birds or spiders don't want anything to do with them after that!



*There are about 5,000 different types, or species, of ladybugs in the world. These helpful insects are so small that many are able to fit on the head of a penny.*

# Fireflies

by
Betty Debnam

Lightning bugs, also called fireflies, are insects that flash tiny glowing signals on warm nights.


Many kids west of the Rocky Mountains might never have seen them in real life. Fireflies prefer warm, humid conditions, and conditions in the West aren't quite right. Fireflies are usually found east of the Rockies.

The peak firefly time is in June and July, but many species don't come out until late August or September.

**Jar light, jar bright**

Have you ever caught fireflies and watched them flicker in a jar? The best way to observe these flashy insects is to:

1. Find a clear plastic container.
2. Poke only one or two little holes in the lid. If there are too many holes, the fireflies could dry out. (Don't worry-there will be enough oxygen in the jar to keep them alive.)
3. Put a damp paper towel or damp piece of cotton inside the jar. Fireflies need high humidity.
4. Remember, the life of a firefly is very short, and you will want to set them free after a few hours.

**Chemical magic**

Fireflies create light by causing a chemical reaction in special cells in their bodies.

When fireflies breathe in oxygen, the oxygen fuels the light-making reaction. The more oxygen, the brighter the light.

The firefly, or lightning bug, is not really a fly. It is a beetle. Flies have only two wings. Beetles usually have four wings. The front wings have a strong covering, and pop up to form a shield when the beetle is flying. The delicate back wings do all the actual flying.

**Messages of light**

Fireflies may signal when they are in trouble. But usually fireflies flash their lights to attract a mate. The female waits in the grass or weeds, flashing her species' signal. In many species, the female cannot even fly.

The males fly about until they spot the female's signals, then they hover around her, sparkling to get her attention.

**Flashing by**

There are more than 1,900 kinds, or species, of fireflies throughout the world, on every continent except Antarctica. In Each species has its own pattern of flashes. The number, length and color of the flashes are different for each species.

Some twinkle and sparkle more. Some make long dashes; others make short little bursts. Others make zigzags of light. One species makes a J-shaped pattern. The colors are usually different shades of yellow or green.

Some flash at different times of the night. Some may twinkle at sunset and stop in an hour. Others come out only when it's completely dark.

In Asia some species flash in unison, so that they all light up at once.

**Lighting up their lives**

When living creatures make light, it is called bioluminescence.

This light from living creatures is unusual because it is "cold" light. It gives off almost no heat.

For example, a firefly turns almost 100 percent of its energy into light. In comparison, an electric light bulb turns only 10 percent of energy into light. The rest is given off as heat.

Most animals that give off light, such as squid or jellyfish, live in the ocean. Light producing land creatures include some other beetles, some fungi, and some bacteria.

**Humans go with the glow**

By studying fireflies, scientists have learned to reproduce fireflies' special light making chemicals. Doctors inject synthetic firefly chemicals into patients to study heart disease, cancer and other diseases.

Because synthetic firefly chemicals light up when they are exposed to certain substances in living creatures, scientists use them to detect bacteria in orange juice, milk, and even water treatment plants.

NASA scientists plan to use artificial firefly chemicals to help them search for life on other planets.

Scientists have duplicated firefly chemicals to make the glowing sticks and necklaces people enjoy during night festivities and special glowing lanterns that don't give off heat.

**Life stages**

1. The female may lay about 100 eggs in the ground. They hatch about a month later.
2. The larva, a wormlike form, hatches from the eggs. Larvae live in the grass or in tunnels underground. In some parts of the world they live in water.

The firefly larva also gives off light, although it has a steady glow and doesn't flash. This firefly larva is often called a glowworm.

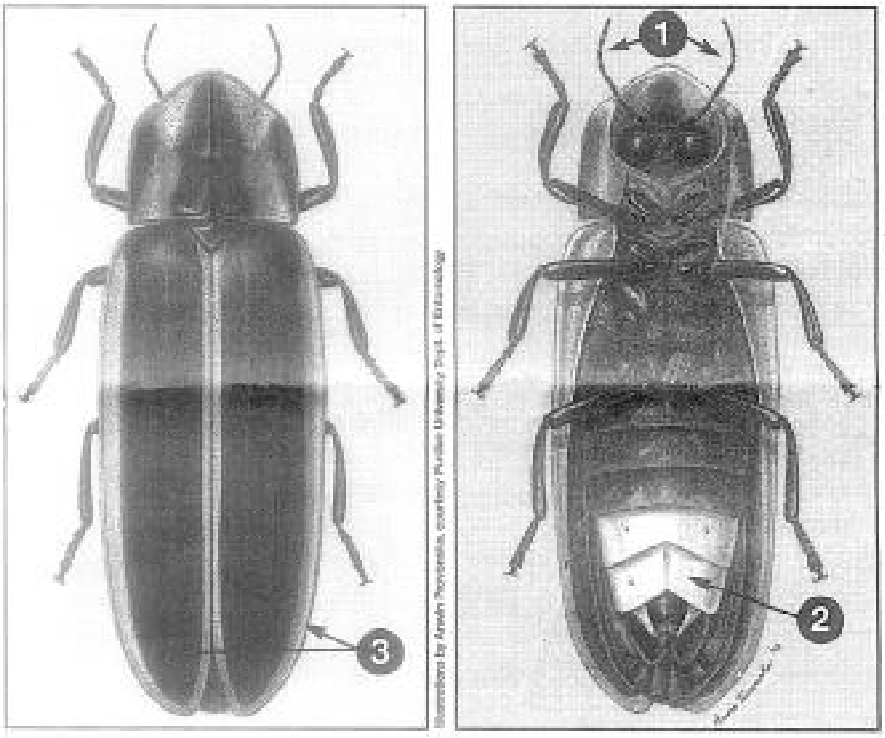
3. In the late spring, the larva builds a little room around itself out of mud. It then changes into a pupa. Inside this pupa everything breaks down and re-forms.
4. About 10 days later, the adult firefly comes out of its pupa. Adults live from three days to a few weeks.

**Firefly feasts**

The larvae eat small animals such as snails and slugs. They inject paralyzing chemicals and digestive juices into their prey. Then they suck out their prey's dissolved insides.

Adult fireflies eat other insects and probably eat nectar. Some types of females mimic the signals of other firefly species. When the male of another species flies to an adult female, she eats him.

Fireflies may be eaten by other insects, spiders or animals. One frog starts glowing when it eats fireflies.




*This illustration shows some firefly parts, including:*

*1. antennae*
*2. abdomen section that lights up*
*3. wings*

## A Call for Research

A "heads-up " for research! The High School Research Project will soon be announcing that funds are available for more research projects from Waldorf high school teachers. Start now to record the journey of your new high school, successes in the classroom, or new curriculae. We are interested in research that is qualtitative (not to rule out quantitative) or anecodotal, and collected from your observations over time. Keep a journal, or collaborate with colleagues to follow a question across the disciplines, or follow the biography of a class. The seemingly ordinary occurences often contain new directions or substantiation that you are on to something worth sharing.

Let us know questions you think are important to research. We look forward to hearing from you!

— Leonore Russell
for the AWSNA WHSRP

# Index of Past Issues

*Waldorf Science Newsletter*: edited by David Mitchell & John Petering

This newsletter is published twice each year and is dedicated to developing science teaching in the Waldorf schools. Teachers are invited to pose questions, seek resource material, discuss experiments, write about their classes (successful and not very successful), and investigate phenomena. The editors also translate relevant science articles from Waldorf periodicals from around the world. The following past editions are available from: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