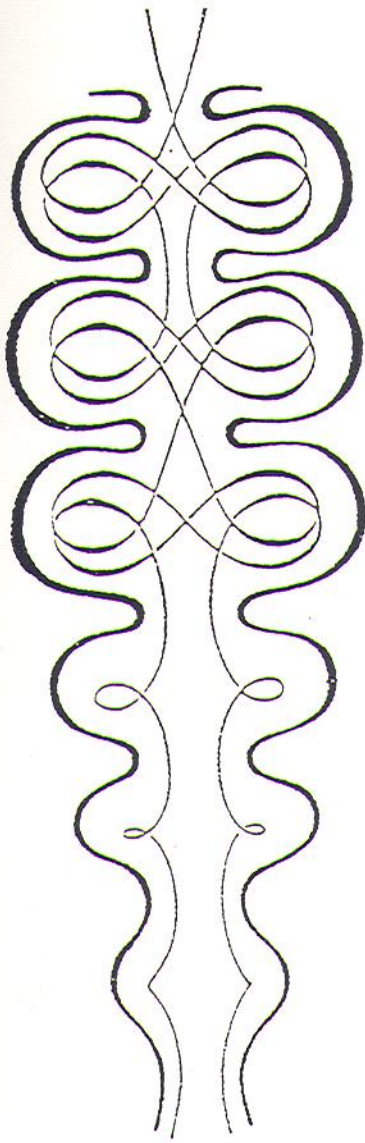




AWSNA REPRINT

Volume 4, #8



WALDORF SCIENCE NEWSLETTER

Editors: John Petering and David Mitchell
1158 Quince Ave.
Boulder, CO 80304
FAX: 303- 541-9244

Toward a Holistic Biology

Illustrated abstract of a talk presented at the Botanical Society of America Symposium Plant morphology - Theory and practice; a tribute to Rolf Sattler and his work, August 4, 1997, Montreal, Canada by Bruce K. Kirchoff, Department of Biology, University of North Carolina at Greensboro, Greensboro, NC 27412. 910-334-5391 ext. 37, e-mail: kirchoff@uncg.edu

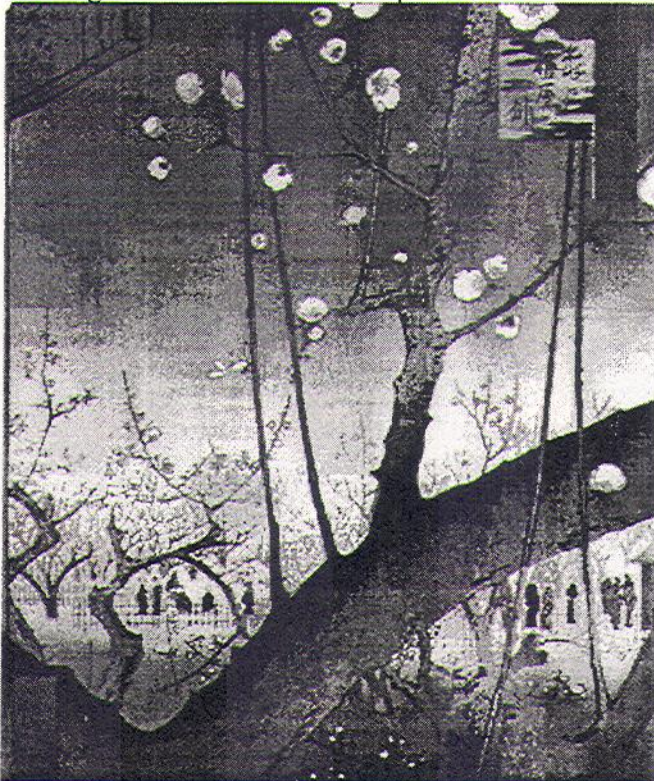
Part and Whole in Art

How do we understand an organism? Biologists often study organisms as if they were collections of unrelated parts. We study pieces of organisms, but seldom work with them as wholes. Can organisms also be understood as inherent wholes, as living organizations?

In our normal way of thinking we regard part and whole as separate concepts. When we think "whole," we think of something that exists above and separate from its parts. A whole is the thing itself, the organism, the essence. A part is merely a piece of the whole. Parts can be removed from the whole without affecting the whole. The whole is essentially the same before and after a part is removed. The part is changed, but not the whole.

In biology the propensity to make either/or distinctions like the one between part and whole is expressed in many areas. For instance, most widely used concepts about homology emphasize either the identity (homology) of two organs or their non-identity (analogy). Two organs are either homologous or they are not. No partial homology is possible. Though some (esp. Sattler 1994) have championed the cause of partial homology, it has not been widely accepted. Perhaps this is because we can only come to this concept if we abandon our propensity to think in either/or terms.

A work of art can serve as a useful tool helping us learn to think and see in terms that transcend this either/or mode. Art can teach us not only to think, but to perceive non-dually. This is because, in art, the distinction between part and whole breaks down. The parts both create the whole and bear its impress. The parts take their meaning from the whole that they participate in creating. Part and whole exist as part/whole.



We can see this by turning to an example from the history of art. Hiroshige's *Plumb Estate* (Figure 1) is a wood block print from 1857. The artist uses three main compositional principles to create the painting: vertical, diagonal and the use of repetitive forms. Note that none of these principles is expressed by only one element of the painting. All are built up through a number of interacting parts that cooperate to form one of the principles. The whole composition is constructed through the harmonious interaction of these principles.

Let us take two examples. The vertical principle is created and reinforced through the vertical branches of the tree in the foreground; the forms of the trunks of the trees in the middle distance; the figures in the distance; even the uprights of the fence and the red signature banners in the corners contribute to this movement.

Figure 1

The diagonal movement is also expressed in many details: the two diagonal branches in the foreground; the diagonal branches in the middle ground (both to the right and left of the foreground branch); the branches of the single tree the left middle distance; the slant of the roof, as well as many additional details.

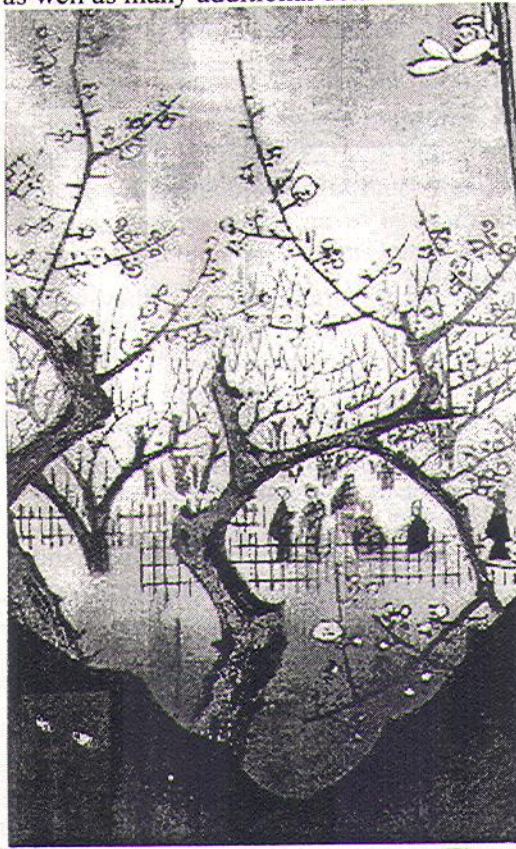


Figure 2

These principles cooperate in creating the composition as a whole. Yet each is itself created by innumerable smaller details that work together to form the vertical and diagonal principles. We are faced with a hierarchy of creations.

The part/whole relation also suggests that the context of the whole gives meaning to the parts. To see this, consider the detail of the trees on the left side of the painting (Figure 2). This detail shows the same compositional principles as the whole picture. The vertical and diagonal principles are both expressed here. The parts reflect the composition of the whole that they help create. Part and whole are united in the part/whole that is the painting.

Study of examples such as this show us that it is possible to enter into a type of aesthetic-creative consciousness where our normal either/or distinctions have no meaning. Following Bortoft (1996) I will call this a holistic mode of consciousness. In the holistic mode, part and whole are not separate concepts, there is only part/whole.

Bortoft, H. *The Wholeness of Nature*. Hudson, NY: Lindisfarne Press.

Sattler, R. 1994. Homology, Homeosis, and Process Morphology in Plants. pp. 423-475. in Hall, B. K. ed. *Homology: The Hierarchical Basis of Comparative Biology*. Academic Press: Montreal.

Part and Whole in Organisms

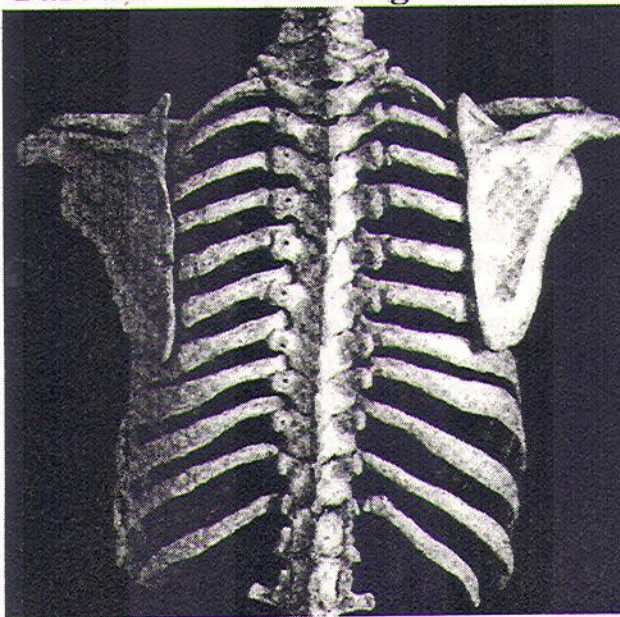


Figure 3

We can use our knowledge of the part/whole to learn about organisms in a deeper, more holistic way. To illustrate this let us turn to human anatomy. We will analyze the skeleton as if it were a work of art. When we do this we find some of the same compositional principles in the skeleton as we did in the Hiroshige's painting. In a dorsal view of the skeleton (Figure 3), the vertical movement is created by the vertical relationship between the vertebra and by the lateral borders of the scapulas. A horizontal movement is created by the ribs, the transverse processes of the vertebra, the superior border of the scapulas, the spine of the scapulas, and by the clavicles.

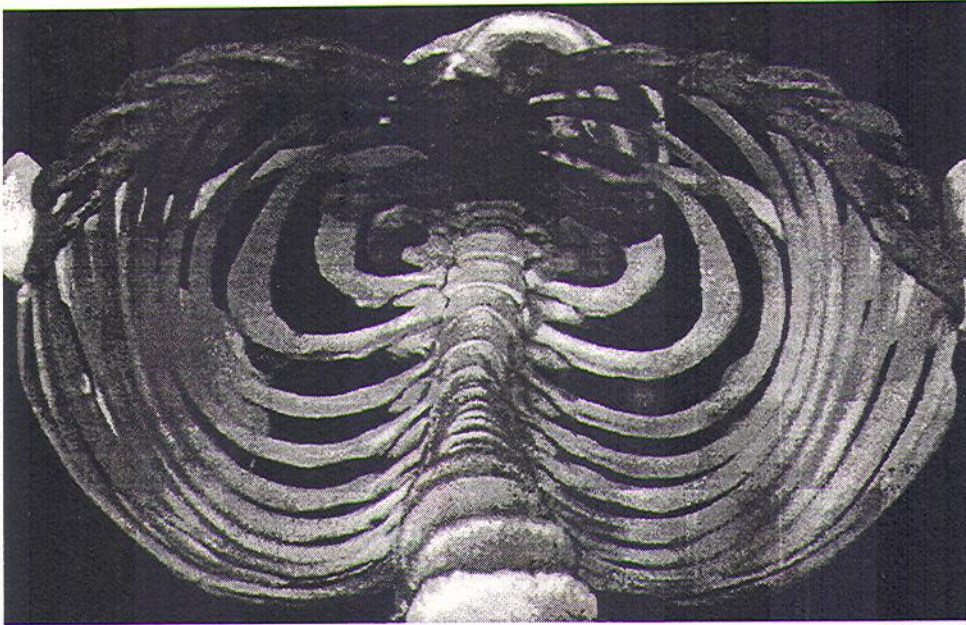
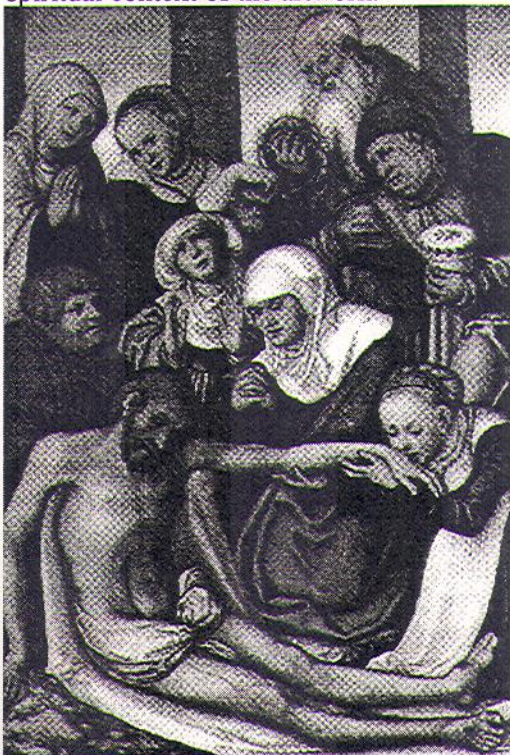


Figure 4

Although the *specific* aesthetic principles we find is an artifact of the aspect of the skeleton we have chosen for study, the fact that we find aesthetic principles at all is an expression of a part/whole relationship that exists in the organism. When we change views we find different principles, but the part/whole remains. If we view the rib cage from below (Figure 4) we find an oval movement. The individual ribs, sternum and connecting cartilage cooperate in creating concentric ellipses that form the chest cavity. The whole is created out of the interrelationships of the parts, which take their meanings from the whole that they help to create. Other examples would show that the part/whole relationship is found at all levels of organismal structure.

The Importance of Context

If we think of the part as the content and the whole as the context, the part/whole relationship shows us that context is as important as content. We can deepen this appreciation of context by returning to art and looking beyond the compositional features to the social and spiritual context of the artwork.



Lucas Cranach the Elder's *Lamentation* from 1538 (Figure 5) shows the same part/whole relation we saw in Hiroshige's painting and in the skeleton. But to understand the social-spiritual context of the picture we need to see it through the eyes of a contemporary worshiper. It is likely that few scientists will be able to identify the figures other than Christ and perhaps the Virgin. But to a contemporary worshiper it would have been obvious that Mary Magdalen, St. Peter, and Joseph of Aramathea are all represented. The forms have meanings beyond the dynamic they create in the composition. They express a social and spiritual meaning that would have been transparently obvious to a contemporary worshiper.

Figure 5



What aspect of nature is analogous to this larger conception of context? When we look at a tree growing in isolation in an open field (Figure 6) we are likely to overlook the fact that it is growing in a specific environment, under specific environmental conditions. These conditions influence the form of the plant, even if they are transparent to us. If we ignore the context, we can view the form of the tree as the most ideal and perfect representation of the species.

Figure 6

This illusion is shattered when we find the same species (a lime in this case) growing under different conditions. In certain contexts we find lime trees with a single tall trunk and little crown (Figure 7: north facing slopes).



Figure 7



Figure 8

In others we find them with an almost shrub-like habit (Figure 8: south slopes). A tree's form is influenced by the environmental conditions under which it grows and these conditions include not only physical factors, but also the forms of the other trees growing in the same area.

