



Waldorf Science

Explorations in Phenomenology as Practiced in Waldorf Schools

A Science News Roundletter

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VOL. 11, #20

Spring 2005

FROM THE EDITORS

This edition of the *Newsletter* represents the sole edition for this year. As important articles come to our attention or as requests come from Waldorf teachers we will continue publish.

A significant amount of attention has been spent on phenomenological science in the past two years. The biannual AWSNA Delegates' meeting has had consistent presentations. The Research Bulletin of the Research Institute for Waldorf Education, Renewal Magazine, the Waldorf Science Newsletter, and the Waldorf Journal Project have all published important articles. This month the first of a three part seminar sponsored jointly by the Waldorf High School Research Project and The Research Institute will be hosted by the Waldorf School of Saratoga Springs. Titled "Teaching Sensible Science" and led by Michael D'Aleo of Saratoga Springs, Gary Banks of the Pine Hill Waldorf School, and Lilli Anthon of the Halton Waldorf School in Canada the intention will be to bring the partici-

pants to an active experience of phenomenology through "knowing how you know." Barbara Richardson will weave her magic by engaging the participants in Eurythmy that will be directly connected with the content of the seminar. This unique approach will be evaluated at its conclusion and the sponsors hope that it will breathe life into the science curriculum of Waldorf sixth, seventh and eighth grades.

The editors hope that you will appreciate the depth of the two main articles in this edition. "How does Sense-Nerve System Activity relate to Conscious Experience?" is addressed by Dr. Siegwad Elsas while Dick van Romunde engages in an article entitled "About Formative Forces in Vertebrates and Human Beings."

As always we welcome your comments, written contributions, and suggestions as we explore the important field of the sciences with emphasis on phenomenology.

Books of Interest

AWAKENING INTELLIGENCE

by Magda Lissau

Waldorf education awakens intelligence at developmentally appropriate times and prepares students for life through exercising a variety of thinking models. In this compelling book Magda Lissau unfolds the process of intellectual consciousness and discipline as practiced in the Waldorf school. After reading this book one will become aware of the depth that the curriculum provides for each student.

ISBN #1-888365-57-9

152 pages 6.5 X 9 inches \$14.00
AWSNA Publications



THE TEENAGE EDGE

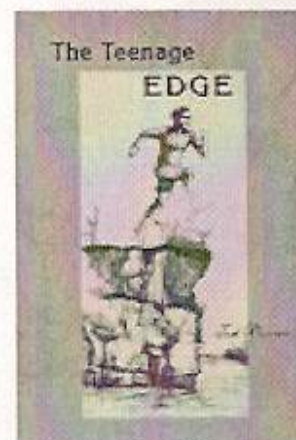
by Ted Warren

Teenagers are seeking to discover a sense of Self during their adolescent years. This search is often lonely and perilous. Ted Warren explores the spiritual significance of this journey with many compelling examples. At the rear of the book he provides a workbook for teachers and parents to assist them in positive involvement. Valuable for parents, therapists, doctors, and teachers, this book provides healthy insights and positive advice on this crucial stage of development.

Many teenagers as of the age of eighteen will also enjoy reading the book to better understand their own paths and to support their friends.

ISBN: 1-88365-51X

254 pages 6 X 9 inches \$15.00
AWSNA Publications



Uprightness, Weight, and Balance: Human Biology in Grade Eight

by Claudia Allgoewer, Andreas Bielfeld-Ackermann, and Manfred von Mackensen

This book presents a phenomenological study of anatomy for the eighth grade. Included are practical exercises that the students undertake to discover the scientific basis for upright-ness, balance, and their polarity with gravity or weight. Many illustrations help to visualize the underlying concepts.

ISBN #1-888365-53-6

92 pages 6 X 9 inches \$12.00
AWSNA Publications



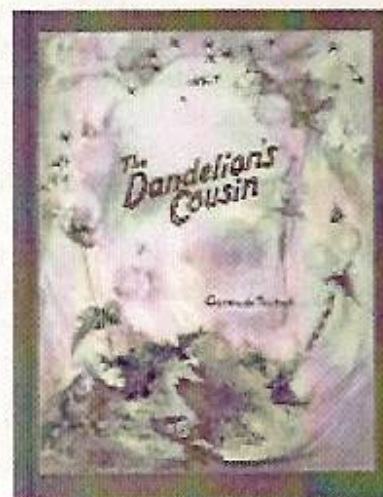
THE DANDELION'S COUSIN

by Gertrude Teutsch

This wonderfully illustrated story of the dandelion follows its many transformations through life. Children and adults alike will find joy in the adventure.

ISBN: 0-932776-31-0

36 pages 8.75 x
11.25 inches
\$13.75
Adonis Press

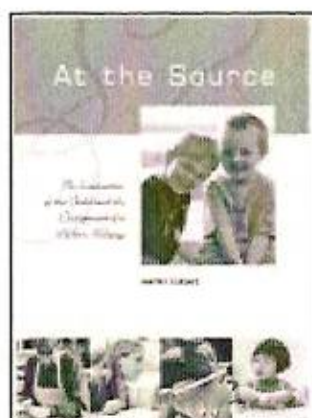


AT THE SOURCE

THE INCARNATION OF THE CHILD AND THE
DEVELOPMENT OF A MODERN PEDAGOGY

by Harlen Gilbert

Children pass through stages of development. The author's unique understanding of these developmental stages based on Rudolf Steiner's spiritual research helps parents and teachers to participate in healthy interaction and guidance.



ISBN: 1-888365-58-7

232 pages 6 X 9 inches \$16.00
AWSNA Publications

COPERNICUS: STRUGGLE AND VICTORY

by Heinz Sponsel

Translator: Monica Gold

This lively biography is an established treasure in Germany. Translated by Monica Gold it depicts the life struggles and striving of the Polish astronomer Nikolaus Copernicus. It is of value as a reader for seventh and eighth graders.



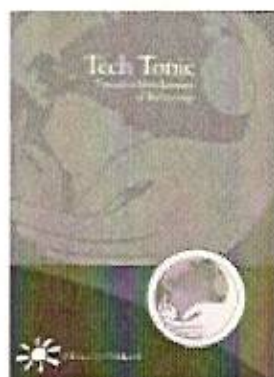
ISBN #1-888365-59-5

180 pages 5.5 X 8.5 inches \$10.00
AWSNA Publications

TECH TONIC: TOWARDS A NEW LITERACY OF TECHNOLOGY

by The Alliance for Children

"Tech Tonic demonstrates clearly, and with abundant evidence, the harm being done to children and youth by their too early and too unregulated exposure to technology. Its call to action is equally clear, direct, and doable. I hope with all my heart that the message of Tech Tonic gets heard, not just by parents, but by those creating and merchandising the many harmful products now available to children and youth." David Elkind, Ph.D., Professor of Child Development at Tufts University, and author.



115 Pages 8.5 X 11 inches \$14.50
AWSNA Publications

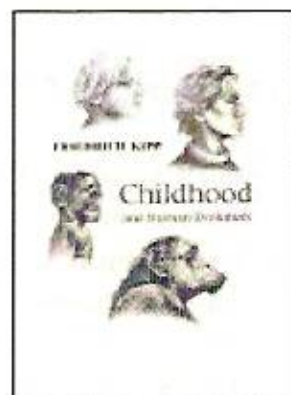
CHILDHOOD AND HUMAN EVOLUTION

by Friedrich Kipp

Kipp's comparative study of the youthful stage in animals and human beings shows an interesting perspective on human evolution and the human's relation to the animal primates.

In the primates the childhood qualities are lost quickly as the animal adapts to environmental questions.

This important book will be of values to teachers, biologists, parents and anyone investigating the place of the human being on earth.



ISBN 0-932776-33-7

123 pages 5.5 x 8.5
Adonis Science Books

A Sampling of poems for Botany

The earth laughs in flowers.

— Ralph Waldo Emerson

To look at anything, If you would
know that thing, You must look at
this green and say 'I have seen spring
in these woods,' will not do - you
must Be the thing you see: You must
be the dark snakes of Stems and ferry
plumes of leaves, You must enter in
To the small silences between the
leaves, You must task your time And
touch the very peace They issue
from.

— John Moffitt

While we are born with curiosity and
wonder and our early years are full of
the adventure they bring, I know such
inherent joys are often lost. I also
know that being deep within us, the
latent glow can be tanned to flame
again by awareness and an open mind.

— Sigurd Olsen

I held a blue flower in my hand,
probably a wild aster, wondering
what its name was, and then
thought that human names for
natural things are superfluous.
Nature herself does not name them.
The important thing is to know this
flower, look at its color until the
blueness becomes as real as a
keynote of music. Look at the
exquisite yellow flowerettes in the
center, become very small with
them. Be the flower, be the trees,
the blowing grasses. Fly with the
birds, jump with the squirrel!"

— Sally Carrighar

Let a man once begin to think
about the mystery of his life and
the links which connect him
with the life that fills the world,
and he cannot but bring to bear
upon his own life and all other
life that comes within his reach
the principle of reverence for
life ...

— Albert Schweitzer

Silently a flower blooms,
In silence it falls away-,
Yet here now, at this moment, at
this place,
The world of the flower, the
whole of the world is
blooming.
This is the talk of the flower, the
truth of the blossom;
The glory of eternal life is fully
shining here.

— Zenkei Shibayama

And the world cannot be discov-
ered by a journey of miles, no
matter how long, but only by a
spiritual journey, a journey of
one inch, very arduous and
humbling and joyful, by which
we arrive at the ground at our
feet, and learn to be at home.

— Wendell Berry

DSM

How does Sense-Nerve System Activity relate to Conscious Experience?

An Anthroposophic Approach to Neurology

by

Siegward M. Elsas, M.D.

In 1780, Galvani found that frog muscles twitch when they come in contact with two different metals; simultaneously he discovered a new source of electrical currents and the foundations of modern neurophysiology [1]. He thought he had found the "essence of life" energy in electricity. Since his time, we have increasingly used electrical technology to study brain function. With the ongoing progress in electrical technology, we have become capable to construct robots, which are capable of sensing and recognizing their environment (including voice recognition), and which are able to perform meaningful acts such as greeting guests or cleaning the kitchen (Fig. 1). Is our brain a sophisticated computer, and are we humans really robots? What would be the moral consequences on society, if we only thought of ourselves in this way?

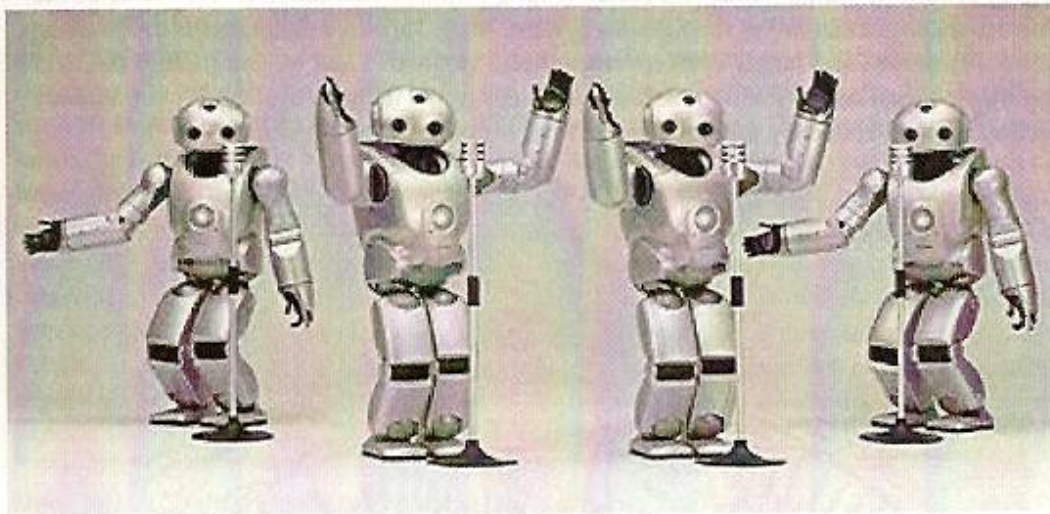


Fig. 1. The Sony SDR-4X is a bipedal humanoid robot. According to Sony, the 2-foot-tall, 13-pound offspring of Sony's Digital Creatures Laboratory can recognize faces, learn new vocabulary, fetch things, and almost hold "conversations." It sings and dances, too.

Let us review the phenomena and findings of electrophysiology. We will try to let the phenomena themselves speak. If we connect a loudspeaker, a voltmeter or a monitor to the human body by means of several wires and skin electrodes, and use a good amplifier connected to an electric power source, we will detect some electrical activity. Most obvious and easily recordable at almost any point on the body will be the electrical activity of the human heart. This activity is commonly described as electrocardiogram (EKG), and we can recognize its rhythmical activity as synchronous with our heart beat and pulse. In a similar fashion, we can record electrical activity from all muscles by proper placement of our electrodes. In contrast to the heart, which tends to have a regular rhythm, the rhythmical electrical activity of our muscles, which are called action potentials, increases dramatically in speed, or more accurately, in frequency, when we exert our muscle strength. For many patients, who have an electromyogram (EMG) performed for diagnostic purposes, it is quite an experience to see how their intentional effort is reflected immediately and accurately in the output of the loudspeaker or the EMG monitor second by second.

Nerve Senses: Touch, Pain, and So Forth

With more effort, e.g. by properly placed needle electrodes, it is also possible to record electrical activity directly from the peripheral nerves or the posterior part of the spinal cord. Again we find rhythmical activity, now at even higher frequencies than in the muscles, which is no longer synchronous to an outer movement. Instead, this recording can be quite painful due to the irritation of the nerves; however this pain can lead us to further insights of the nature of the activity of the nerves. When we pinch the skin area to which the nerve is connected, we may find that the frequency of the electrical activity in the nerve increases according to the intensity of the pinch. Of course, the stronger the pinch, the more pain we feel from it as well. Thus, it seems that the intensity of our pain experience is reflected in the frequency of the electrical activity in the nerve or spinal cord. Feeling the pain is really a personal and internal experience which cannot be observed from outside like a muscle movement. Similar observations can be made just from touching the skin. Maybe the pain or the experience of touch could be described like an inner movement in the arena of our consciousness. When another skin area is pinched or touched, which is not connected to the nerve or the portion of the spinal cord from which we are recording, we will not find a response. In this way, we find that the spatial organization of the nervous system is closely reflecting the functional organization of our body. Specific skin areas correspond to specific peripheral nerves, to specific portions of the spinal cord and brain stem, and finally even to specific portions of the thalamus and cortex (Fig. 2). This phenomenon is referred to as the "somatotopic organization" of the nervous system. More sensitive skin areas are associated with thicker nerves and larger corresponding brain regions. Thus we can picture the ever changing electrical activity along all these pathways in the nervous system as continuously reflecting both in frequency and in location what is going on on our skin.

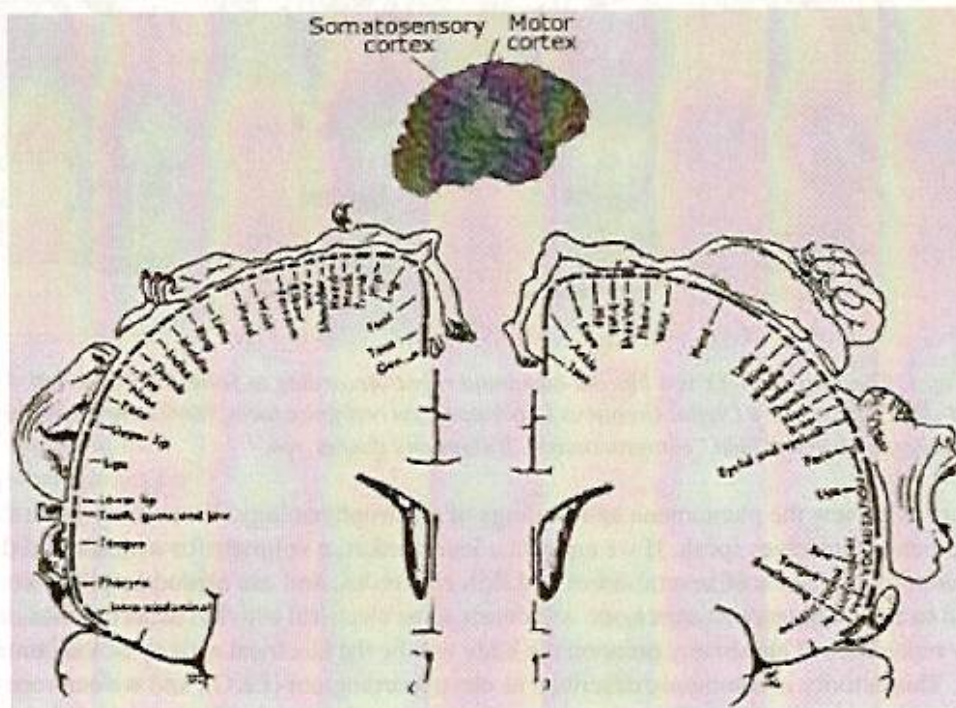


Fig. 2. Somatotopic organization of "somatosensory cortex" (left) and "motor cortex" (right).
(After Penfield & Rasmussen)

Sensory Activity

With even more sophisticated recording techniques, it is also possible to record electrical activity from our sense organs and the corresponding nerves, such as the ears and the cochlear nerve and brain stem, and the eyes, the optical nerves, thalamus and optical cortex. In each case, we can find how both the properties of an observed external object (a flower, an

animal or another person) and of our inner sensory experience (a color or shape, a tone, a melody or words) become immediately and accurately reflected in the frequency and the distribution of electrical activity of the examined sensory system. Thus, in analogy to the somatotopic organization, we can also speak of "tonotopic" organization of the auditory nerve, the medial geniculate region of the thalamus and the auditory cortex in the temporal lobe [2] as well as of "retinotopic organization" of the optical nerve, the lateral geniculate region of the thalamus and the optical cortex.

We can also record the overall electrical activity of the brain, by placing electrodes evenly spaced over the entire skull; this is referred to as an electroencephalogram (EEG). We find a mixture of frequencies, ranging from about 1 wave per second (1 Hz) up to 16 Hz in standard recording, and with more sophisticated analysis we may find activities up to more than 500 Hz. The most striking observation in studying the complex patterns of EEG activity is their dependence on our state of consciousness. By far the easiest distinction to make from EEG recordings is whether the individual from whom it is being recorded, is awake, drowsy or asleep. If he or she is falling asleep, we can tell exactly when he or she is becoming drowsy, possibly more accurately than by external observation. Again we find how the electrical activity of the brain accurately reflects our inner experience, in this case the state of our consciousness.