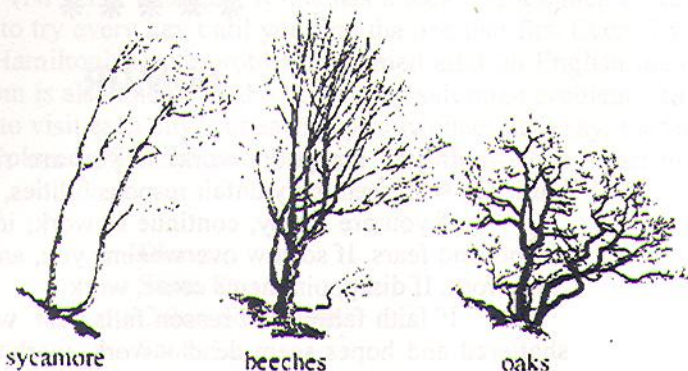
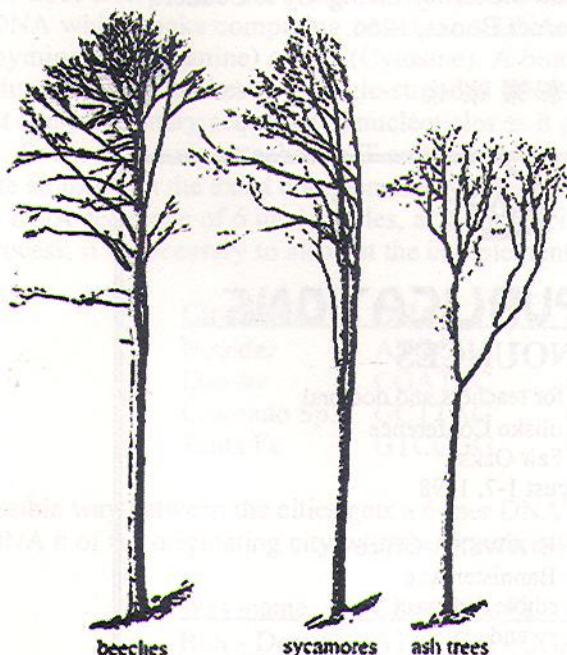


Figure 9

On a south facing slope we find trees with the same, bushy form as the south slope limes (Figure 9).



On a north-facing slope all of the trees have the same tall trunks and small crowns that we found in the north slope limes (Figure 10). The trees themselves create the context (the biotic environment) out of which they take their form. The individual trees and the context in which they grow have a part/whole relation. The individual plants create the environment out of which they take their form. Context is as important as content!

Figure 10

Acknowledgments

The art scans came from Mark Harden's texas.net Museum of Art, with permission. Daniel Smith photographed the skeleton. The images of trees are from Buess (1992) and are used with permission. Special thanks go to all of the people who helped me develop the ideas presented here: Andrea Shapiro, Ted Kaptchuk, Marti Skinner, Henri Bortoft, Rolf Sattler, Arthur Zajonc, Kenneth Caneva, Carol Sanks, Rudolf Steiner, Wolfgang von Goethe, Owen Barfield, Evelyn Fox Keller, Linda Shepard, Helen Longino, Wolfgang Schad, Adolf Portman, and all my Art History professors at the University of Michigan. However, I retain all responsibility for the view expressed here. I am a part of the context that helped create me.

References

- Bortoft, H. *The Wholeness of Nature*. Hudson, NY: Lindisfarne Press.
Buess, M. 1992. Getting to know a landscape. In J. Bockemuehl and N. Sombart, eds. *Awaking to Landscape*. Dornach, Switzerland: Natural Science Section, The Goetheanum.
Sattler, R. 1994. Homology, Homeosis, and Process Morphology in Plants. pp. 423-475.
In Hall, B. K. ed. *Homology: The Hierarchical Basis of Comparative Biology*. Academic Press: Montreal, Canada.

* * * * *

HUMOR

If you are poor, work. If you are rich, work. If you are burdened with seemingly unfair responsibilities, work.

If you are happy, continue to work; idleness gives room for doubts and fears. If sorrow overwhelms you, and loved ones seem not true, work. If disappointments come, work.

If faith falters and reason falls, just work. When dreams are shattered and hopes seem dead – work, work as if your life were in peril; it really is.

No matter what ails you, work. Work faithfully, and work with faith. Work is the greatest material remedy available. Work will cure both mental and physical affliction.

– from *Seven Cats and the Art of Living* by J. Coudert,
Warner Books, 1966.

* * * * *



AWSNA PUBLICATIONS ANNOUNCES

A book **Sale** for teachers and doctors!

At the Kolisko Conference

Fair Oaks

August 1-7, 1998

VISIT THE AWSNA Office

3591 Bannister Ave

for an edible free treat

and

AN AMAZING SALE ON SELECTED OVER-STOCKED BOOKS

Don't Miss It!!!

STUDENT WORK

10th grade Embryology Class Research paper

How DNA Computers Work

by

Max Clemens Schroeder (16 years old)

On the 11th November 1994, Leonard Adleman, an expert on computer security and cryptography, invented a computer that works with Deoxyribonucleic acid (DNA) instead of semiconductors. DNA is a molecule that stores the "code of life" in every living cell, telling the cell how to develop. Adleman discovered that DNA stores information using a four letter-alphabet (consisting of the four nucleotides Adenine, Thymine, Guanine and Cytosine) similar to a computer using I's and O's. But does it work as efficient as a computer does? And, first of all, how does it work?

DNA-Computers are not very good at conventional math problems like multiplication. The kind of problem that turned out to be especially suitable for the first experiments with DNA-Computing, is the so-called "non-deterministic polynomial time problem" (NP). For example, if one has a lock and a bunch of keys and it isn't known which key fits into the lock, you have to try every key until you find the one that fits. Every NP problem can mathematically be reduced to the so-called "Hamiltonian path problem." named after an English mathematician in the 19th century. The Hamiltonian path problem is also known as the "Traveling salesman problem." In this problem are a couple of cities and a salesman who has to visit each city, but each city only once. Let's say, the salesman starts in Boulder and goes to Santa Fe, visiting Colorado Springs and Denver. To simplify the experiment, only the following ways are possible:

Boulder	- Denver
Denver	- Santa Fe
Denver	- Colorado Springs
Colorado Springs	- Santa Fe

Obviously, you can solve that problem in a few seconds in your mind just sorting out the "wrong way" (Denver - Santa Fe), but as the number of cities increases, it becomes too complex even for today's fastest supercomputers.

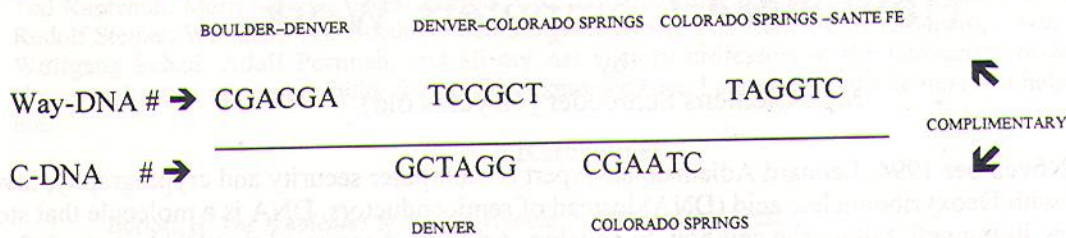
Now, how does DNA solve the problem? Before answering this question, one has to take a look at some of the qualities of DNA which make computing possible. A DNA-molecule is stringed together by four nucleotides: A (Adenine), T (Thymine), G (Guanine) and C (Cytosine). A binds only to T and G binds only to C. Polymerase, the enzyme that produces DNA, attaches to a single-stranded DNA and runs down the strand, nucleotide by nucleotide, building the exact complementary sequence of nucleotides as it goes. The complementary of a sequence TG would be AC, for example. Because A only attaches to T and G only to C, we see that the only strand which attaches to the origin strand is the strand with the exact complementary sequence. Back to the salesman: Each of the four cities gets a randomly chosen DNA sequence of 6 nucleotides, a "6-mer DNA#", for example ATGCGA for Boulder. In order to understand the process, it is necessary to also list the complementary DNA# (C-DNA#) of each city.

City-name	DNA #	C-DNA #
Boulder	ATGCGA	TACGCT
Denver	CGATCC	GCTAGG
Colorado Sp.	GCTTAG	CGAATC
Santa Fe	GTCCGG	CAGGCC

Every possible way between the cities gets a 6-mer DNA # also, created simply by combining the last three letters from the DNA # of the originating city with the first three letters of the destination city.

Way-name	City-DNA #'s	Way DNA
Bldr.- Denver	ATGCGA - CGATCC	CGACGA
Denver - S. Fe	CGATCC - GTCCGG	TCCGTC
Denver - C. S.	CGATCC - GCTTAG	TCCGCT
C. S. - S. Fe	GCTTAG - GTCCGG	TAGGTC

Now, in a process called "synthesis," trillions of single-stranded DNA molecules with the four C-DNA #'s and the same amount of molecules with the four way- DNA #'s are thrown together in a test tube and stuck together, following the rule that A only binds to T and G only to C. A newly created double-stranded DNA- molecule that contains the solution would look like this:



How do you know now which of the molecules in the test tube and which not? Only the molecules which are going through every city are possible solutions. In the second process, called "sieving", the DNA-molecules which are 4 cities long are separated from the rest, going by weight (sequences which are longer or shorter than 4 cities cannot be possible solutions). Then, magnets pick out all molecules containing Boulder (sequences which aren't containing Boulder, cannot be possible solutions). The same happens for Denver, Colorado Springs and Santa Fe. In the end only those molecules are kept which contain all and only 4 cities. After analyzing the molecule we've got the solution: The salesman visits each city once.

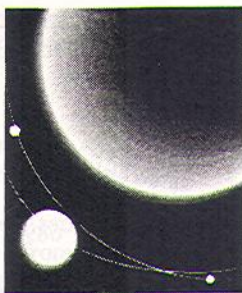
Unfortunately, the process of sieving takes almost a week, whereas the actual process of Synthesis only takes a few seconds. As we said, the example was simplified and you could have solved it in your mind in a few seconds without DNA-Computers, but as the number of cities increases the problem becomes too complex for today's supercomputer. Adleman used the first DNA-computer to solve the traveling salesman with 7 cities and a 20-mer DNA # for each city. In the mean time, DNA- Computers did jobs already impossible to solve for supercomputers.

Since 1994, researchers have built a so-called GeneChip, a DNA-device embedded in a silicon-interface which reduces the time for the "sieving".

They found even novel applications: A GeneChip recognizes bacteria and viruses in the human body at a genetic level and can reduce the turnaround-time on blood tests for HIV, tuberculosis or cancer. Considering the quickness in which the new technology developed, it seems to be possible that DNA-Chips may one day become a part of our lives like the silicon-based computers did.

Bibliography

- <http://www.clearlight.com/-morph/dna.html>
"DNA Computers" by Yali Friedman
- <http://www.clearlight.com/-morph/dna/dne.htm>
"Everyone's guide to DNA Computers" by Yali Friedman
- <http://www.wired.com/wired/3.08/features/molecular.html>
"GeneGenie" by Thomas A. Bass
- <http://www.wired.com/news/news/technology/story/90.7.3.html>
"DNA Biochips speed up Diagnosis"
- <http://www.konrad.stern.de/bookmarks/unter-book-inhalt/gen.htrn I>
Bibliography Of Internet-sources for DNA-Computing
- <http://www.affymetrix.com>
Homepage of the company producing the GeneChip



Solar System Facts

I have been told that if you could count the number of stars you can see with your naked eye on a clear evening you would have around 10,000 stars.

If you could count the number of grains in a handful of sand that you scooped off a beach, the number would be 10,000.

There are as many stars in the heavens as there are grains of sand on the entire earth. That's a pretty big number.

The following facts on some of the planets might prove interesting and useful during the Astronomy main lessons.

– DSM



Sun

The Sun holds all the planets in their orbits. The central part of the Sun is so dense that one half of the Sun's mass (1.98 X 10³⁰ kg) is compacted into 1.6% of its volume. Approximately 650 million tons of hydrogen is converted into 645.5 million tons of helium every second. Temperatures higher than 10,000,000 K are needed for this reaction. Don't worry about the Sun burning out soon – its mass is sufficient to give the sun about 5 billion more years of life.

- * *Length of day:* 27.6 Earth days
- *Period of rotation:* 200,000,000 years around galaxy
- *Gravity:* 273.4 newtons per kilogram (100 lb person would weigh 27,090 lbs)
- *Surface composition:* mostly hydrogen and helium
- *Temperature at the surface:* 6,600 K in the photosphere to 2,000,000 K in the corona
- *Atmospheric composition:* photons, charged particles
- *Number of Known Planets:* 9



Mercury

Mercury is the second smallest planet in our solar system. Its surface is heavily cratered. Mercury moves around the Sun much more quickly than any other planet, due to its close proximity to the Sun. Its "day" is surprisingly long – two thirds of its year! Hence, 176 Earth days must elapse between one Mercury sunrise and the next.

- *Length of day:* 1,416 hours (59 Earth days)
- *Number of our Days in a Year:* 88
- *Gravity:* 3.4 newtons per kilogr. (100 lb person would weigh 35 lbs)
- *Surface composition:* craters, nickel-iron silicates
- *Temperature at the surface:* -173 to 427 °C
- *Atmospheric composition:* hardly any atmosphere, but made of helium, hydrogen, sodium
- *Number of Known Moons :* 0



Venus

There is no magnetic field on Venus. The terrain is extreme: Venus has mountains higher than Mt. Everest, valleys deeper than the Grand Canyon. The main reason for Venus' high surface temperature is the greenhouse effect. The thick clouds trap the Sun's heat while winds blow it around the planet, making day and nighttime temperatures nearly the same in spite of Venus' eight-month-long day. If a bright enough beam of light could penetrate Venus' dense atmosphere, the thick atmosphere would create the illusion of multiple objects.

- *Length of day:* 5,832 hours (243 Earth days)
- *Number of our Days in a Year:* 224
- *Gravity:* 8.09 newtons per kilogr. (100 lb person would weigh 83 lbs)

- *Surface composition:* rock, sulfur compounds, nickel-iron, silicates
- *Temperature at the surface:* 480 ° C
- *Atmospheric composition:* carbon dioxide, water vapor, sulfuric acid
- *Number of Known Moons:* 0



Earth

A molten iron core gives the Earth a magnetic field which shields the Earth from the Sun's harmful radiation. Seventy percent of the surface is liquid water. The early years of the Earth were apparently rather violent, as no geological record is preserved of the first 1/2 billion years of its existence. The Earth-Moon system is often referred to as a double system, because compared to the Earth, the moon is abnormally massive. The Earth is the only planet in the solar system known to sustain life.

- *Length of day:* 23 hours 56 minutes (1 Earth day)
- *Number of our Days in a Year:* 365.25
- *Gravity:* 9.8 newtons per kilogr. (100 lb person would weigh 100 lbs)
- *Surface composition:* water, rock, nickel-iron silicates
- *Temperature at the surface:* -89.2 to 57.8° C
- *Atmospheric composition:* nitrogen, oxygen, hydrogen, carbon dioxide, ammonia
- *Number of Known Moons :* 1



Mars

Mars has long been regarded as a possible abode of life. However, experiments conducted by the Viking Spacecraft Lander found no evidence of life. It has been discovered that the Martian surface contains compounds incompatible with any form of life as we know it. The rocks and soil on the surface are strikingly red because they are composed of fer-

rous oxide (rust). The Mariner 9 spacecraft observed on Mars what appear to be dry riverbeds. But it is unknown how old these "channels" are.

- *Length of day:* 24 hours 37 minutes (a little more than an Earth day)
- *Number of our Days in a Year:* 689
- *Gravity:* 3.6 newtons per kilogra. (100 lb person would weigh 37 lbs)
- *Surface composition:* silicon, ice caps at poles, iron, silicates
- *Temperature at the surface:* -120 to 10° C
- *Atmospheric composition:* carbon dioxide
- *Number of Known Moons :* 2



Jupiter

Jupiter is the largest of the Gas Giants, the first of the Jovian planets. Jupiter has an atmosphere so dense that the pressure causes the liquid hydrogen on the surface to become conductive, or metallic. Jupiter's long-lasting Red Spot was actual discovered to be a storm in the atmosphere. The Spot has a diameter three times that of Earth. Jupiter radiates twice as much energy into space as it absorbs from the Sun. It is possible that certain microorganisms that do not require oxygen or carbon dioxide may exist in die atmosphere.

- *Length of day:* 9 hours 55 minutes (2/5 Earth day)
- *Number of our Days in a Year:* 4344
- *Gravity* 24.6 newtons per kilogr. (100 lb person would weigh 251 lbs)
- *Surface composition:* liquid hydrogen
- *Temperature at the surface:* 40 ° C
- *Atmospheric composition:* hydrogen, helium methane, ammonia, water vapor
- *Number of Known Moons :* 16 plus Rings



Saturn

Saturn, like Jupiter, radiates twice as much energy into space as it receives from the Sun. Its gaseous composition makes it very light for its size. In fact, if you could find an ocean large enough, Saturn would float! Saturn is so large, that 750 Earths could fit inside it. Saturn has rings that extend 400,000 km into space.

- *Length of day:* 10 hours 40 minutes
(1/2 Earth day)
- *Number of our Days in a Year:* 10,764
- *Gravity:* 10.4 newtons per kilogr.
(100 lb person would weigh 106 lbs)
- *Surface composition:* hydrogen ice
- *Temperature at the surface:* -198° C
- *Atmospheric composition:* helium, methane, liquid hydrogen, clouds of ammonia
- *Number of Known Moons :* 17 plus Rings



Uranus

The atmosphere of Uranus can store heat for up to 600 years. Uranus is the planet that got knocked on its side – it's tilted at about 90° to its orbital plane. It has two axes of rotation: one around its poles and a slower one about its equator. So, one side of the planet gets sunlight for 20 years.

- *Length of day:* 15.5 hours
(3/5 Earth day)
- *Number of our Days in a Year:* 30,787
- *Gravity:* 8.23 newtons per kilogr.
(100 lb person would weigh 84 lbs)
- *Surface composition:* ammonia and methane
- *Temperature at the surface:* -197° C
- *Atmospheric composition:* helium, hydrogen, clouds of ammonia, and methane
- *Number of Known Moons:* 15 plus Rings



Neptune

The interior of Neptune lies hidden beneath a thick, active atmosphere. Neptune apparently has some source of internal energy. It radiates into space 2.7 times as much energy as it receives from the Sun. A wobble in Neptune's orbit is caused by Pluto, and perhaps by an unseen tenth planet.

- *Length of day:* 18 hours 0 minutes
(4/5 Earth day)
- *Number of our Days in a Year:* 60,395
- *Gravity:* 11.2 newtons per kilogr.
(100 lb person would weigh 114 lbs)
- *Surface composition:* no solid surface
- *Temperature at the surface:* -214° C
- *Atmospheric composition:* hydrogen, helium
- *Number of Known Moons :* 8 plus Rings



Pluto

Pluto is composed of methane ice, which is slowly evaporating into space. There is some mystery about Pluto and the orbits of Neptune and Uranus. Pluto seems to affect their orbits by pulling them farther away from the Sun. But Pluto is not massive enough to create such an effect. Some suggest that a much larger, but darker, planet beyond Pluto is the culprit. The origin of Pluto is uncertain. Speculation suggests that Pluto was one of Neptune's moons but was pulled out of orbit by some passing gravitationally heavy body. Some believe it is a trapped comet.

- *Length of day :* 153 hours
(6.5 Earth days)
- *Number of our Days in a Year:* 90,509
- *Gravity:* 66 newtons per kilogr.
100 lb person would weigh 7 lbs)
- *Surface composition:* methane ice, rock, water ice
- *Temperature at the surface:* -231° C
- *Atmospheric composition:* argon over methane
- *Number of Known Moons :* 1

Mathematicians describe tendril perversion

The twisting tendrils of climbing plants have intrigued biologists for well over a century. A tendril can coil first in one direction and then in the opposite direction. This phenomenon, called perversion, also shows up in kinky telephone cords.

Now, mathematicians have shown that such reversals of direction result from the curviness inherent in tendrils and cords.

By solving mathematical equations that describe the idealized behavior of thin, flexible rods such as telephone cables or licorice sticks, Alain Goriely of the Université Libre of Brussels and Michael Tabor of the University of Arizona in Tucson show that putting such a rod under tension can spontaneously generate left-handed and right-handed twisting behavior.

"We are modeling the vine tendril as a thin elastic rod, and our results suggest that's not a bad physical representation," says Tabor. The findings appear in the February 16 *Physical Review Letters*.

"I am repeatedly amazed at the range of applications of the theory of the deformation of elastic rods, from DNA to climbing plants," says Ellis H. Dill of Rutgers University in Piscataway, N.J. "They've shown that this interesting phenomenon, climbing plants, is explainable by classical physics."

The rods behave this way "because of the elastic nature of the substance, independent of any [specific] molecular structure," he adds.

The key to the reversal of twist, Tabor says, is a property called intrinsic curvature. "if you take your phone cord and stretch it out, it's straight," he says. "If you let it go, it has loops. So you would say it naturally wants to have loops."

Goriely and Tabor figured out the importance of intrinsic curvature by finding solutions to Kirchhoff's theory of thin elastic rods, a 100-year-old set of equations. Solving the Kirchhoff equations was very difficult, however. To do so, the two mathematicians developed some new analytical techniques and used computer algebra (SN: 3/22/97, p. 176).

The results show how to build what Tabor calls a twistless spring - a spring that starts by coiling one way and then reverses, and thus has a net twist of zero. Both vine tendrils and telephone cords form such springs.

"Here's the funny thing," Tabor says. "The vine is locked on two ends. It has no twist in it, yet it would really like to be like a spring, to absorb motion. . . . It winds up one way, and then it changes direction and winds the other way. The right-handed twist and the left-handed cancel."

The two different directions of twist represent two different solutions to the Kirchhoff equations. Each solution describes a different state, and these states alternate back and forth.

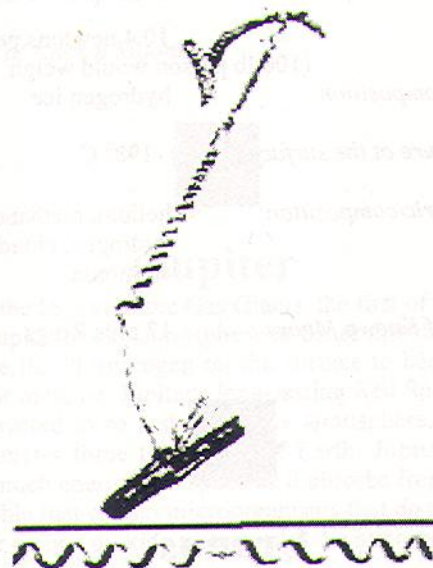
Cycling among different states has been predicted mathematically for a wide range of systems that have suitable symmetry. For example, animals can, in principle,

switch between right-footed and left-footed gaits. Such cycling has been observed only rarely in nature.

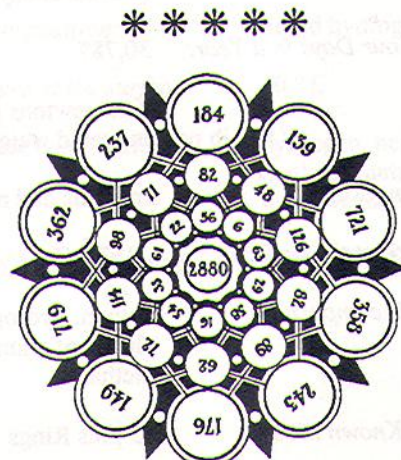
"In systems with symmetry, it's one of the things you expect to have happen," says Martin Golubitsky of the University of Houston in Texas. "I have been sitting around with colleagues for the past 2 years muttering about why we don't see these cycles, because mathematically we know they're there."

"I am happy to see it come about in this really pretty physical manifestation," he adds. "We learn something about the mathematics by seeing how it is realized in the physical system."

- M.N. Jensen, *SCIENCE NEWS*, Vol. 153, 2/28/98



Tendrils of Bryonia dioica (top), a plant in the squash family, exhibit perversion in this 1875 drawing from J Sachs' Textbook of Botany. The bottom half of the tendril coils one way, while the top half coils in the opposite direction. Close-up of a telephone cord (below tendril) shows the junction of the right-handed and left-handed coils.



Magic Number Explosion

What is Goethean Science?

"A spiritual understanding of nature on the basis of Goethe's method of training observation and thought"

Goethean science is science based on the approach of Johann Wolfgang von Goethe, author of FAUST, and who is most generally known for his poetry and literature.

In fact, Goethe himself saw his principle contributions to culture as being in the area of science. He authored many works on science, notably *The Metamorphosis of Plants* and his *Theory of Color*. Goethe stressed that one had to start with the actual phenomenon, and that it is impossible to divorce oneself from participation in nature, contrary to the method of contemporary science. As a generalization, it could be said that he was one of the first holistic thinkers, in the modern sense, to emerge in western culture.

His contributions are variously acknowledged. Using his morphological technique, he proved that the intermaxillary bone, known to exist in animals, could also be found in the human skull. At the time, the supposed lack of this bone was considered to be a significant differentiator between man and animals, this at the time just prior to the development of evolutionary thinking along the lines of Darwin.

He opposed with might and main the concept of Newton's own theory of color (specifically, the idea

of white light being "comprised" of the different wavelengths of colored light), and although his approach is discredited in the company of Newtonian and Quantum physics, the approach and understanding his Theory provides remains of ongoing interest to both artists and some among the more thoughtful scientists. It begins with the classic Aristotelian notion of "cool and "warm" colors (blues and reds); blues represent a lightening of black, reds a darkening of white. This conception is expressed poetically in the words "colors are the deeds and sufferings of light."

His idea of the "Urpflanze" or primal plant was the central theme of his *Metamorphosis of Plants*; he was a great opponent of the mere categorization of species after the manner of Linneaus, without understanding how the various forms and species developed as metamorphoses of each other. Simplistically stated, he saw all plant forms as transformations of the leaf. His method led him to what is sometimes rendered "exact perceptive imagination." In other words, a direct perception of a supersensible reality from which a living thing derives its form.

Many of the approaches embodied in Goethe's scientific world-view are later found, metamorphosed, in the teaching of Rudolf Steiner's anthroposophy or spiritual science. An excellent overview of Goethean science, as informed and extended by anthroposophy, is found in Ernst Lehrs *Man or Matter*.

—via Internet from an Anthroposophical web site.

* * * * *

VERSE

In the milk is the butter, but before it is gained we must shake the milk.
By itself, no butter is formed,
So is God's spiritual force in every one of us;
We merely have to shake ourselves,

or

We will be shaken by fate or necessity,
Be it as individual or as a Nation.
As the butter at first is concealed within the milk,
So is the divine consciousness and the freedom concealed within us.
Because of that, man denies both,
When he is not able to conceive the butter in the unshaken milk.

— by Rudolf Steiner



Human Movement and the Nervous System

by

Siegward-Markus Elsas, MD
Department of Neurology, UCLA Medical Center
and 10211 Seabury Ln, Los Angeles CA 90077

The following is a brief summary of a presentation given to the Society for the Evolution of Science, at their recent meeting, November 1997, in Fair Oaks, California. In **Riddles of the Soul**, when discussing the bodily basis of thinking, feeling, and willing in 1917, Rudolf Steiner strongly dismisses the idea held by conventional physiology that the impulse for movement is given by so-called "motor nerves." Instead, Steiner proposes that *all* nerves - including the so-called "motor" nerves - have a sensory function, and the "motor" nerves would be thought of as sensing the metabolic activity which is the necessary foundation for the will to bring forth movement. Steiner holds that all parts of the nervous system serve only perception and thinking by means of what he calls "true nerve activity" which is difficult if not impossible to measure by the methods of conventional physiology.

"We would be extremely separated from each other spiritually if we developed all our feeling and willing [only] by our nerves in our body, and the human being would be encapsulated in its own skin. Souls would become very isolated. People today are feeling like this, and a natural reflection of this feeling is the antisocial condition of the world - which continues to become more and more antisocial." (Rudolf Steiner 1920)

The physiological concept of "motor nerves" arose from the observation in humans that paralysis of muscles or entire limbs ensues if peripheral nerves are cut (especially the anterior roots of nerves leaving the spinal cord). Also, electrical stimulation of nerves, of the anterior roots of spinal nerves, or of so-called "motor areas" of the brain results in muscle contractions. Such induced movement, however is always perceived by the moving individual as induced from outside, not by their own will - "you did it" is what such individuals may say when their hand moves during stimulation of the brain (Penfield 1950). During intentional movements, small electric impulses can be detected to travel from the brain *outwards* through the spinal cord and peripheral nerves to the muscles. This is referred to as "efferent conduction" while sensory stimuli induce small electric impulses traveling from the periphery *inward* to the spinal cord and brain in "afferent conduction." A problem arises only when we interpret such findings to imply that our brain is some sort of command center of the mind, and "motor nerves" send commands to the muscles. [This misconstrues the nerve sense system as playing the center role in movement, rather than the metabolic-limb system - Editors]. To find a new understanding of the relationship of the nervous system to human movement which is not misled by preconceived ideas, let us develop a phenomenological view of the range of human movement and of the human senses.

Threefold Human Movement/Activities

Let us consider the whole wide range of movements found in the human body. We can bring some order to this multitude of phenomena by arranging them into a kind of spectrum, or metamorphic sequence, following Goethe's way of a new organic science (Bortoft 1997). Human movement ranges from the most conscious of activities, such as speaking and moving our eyes, through skilled movement of our fingers and hands, to dreaming rhythmic activity like walking, or even our breathing and heartbeat. Hidden from our awareness in a sleeping consciousness remain the slow, writhing movements of the gut or the uterus, the movement of the flowing blood, or even the slow, constant movement of the cells of our immune system, causing inflammation wherever bacteria or foreign substances need to be digested.

Chart I

Threefold Movement/Activities

Inflammation	Blood flow uterus	contraction of gut, bladder,	heartbeat	Breathing	Walking	Hand movement	speech & eye movement
Lymphokines	Hormones	specialized muscle	>	spinal cord	>	cerebellum, basal ganglia & cortex	Cortex
← sleeping consciousness			dreaming		awake consciousness →		

Roles of the Nerve System

Now let us consider the involvement of the nervous system in this spectrum of human movement. Only in the **most conscious** of movements, such as speech and eye movements, does the cortex of the brain have any great importance (Figure 1).

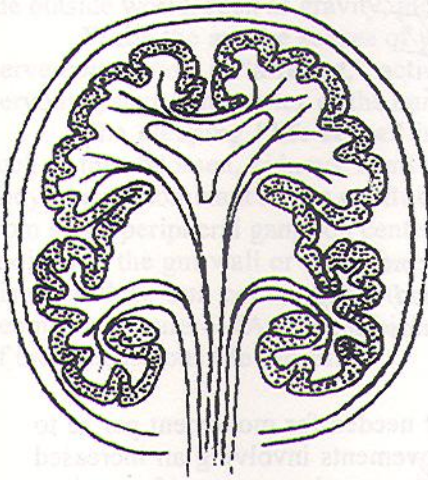


Figure 1

THREE REGIONS OF THE NERVE SYSTEM

Vertical section of skull, showing brain with folded gray matter (cortex) at its surface, traversed by white matter fibers, arising from spinal cord.



Figure 2

Cross-section of spine and ribs, showing skeletal muscle (hatched) and spinal cord, with central gray matter surrounded by white matter, sending spinal nerves out to the skeletal muscles and skin.

After a cortical stroke, it is possible to lose the ability to speak even when mouth and tongue movements (such as swallowing) are preserved. In skilled finger and hand movements which are more automatic, the cortex is still important, but an important role is also played by the cerebellum (as shown by the effects of alcohol intake) and by the basal ganglia (as shown by effects seen in Parkinson's disease).

In a dreaming rhythmic activity, such as breathing or walking, the spinal cord (Figure 2), or its extension the medulla in the brainstem, are sufficient to allow for movement without the [higher] brain [centers of the cortex]. Patients with a complete spinal cord transection can actually learn to "walk" on a body-weight supportive treadmill when appropriate *sensory* stimuli (such as joint position and muscle stretch) are provided in the right way (Harkema 1997). [To see this video was truly remarkable, and really made you reexamine the common notion of cortex-controlled motion via "motor" nerves! – Editors]

In rhythmic movements of the heart or the gut, specialized muscle cells such as the sinus node in the heart and so-called "pacemaker" in the abdomen, provide the rhythm for spontaneous contractions. They are modulated by the secretions from the autonomic nervous system (Figure 3) - acetylcholine and norepinephrine - which act like local hormones. The movements of blood and immune cells are profoundly modulated by hormonal secretions involving the whole body, which influence blood pressure (e.g., angiotensin) as well as immune responses (lymphokines).