Nerve System as Mirror

Taking together all these striking phenomena of nervous system physiology, we may arrive at an archetype of nervous system function. In contrast to all other organs, which develop their own function in the body, e.g. the lungs take in the air to refreshen the blood, the liver builds up and secretes proteins for the blood, the kidneys filter the blood and secrete urine, the heart stops the blood flow and creates blood pressure, the nervous system does not have a function on its own. Instead, like a mirror it reflects in its activity everything else that is going on around it. In neurophysiology terms this is referred to as "representation". The electrical activity of the nervous system, more precisely its time structure in many frequencies, reflects how and where we touch something with our skin, it reflects what we see and hear around us, it reflects the activity of our inner organs via the autonomic nerves, and it even reflects our intentions to move and what we feel and think. All described sensory experiences, which are reflected in the time-structure of brain electrical activity, are internal experiences, which we might call "mental images."

Does Nerve System Produce Experience?

If this is the case, we may be tempted to think that the electrical activity of the nervous system actually does have a function on its own, namely in producing our inner experiences, or mental images, as well as our outer movements, similar to how the liver produces proteins for the blood and excretes bile. Let us examine this hypothesis. If this hypothesis were true, electrical activity of the nervous system would be both necessary and sufficient for our inner experiences and body movements to occur.

To test its necessity, we need to examine where all or part of the nervous system electrical activity is eliminated and see what functions are left. All physiological electrical activity is based on the relative concentration of salts in solution, specifically the difference between concentrations of anions in the blood and inside the nerves and muscles. If this balance is disturbed by loss or increase of salts, or by a change in properties of the dividing membranes, global dysfunction of the nervous system is the result. Similar to experiences caused by excessive deep breathing (hyperventilation), we may feel tingling of the skin, especially on the most sensitive areas such as hands, feet and around the lips, our muscles may involuntarily contract or be limp and cease to follow our will, and we may develop colored visual hallucinations or slowly drift into drowsiness and eventually into unconsciousness. In extreme cases, effects similar to those on our muscles may result in disturbances of heart rhythm and could cause death.

Local damage of nerves or brain tissue, as in an injury or by a stroke, will result only in the local loss of electrical activity in the nervous system. In each case, there will be a very specific loss of function, related to which part of the nervous system was affected. If a peripheral nerve is injured, we may lose sensation and muscle strength in the affected part of the limb. If brainstem or cortex becomes damaged on one side, sensation and muscle strength may be partially or completely impaired on the other half of our body. Other specific cortical brain lesions may cause loss of vision, the ability to speak or to understand, or even the ability to recognize specific objects in the presence of good vision.

The loss of comprehension of language in the presence of good hearing, or the loss of object recognition in the presence of good vision, could be described as an inability to form an appropriate mental image of the perceived sensory experience. The sensory experience remains raw, we are unable to connect a known concept to our percept. Apparently, the normal function of specific brain regions is necessary for the formation of specific mental images. In this regard, nerves and brain tissue appear similar to sense organs; when we lose the organ, we can no longer perceive objects via the particular sense quality or sensory area in question. In case of the nervous system, we lose the ability to form mental images, and with it we lose the conscious awareness of specific aspects or sometimes the whole of an object.

Taking this evidence together, we may safely conclude that electrical activity of the nervous system is indeed necessary for the occurrence of our inner experiences, body movements and even conscious object awareness.

Is Nerve System Activity Sufficient for Normal Experience

We will now test whether in the presence of otherwise general health, electrical activity of the nervous system is sufficient to produce our inner experiences and body movements. To test this, we need to experimentally induce electrical activity in the muscles or the nervous system, which is as close as possible to physiologic conditions. Let us follow the same sequence of phenomena as above and begin with the human heart. When in a medical emergency someone's heart has stopped beating, it may have stopped completely (asystole), or it may be caught in very small and fast contractions (called fibrillations). The difference becomes apparent most easily from the EKG. In the second condition, a strong electric shock by a defibrillator may stop the fibrillations and allow the heart to return to rhythmic contractions. In the first condition (asystole), the electric shock has no effect at all. In this case the electric shock cannot produce the rhythmical contractions of the heart, but is only able to stop unrhythmical activity. A cardiac pacemaker, used for irregularities of the heartbeat (arrhythmias), only has an effect when the heart is already beating. Apparently, in the case of the heart, externally induced electrical activity is only capable of modulating movement activity which is already present, but cannot initiate it.

Direct electrical stimulation of limb muscles will cause muscle twitches or sustained contractions, depending on the duration of stimulation, but no meaningful limb movements. Electrical stimulation of the peripheral nerves, e.g. during diagnostic nerve conduction studies, is quite painful and will cause similar muscle twitches or contractions. In both cases, the individual who is stimulated experiences the induced movements as involuntary and as forced from outside.

Similar to the "somatotopic" representation of touch sensations in electrical activities of the postcentral gyrus of the brain, conscious movement activity is reflected in the precentral gyrus of the brain in somatotopic fashion (Fig. 3).

► Lateral View of the Left Side of a Human Brain

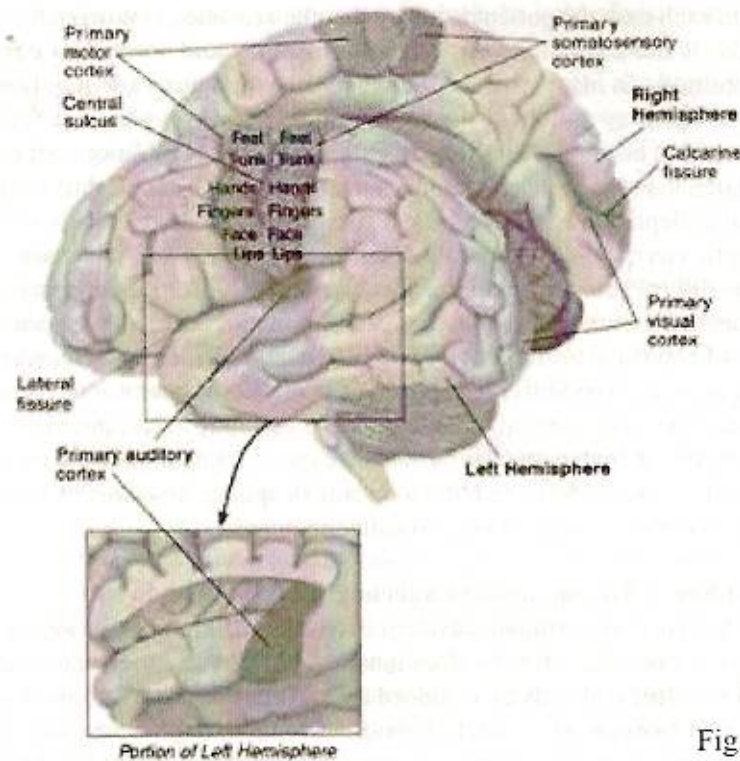


Fig. 3

When this region, termed the “primary motor cortex,” is directly stimulated by a small electrical current (a few milliamperes), e.g. during brain tumor surgery, or by transcranial magnetic stimulation (TMS) through the skull, muscle twitches or contractions similar to direct muscle or nerve stimulation can be induced. At the same time, voluntary movements are impossible during stimulation. Stimulation just anterior to this area, termed “supplementary motor area” (SMA), can induce somewhat more complex movements or even the sensation of “an urge to move.” However, such induced movements or sensations are always perceived as involuntary and as imposed by the experimenter.

A stroke in the “primary motor cortex” area results in weakness or paralysis of the contralateral limbs; damage anterior to it in the “supplementary motor area” results in apraxia, the inability to perform learned complex movements such as brushing one’s hair or teeth, using a hammer or writing with a pen. Difficulty or inability to speak while still being able to use mouth and tongue, called aphasia, is a special example of apraxia from this viewpoint. One might say that in these situations we have lost the capacity to form a mental image of the intended movement. Similar to the sensory regions of the brain contemplated earlier, it appears that intact function of specific brain regions is necessary to form a mental image of the intended movement. Seen in this way, the “motor” regions of the brain are similar to sense organs for movement since we need them to form the associated mental images. Without mental images, meaningful and conscious movements are impossible.

Can induced electrical activity in the brain produce mental images and conscious experience? Most electrical stimulations of the awake brain have been and still are being carried out in the context of surgery in epilepsy patients to remove an epileptic focus in their brain. Stimulations of primary sensory areas can induce elementary hallucinations of being touched, buzzing sounds, light flashes, and so forth. In contrast, stimulation of secondary and tertiary sensory areas, such as Wernicke’s area which is needed for the comprehension of speech, does not usually result in hallucinatory phenomena but mainly in a temporary loss of function. Stimulation of certain regions of the temporal lobe, including

hippocampus and the entorhinal cortex, can induce complex feelings such as the sensation of "I have experienced this situation before" (termed *deja vu*), fear or complex visual memories. However, in each case the patient is aware that the sensation is artificially induced by the experimenter, is not a spontaneous feeling or memory and normal awareness of the surroundings continues. In many aspects, such induced experiences are quite similar to the experiences of an epilepsy patient at the beginning of a seizure, which are called auras. Epileptic auras tend to consist of similar, stereotypical sensory or emotional experiences which do not match the sensory surroundings and are outside the control of the patient.

Even in non-epileptic individuals, cortical stimulations as described above can induce brief focal epileptic electrical discharges. Spontaneous epileptic auras are usually accompanied by electrical discharges in the epileptic focus in the brain. Thus, both situations have in common that electrical brain activity occurs out of context. As we have seen above, the normal context of electrical brain activity is to occur as a reflection or representation of sensory or other internal experience, in short, of conscious or subconscious mental images. In both abnormal situations, cortical stimulations and epileptic auras, internal experiences are elicited. However, in both cases the individual experiencing the elicited mental images is clearly able to discern that they are not real events or spontaneous memories or feelings, but that they occur out of context, similar to hallucinations.

Overall-Role of Nerve System in Our Experience

Let us take together the considered evidence for the question whether electrical activity in the nervous system is sufficient to produce inner experiences and body movements. While artificially induced electrical activity is indeed able to elicit movements and inner experiences, such induced movements or inner experiences remain fragmentary, and always have a character of involuntary or hallucinatory events. One might argue that this finding is only the result of imperfect stimulation due to technical limitations. Another view, consistent with the archetype of nervous system mirroring function developed above, would conclude that electrical brain activity in itself is not sufficient to produce meaningful movements or inner experiences. In this view, what we normally experience as our "own" meaningful movements or inner experiences would require that external realities (such as objects or changes in our body) or internal realities (such as mental images or intentions) become reflected or represented in electrical brain activity.

Such a view would also be consistent with our own natural inner experience of our thoughts, feelings and intentions. We experience them as our inner realities and not as hallucinatory by-products of our brain. We know with certainty from inner experience that the content and direction of our thoughts are independent of our body organization [6, Chapter 9]. In thinking, we are capable of finding universal truths such as $3 \times 4 = 12$, independent of who has the thought, and relatively independent of our physical or emotional state. In situations where our body does have an influence, such as when we are tired, drunk, obsessive-compulsive, or schizophrenic, our thinking becomes impaired. Usually we (or others) are then aware we cannot fully trust our own reasoning.

Similarly, we experience our intentions as truly our own, and not as involuntary reactions of our brain. Again, in situations where our body does have an influence, such as when we are intoxicated or suffer from mental illness, in short, when we are "out of control," we (or others) will know that such actions were not in line with our true intentions.

Summary

Thus, while we experience the process of thinking and our intentions as independent from our body organization, we know from electrophysiological (e.g. [3, 4]) and functional imaging studies that our thoughts or mental images always are correlated with specific neuronal electrical activity and a corresponding local increase in blood flow in the brain. Thus it appears that the thinking process, just as all the sensory processes studied above, leaves an imprint or reflection in the brain. If the corresponding part of the brain becomes damaged or lost, we become incapable of forming the particular kind of mental image which is associ-

ated with that part of the brain – just as we lose the capacity to see when we lose an eye. It seems then, that just as in all other areas of brain function, the brain does not produce the thoughts or mental images, just as it does not produce the light of vision or the strength of our movement, instead the brain serves to bring the thought or mental image to consciousness by allowing it to be imprinted. Somehow the “resistance” the brain presents to the thought images may allow them to become conscious. In this way, the brain may serve as kind of a “sense organ” for thoughts and concepts, which may have an independent existence from our being.

Steiner's Comments on Nerves and Consciousness

While comments on the function of nerves are found frequently throughout many of Steiner's lectures, two central passages are found in two key written works, *Riddles of the Soul* [5] (first published 1917) and in the 1918 edition of *Philosophy of Freedom* [6]. Both passages are given below in translation by the author (S. Elsas).

A description of thinking from the perspective of inner experience is given in [6] *Philosophy of Freedom*, chapter 9 “The Idea of Freedom” as follows:

1. He who truly comprehends what thinking represents will recognize that in perception lies only one part of reality and that the other corresponding part, which only lets the percept appear as full reality, is experienced in the penetration of perception with thinking. He will recognize that what appears as thinking in the field of consciousness is not a shadow-like reflection of a reality, but a spiritual essence resting in itself. One recognizes that the human body-soul organization cannot affect anything of the essential being of thinking.

2. It will not escape the observation how remarkable the relationship of the human organization is to thinking. She does not effect anything on the essential being of thinking, rather she retreats, when the activity of thinking appears; she abolishes her own activity, she creates a free space; and in the free space appears the thinking.

The essential being which is active in thinking accomplishes two tasks: First it pushes back the human organization in its own activity, and second it places itself in its place.

3. He who walks over a soft ground will imprint his footprints into the soil. One will not be tempted to say the forms of the footprints were pushed up from below by forces in the soil. Similarly, he who observes the essential being of thinking in an unbiased manner, will not ascribe any part in this being to the traces in the body organization, which arise from the preparation of thinking for its appearance by means of the body.

A description from the perspective of physiology is in [5] *Riddles of the Soul*, Addendum 6: “The physical and spiritual interrelationships of the human being” as follows:

“One has to connect with metabolic activity the will, with rhythmic activity feeling, regardless in which organs metabolism or rhythm become manifest. But in the nerves something completely different from metabolism and rhythm occurs.”

1. The bodily processes in the nervous system, which provide the basis for thinking in mental images, are difficult to grasp physiologically. Since, where “nerve activity” takes place, there is thinking in mental images of the usual consciousness. This sentence is also true in reverse: where thinking in mental images is not present, nerve activity can never be found, but only metabolic activity in the nerves, and some rhythmical activity.

2. Physiology will never come to concepts in neuroscience which are true to reality as long as it does not recognize that true nerve activity cannot be an object of physiological sense observation. Anatomy and physiology will need to recognize that they can find nerve activity only by a method of exclusion.

Nerve activity is that in the nerves which is not observable by the senses, but whose necessity of existence and specificity of action is given by sense-like observation.

3. One can reach a positive description of nerve activity if one recognizes in it the material process by which ... "the pure soul-spiritual essential being of the living content of mental images is paralyzed into the unliving thinking in mental images of the usual consciousness. Without this concept, which needs to be introduced into physiology, there will be no possibility to describe what nerve activity is."

The two descriptions, from the perspectives of physiology and from inner experience, may be unified by the idea that "true nerve activity is thinking activity appearing as a body process" [7]. With this idea,

1. True nerve activity is only present when thinking of the usual consciousness occurs,
2. This true nerve activity itself is not observable by the senses, only its traces or "footprints"
3. As a result of the imprinting, the living content of thinking is paralyzed into abstract thoughts and conscious awareness of them arises.

REFERENCES:

1. Galvani, L., *De viribus electricitatis in motu musculare commentarius. De Bononsiensi Scientiarum et Artium Instituto atque Academia Commentarii*, 1791, 7: p. 363.
2. Pantev, C. and B. Liitkenhoner, *Magnetoencephalographic studies of functional organization and plasticity of the human auditory cortex. Journal of Clinical Neurophysiology*, 2000, 17(2): p. 130-142.
3. Rodriguez, E., et al., *Perception's shadow: long-distance synchronization of human brain activity. Nature*, 1999, 397: p. 430-433.
4. Kornhuber, H. and L. Deecke, *Hirnpotentialänderungen bei Willkurbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale. Pflügers Archiv für die Gesamte Physiologie*, 1965, 284: p. 1-17.
5. Steiner, R., *Von Seelenratseln. Rudolf Steiner Gesamtausgabe. Vol. GA 21. 1983, Dornach: Rudolf Steiner Nachlassverwaltung*.
6. Steiner, R., *Die Philosophie der Freiheit. Rudolf Steiner Gesamtausgabe. Vol. GA 4. 1967, Dornach: Rudolf Steiner Nachlassverwaltung*.
7. Gutland, G., *Spuren des menschlichen Bewusstseins. Der Merkur*, 1994, 47(3): p. 256-268.

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Acoustics in 6th Grade

When teaching acoustics in the sixth grade I like to read the following to my students after they have had the experience of identifying the qualities of different sounds I generated from behind a screen.

— DSM

Helen Keller, blind and deaf from birth, gives a most illuminating account of her discovery of the power of the word in her autobiography. It commences with an account of her teacher taking her out for a walk:

:

“She brought me my hat, and I knew I was going out into the warm sunshine. This thought, if a wordless sensation may be called a thought, made me hop and skip with pleasure

“We walked down the path to the well-house, attracted by the fragrance of the honeysuckle with which it was covered. Some one was drawing water and my teacher placed my hand under the spout. As the cool stream gushed over my hand she spelled into the other the word water, first slowly, then rapidly. I stood still, my whole attention fixed upon the motion of her fingers. Suddenly I felt a misty consciousness as of something forgotten – a thrill of returning thought and somehow the mystery of language was revealed to me. I knew then that w-a-t-e-r meant the wonderful cool something that was flowing over my hand. That living word awakened my soul, gave it light, hope, joy, set it free! There were barriers still, it is true, but barriers that in time could be swept away.”