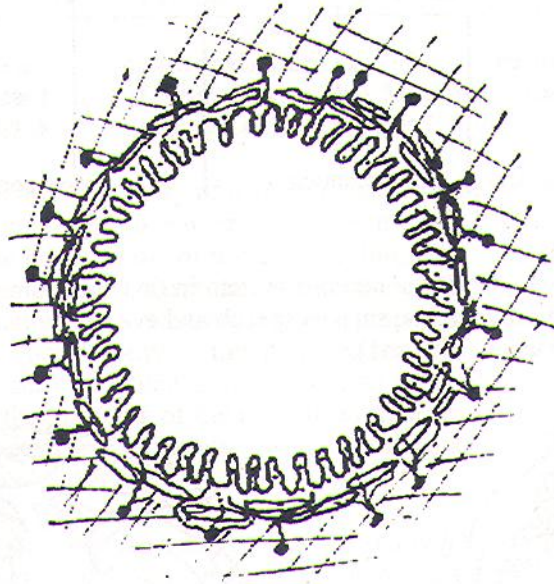


Figure 3

Cross-section of the gut, showing the mucosal folds and circular smooth muscles (hatched) being innervated by the nerve ganglia of the autonomic nerve system (black circles)

In summary, we can see, that the nervous system is not needed for movement per se to occur, however, it does become increasingly important for movements involving an increased level of conscious awareness of our movements. That the human cortex is an organ of conscious conception, and thus also an *organ for the conception of movement* in the moments just preceding actual movement, is further illustrated by the following interesting observation. Functional MRI scanning allows us to follow patterns of blood flow within the brain from moment to moment as it changes with neural activity. When volunteers in the scanner are asked to just imagine a finger movement which they actually performed previously, the pattern of activation in the pre-motor and motor cortex is almost the same for imagined and for real movement (Cohen 1996).

Threefoldness of Human Senses

As a second step, let us now consider the human senses and their relationship to the nervous system. The human senses too, can be arranged in a spectrum or metamorphic sequence as we have done above with types of movement. The senses of vision and perception of speech are again those which are the *most awake* and conscious ones, along with the sense of hearing (see Chart 2). [Now, moving towards the metabolic-will pole], the senses of touch, balance, body position and weight which are most directly connected with human movement are normally in a more *dreaming* kind of awareness, unless perturbed. The senses of warmth, smell, and taste may be even less conscious; and in their connection to substance, they relate closely to our overall sense of well-being, our "life-sense" as Rudolf Steiner termed it. This "life-sense" is experienced at a sleeping level of consciousness.

Chart 2

Threefold Senses

Life sense, well-being	smell, taste	warmth sense	touch, weight	Balance, position	Hearing	Speech perception	Vision
Autonomic Cortex nerve system	modified autonomic system	spinal cord		>	spinal cord, brainstem	brainstem, cortex	
← sleeping consciousness			dreaming		awake consciousness →		

The fully awake senses of vision, hearing and speech perception, connect our inner consciousness to the world around us; they lead our soul from inside *outward*. In contrast, our least conscious sense, the life-sense, brings us from the outside periphery inwards into our body, as we can experience every morning upon waking up, or even more intensely in a situation of pain. The movement-related senses such as the senses of balance, touch, body-position and weight, live in between - they mediate and connect between our inner intentions and the forces of the outside world, such as gravity, inclination, surfaces, and resisting forces.

While the **awake senses** of vision and hearing move our soul outward, the predominant nerve *conduction* is "afferent," acting from the sense organ inward to the very center of the nervous system - the cortex of the human brain (Figure 1, above).

The **sleeping "life-sense"** is based on the autonomic innervation of our inner organs, such as the abdomen, kidneys, heart and others. While this sense moves our soul inward into the body, the predominant **nerve conduction in the autonomic nervous system** is "efferent," acting from small peripheral ganglion centers out into small un-mylenated [post- ganglionic] nerve fiber endings in the gut wall or other inner organs (Figure 3, above). While the awake senses such as vision follow our conventional conception of Euclidean space (Figure 5), a counterspace geometry (Figure 4) (Adams, Whicher 1982) seems appropriate for understanding the processes of the unconscious life senses.

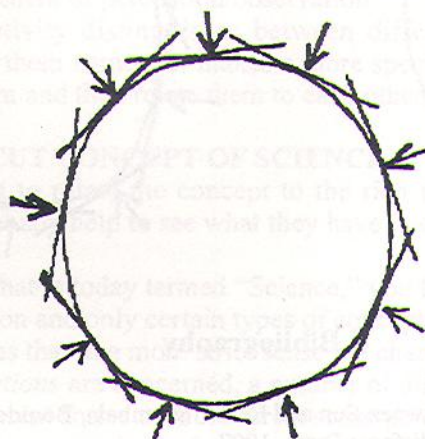


Figure 4

Sphere in counter-space, formed by planes converging from the periphery

The **dreaming senses** of movement, which are connecting our intentions with the forces of the world are based on afferent-efferent reflex arcs, or better "circle" between the spinal cord as part of the central nervous system and the striate muscles in the periphery (Figure 2, above). Victor von Weizsäcker (1940) has described this circular or limniscatory activity between movement and sensation very beautifully in his work entitled "Gestaltkreis" with the subtitle "The Unity of Perception and Movement."

All senses together constitute much of what allows us to experience ourselves as conscious ego-beings. "Our ego lives in the basic rhythm of sleep at night and wakeful

consciousness during daytime. During the night's sleep, we find ourselves connected to our immortal higher self, which is at home in the spiritual world, expanded into the spheres of the cosmos, developing our life events from prior existences. During the day, we experience our small personal ego as if concentrated in a point behind our forehead. Then, our higher self meets us in the events of daily life, coming towards us from the outside as the forces of the outside world. **Our movements arise out of this periphery, the nervous system only functioning to bring the movements to consciousness through the senses.**

In summarizing the latter consideration, we can see that *both* afferent as well as efferent nerves are part of the sense-process. Thus, the efferent nature of the so-called "motor nerves" is only showing us that their sense process is not very awake one, but similar to the sleeping consciousness of the life-sense, which brings our soul from the periphery inward into our body, in this case incarnating our unconscious "night-ego" from the periphery into our muscles, allowing us to move. In contrast, our central "day ego" which we experience concentrated behind our forehead, is involved in making conscious imaginations of planned movements using the center of our nervous system, the cortex of the brain. For real movements to take place, both of these polar activities [sensing-inward, willing-outward going] must come **together in the lemniscatory meeting of space and counter-space** (Figure 6, Adams 1982), of central and peripheral ego, in the afferent-efferent reflex "circles" of the spinal cord and the muscle periphery.

In balancing ourselves [with our middle system] between inside and outside forces, we can thus become true social beings.

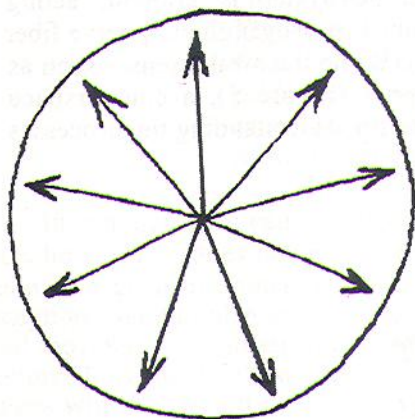


Figure 5

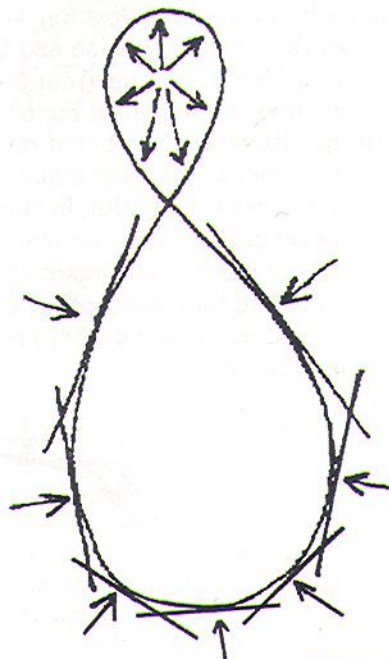


Figure 6

Bibliography

- Adams, G, and Whicher, Olive, 1982: "Plant Between Sun and Earth" Shambala, Boulder, 1982
- Bortoft, Henri, "The Wholeness of Nature," Lindisfarne Press, 1997
- Cohen, Mark S., 1996, personal communication, unpublished data from Functional MRI studies at UCLA. see also, Robert Hotz, "Unraveling the Riddle of Identity" Los Angeles Times, Oct. 16, 1996, <http://www.latimes/thebrain.html>
- Harkema, Susan, 1997, Video- "Neuromuscular Plasticity, Recovery after Spinal Cord Injury" personal communication and observations at UCLA
- Newland, Sherwin, "Wisdom of the Body,"
- Steiner, R, 1917 "Riddles of the Soul" GA 21, English ed. "The Case for Anthroposophy" (tr. O. Barfield), London, Rudolf Steiner Press, 1970.
- Steiner, R, 1920: GA 301, Basel 1920, Lecture 2.
- Weizäcker, Victor v, (1940): "Der Gestaltkreis. Theorie der Einheit von Wahrnehmen und Bewegen." Stuttgart, 1940.

What is Science?

Some viewpoints from the perspective of the theory of science
by

Sune Nordwall

If you want to understand, if you want to come to a picture of what science is, what knowledge is, it could be a good start to try to become clear about the general content of the concept.

Many activities are today characterized as "Science", while other activities are just as definitely characterized as "Pseudo science," maybe without the one making the judgment always having made it clear to himself what he really means with the words he is using. Especially, when you try to come closer to an understanding of what "an anthroposophically inspired art of healing" could mean, it becomes important to become clear about the different aspects of the concept and the problems with which it is connected.

THE GENERAL CONCEPT OF SCIENCE

Every scientific activity is characterized by two activities.

One is some form of observation/perception. It can take place directly, through the senses, somewhat more indirectly via some form of, (in one or another respect) sense improving instrument like a microscope, a telescope or stethoscope, or even more indirectly via some detecting instrument like a Geiger counter, an electrocardiograph or an X-ray apparatus (Harré in 1976).

The other part is some form of thought activity. It "surrounds" and penetrates the observation/perception; A more or less conscious thought activity takes place as an introduction to the observation. It directs the attention in a special direction, "chooses" observations, steps somewhat back during the direct moment of perception/observation, to dominate once more after the direct moment of perception/observation.

The thought activity distinguishes between different parts of that which is observed/perceived, gives them names, or makes a more specific conceptual analysis of them, it may also quantify them and then relate them to each other, logically or mathematically.

A "CULTIVATED," CUT CONCEPT OF SCIENCE

But if you want to relate the concept to the rich flora of activities that are today termed "science" and get any help to see what they have in common, you have to specify the concept a step further.

If you look at what is today termed "Science," you find that you are able to use only certain types of perception and only certain types of conceptual formulations are permitted in connection with activities that in a more strict sense are characterized as scientific.

As far as *perceptions* are concerned, a number of different types of instrumental perceptions dominate. Different forms of more direct sense perceptions have a more ambiguous status. If you continue to perceptions of various forms of inner, psychic states, states of the soul, you come to a type of perception with a very dubious status, to put it mildly, as something on which to base scientific knowledge. When you come to perceptions of a more spiritual nature, you have passed outside the border surrounding those types of perceptions that are discussed in conventional science.

On the *conceptual* side, spatially oriented concepts of a mechanical character dominate. They should preferably relate to something that is quantifiable. Also, it is usually preferred if the quantified perceptions have been chosen in a random way (especially when one of the non-exact sciences is concerned), and when the data exist in such great number, and then have to be put through a computer program to make it possible to describe the results with the help of a mathematical model, or to make it possible to point to more definite con-

nections (significant correlations) between factors, that you otherwise don't quite understand how they relate to each other.

How has this situation come about?

THE "PARADIGM" CONCEPT

In 1962, a historian and philosopher of science, Thomas Kuhn, put forward the concept of the "paradigm," to make it possible to understand how scientists work and why, at different times in history, they have chosen a specific way to describe a phenomenon that would otherwise be difficult to understand. It remains a question why they have chosen observations of certain aspects of the phenomena and certain types of models to describe them, when other observations and models might have been just as good.

A scientific concept is a summarizing term for those factors that direct and put a limit on how you are permitted to work within a group of researchers and what is understood as "science" and "non-science" within that group.

Within the theory of science in Sweden today, you find a distinction being made between at least six such factors. They are: a definite *picture of the world*, a specific *concept of what science is*, a special *ideal of science*, a number of *esthetic ideals*, a certain *ethic*, and also a certain *"self perspective"*. All are opinions of the role of the researcher in research (Törnebohm 1974, Wallén 1974, Lindström 1974).

As will be more clear later, a definite *concept of matter* also plays a very definite role as a paradigmatic factor.

At first glance, the exact concept of paradigm may seem somewhat bewildering (Mastermann in 1970 pointed to 21 different connotations in which Kuhn used the term), but it becomes clearer if you look at it as a way to describe how every question, problem and hypothesis that you formulate during daily experimental research (independent of whether you are conscious of it or not), is connected with a more or less explicit position in relation to basic philosophical problems. With the paradigm concept the basic philosophical problems have become visible again in science, but now related to empirical scientific research.

It makes it possible to characterize different groups of paradigms in a broader perspective, from the point of view of how they are related to the questions that have been discussed by philosophers for a number of centuries, the basic questions concerning the nature of reality (ontology), the nature of knowledge (epistemology) and the questions of the nature of values ("practical philosophy").

It also makes it possible to start to try to understand and characterize the relation between the more natural-scientifically oriented medicine of today and the more spiritual-scientifically oriented art of healing that also exists today, such as Anthroposophically-extended medicine.

In philosophy

Questions of knowledge

Science ideal

Questions of value

Questions of reality

In the theory of knowledge

Concept/picture of science

Esthetic ideals

Ethics

Picture of matter

Picture of (wo-)man/ "Self perspective"

World picture

PICTURE OF REALITY

The most basic orientation of a paradigm is determined by the picture of reality that comes to expression in its "world picture." Here you find a dominant orientation towards an "Idea"-pole during the whole period of Greek science, with Aristotle as the all overshadowing character, all through the Middle Ages into the time of scholasticism.

As part of a reaction against scholasticism, you thereafter find a growing reorientation of interest in the direction of the more spatial-material side of reality, which then comes to blossom with modern natural science.

This description is modified by wefts of more "matter-oriented" paradigms (with Leucippus, Democritus, Strato, Epicurus and others) during the first period (Farrington 1965) and by more "idea-oriented" wefts during the latter period (with among others the whole natural-philosophy oriented scientific tradition) (Eriksson 1969), but this does not change the main impression.

"FUNCTIONALISTS" AND "PHYSICALISTS"

With all the idea-oriented, or "idealistic" world views of science, (from its first beginning in Greece through the time of scholasticism, along with the modern, materialistic "reality-orientation" of science), you also find interwoven specific positions relating to the questions of what matter is and what knowledge is.

Toulmin and Goodfield (1964) distinguish between three different polarized fields in which the conceptual understanding of matter has been moving through history. They are the polarized field between a more *organic* and a more mechanistic conception of matter, between a more *functional* and a more structurally oriented view of matter, and between more "*continuistic*" and more atomistic opinions on the nature of matter.

It is not difficult to see an inner connection between an organic, a functional and a continuistically oriented conception of matter as different expressions of a common, underlying "idealistically" oriented understanding of reality, even though the connection has not always been unambiguous in all cases (different researchers have not always been consistent). It is also those aspects that dominate all research into the nature of matter up to and partly also after the time of scholasticism.

It is also not difficult to see a more mechanistically, structurally and atomistically oriented conception of matter as three different expressions of an underlying, and in a more proper sense "materialistically" oriented understanding and conception of reality. This conception, as mentioned earlier, has its proponents already during the time of early Greek science, but lives on in seclusion right into the time following the scholastic period.

A historian of science, Northrop, coming from a somewhat different perspective, also distinguishes between a "functionalistic" (Aristotelian) and a "Physicalistic" theory of nature, as two of three basic theories of nature during the period of Greek science (ref. by Törnebohm 1977). The two terms generally coincide with what here has been described as an "idealistic" and a "materialistic" view of reality. We will return to the third theory of nature later.

VIEW OF KNOWLEDGE

Connected with the two opinions/views of reality and their respective opinions/views of matter, you also find connected definite points of view on the problem of knowledge.

The view of knowledge as a paradigmatic factor has two components (according to Törnebohm). One is a more theoretically oriented part, "view of science." The other, termed "science ideal," refers to that science, which within a paradigm is considered to be the best expression/reflection of what science "is" and should be.

It is most common among non-physicists today to point to "physics" as a science ideal, whereby they normally have an inner picture of classical physics, as it looked during the first part of the last century (neither within the natural scientifically oriented tradition of medicine nor within the theory of science one has forgiven Planck and Einstein that they popped up during the 20th century and confused the concepts).

To understand the more theoretical part of the problem of knowledge, it is possible to take the general concept of science as a starting point.