“I left the well-house eager to learn. Everything had a name, and each name gave birth to a new thought. As we returned to the house every object which I touched seemed to quiver with life. That was because I saw everything with the strange, new sight that had come to me.”

One will find it extremely profitable to pause for a time and to meditate on the burden of that passage. Projecting oneself into Miss Keller's experience can suddenly awaken an awareness of the word, and how it is in reality the human being's light – our power to know.

Fun Facts of Physiology

HEART & BLOOD

The heart is a hollow muscle which weighs between 8-12 ounces.

The heart beats 104,000 times every day

The blood makes more than 1,000 circuits/ day.

Every day 2,000,000 (two million) blood cells per second are produced in your body.

LUNGS

We breathe 23,000 times a day.

The surface area of your lungs is 1,000 square feet. This is 20 times greater than the surface of your skin.

EYE

The eye blinks 17,000 times per day; this would totals 30 minutes if all at once.

We move our eye muscles 2000,000 times per day.

The eye can distinguish 8 million differences in color (hues).

Your eye and brain can build color from waves of energy.

EARS

Your ear can distinguish more than 300,000 tones.

NERVES

Nerve impulses travel at the rate of 350 feet/second.

Every night we move 40 -70 times during sleep.

MUSCLES

If all 600 muscles in your body pulled in one direction you could lift 25 tons.

The tongue is the strongest muscle for its size in the body - the gluteus maximus (rear end) is the biggest.

DIGESTION

Your digestive tract is 30 feet long.

HAIR

In the average lifetime your hair will grow 25 feet.

We lose 45 scalp hairs every day.

BONES

The body has 206 different bones, more than half of these are in your hands and feet.

The human skull is made up of 29 different bones.

One cubic inch of bone can withstand a two-ton force.

The foot has 26 bones, 107 ligaments, 19 muscles, all of which interact in an intricate manner.

The interior of the spine looks like melted icicles. It has two distinct areas which allows the bones to be both light and strong - (1). the dense, ivory-like outside, and (2) the airy, canal-like interior.

SKIN

Every day we shed 14.4 million dead skin particles (keratin).

A square centimeter of skin has: 100 sweat glands, 12 feet of nerves with 100 nerve endings, 10 hair follicles, 15 sebaceous glands, and 3 feet of blood vessels.

The skin has 2 million pores to rid the body of water, salt, and other wastes. We eliminate 500 grams of waste products every day. This creates body odor.

Every pound of excess fat requires 200 miles of capillaries to support it.

When we shiver we involuntarily warm our body.

About Formative Forces in Vertebrates and Human Beings

by
Dick van Romunde¹

Two forms of thought exist. The first form is intellectual thinking. Its character is analytical in that it focuses attention on parts of the sense perceptible world. In physics, attention is directed to the smallest parts, and through this the whole of perceptible appearance takes on the character of the "sum of the parts." Similarly, in biology, thought is increasingly directed towards the development of genetic engineering. The second form of thought has a distinctly synthetic² character because attention remains strongly focused on the totality of sense perceptible phenomena: the gestalt³ and behavior of humans, animals and plants, the totality of landscapes, or the starry heavens. This second form of thought can be called "experiential thinking".

Because synthetic experiential thinking plays such a small role in contemporary science, it will be helpful to further characterize it through a few examples. A skilled social worker gave a lecture about his experiences during the treatment of a very disturbed young man. Initially, he was unable to make contact with the young man and asked himself how he could get in touch with him. Then he got the idea to imitate the young man inwardly and outwardly to the best of his ability (of course without the man being present). He tangled up his hair, took on the young man's grumbling way of speaking and his shuffling way of walking, etc. To his surprise, in the course of time the man was less rejecting in his attitude and the social worker started to have access to him. As a result of this breakthrough, which took quite some time to achieve, the young man was accepted into a social community that had previously rejected him. It may have become clear from this example that experiential thinking is related to the way a gifted actor experiences his or her role.

The question can be asked if this way of thinking is useful as a scientific method. A confirming answer can be found, among others, with the famous European biologist Adolf Portmann⁴. He not only possessed a clear intellectual mind but also had a considerable talent for drawing, and his books were illustrated by his own hand in an admirable way. In the introduction to his book *At the Boundaries of Knowledge*⁵, Portmann distinguishes between the two above mentioned forms of thinking. To illustrate his idea, he uses a comparison between a play and natural scientific thinking. The audience in the hall perceives the play with their senses: the language of the gestures, the facial expressions, and the use of the actor's voice to depict the characters are experienced and taken in. Truly great actors are masters of this experiential, imitating way of thinking. We take a different perspective when we look at what goes on backstage. This is indirectly perceptible to the viewer, but necessary to perform the play: the light and sound installations, the design of the costumes, the makeup, and so forth. This is the technical side of the performance and the intellectual thinking of the various technicians play a large role in bringing it about.

Portmann asserts that both forms of thinking are necessary in scientific research to prevent our impression of nature from becoming one-sided and purely mechanical. Such a circumstance would lead to a major denial of the impressions that natural phenomena make upon most of humanity, which can be expressed with the words: *Natura Artis Magistra* (Nature is the teacher of the arts).

When the famous poet Johan Wolfgang von Goethe⁶ was asked about his religious views, he answered that if you cannot bring together art and science in yourself, you will need religion; if you can, then you are religious. That this pronouncement is connected to the essence of Goethe's being is evident in his studies of the changing forms of plants published in his *Metamorphosis of Plants*⁷. Goethe experienced a "gesture

language" in these changing forms, and he considered the whole of nature as a book written in this gesture language. He strived to understand this language through an inward artistic rendering. Goethe wrote about this hidden capacity in the human being as a desire for art and imitation (see *Scientific Studies*⁸, a volume of selected scientific writings by Goethe).

In this article, the attempt will be made to show something of the gesture language expressed in the forms of vertebrates. The work of Adolf Portmann and Hermann Poppelbaum⁹ will also be used with gratitude. It is a good idea however, to begin with a specific description of the method underlying the formation of thought, which was described by Rudolf Steiner¹⁰ in a lecture given October 3, 1920¹¹. Rudolf Steiner's intention is to go beyond the boundaries of natural science through the indicated path of schooling with its two parts: one related to perception and the other to thinking.

The aim is for one to silence pure intellectual thinking while perceiving. Intellectual thinking is inclined to systematize: while perceiving a plant it will be directed to the question of family, species, common name, and other facts. In so doing, the taking in of form and color is thwarted and the possibility of sincere veneration subdued. If we find the strength to silence our intellectual thinking during perception, then we intensify the reception of the object in such a way that our inward imitation is awakened. This leads to a clear and expressive picture that remains in our memory. This picture must be subjected to a "meditative treatment" when, from time to time, it is called back into memory while intellectual thinking remains silenced. Through this treatment our imitation of the object becomes ever stronger and we begin to experience inwardly the forms and movements of plant, animal, etc. We can by this means come to know the forces that underlie the perceived object. We perceive these forces through our experiential thinking.

The state of "inner silence" in relation to intellectual thinking cannot be achieved without a great deal of effort. When we are in a museum to admire the paintings of masters and direct our attention toward the visitors, it can be surprising to see that only a few allow sufficient time to take in the art. You get the impression that many people do not give the artwork the time to truly speak to them. For the few who do, the words of the great Flemish poet Guido Gezelle¹² resound: "If the soul listens all things speak a living language".

To achieve the very patient experiential way of thinking, Rudolf Steiner recommends schooling through the study of his book *Philosophy of Freedom*¹³. Its content is such that the reader is continuously guided in the use of this living experiential thinking and by this means it becomes stronger. Experiential thinking also gives one the strength to silence intellectual thinking wherever it is a disturbing factor. (It is obvious that intellectual thinking is in many cases extremely useful and has to be applied. In many cases, however, experiential thinking needs to be given priority.)

The application of this experiential thinking method, which is based on the activity of inwardly imitating, can be directed to a variety of fields. In this article attention will be directed to the physical structure and posture of the vertebrates and the human being in the sequence they have appeared on earth in bodies possessing a skeleton. This sequence is: 1. Fishes, 2. Amphibians, 3. Reptiles, 4/5. Birds and Mammals and, 6. Human Beings.

Fishes

The majority of the fishes are distinguished by an almost horizontal spinal column and a vertical symmetry plane. The "unpaired" fins – dorsal fin, caudal fin and anal fin – exist in this symmetry plane. These fins and this body plane dominate the appearance of the fish. The vertical symmetry plane can be the starting point for the imitation. The body of the fish "arises" from the vertical symmetry plane as a broadening in the directions perpendicular to it. Over its horizontal length, the polarity of the clenched head and the radiating caudal fin becomes visible in the structure of the fish (Figure 1).