Scientists pursue scientific research with the goal, among others, of attaining knowledge. Knowledge can be characterized as "a summarizing description of perceptions/observations in a conceptual or mathematical form." But let us look at man/woman to understand the problem better.

A person has experiences. We make observations and form concepts, ideas and judgments. At our disposal we have four senses, more bound to organs, localized in the head, sight, hearing, smell and taste, and a fifth sense, touch – which is more "spread out" over the whole body.

"PRIMARY" AND "SECONDARY" QUALITIES

How do people make use of the human senses within the "physicalistic" and the "functionalistic" research traditions?

Within both traditions one distinguishes between what are termed "primary" and "secondary" qualities (Marti, 1974). With the term "primary qualities" one referred to the unchangeable qualities of reality as such. The term "secondary qualities" referred to those qualities that man experiences via the senses, the changes of which could be understood as the result of changes in the relation between the unchangeable, "primary" qualities. On this point one finds agreement between the two traditions.

But when asked what is "primary" and what is "secondary" the answers differ. To the "physicalists" it is the spatial qualities passively experienced by sight and ascribed to the indivisible building stones of matter, "*the atoms*," that one experiences as most real. To them belong extension ("fullness"), form, size, position in space and the state of movement or rest. As "secondary" qualities one counted the other half of sight impressions; sight color, as well as the other sense impressions: sounds, smells, tastes and touch impressions.

The "functionalists" have an opposite orientation. They take their starting point, not in a part of the sight experience, but in the most opposite sense; the touch sense and the active experience of touch (Eld-Sandström 1971). Here they distinguish between degrees of two basic touch qualities; warmth and humidity with the extremes hot-cold and wet-dry. These four (two) basic qualities are however considered to be "secondary" in relation to the four "primary" qualities "Fire", "Air", "Water" and "Earth"; "*the elements*," approximately corresponding to the four states of matter: "plasma", "gas", "fluid" and "solid."

It is interesting that one meant that each of the elements only could be experienced by a simultaneous experience from two directions, via two of the basic secondary qualities: simultaneous dryness and warmth for "Fire", simultaneous wetness and coldness for "Water," warmth and humidity for "Air" and coldness and dryness for "Earth."

The division of the touch qualities into warm-cold and humid-dry can seem somewhat confusing against the background of the richness of the different touch experiences that one can have as an experiencing subject. But it is interesting, if seen in relation to the fact that with the special touch-sense in the head—taste, one finds a differentiation into four basic types of experiences: sweet, sour, bitter and salty, in spite of the fact that the taste buds for the different tastes do not differ anatomically from one another in any obvious or principal way. In the Chinese culture, at about the same time as the doctrine of the elements was developed in the Greek culture, it is also the taste experiences that are put at the base for their variant of a doctrine of elements (6th-4th century B.C.).

During the "idealistic" period of science people built the world picture on the basis of the doctrine of the elements, just as during the following "materialistic" period of science, they put much energy into the work of building a consistent world picture, based on the idea of the atom.

TWO SIDES OF REALITY, OR THREE?

While the experience of the physicalists' reality had its roots in a thought-experience (no one probably meant that he had seen the atoms with his own eyes during the 5th-4th century B.C.); the reality-experience of the functionalists had its roots in an experience of the will, the touch. While the physicalists look more at the possible static aspects of matter, the functionalists look more at the possible dynamic states of matter.

But Northrop also characterizes a third basic theory of nature during the period of Greek science.

To the physicalists the ultimate reality appears to be an infinite number of indivisible bodies in space. The functionalists look upon the four elements (or five, really, as they also included a fifth "heavenly" element, the "quintessence") as being the same ultimate reality.

These two opinions now stream together in a third theory of nature, cultivated by the Pythagorean-Platonic tradition.

Here one fuses the idea of the atom with the idea of the elements, by pointing to the five regular polyhedrons, the five "platonic" bodies, as the real, ideal "Ur-atoms," each of which was understood as an exact, geometric expression of one of the elements (Plato 1971, Lossee 1972).

If the Pythagorean-Platonists should point to something else as "primary" qualities, except the Creator and the two types of triangles (right-angles with equal or unequal legs) that he used to create the platonic bodies, it should be the basic, whole numbers and the relations between the whole numbers that come to expression in the "harmonies of heaven." To the modern observer the "secondary" experience would be "hearing."

The original Pythagorean tradition, with its more rational-mathematical form, had its base in the school in Croton in the south of Italy during the 6th-5th century B.C. Later, during the 5th- 4th century B.C. it was developed in a more artistic-poetic direction by Plato's Academy in Athens.

THE SENSES, THE ELEMENTS AND THE SCIENTIFIC TRADITIONS

If you look at the picture you come to, you see that it opens the way to a possible understanding of not only the sense-organism as such, but also the "roots" of the basic ontological traditions.

What may strike you is that the senses display the same relation to each other as the elements with sight (when the four senses bound to organs in the head are concerned) and taste as the basic polarity, and the hearing and smelling as two intermediate senses. The more "spread out" sense of touch – as a more totally encompassing (heavenly) sense – displays the same form of inner relation to taste (as the touch sense in the head), as the "Quintessence" to "Water."

In connection with the purely spatial quality of half of the sight experience, develops the atom idea and the "physicalism," that constitutes one of the two pillars upon which modern "Natural science" rests.

In connection with two willfully experienced touch qualities, (warmth and humidity in Europe – taste qualities in China) develops the "element-idea" and the Aristotelian functionalism, that constitutes one of the two pillars upon which modern "Spiritual science" rests.

But both traditions also rest on a second pillar each.

In connection with the hearing experience, the Pythagorean develops the mathematical tradition that constitutes the second pillar upon which modern "Natural science" rests. Out of the Pythagorean inspiration this tradition developed not only a musically based understanding of cosmos, but also the understanding of the five regular spatial "platonic" bodies as the pure mathematical expressions of the elements and of the natural numbers as "Ur-wesen." From a more Aristotelian perspective Rudolf Steiner (1920) points to other roots of the mathematical processes in man, that I will not discuss here.

As a possible inner consequence of this picture you are confronted with the question of the smelling experience as the "basis" for the platonic tradition. This may at first seem absurd, but appears in a new light when you see that the olfactory ("smelling") part of the brain is that part from which developed the cerebrum, which constitutes the physical basis for higher thinking in man.

This platonic tradition constitutes the second pillar, upon which the tradition of "Spiritual science" rests.

The "natural scientific tradition" of today has been developed in cooperation between the "atomists" and the "Pythagorean-mathematicians." The "spiritual scientific tradition" has been developed on the basis of the "idealistic tradition" in cooperation between the "Aristotelians" and the "Platonists." In this perspective you see that they appear as mirrors of each other, that in two ordered ways reflect the experiences of the four (or five) basic experiences of reality in wo/man.

You also see that the opposition and conflict between the "natural scientific" and the more "spiritual scientifically" oriented medical traditions appears in a deeper sense as an expression of the difference between the perspectives you come to when you develop a thought-sight experience or a will-touch experience in a too one sided way.

THE DEVELOPMENT OF THE MECHANISTIC WORLD PICTURE

Different scientists today frequently and gladly refer to the Aristotelian concept of matter as "speculative" (for example Wagner 1972) and the physicalistic concept of matter as more scientific."

Northrop's description shows how much more the functionalistic description of matter corresponds to what you experience with the senses. Also, it is more correct (in the deeper sense of the word) to use the term "speculative" to describe the atomistic concept of matter during the whole period from the early Greek, through the Alexandrine, the Arabic, the scholastic period of science, all the way up to the 19th century, as it remained a purely theoretical idea during the whole period, without the possibility of connecting it more directly to a specific empirical phenomenon.

This became possible only at the end of a long development, where the structural, the mathematical and the mechanistic idea first had to show their fertility.

Important mile-stones on the way were the "De humani corporis fabrica, libri septem," finished in 1543 by the then 28 year old Andreas Vesalius, "New astronomy with commentaries on the movement of Mars" (1609) and *Epitome Astronomiae* (1618) by Kepler and "Dialogo sopra il duo massima sistemi del mundo" (Dialogue concerning the two most important world systems, (1633) by Galilei.

But it is only, for the first time with the help of the 42 year old John Dalton that the idea of the atom comes all the way down to earth, with his book *A New System of Chemical Philosophy*, published in 1808, where he attaches the ancient idea to the observed fact that chemical substances join with each other in proportions of whole numbers, and to the fact that different gases expand to the same extent when heated.

The development within biology takes a parallel course to that within chemistry and physics, with the opinion of the cell as the "atom of life" becoming more general during the first part of last century, with the 29 year old Theodor Schwann being the first person to give an adequate description of the theory of cells (1839).

The research into the atomic aspect of matter and the life processes then developed quickly during the 19th century. The kinetic theory of gases, the spectral analysis of light and the invention of the "gas diffusion vacuum-pump" make it possible to investigate the phenomenon of electrical discharge in highly rarefied gases between 1856 and 1859, in a way that leads to a more consciously formulated theoretical atomism (Martin 1961).

At about the same time the 36 year old Rudolf Virchow formulates his cellular pathology in the field of medicine ("Die Cellularpathologie in ihrer Begründung auf physiologische Gewebslehre," 1858), the theory that all diseases have their roots in pathological changes in individual cells of the diseased organism.

Earlier an "idealistic" science, had reached a certain height during the time of scholasticism. Now, during the 19th century, a mechanistic world picture, reaches its high point.

But with the turn of the century and the first three decades of this century, the situation changes in a dramatic way.

THE CONCEPT OF MATTER TODAY

The discovery of radioactivity by Becquerel in 1896, the quantum theory formulated by Planck in 1901, and the acceptance of the general theory of relativity formulated by Einstein in 1916 led to radical reformulations of the theory of atoms and classical physics. Among other things one had to give up the ideas of

1. The atom as the smallest indivisible unit of matter;
2. The unchangeable material identity of atoms and,
3. The principle that it should be possible (in theory at least) to calculate and predict exactly the behavior of single atoms.

In their place came, among other things, the "principle of complementarity," mathematically formulated by de Broglie in 1925, that says that matter in some cases can appear as a "ring" that streams through the room (space), while in other cases it is better to describe it from the aspect of a particle-model of matter, and that the way it "chooses" to appear depends upon the limit conditions, the experimental conditions, you give it for its appearance.

Another principle is the uncertainty-principle of Heisenberg, that specifies the limit for how exactly you can describe certain pairs of aspects of atomic phenomena.

A third important discovery has been that the law of the principle of conservation of matter and energy is valid only as a statistical mean by elementary particle processes, and

that it is sometimes possible for "elementary" particles to "borrow" together more energy than there is really available at the moment, to "use" it for some non energy-consuming purpose, and then let the energy coming from "nowhere" disappear into "nowhere" again.

The original idea of material atoms as the smallest building stones of matter has evolved to "a mathematical scheme for the calculation of the probability of observing particle-like phenomena" (Unger 1952). What thereby remains of the materially conceived atoms of the mechanistic world picture is, once again, "only" mathematical structures, even though in a more developed form (than that described by Plato).

THE PROBLEM OF KNOWLEDGE IN A NEW LIGHT

The investigation of matter has thereby led to a dissolving of the concept of matter in a way that has shown the impossibility of basing the description of reality in an ultimate, unchangeable, "objective" and "material" reality. With the principle of complementary and the uncertainty relation of Heisenberg, the investigating subject who formulates the questions and sets the limits for the form of the answers, has taken its place as the center of the research process.

From the perspective of the theory of knowledge during the last decades, we also find a severe criticism of the thesis of the subjectivity of the "secondary" qualities in relation to the "primary" qualities, as described by the "physicalistic" tradition, (Hegge 1957, 1975, Naess 1974).

The "physicalistic" way of separating off "spatial-material" qualities (as more "primary" in relation to the other sense qualities) has thereby been shown to be untenable as an argument for the restriction of the concept of science that was described in the beginning of the article, a restriction that still continues to govern the greater part of all research-activities, just as if nothing had really happened.

Thanks to modern physics (wo-)man has once more become free to start out from and use his/her own experiences, his/her own senses and her/his own thinking efforts to understand reality. Once again, the human being has become free, also in an epistemological sense, to try to understand the inner regularities in the various sense-worlds and how they relate to each other. S/he is once more completely free to form concepts out of the reality in which she lives as a human being and to try to develop her ability to attain knowledge as a human being and to try to develop her ability to attain knowledge, without having, in the end, once more to "reduce" and ground his/her observations and her concepts in the seemingly "primary" qualities of a lowest level of spatial, material "parts" of matter.

A NEW RESEARCH IMPULSE

A first attempt to develop such a type of research in modern times was made by Goethe (1749- 1832), when he developed his "Theory of Color" and when, in 1790, he made an outline of a description of the metamorphosis of plants. That the MIT Press published an American translation of Goethe's "Theory of Color" about 1976 gives a hint that the insights of the consequences of modern physics for the theory of knowledge is now slowly spreading.

A pioneering contribution to further develop the attempt begun by Goethe, was later made by Rudolf Steiner (1861-1925), at first in a number of treatises, dealing with the theory of knowledge (1886/1979, 1892/1980, 1894/1987), and later in a number of other fields of science and practical life.

The results, in the form of the possibilities to deepen the process of acquiring knowledge that he demonstrated (1904-5/1982, 1905-8/1979, 1910/1989, 1913/1987) and later the extent of the research results that came out of it, can make an overwhelming (on pure "physicalists" for different reasons often indigestible) impression, when you start to dig into them. Beside the publication of 28 books, he held about 6,000 lectures, during the last 20 years of his life, of which about 3,000 have been published.

During the second part of that period, among other things he also lay the foundation and started to build up an "Independent College for the study of spiritual science," within which were the beginnings of a medical section, a natural-scientific section, a mathematical-astronomical section, a pedagogical section, a section for "spoken and musical arts," a section for the spiritual striving of youth, and later a social-scientific section, near Basel in Switzerland.

At the Goetheanum, (the name that he gave to the College), and in other places a number of people have continued working to deepen and develop further the many suggestions and new ideas which he contributed to the development of different sciences and other fields of practical life as a result of his researches.

AN OUTLINE OF A KNOWLEDGE OF MAN - ANTHROPOSOPHY

During the 72 years that have passed (in 1998) since his death, it has only been possible to start scratching on the surface of the body of ideas, research results, and practical suggestions that he left behind. It will probably take a long time before it becomes possible to survey the extent of the contribution that he left behind.

The core of "anthroposophy," the name that he gave to his contribution, is its picture of the striving human being. With the development of consciousness of wo/man as a starting point he describes history. Out of the relation of wo/man to the world of minerals, of plants, of animals and out of that which is specifically human in wo/man, he describes the common development of wo/man, nature and the earth, as it appears to a meditatively developed research process (Steiner 1910/89 and other works).

Through all fields of "anthroposophy," wo/man, the development and individuation process that s/he has undergone runs as a red thread, a process that has now made it possible for her/him to start standing on her/his own legs in relation to her/his origin, and thereby also start taking over the responsibility for her/his own development, both as a human and as an individual being.

AN EVALUATION

Today we have the possibility, as emerging free beings, to look back at history without prejudice to see what we have achieved in the form of an understanding of the reality surrounding us and of ourselves.

After a long period of "idealistically" oriented research into reality, for a number of centuries we have now gone through a fascinating and interesting period of research into reality from a "materialistically" oriented perspective. The former period has made it possible to understand more consciously certain general, deep laws of nature and of wo/man. The latter has, among other things, contributed in a decisive way to the possibility for wo/man to develop a clear and independent thinking. But this second period has now also come to a kind of an end.

Today we have the possibility to look through the one-sided way of working during both these periods. "Anthroposophy" is the beginning of an attempt to develop an understanding of reality, once more starting from a clear, wakeful, fact-oriented consciousness of that which is observable with the senses and developing the thoughts that arise out of what you observe. The result is a renewed orientation in a "functionalistic" direction, but now against the background of the extensive fruits of a long and fascinating period of "physicalistically" oriented research.

A gigantic amount of work now remains to be done, to not only survive the maturity-crisis that we now pass through, and must pass through, as humanity during the end of this century and the beginning of the next, but also let the insights that have come out of the "matter-scientific" research of the last centuries fertilize and be fertilized by the insights that have and can come out of a "spiritual-scientifically" oriented research.