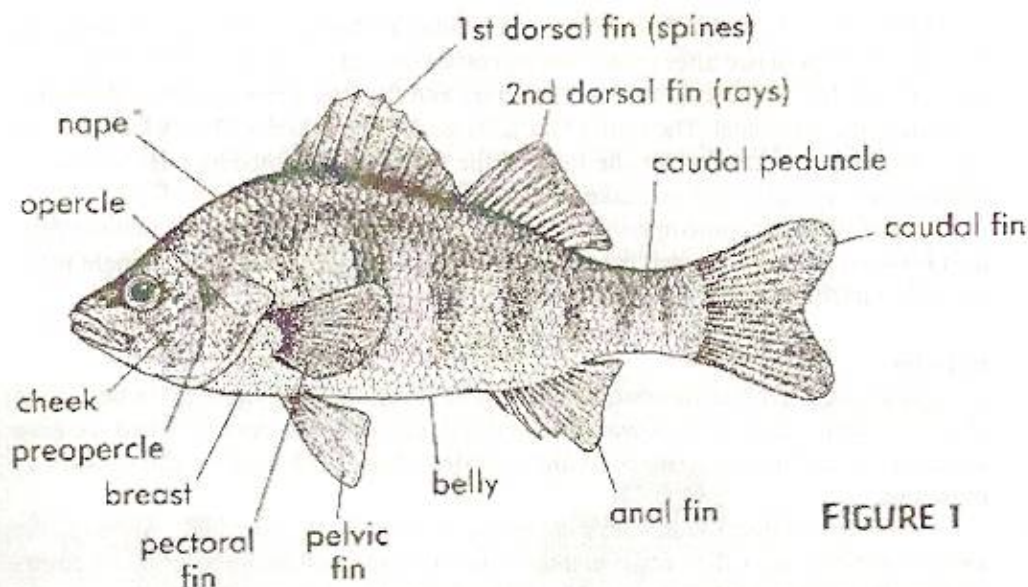


FIGURE 1

Another polarity appears in the paired fins: in front, immediately behind the head, are the two pectoral fins connected to the head through a small shoulder joint and, further back, are the two pelvic fins which have no bone connection with the skeleton. Both are expressions of the polarity existing between the clenched head and the radiant tail. The degree to which the pelvic fins are disconnected from the skeleton is also expressed by their location: some fishes have them close to the anal fin while others are located close to the pectoral fins.

The connection with water is expressed by the extent to which a fish skeleton is calcified. In the so called cartilage fishes to which the shark belongs, the skeleton remains in the cartilage phase. In the boney fishes, to which most fishes belong, calcification is less than in other vertebrates. The connection with solid matter expressed by calcification is considerably less in fishes than in other vertebrates.

A remarkable variation to the described main theme of physical structure appears in fishes having a strong connection with the ground, such as the sole or plaice. These fishes have a body that secondarily relates to the horizontal symmetry plane. The transition from the vertical to the horizontal plane takes place when the fish is very young. During the transition period the eye which would be on the bottom side moves to the top side. A still more remarkable variant appears in the sea horse with its dominant verticality.

Amphibians

Three orders of animals belong to this group. One of the three orders includes frogs and toads, which have their spinal columns slanted in a slightly upward direction. The second order includes salamanders, which have their spinal column primarily in the horizontal plane. Frogs, toads and salamanders have four legs. Limbs are missing in the worm-like animals of the third order, the caecilians.

Frogs, toads and salamanders undergo a metamorphosis in their early state: they are born "fish-like" with external gills and live exclusively in the water. After their metamorphosis they can also live on land.

The salamanders have a long tail, which in some cases is half the length of their body. The front and back legs do not differ much in their structure, although the number of toes is different. The salamander hardly lifts itself from the ground.

When frogs and toads are adults they no longer have a tail. A considerable difference can be observed between the front and back legs: the back legs are much longer and more muscular than the front legs. The back legs allow these animals, especially the frogs, to make remarkably long jumps.

When we apply the method of mental imitating to the form of the salamander and the frog, we experience after some time an enormous and essential difference between the horizontality of the salamander's structure and the frog's structure that slants upward from the horizontal. The form of the salamander is emphasized by its long tail and earth-bound movement, while the form of the frog is highlighted by tail loss during metamorphosis and jumps that take it off the ground.

In the following contemplation of reptiles and mammals, it appears that the contrast between horizontality and the action of a vertical impulse toward the upright is the main characteristic in the structure of vertebrates and the human being.

Reptiles

The above described contrast, between those forms that are bound to the horizontal and those forms that move toward the vertical, comes to expression when we give attention to the famous series of extinct reptiles whose skeletons we can observe in museums.

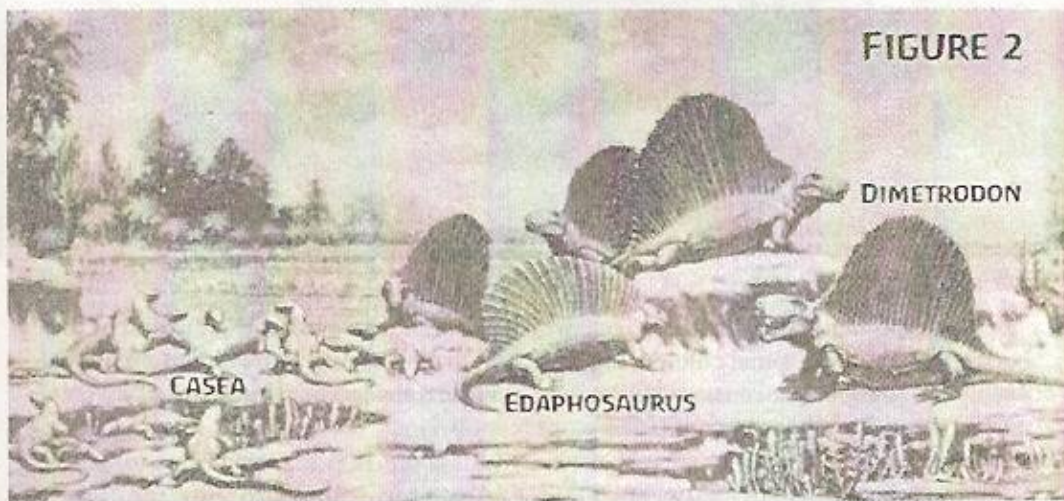
We begin this discussion with a contemporary reptile: the crocodile. Although the form of its body has a clear resemblance to the salamander, through its armored covering consisting of horned scales on a thick skin, it is strongly closed off from the external environment. Consequently, it makes an earthy impression upon the observer. This contrasts with the fact that a crocodile can reach high speeds on land while chasing prey. The crocodile's unmistakably horizontal body structure is emphasized by its very long tail.

Table 1 – Geologic Relative Time Scale

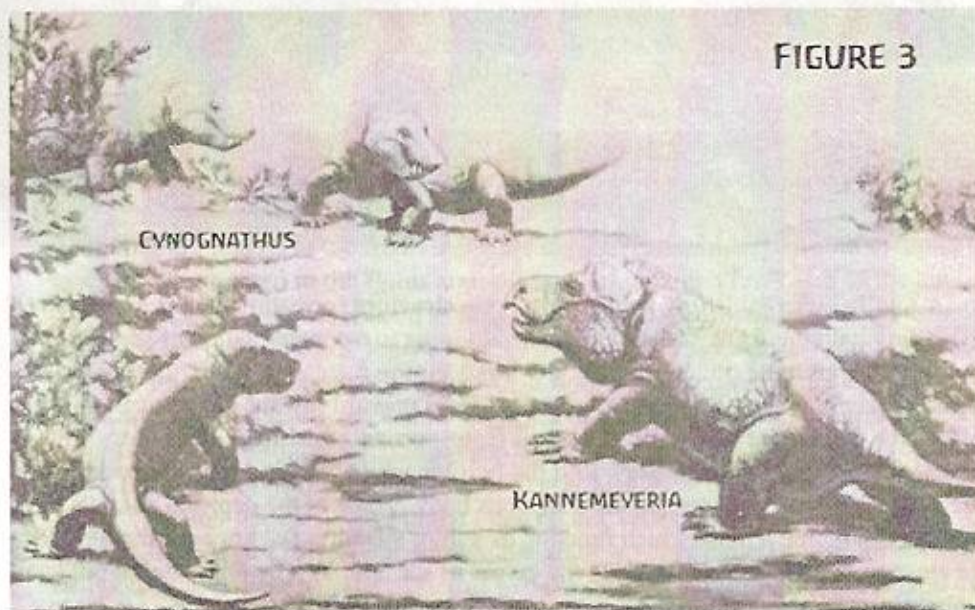
Eon	Era	Period	Epoch	Time	↑	Events
Phanerozoic	Cenozoic	Quaternary	Holocene	Present	↑	Modern Humans
			Pleistocene	10 k ya	↑	First Humans
		Tertiary	Pliocene	1.6 m ya	↑	
			Miocene	5 m ya	↑	Abundant Grazing Mammals
			Oligocene	24 m ya	↑	Large Running Mammals
			Eocene	37 m ya	↑	First Bats, First Whales
			Paleocene	58 m ya	↑	First Placental Mammals
	Mesozoic	Cretaceous		66 m ya	↑	Flowering Plants
		Jurassic		144 m ya	↑	First Mammals
		Triassic		210 m ya	↑	First Dinosaurs
	Paleozoic	Permian		245 m ya	↑	Aggregation Of Pangaea
		Pennsylvanian		285 m ya	↑	Coal Forming Swamps
		Mississippian		320 m ya	↑	First Reptiles
		Devonian		360 m ya	↑	First Amphibians
		Silurian		410 m ya	↑	First Insects
		Ordovician		440 m ya	↑	First Land Plants
		Cambrian		500 m ya	↑	First Fish
		Pre-Cambrian		550 m ya	↑	Earliest Shelled Animals, Earliest Fossil Record Of Life

When we focus our attention on the many extinct reptiles, we discover that the same contrast found in the amphibians between salamanders and the frogs can be found in the extinct reptiles as well. Many of these prehistoric reptiles have a physical structure with a strong horizontal character: the spine is almost parallel to the surface of the earth. When contemplating these reptilian forms, it is noticeable that some of them have raised this horizontal plane away from the earth, although the extent of it varies. To illustrate this idea, consider the following examples of four footed (quadruped) reptiles from different periods, including the Permian, Triassic and Cretaceous (see Table 1).

Figure 2 depicts animals with spinal columns as close to the ground as the crocodiles (Permian).

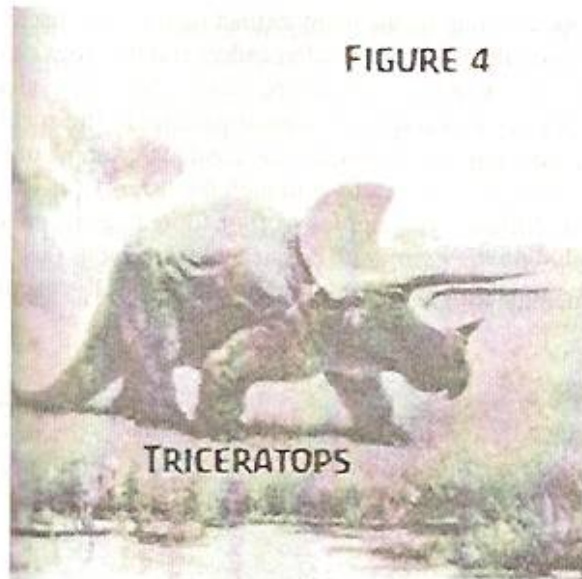


The spinal columns of the reptiles shown in Figure 3, although horizontal, are somewhat elevated from the ground. These animals still have the upper part of their four legs (thigh bone) directed to the side. The lower parts (shin bone) are almost but not completely vertical (Triassic).



The horizontal spinal column of the Triceratops shown in Figure 4 is much more elevated from the ground. Not only are the shins almost vertical to the earth, but the position of the leg above the knee also approaches verticality (Cretaceous).

FIGURE 4



All of the depicted animals have a tail that is rather thick and long.

It is important to take these images, which show an increase in the elevation of the horizontally aligned spinal column, together with the increasing verticality of the limbs deeply into our consciousness with the help of inward rendering. This series of images covers the crocodile through the triceratops.



A totally different lifting tendency in body structure formation can be experienced by starting with the amphibian frog and then moving to a contemplation of some extinct reptiles. The animals pictured in Figure 5 and Figure 6 lived in the Cretaceous time. These are reptiles with a spinal column that slants upward toward the vertical. A large difference can be seen between the small front legs and the heavy hind legs of these animals. The front legs withdraw into the heights while the hind legs are completely directed to carrying and moving the enormous body. Three of the depicted animals have tails of remarkable length, which function as a third support. The knees of the hind legs are close to the body, which adds to the height of the animal. The long, drawn out head is also a remarkable feature.

When these images are called to mind for some time using the method of inward rendering, the experience can be as follows. A strong elevating formative force is expressed in the orientation of the spinal column, yet the formative force doesn't com-

pletely raise the spinal column to the vertical orientation that dominates the human body. Through this experience of the diagonally slanted structure of the two legged (bipedal) reptiles, we see that both types of formative forces are expressed: those that bring about verticality and those that bring about horizontality.



Birds

The appearance of a flying bird differs from the same animal on the ground. In the air, the bird's horizontal stance dominates, while on the ground, the bird's posture is more or less upright. The thoughtful observer may be of a mind to imagine both pictures. If the observer focuses on a bird moving over the ground, then its more or less diagonally erect form can be revealed. The degree of erectness can be seen to vary from a slight amount with the duck to a greater amount with the parrot. In two-legged reptiles, the effect of the elevating formative forces is coupled with a significant dissimilarity between the front and rear legs. This difference also appears in birds, but in a way completely opposite to the two legged reptiles. Whereas most of these reptiles have mighty rear legs that provide mobility and rather small front legs, the emphasis in almost all birds is on two well-developed front limbs that have formed into wings and hind legs that are rather lean.

It is important to become very conscious of the contrast between earth-bound and air-bound vertebrates. By this means we receive the impression that this contrast is not only founded on adaptation, but much more on a relationship between the formative forces. The formative forces found in birds are related to the air. The formative forces in reptiles are related to the fluids and solid matter. The formative forces in reptiles are in most cases related to the fluids and solid matter, and in a few cases to the air.

In the case of reptiles related to the air, the emphasis is on the front legs which are much longer than the back legs. Those of the *Ramphorhynchus* are almost six times longer; those of the *Pteranodon* more than four times longer. Thin skin membranes enabling the animals to "fly" are connected to these long front legs, similar to bats (mammals) which flutter through the air. These reptiles lived in the periods of Jurassic and Cretaceous divisions of the Mesozoic era. The birds discussed later, with only a few exceptions, appeared later in the more recent Tertiary era. It was in this later time that the front legs evolved into wings that show a very refined and complex feather structure enabling these newer animals to develop a true art of flying. The build of the flying, fluttering reptiles, it is possible to see an early impulse of the formative forces connected with the air that eventually comes to complete expression in the birds.

The relationship between the flights of birds and movements in the air made a deep impression on the famous biologist Konrad Lorenz¹. For many years he observed

the behavior and flight of jackdaws² belonging to a colony living on the roof of his house. Lorenz describes the art of the jackdaws' flight in *A Conversation with the Cow, the Bird and the Fish*³. "At first sight it seems that the wind plays with the birds as a cat plays with a mouse. But the roles are reversed: the birds play with the storm. Over and over they let the storm almost be in control. They let themselves be thrown high up into the air – it seems that they are falling upwards – then they turn on their back with a casual turn of one wing, for a split second they open their wings against the wind, and then crash down with a speed seemingly faster than a falling stone. Again, with a small turn of their wings they return to their normal position of almost closed wings and dash at full speed hundreds of meters westward against a storm wanting to blow them eastward." The almost incomprehensible mobility of bird flight shows its relationship to the air with its mixture of turbulence and currents.

The bones of most birds are hollow; instead of marrow they contain air. This quality points not so much to a necessary adaptation to save weight, but instead points to their essential relationship with the air. This idea is supported by the fact that small songbirds have marrow in their bones while the earth-bound ostrich has hollow bones.

Because the air is the main carrier of sound, through their songs, many songbirds bring to expression another relationship that birds have with the air. After all, a bell rung in a vacuum does not make a sound.

The many migrating birds demonstrate another connection to the air. No other state of matter is as encompassing as the air. The problem of worldwide air pollution points to this fact. Migrating birds show their worldly character and accomplish travel distances of more than 7,500 miles. To this group belong the stilts, whose breeding place is the within the Scandinavian Arctic Circle and their summer hibernation place is in New Zealand.

Mammals and the Human Beings

Most mammals have a spinal column that deviates only slightly from the horizontal, although the neck can become erect to a varying degree. A few mammals have their entire spinal column such that it points diagonally upwards, more or less approaching verticality. The elevation of the horizontal spinal column leading in the course of time to our horses, donkeys and zebras has, through many discoveries, become so well known that one speaks of it as a primary example in geology. This development took place in the Cenozoic era, the most recent of the three main eras of geology, which is further divided into the Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and the contemporary Holocene epochs (Figure 7).

The ancestor of the modern horse, named Eohippus, was about the size of a fox terrier; its five fingers and toes were "reduced" to four, which indicates a weak influence by the elevating formative forces. As the effects of the formative forces continue to increase, the horizontal spinal column becomes elevated and the neck becomes more erect. Under the continued influence of these formative forces, the reduction of toes and fingers increases such that only the middle of five remains in the hoof of the modern horse (Figure 8). The elevation is also expressed in the ankles and wrists: they are positioned halfway along the length of the leg between the ground and body. The elbows and knees are very close to the body. In the course of development from Eohippus to Equus, the modern horse, the neck moves diagonally upwards.