"Anthroposophy," as a first attempt towards a possible synthesis of the two traditions, has taken its first stuttering steps. An "Anthroposophic" art of healing, as a first step towards a future, widened, more factually human art of healing, is also beginning to take form. This article has wanted to be a contribution to that art of healing.

* * * * *

REFERENCES

1. ELD-SANDSTRÖM A E: Från Thales till Einstein (From Thales to Einstein). Stockholm: Aldus[Bonnier, 1971.
2. ERIKSSON G: Romantikens världsbild speglad i 1800-talets svenska vetenskap (The world picture of romanticism, mirrored in Swedish science of the 19th century). Stockholm: Wahlström och Widstrand, 1969.
3. FARRINGTON B: Greek science. Harmondsworth: Penguin Books, 1961.
4. GOETHE J W: Die Metamorphose der Pflanzcn. In: Goethes Naturwissenschaftliche Schriften (Ed Steiner). Stuttgart/Berlin/Leipzig/Jena, 1790.
5. HARRE: R: The Philosophies of Science. An Introductory Survey. London/Oxford/ NY: Oxford Univ Press 1972/1976
6. HEGGE H: Erkjennelse og virkelighet. Et bidrag til kritikk av teorien om sansekvalitetenes subjektivitet (Knowledge and reality. A contribution to the criticism of the theory of the subjectivity of the sense-qualities). Oslo: Univ forl, 1957.
7. - Menneskets forhold til naturen i historisk og filosofisk perspektiv (Man's relation to nature in a historical and philosophical perspective). In: Ökologi. Ökofilosofi. (Ed Hofseth/Vinje). Gyldendal Norsk Forlag, 1975.
8. KUHN T: The Structure of Scientific Revolutions (1962). Chicago/London: The Univ of Chic Press, 1970.
9. LAUENSTEIN D: Die vier- Denkmodelle des Abendlandes. Stuttgart: Verl Urachhaus, 1976.
10. LINDSTRÖM J: Dialog och förståelse (Dialogue and understanding). Göteborg: Vetteor inst., Göteborgs Univ., 1974.
11. LOSEE J: A historical Introduction to the Philosophy of Science. London/Oxford/ NY: Oxford Univ. Press, 1972.
12. LUCRETIUS: On the Nature of the Universe. Harmondsworth: Penguin Books, 1978.
13. MARTI E: The Four Ethers. Chicago, Schaumborg Pub., 1980..
14. MARTIN M: Atomismus und Moderne Physik. Goldach SG (Schweiz): AG für Verlag und Druckerei, 1961.
15. MASTERMAN M: The Nature of a Paradigm. In: Criticism and the Growth of Knowledge (Ed Lakatos and Musgrave). London: Cambridge Univ. Press, 1970/1974.
16. NAESS A: Ötology, samfunn og livsstil (Ecology, society and lifestyle). Oslo: Univ. Forlag, 1974.
17. PLATO: Timaeus and Critias. Harmondsworth: Penguin Books, 1971.
18. SINGER C: Naturvetenskapens utveckling Lund: CWK Gleerups Bokförlag, 1972.
19. STEINER R: Theory of Knowledge, Dornach: Steiner Verl., 1979.
20. - Truth and Science, (1892). Dornach: Steiner Verl., 1980.
21. - The Philosophy of Freedom, (1894). Dornach: Steiner Verl., 1987.
22. - Knowledge of the Higher Worlds, (1904/1905). Dornach: Steiner Verl., 1982.
23. - Die Stufen der höheren Erkenntnis (1905-1908). Dornach: Steiner Verl., 1979.
24. - Die Schwelle der geistigen Welt (1913). Dornach: Steiner Verl, 1987.
25. - Die Geheimwissenschaft im Umriss (1910). Dornach: Steiner Verl. , 1989.
26. SALLSTRÖM P: Goethes färglära (Goethes Farbenlehre). Stockholm: Kosmos förl, 1976.
27. TOULMIN S, GOODFIELD J: Materiens arkitektur (Sw transl. of The architecture of matter) Stockholm: Natur och Kultur, 1966.
28. TÖRNEBOHM H: Paradigm i vetenskapernas värld och i vetenskapsteori (Paradigm in the world of sciences and in the theory of science). Göteborg: Rapport 59, ser 1, Avd f vet teori, Göteborgs Univ., 1974.
29. - Three Theories of Nature in Greek Science. Göteborg: Report 30, ser 2, Avd f vet teori, Göteborgs Univ., 1977.
30. UNGER G: Gibt es einen Begriff der Substanz? In: Beiträge zur Substanzforschung Bd 1. Dornach, 1952.
31. WAGNER J: Vad Einstein verkligen sagt (What Einstein really said). Stockholm: Raben o Sjögren, 1972.
32. WALLEN G: Kunskapsbildning på empirisk väg (The forming of knowledge in an empirical way). Göteborg: Rapport 62, ser 1, Avd f vet teori, Göteborgs Univ. , 1974.
33. WERNER A: Introduktion till kunskapsteoriens historia (An introduction to the history of the theory of knowledge). Lund: Argos, 1978.

The article was first published in *The Nordic Journal for Anthroposophic Medicine*, number 1, 1990.





What Is Meant by "Teaching the Children to Breathe"

in the First Lecture of *Study of Man?*
A Lecture Given in Zeist, Holland on 19th April 1997

by
Ernst-Michael Kranich

Several months ago I was asked whether I would be able to speak about the connection between thinking and feeling. I was very happy to accept this invitation, for this is one of the most important themes of our time. However, the relationship between thinking and feeling has in fact altered in the past few decades.

We experience our own being in our feelings as well as in our wishes and interests. For each one of us it depends on our feelings as to what we consider important or worthwhile. And it is precisely in this very personal area that a change is taking place, one that I would like to illustrate with a few figures. These are taken from two highly respected German opinion polls. In 1974, when asked what was most worth striving for in life, 27% of the respondents answered that it was what gives pleasure. Twelve years later, in 1986, it was 44%. And in 1994, 54% of the respondents between the ages of 14 and 29 replied that for them the meaning of life was to be found in pleasure, the pursuit of happiness.¹ These figures clearly show a narrowing-down of people's feelings and interests, that people are separating themselves off from an inner connection to social life and the world in general.

The soul-life of more and more people is taking on a configuration in which feeling is no longer touched and illuminated by the light of insight, by an understanding of those around us and of life itself. For through insight and understanding feeling opens up and expands. Rudolf Steiner describes the consequences of that not taking place in the following way:

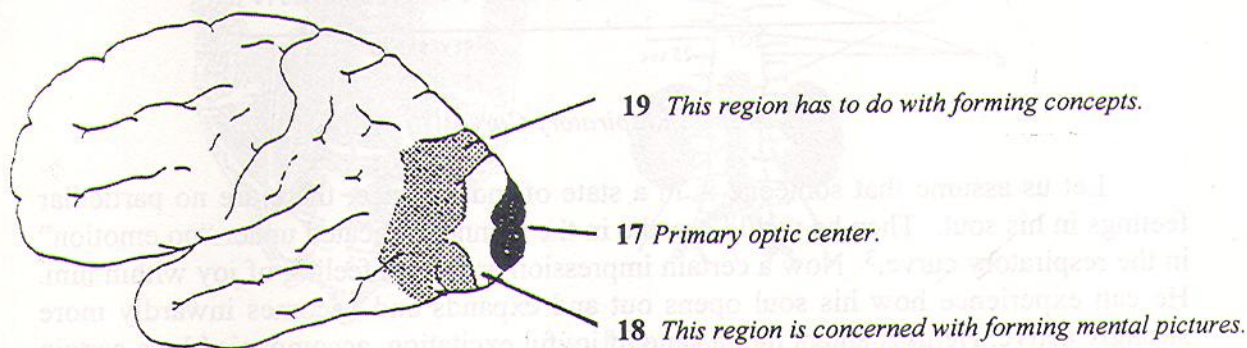
*"....then the human being must plunge down into the unconscious that lives in his animal nature. Then, in his feeling-life, he will be tossed hither and thither, totally at the mercy of his inner well-being or its opposite, of his instincts, drives and needs that are not illuminated by the light of consciousness."*²

These feelings which arise out of our drives, instincts and desires are those of enjoyment and pleasure.

So we can see that a very serious change is taking place in our times: the human personality can have an inner greatness and breadth, or it can sink to a low level, in other words become decadent. And this process of the personality's decline into decadence must above all be studied and understood wherever student teachers today are being prepared to face the present tasks of education. We have to know the root-causes of this process, and what counteracts it.

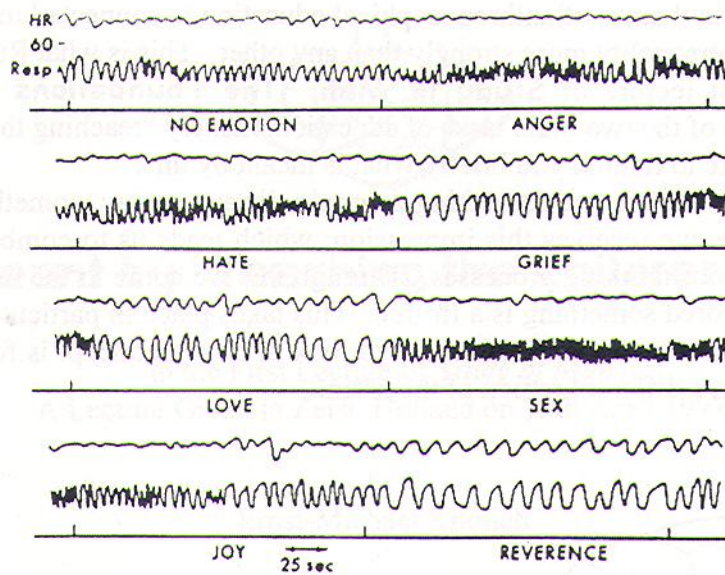
One of the main themes of anthroposophical education is connected to this present crisis of the human personality more strongly than any other. This is what Rudolf Steiner refers to in the first lecture of **Study of Man, (The Foundations of Human Experience)** as one of the two main tasks of education, namely "teaching the children to breathe." I would like to remind you briefly what is meant by this:

Let us imagine we can see something a certain distance away, something tall and of a dark color. The eye receives this impression; which leads us to combine it with a mental picture from our thinking processes. Through this we come to the understanding that the tall, dark-colored something is a fir tree. This takes place in particular regions of the brain. We can then continue by going on to look at how a concept is formed. This process takes place in a different region of the brain.



Rudolf Steiner calls this the "nerve-sense process." We are not concerned with the mental images and concepts as such, but with the forming of mental images and concepts based on our sense impressions. According to Rudolf Steiner, the breathing is to be organized into these processes. Breathing is here to be understood in an anthropological-anthroposophical sense. To begin with it is a rhythmical process of a very special kind. Rhythm is of course to be found in all life-processes and is indeed an essential attribute of living things. Each life process builds up in intensity, dies down a little and then is filled with a new impulse as it builds up again. All living things are permeated by such inwardly alive, self-renewing activity. These rhythmical processes usually take place in our inner organs, where they are hidden from normal observation. But in our breathing, this rhythmical life-process has such a strong effect that it penetrates the whole organ, right down into what is physically visible, and the whole organ pulsates rhythmically in a continuous alternation between active breathing in and passive breathing out. That is breathing considered from an anthropological point of view.

This breathing rhythm does of course vary considerably, both with regard to the speeding up or slowing down of the frequency, and also with regard to the increase or decrease in amplitude.

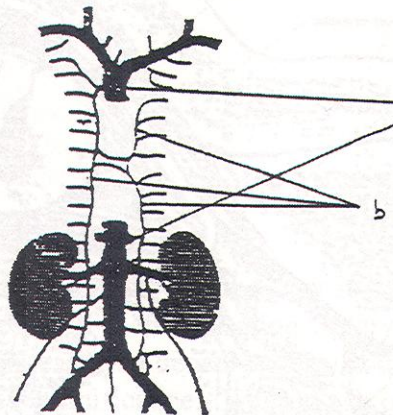
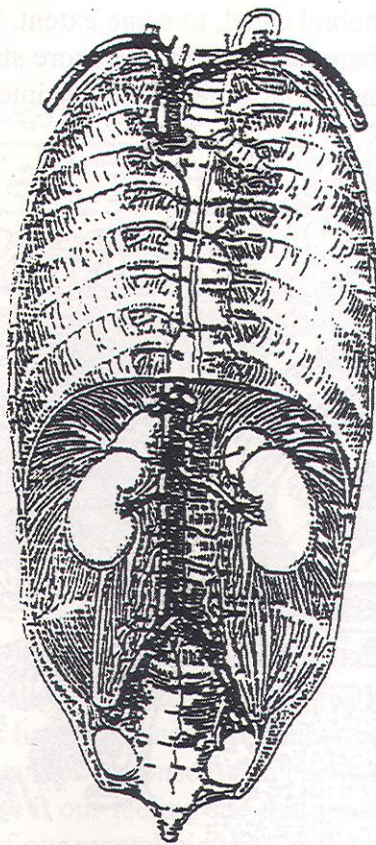


Resp. = Respiratory Curve

Let us assume that someone is in a state of indifference; there are no particular feelings in his soul. Then he would breathe in the manner indicated under "no emotion" in the respiratory curve.³ Now a certain impression arouses a feeling of joy within him. He can experience how his soul opens out and expands and becomes inwardly more strongly active. He thus enters into a state of joyful excitation, accompanied by a certain depth of experience. We can observe outwardly how the breathing speeds up somewhat, and also deepens (see graph labeled "joy") In a different situation anger arises; a strong inner disquiet, a much stronger stimulation of the soul. The breathing rate accelerates, becoming irregular as it does so. (see "anger" graph) Or let us suppose someone experiences a much more spiritual feeling, such as reverence, for example. All excitement vanishes from the soul; and from this inner stillness the soul then opens itself, in feeling. This leads to a strong deepening of the experience, for it is out of the depths of our soul that we turn to that which we revere, and we wish to take it deeply into ourselves. The breathing rhythm becomes quieter, slower and also much deeper (see "reverence" graph).

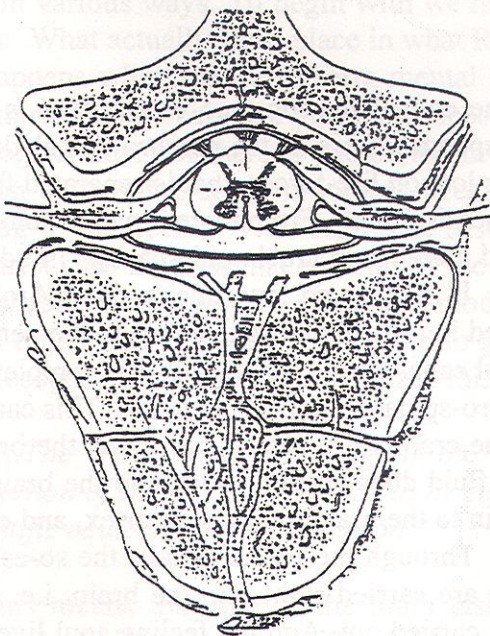
If we discuss such observations, particularly those relating to inner soul processes, with student teachers, then they can see clearly how the dynamics of different emotions manifest themselves in variations in the breathing, i.e. in variations in pulsating life-processes. So we can begin to grasp what breathing is, in an anthropological-anthroposophical sense.

The feeling soul, therefore, with its inner experiences, lives in and affects the variations in our breathing rhythm. And now this breathing rhythm, in which the feeling soul is pulsating, penetrates more deeply into our organism.



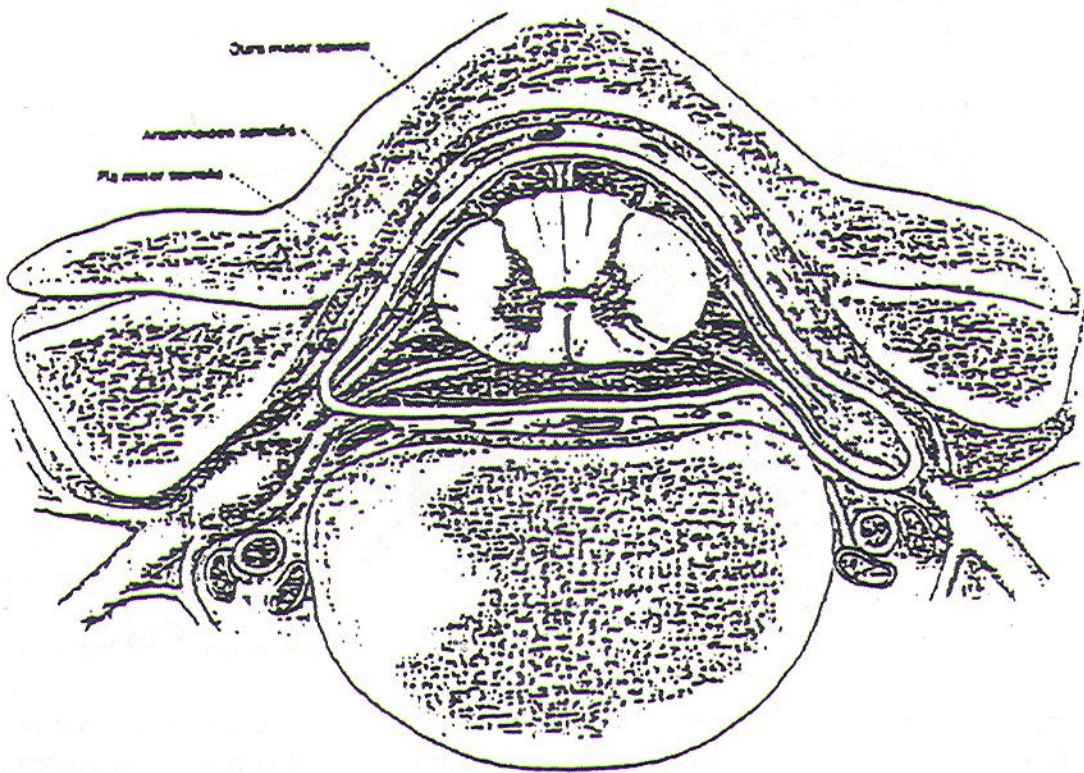
a) Vena cava b) Azygos veins

Initially it affects the veins which run parallel to the spine at the rear of the bodily cavity. These are the veins of the azygotic system. They receive the blood that comes from the interior of the spine, which flows out of the so-called vertebral canal. These veins do not have any valves. So when we breathe in, the pressure on them causes the blood to be held back, dammed up, so to speak.



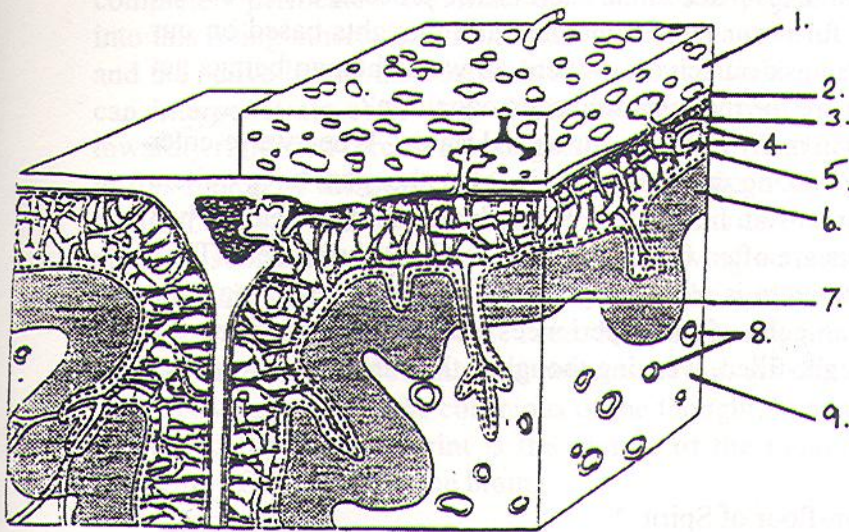
The spinal cord-surrounded by the dura mater - in the vertebral canal. We can see how the veins in part pass through the vertebra on their way from the vertebral canal to the exterior.

It then pulsates back into the core of the vertebral canal, to some extent. In part the veins pass through the vertebrae, and when we exhale, the blood flows more strongly out of the vertebral canal into the larger veins to left and right of the spine. The interior of the vertebral canal has a unique configuration



Between the dura mater and the vertebra are the veins belonging to the inner vein plexus.

Approximately in the middle – up to the end of the thoracic vertebrae – is the spinal cord within its protective skin. It is suspended there in the cerebro-spinal fluid. (The cerebro-spinal fluid is a clear liquid, rather low on life-forces, that is separated from the blood in the inner cisterns of both cerebral hemispheres. From there it passes into the space between the pia mater and the arachnoid mater [sub arachnoid space]. In adults there are about 140 ml of cerebro-spinal fluid. It is renewed few times a day.) Around the protective skin is a tangle of veins embedded in semi-liquid fat. So when the venous blood is held back in the interior of the vertebral canal during inhalation, this complex of veins swells up and exerts pressure on the cerebro-spinal fluid from all sides. This causes some of the fluid to be forced upwards into the cranium, where it surrounds the brain. But this rhythmically pulsating cerebro-spinal fluid does not only surround the brain, it also penetrates through very fine pores into it, in to the gray matter, the cortex, and even through the gray matter into the white matter. Through these fine canals, the so-called Virchow-Robin spaces, the breathing rhythms are carried right into the brain, i.e. into those regions where our nerve-sense process is carried out. And the feeling soul lives in these rhythms.



1. skull
2. dura mater
3. arachnoid mater
4. subarachnoid space
5. pia mater
6. gray matter (cortex)
7. fissure in pia mater
8. Virchow-Robin space
9. white matter

However, it lives in the cerebro-spinal fluid differently to the way it lives in the lungs. From living in the pulsating air it submerges itself in the pulsating watery element. And, as always happens when our soul nature plunges into a denser region of the human organism, it becomes unconscious. This is of great significance. We can ask ourselves: How would it be if our feeling life did not become unconscious, and worked directly into the formation of our mental pictures and thoughts? The human being would never be able to form impartial, objective mental pictures and thoughts.

In this way the feeling soul pulsates ceaselessly in this peculiar manner into those regions in which the nerve-sense process takes place. And a quite specific way of working is necessary, if what lives in the feelings is to be organized into the nerve-sense process in such a way that it maintains it, as Rudolf Steiner puts it; in other words keeps it going and enlivens it.

What we have so far described is a rather superficial account, which we must now deepen in various ways. To begin with we have to put a certain question to our student teachers: What actually takes place in what Rudolf Steiner calls the nerve-sense process? What happens when we try to form mental pictures and thoughts based purely on our sense-impressions? There is a historical aspect to this question as well as a physiological-psychological one. For there is one period in human evolution in which cognition based purely on such nerve-sense processes became an ideal, and that is the scientific age beginning in the 15th to 17th centuries. Scientific cognition is a form of cognition in which strict care is taken that nothing of the nature of personal experience should flow into this act of knowing. A distanced mode of observation, and a strict separation between object and subject are supposed to guarantee the objectivity of such cognition. The philosopher Hans Jonas characterized this basic attitude in the following way:

"...The transfer of anything of the character of inner experience into our interpretation of the outer world was to be strictly avoided. Anthropomorphism became the scientific equivalent of high treason." ⁴

This means that one of the main tasks of Steiner/Waldorf Education, namely "teaching the children to breathe," would be, to use Hans Jonas' words, scientific high treason – indeed, quite consciously so.

If we want to understand what takes place in the nerve-sense process, then we must not only consider the fact that we form our mental pictures and thoughts based on our sense-impressions, but we must also ask ourselves: Where do we as human beings get our thoughts from? And also: what are the thoughts we use in cognition?

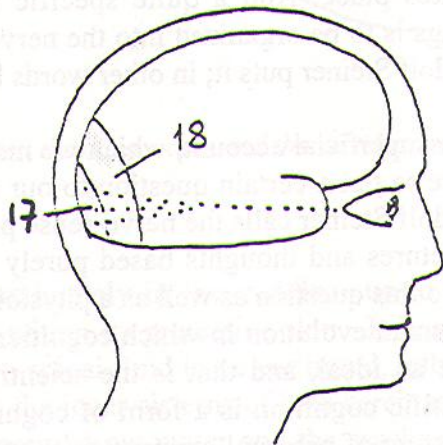
Of course we know thoughts in many different forms and states. When we re-enter our bodies with our inner being on waking up in the morning, our thoughts have quite a different character than they do perhaps an hour later. If we think about something just after having woken up, our thoughts are often filled with a strong inner brightness. They have a spiritual breadth, and each thought is woven together with others in a living way. What we are experiencing here is an echo of the experiences we had before waking up. There our thoughts are a world of light-filled, weaving thoughts; they are, in the words of a morning meditation:

Light-streaming Archetypes

Flashing and quivering Ocean-floor of Spirit. ⁵

From this world we take thoughts into waking life. But we soon notice: now when I think, thoughts have changed. My day-time thoughts are no longer light-filled, no longer expansive, weaving one into the other. They isolate themselves, once we take them into our body, to single concepts. Their inner life has vanished. They have hardened, as Rudolf Steiner once described it. ⁶ We can experience that they have become hardened spiritual entities.

What actually happens, when we think about a sense impression, for example, a tree, or an animal?



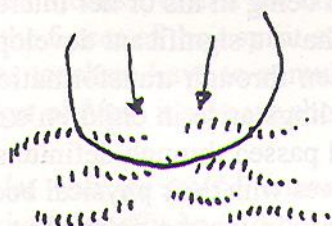
➤ A

(A) An object in the outer world.

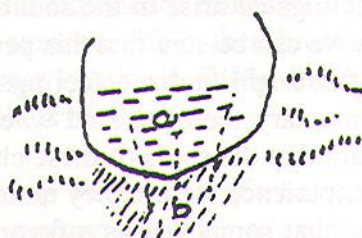
Here, for example, is an external object (A). Certain impressions enter the eye from it, and from the eye these impressions pass via the optic nerve into a certain region of the brain, the primary optic center (area 17). Now we relate our thinking activity to these impressions. A mental picture is formed when the thinking activity relates to these impressions in area 17. The thinking activity then penetrates into the nerves of area 18. These are the nerves that connect together and combine the single impressions of area 17. Now these nerves are alive inside, there is living substance in them, which flows very slowly through the nerve fibers. This is actually living protein, that is formed in the nerve cells. This protein is therefore physical-etheric substance; i.e. the physical matter is

completely permeated with inner etheric life activity. Now the hardened thought comes into this living-etheric activity. It penetrates this active life. For the thought supersensible and the active life of the etheric is also supersensible. In the supersensible realm entities can interpenetrate each other. This thought permeates the life in the nerves with its inwardly rigidified forces; it extinguishes this life. The thought deadens the life-processes in this region of the brain. This is a very significant process. What does this deadening signify? As the life dies, so the activity of this living substance is extinguished. The physical substances which were filled with living activity now separate themselves off. They become inert and are deposited along the respective nerves. This dying off is a consequence of thought activity. Preceding this bodily process, however, is the other one: namely the thought working into what is living. As this deadening process works into what is living, we become conscious of the thought. For the thought creates an imprint in this dying life. This imprint is the picture of the thought. This is how we come to a mirroring of a thought in the brain.

i



ii



i) *The thought penetrates into the living substance*

ii) *The living substance dies (a), and the dead matter is deposited (b).*

We note that the thought is mirrored in this imprint, but does not itself pass into the material existence of the brain.

And what is the result of this process in our consciousness? As we turn our attention to a sense-impression, then the hardened thought mirrors itself, is reflected; and the result is the mental picture of this tree, this fir-tree. This mental picture is fixed, however, rigidified in its configuration. How could it be otherwise, when it is the hardened thought which is being reflected? If we carefully bring all this to consciousness, then we can begin to understand what Rudolf Steiner speaks of in the first lecture of **Study of Man, (The Foundations of Human Experience)** as the "nerve-sense process in the human being."

We can only use this nerve-sense process to perceive things in the world around us that correspond to these fixed mental images to things that have already taken on a definite form. We are continually confronted with what has already come into being. Such an end product, a tree, for example, contains that form of the trunk, the crown, the leaves, etc., all juxtaposed. The inner connection between these forms, however, is a closed book to this type of consciousness. We are therefore confronted with an infinite number of riddles, and are powerless to solve them. The materialistic interpretation of the world has arisen out of such powerlessness.

This conception of the world has no relationship to the feeling human soul; since of course in striving for total objectivity all inner feelings and experiences are to be strictly avoided. For centuries the feeling soul has been excluded from cognition, and that is

leading today to the gradual decay, or decline, of the personality. So it is gradually becoming clearer that "teaching the children to breath" has an individual and a universal human dimension. What lives in our breathing above all is the feeling soul, a complicated and complex entity with a very wide range of emotions. These range from basic dull feelings of pleasure and displeasure to those of admiration, empathy, reverence. In these higher emotions the soul force of sympathy, which is active in the feeling of pleasure, is ennobled. If we admire someone's character, then sympathy is active there; but this sympathy in all its warmth is completely illuminated by the spiritual light of understanding. In feelings of empathy the soul force of sympathy, so narrow and egocentric in feelings of pleasure, is selfless, and has become a power of deep understanding, opening itself to what concerns another being. And wonder? We come face to face with something and feel: this contains something which greatly exceeds what I know and understand. We have the feeling that we have to reach into the depths of our own being to bring to the surface something which is spiritually adequate to complement the impression causing our wonder. Wonder is like a resonance deep in our own being. If this resonance is not there, then we just find the whole experience to be rather strange and peculiar.

When such feelings do arise in the soul of a human being in his or her interaction with the world, then we can be sure that this person must have a significant development behind them. For these spiritualized feelings have arisen through transformation, by ennobling more elementary feelings. And when such feelings arise in children's souls, then we can be certain that the souls of these children had passed through definite stages of development, of experience, before they united themselves with their physical bodies.

Let us assume that someone has a favorable destiny, in that he or she has many experiences that stimulate feelings of pleasure and joy. As we have already mentioned, a feeling of joy causes the soul to expand. The soul's inner life is stimulated in such a way that the sympathy streams towards what is causing the joy and unites with it. When this person dies, amongst many other things this activity of joy lives on in her or him. For life after death consists above all in what has been stimulated in earthly life being permeated with spiritual forces in the higher worlds, and thus brought to fruition. When something matures, is brought to fruition, then it is not only reacting to external stimuli, but is working from within outwards. In this manner the joyful feeling, in which the soul has united itself with something other matures and ripens, and out of the joy there develops the faculty which enables us to actively experience with our forces of sympathy what another being is. Joy becomes empathy, understanding on a soul level, an active, inner participation in the other. A predisposition arises which enables us to experience the world quite differently, much more deeply and intensively than in previous incarnations. What we are considering at the moment is what Rudolf Steiner refers to in the first lecture of **Study of Man, (The Foundations of Human Experience)** as the spirit-soul - the soul-spirit is something quite different. The significance of the spirit soul, which comes to life in the breathing, is that, by means of the varying emotions of the spirit-soul, the young child and the adolescent come to an experience of the world.

In what we experience when we meet another person, look at a beautiful landscape or a work of art, there lies far more than just what we perceive with our senses. What we can experience when we see a rosebush in bloom, a wonderful view, or a work of art, has far greater depths than the individual particulars we can establish through observation. And if we are filled with a sense of wonder when viewing a work of art or a tree, then out of this wonder there arises the question as to its hidden essence or being.

In the dialogue "Theaitus", which deals with human cognition, Plato has Socrates utter the following words:

"....This is the state of a man who loves wisdom – wonder; for indeed there is no other starting point for philosophy than this (wonder)."

Initially wonder lives in the breathing; we feel: there is something in these things I do not yet understand. In this way wonder acts as a spur to us to think about things. It gives impulses to the nerve-sense process, indeed in a quite particular way. For we often ask ourselves whether in thinking about something there arises in us that which enables us to really understand it. Our feelings of wonder direct the nerve-sense process towards an inner grasping of the essence of what we are concerned with. What actually takes place in us? Here we can see how what lives in our breathing as wonder becomes an activity in our nerve-sense process, or, as Rudolf Steiner puts it: it supports it, maintains it, and enlivens it with new impulses.

This does not only hold true for wonder, but also for all deeper experiences, in which we are touched by the essence, the being of something. "Teaching the children to breath" then means: At first the children should experience things in a strong, profound way with the forces of their spirit-soul, which comes to life in their breathing. And this is what we as teachers have to stimulate and bring about. **In A Meditatively Acquired Knowledge of Man** it says we should as teachers be able to:

*"....let what we say be determined solely by the content of what we are to present. Thus we should really be in a position as we picture one thing to speak tragically, (but out of the nature of the thing itself) and then to shift over to a humorous vein as we proceed with our description, surrendering ourselves completely to the subject."*⁷

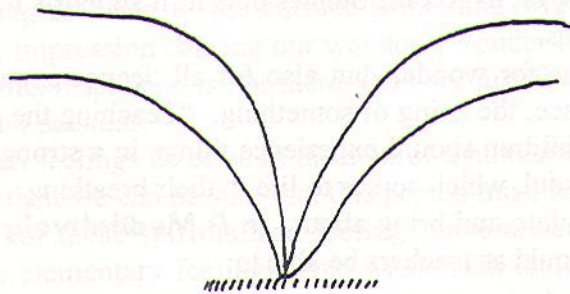
So, we are to stimulate the children to an inner experience of things, so that these experiences can then penetrate into the nerve-sense process. The feelings in these experiences thus contain something of the essence the very being, of the things they are concerned with, they are "cognition which has not yet fully come into being." That is why the following, which Rudolf Steiner describes in the passage on teaching the children to breathe, can then come about:

*"Thus the most important measures in education will consist in paying attention to all that rightly organizes the breathing process into the nerve-sense process. In the higher sense the child has to learn to take up into his spirit (into his thinking) what is bestowed on him in that he is born to breathe."*⁸

Thus the forces of feeling experience are stimulated in the child, those forces which have developed in his or her spirit-soul in that this child went through certain experiences as a human being in a previous incarnation, and passed through the world between the previous life and this present one with what these experiences had stimulated in his or her inner life. These forces now work into the processes that lead the child to an understanding of the things of his or her environment.

I should like to take a closer look at this. Let us imagine, for example, that in their lessons the children have been led to a strong experience of summer, and of the beauty of a rose bush in bloom. They have had this rose bush described to them in a way which has encouraged feelings of empathy and interest to arise. When the rose bush is then

considered on the following day, then these forces are active in the child. Because of these the child can really experience the intensity of the growth-impulses in the runners (a), which are so strong that the runner can grow to a length of up to three meters in a few weeks. The child grasps this gesture of strongly reaching out into the surroundings. The leaves on these runners do not have the simple form we find on many other shrubs (b). The child can see in their form how the impulses of growth permeate the leaves, break them up, so that the pinnate leaves point in all directions. When the rose blooms, these strong life forces are refined in the delicate pink petals. In the wide open gesture of these beautiful flowers (d) the child can gain an impression of inner devotion, even in the form of the five petals (e), which differ in a characteristic way from the forms of most other flowers. And the numerous stamens in the center of each flower are like an intensive merging into the summery atmosphere, permeated with light and warmth.



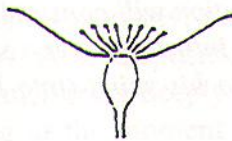
a.



b.



c.



d.



e.



f.

In the child the forces of soul-experience work right into the nerve-sense process. Each individual mental picture (runner, leaf, etc.) is enlivened by feelings of devotion and inner interest. The breathing, and the feelings that live within it, is organized into the nerve-sense process. In this way there lights up in the child a realization of the *being* of the rose, which is "a giving itself up to the surroundings of these powerful life-forces."

We can encourage the children to understand each plant and each animal in this way. When the child is listening with devotion and inner interest, he or she takes hold of the sounds of what is said in their inner nature, takes hold of the words as resounding imaginations. He or she experiences the inner nature of the tenses, the parts of speech. Similarly, through this power of devotion, the children get to know how colors relate to one another, the world of music opens up to them, etc. The example of the rose illustrates a comprehensive principle that can re-enliven virtually all areas of teaching. We can find several indications of this in the first lecture of **Practical Advice to Teachers**, which follows on directly from what Rudolf Steiner said about “teaching the children to breathe.” Organizing the breathing into the nerve-sense process this way has a twofold effect. We have seen how our weaving thought-life changes and loses its vitality as the thoughts harden into rigid mental pictures and concepts. But the feelings remain alive. Feelings are gesture-like movements of the soul. A state of devotion, for example, fundamentally affects the way mental pictures are formed when observing a rose bush. The mental pictures themselves become mobile and dynamic and then the connection between the runners, the leaves, etc., lights up in them, becomes apparent: i.e. the very being of the rose.

What here takes place in the young person is a rejuvenation of the dead life of thought and mental picturing, through which he or she comes to an understanding of the very being of things. In this understanding the forces of the feeling spirit-soul are at work. The child’s spirit-soul comes to life in this act of understanding.

This is why Rudolf Steiner says:

“By harmonizing the breathing with the nerve-sense process we draw all that is soul and spirit into the physical life of the child.”⁹

That is one of the effects. The other one is directly connected to the first. If the mental pictures and concepts are not so rigid as was described earlier, then the effects in the child’s brain are quite different. There is not such a strong extinguishing of the life-forces in the corresponding regions of the brain. The life-forces in the brain’s nerve-complexes are certainly dampened down in the mirroring process referred to previously, but are not killed off, extinguished, as intensively as they would be by rigidified mental pictures and concepts. We are hereby battling against a specific danger which is particularly relevant to present times. Space does not permit me to elaborate on what needs to be said on this point, so I will confine myself to a few sentences of Rudolf Steiner’s:

“For when the human being forms his ordinary thoughts relating to the external world, when he has quite materialistic thoughts about external events, then his thoughts enter the brain in such a way that it excretes substances (indeed dead substances) which Ahriman can very well use..... And the more materialistic we are (and therefore, the deader these substances will be), the more Ahriman takes possession of us.”¹⁰

This being possessed is increasing in the present time and will reach a kind of culmination in the year 1998; it will further the process of decline enormously. By “teaching the children to breathe” we are working against this.

It would now also be necessary to look at how this “teaching the children to breathe” can be enhanced as the years of school pass, if we are really able to carry out our

teaching in the manner indicated by Rudolf Steiner's Curriculum. This is an important, but rather far-reaching theme.

Finally I should like to mention something connected with our theme of membering the breathing, or rather the spirit-soul, into the nerve-sense process. We have seen that a way of looking at the world based solely on the nerve-sense process is quite powerless to solve the riddles of the world. On the other hand a form of cognition, of knowing, which is filled with impulses from the breathing, from the spirit-soul, leads us to understanding. What happens when we understand something? The essential nature of the thing lights up in us, as it did with the rose. And in this moment a response comes from the spirit-soul - an inner affirmation, a feeling of deep agreement. This feeling rises up from the soul and flows to that part of the brain where the insight lights up. Here it unites itself with the content of our cognition. But how does this feeling reach the brain, the region where cognition takes place? It gets there via the rhythm of the breath through the cerebro-spinal fluid. Rudolf Steiner points to this in **A Meditatively Acquired Knowledge of Man**:

".....We only understand...because the rhythmical process regulated by the heart and the lungs proceeds through the brain fluid to the brain. We can understand, because we breath."^{1 1}

So by means of this feeling, the thought, filled with essential content, unites itself with the soul. After a short time it sinks down into the child's unconscious regions. There it lives in the soul and works upon it. In this way the soul grows and expands, and feelings arise in it through which we can inwardly experience the essential nature of things. A transformation of the soul takes place, which works directly against the decline we see increasingly around us today. This is a development in a quite particular direction. I should like to illustrate this with a thought from Chapter 6 of **The Philosophy of Freedom**. In our normal feelings and emotions we are all individuals, with our own personal inner lives. We become conscious of the objective laws of the world by means of our thoughts. To begin with these are opposites. But then, by developing our feelings we can inwardly live in harmony with the objective essence of things and of the world. So our inner being raises itself more and more above the narrow bounds of personality. We are taking steps that will lead us from personality. We are taking steps that will lead us from personality to individuality.

"He will be a true individuality who reaches up with his feelings furthest into the region of the ideal."^{1 2}

We become individuals in that our feelings live in harmony with the spiritual world. This is where evolution should be heading today; it should be a transition from the personality to the individuality. This is valid above all for student teachers. They should gain a deep understanding of what I have sketched here, and really experience the significance of it right into its consequences for humanity. This can touch their feelings, perhaps even shake them deeply. Such things are an essential part of an anthroposophical teacher-training. Rudolf Steiner once characterized this in the following way:

"Now you could ask: 'Which is the right teaching method from the point of view of spiritual science?' And the correct answer would be: The best spiritual-scientific method of teaching is for as many teachers as possible to engross themselves in spiritual science

*in a living way, and to acquire the feelings that come from spiritual science. This is less convenient, of course, than reading a text book on the art of spiritual-scientific education....But spiritual science itself must become life. Spiritual science must be absorbed and brought to life within us."*¹³

That means, however, that student teachers must go through a process during their training that helps to transform the personality into an individuality. Anthroposophical pedagogy has its appropriate place not on the level of personality, but on that of individuality.

* * * * *

END NOTES

1. Alensbacher Berichte 1986 no. 14.
Spiegel Spezial, "Die Eigensinnigen," Nov. 1994.
2. Rudolf Steiner, **Anthroposophie- ihre Erkenntniswurzeln und Lebensfruchte**, (GA78) Lecture 1, Aug. 29, 1921 Stuttgart, (untranslated).
3. These graphs come from *Individual Respiratory Patterns Affecting Metabolic Processes and CNS Functions*, by K.E. Schaefer in **A New Image of Man in Medicine**, Vol. II. New York 1979.
4. Hans Jonas, **Das Prinzip Leben**, p. 68 Munich, 1994.
5. Rudolf Steiner, **Guidance in Esoteric Training** p. 46 (GA245) Rudolf Steiner Press 1994.
6. Rudolf Steiner, **Occult Reading and Occult Hearing**, Lecture 7, (GA 156) Dornach Oct - Dec 1914, (untranslated).
7. Rudolf Steiner, **A Meditatively Acquired Knowledge of Man**, p. 12 (GA 302a) Stuttgart 1920, Wynstones Press 1982.
8. Rudolf Steiner, **Study of Man**, p. 21 (GA293) Rudolf Steiner Press 1966, or **The Foundations of Human Experience**, Anthroposophic Press, New York 1996.
9. Ibid.
10. Rudolf Steiner, *Inter-Activity of the Good Progressive Powers and of the Retarding Forces* lecture of Mar. 14, 1913 held in Augsburg, printed in *Anthroposophic News Sheet*, no. 45/46, Nov 14, 1948.
11. Op.cit., **A Meditatively Acquired Knowledge of Man**, p. 26.
12. Rudolf Steiner, **The Philosophy of Freedom**, Chapter 6 (GA4), New York, Anthroposophic Press, 1992..
13. Rudolf Steiner, **Art as Seen in the Light of Mystery Wisdom**, pp. 122-123 (GA 275). Rudolf Steiner Press, London, 1984.



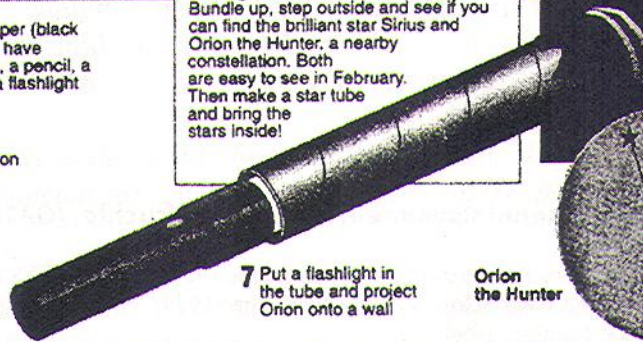
EXPERIMENT

Try this: Star tube

You'll need: Construction paper (black or dark blue), tracing paper (if you have some), scissors, a cardboard tube, a pencil, a rubber band, a thumbtack or pin, a flashlight

- 1 Cut a 4-inch square from construction paper.
- 2 Lay tracing paper over "Orion the Hunter" on this page.
- 3 With a pencil, mark each star with a dot.
- 4 Lay the tracing paper over the construction paper. Press the point of the pencil on each dot, leaving marks on the construction paper.
- 5 Using the pin or tack, punch a small hole through each mark on the construction paper. (If you don't have tracing paper, just try your best to punch holes where you think they should be).

Cold, clear nights are perfect for viewing stars with the naked eye. Bundle up, step outside and see if you can find the brilliant star Sirius and Orion the Hunter, a nearby constellation. Both are easy to see in February. Then make a star tube and bring the stars inside!



- 6 Place the construction paper over one end of the tube. Make sure the holes are over the tube's opening. Fold the excess paper over the sides and secure with a rubber band.

- 7 Look through the tube at Orion! In a dark room, put a flashlight in the tube, turn it on and project Orion onto a wall.

- 8 Go outside and look for Orion in the southern night sky. You'll find it midway between the horizon and the point straight overhead.

- 9 Find pictures of other constellations and trace them for your star tube.

- 2 Trace stars, then center on 4-inch by 4-inch paper

SOURCE: Michael Jones, 7th grade science teacher at Shumate Middle School in Gibraltar, Mich.

EXPERIMENT

MEASURING REACTION TIME

Reaction time is the amount of time required for an individual to respond voluntarily to a sensory stimulus. The ability to react quickly when confronted with danger has saved all of us from injury on many occasions. Reaction time is an important criterion for successful participation in athletics, for driving an automobile, and for performing many types of industrial tasks. It is also one of the easiest aspects of human performance to measure in the classroom.

Reaction time can be measured in a variety of ways. In all cases, the testing procedure must be followed carefully to minimize variation in the results. Students at all age levels can design and perform their own experiments, testing the effects of varying degrees of fatigue as well as prescription and non prescription drugs (including caffeine and nicotine). These experiments can be an excellent introduction to the fundamental procedures used in scientific data collection and analysis. Some variation in responsiveness to different test conditions will be observed among the subjects in any sizable group.

Reaction Time Ruler

The simplest and least expensive method of measuring reaction time accurately is with a reaction time ruler (available from Carolina Biological Supply). The ruler is similar to a yardstick, except it is scaled in milliseconds (ms) to correspond with the progressive acceleration of a falling object. This test can be performed by groups of two or three students, with one serving as the subject, another as the releaser (of the reaction time ruler), and the third as the recorder of data. Reaction time measurements are performed in the following manner.

1. The subject sits upright in a chair.
2. The releaser stands facing the subject and holds the "release" end of the reaction time ruler at eye level (or higher) between the thumb and index finger (Fig. 1)
3. The subject positions their thumb and index finger over the "thumb line" of the reaction time ruler. The space between the subject's thumb and index finger should be approximately 3 cm (1").
4. When ready, the subject must tell the releaser to start. The releaser may then drop the reaction time ruler *at any time* within the following 10 seconds. It must not be thrown downward. At no time during the test may the releaser look at the subject (to prevent non verbal cueing).
5. The subject tries to catch the reaction time ruler between his thumb and index finger as soon as it begins to fall.
6. When the reaction time ruler has been caught, the point corresponding to the center of the subject's thumbnail should be noted. This point represents the number of milliseconds that passed before the reaction time ruler was caught. If the thumb is not centered over a time mark, interpolate the reaction time (185 ms) as shown in Figure 2.
7. After at least 10 practice drops, the next 10 measurements should be individually recorded. The average (mean) of these 10 measurements is the subject's reaction time.



Figure 1

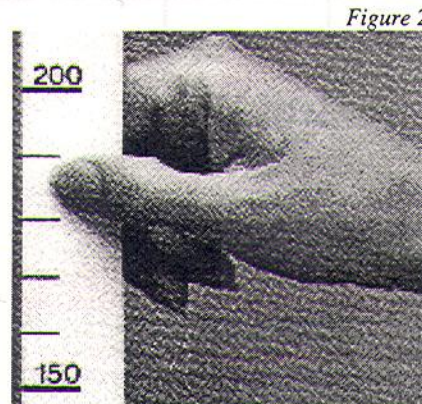


Figure 2

ADDITIONAL EXPERIMENTS

Regardless of the testing method employed, several interesting further experiments can be performed as classroom demonstrations or by interested groups of students as special projects. Since considerable variability in individual responsiveness to the test conditions may be expected, it is wise to use several subjects and examine the results for trends.

Try examining the effect of attention, by having the subject count backwards (100, 99, 98 ...) while awaiting the drop period.

Also, the influence of caffeine (e.g., from Pepsi) on reaction time could be measured over a two hour interval.

MEASURING REACTION TIME (continued)

REACTION TIME EXPERIMENTS

Peripheral Nerve System

DATA TABLE

Reaction Time

Name _____

Date _____

Trial No.								Comments
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Total								
$\bar{X}^*$								

$$*\bar{X} = \frac{\text{Total}}{10}$$