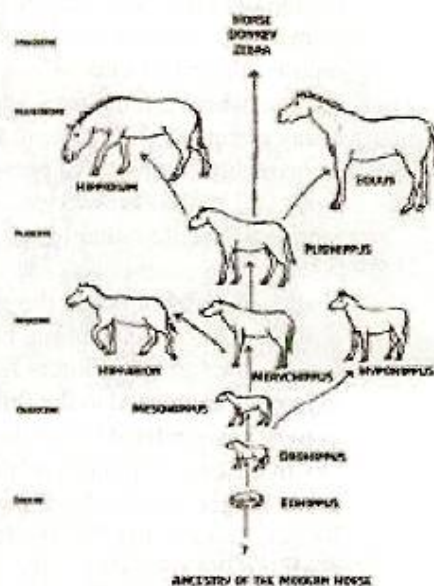


FIGURE 7

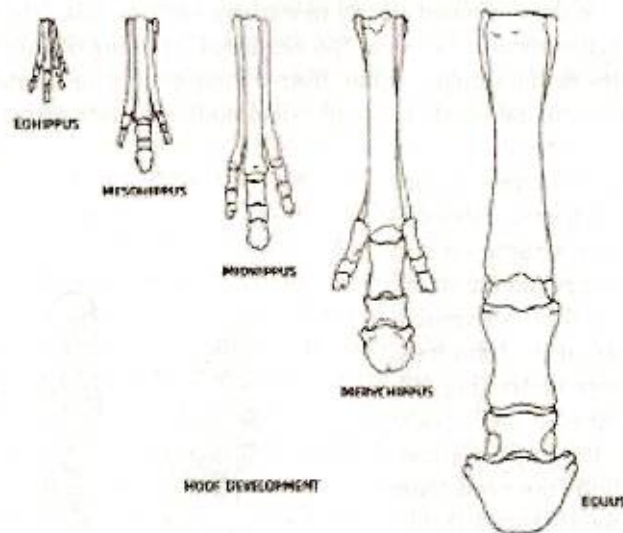


FIGURE 8

Similar to the horse, the elk is an animal that has this important elevation of its structure. Although the elk retains not one but two parts from the reduction of the toes and fingers, in the male elk this is brought into balance by impressive antlers during most of the year. This arrangement makes an impression on the serious experientially thinking observer as being founded by formative forces that lead upward (Figure 9).

If we also focus our attention on the movements of horses and deer, it is possible to notice that they not only develop great speed, but also seem to make great jumps effortlessly.

A much stronger "faithfulness to the earth" is displayed in the structure of feline mammals than in hoofed animals. The reduction of fingers and toes is almost not realized in the catlike mammals: in five fingers it is not realized at all and in the four toes it is only partially realized. The "wrist" of the front legs is close to the ground; the "ankle" of the hind legs is in many cases slightly elevated from the ground. Most cats, including the panther, tiger, leopard and our modern house cat are natural low-to-the-ground stalkers.

Members of the canine family, to which wolves, foxes and dogs belong, are more elevated from the ground than the cats. Although the reduction of fingers and toes in dogs is equal to the cats (five fingers on the front legs and four toes on the hind legs) the proportion between the length of the legs and the length of the body by which the elevation is measured, is substantially larger in the dogs, which stand high on their legs. (The proportion of the length of legs to length of body in dogs is between 0.6 and 0.8 and in cats between 0.3



FIGURE 9

and 0.5) This difference is demonstrated clearly in the way the cats stalk. The way dogs stalk looks "amateurish" when compared with the "professional" stalking of catlike animals.

The tendency to elevate the spinal column, from a more or less horizontal direction to a diagonally upright direction, manifests in the physical body structure and stature of a relatively small number of mammals.

In the kangaroo this movement toward verticality is coupled with a remarkable disparity between its heavy structured and strongly muscular hind legs and the small, somewhat delicate front legs. Movement is only possible by way of the hind legs, while the front legs facilitate feeding. Although this tendency toward the vertical clearly manifests in the kangaroo, verticality in the build of the body does not come completely to expression (Figure 10). The sole of the foot points obliquely backward, the shin obliquely forwards, and the thigh again obliquely backward. The chest is also directed obliquely forward. The formative forces creating verticality play a strong role here, but they still don't penetrate the whole physical structure of the body.

The formative forces creating "verticality" in the apes manifest much more strongly than in the kangaroo (Figure 10). The hind legs of the ape can be placed almost completely vertical under the body. On closer inspection, it is apparent that complete verticality has not been achieved:

1. When the ape is observed moving over the ground with increasing speed, its very long front limbs are being used.
2. The head of the ape demonstrates through the strong frontward directed jaw that horizontality continues to influence its shape. Dr. Hermann Poppelbaum discussed the development of the head of a chimpanzee during the first weeks after birth, referring to the research of A. Naef¹. Poppelbaum pointed to the initial resemblance between the heads of chimpanzees and human beings and the changes in the form of the chimpanzee shortly after birth when the jaw shoots forward and the rounded back of the head changes into an angular skull. These changes clearly occur in a horizontal direction (Figure 11).

FIGURE 10

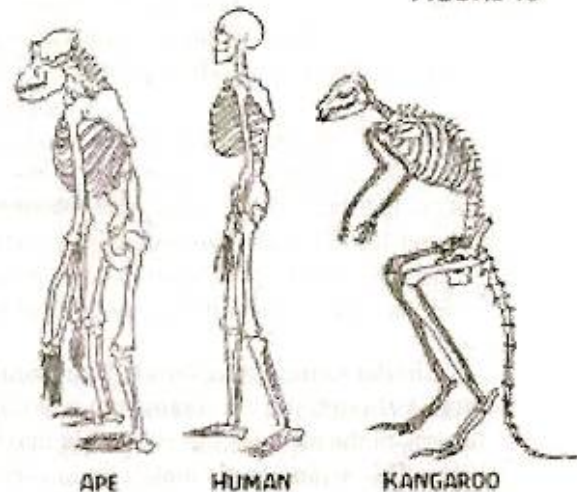
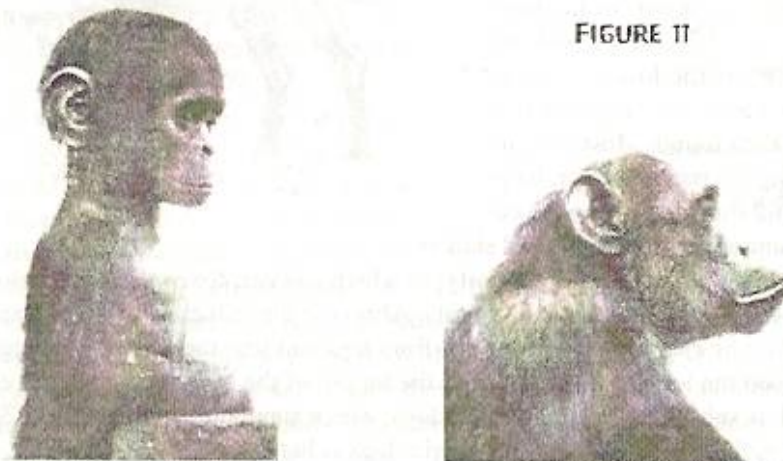


FIGURE 11



When at last we contemplate the human form with the imitating, experiential thinking method, then we experience the dominating effect of the formative forces that lead to verticality (middle form in Figure 10). The spinal column of a healthy human being remains vertical during waking hours. When the head develops, the curve of the back of the head remains and the jaw does not change in the horizontal direction.

If we inwardly imitate these forms for some length of time, one can have the impression that only in the human being is verticality dominant. H. Poppelbaum said "Only man takes the vertical into himself". When this impression is connected with the fact that the human being has the only physical organism with the capacity to think, the question can be asked whether conscious thinking is related to the vertical structure of the human body. I am aware that some people are inclined to contribute some thinking capacity to animals. I have the impression that this inclination is the result of a true admiration of the great wisdom in the animal kingdom, often far exceeding human wisdom. But this wisdom is instinctive or inborn because it is largely transferred from the parents to the young animal. As far as I am aware, a strenuous thinking process does not take place in the animal similar to the thinking process the human being knows. Strenuous work is necessary to develop our human thinking capacity, and this can not take place without lower, middle and higher education. Even when this development has been somewhat successfully achieved, we as human beings are still confronted with riddles that point to the limitations of our acquired insights. My use of the word "thinking capacity" is connected with the perceptible efforts necessary to acquire insight. The wisdom of animals has a more or less instinctual character; it is part of the almost unlimited wisdom that rules in Nature.

Pondering this impression for some time can lead to the insight that the uprightness of the human being expresses a certain holding back. In order for our faculty of thinking to advance, it is necessary for the human being to hold back the more animalistic instincts, drives and desires and, in so doing, strengthen the faculties of contemplation. From experience it is known that contemplation has a beneficial influence on social life. This way, the reverence and non-sentimental warmth of soul for humans, animals, plants and minerals is increased. It seems plausible to me that we as human beings carry the potential of contemplation and holding back in the soul and spiritual life, and that this potential comes physically to expression in the vertical structure of the body.

This idea opens a perspective for a future evolution leading to the ennobling of the human being and harmony in the social sphere. The poet Johann Wolfgang von Goethe experienced this ennobled "future human being" as a spiritual reality and expressed it in the first six lines of his poem²¹ entitled "The Divine";

Noble be man,
Helpful and good!
For that alone
Sets him apart
From every other creature
On earth.

NOTES:

- ¹ Dick Von Romunde was born October 20, 1916 in the Netherlands. He studied electro-technical engineering at Delft University of Technology and worked as a teacher in the Geert Groote School in Amsterdam for twenty-two years. Since 1971 he has worked with the Goetheanistic Natural Science Foundation. He is the author of articles and several books on natural science based on a phenomenological approach, including *About Formative Forces in the Plant World* (available from AWSNA Publications) and *Perceiving Plants: Experiencing Elemental Beings* which have been translated into English by Jannebeth Röell and James Lee. He currently lives with his wife Tila in Amerongen, the Netherlands.
- ² The action of combining separate elements of sensation or thought into a whole is the intended meaning of "synthesis". This is opposite of analytic, which is the action of separating things into their constituent elements in order to study or examine them.
- ³ Gestalt is sometimes translated as structured or physical form.
- ⁴ Adolf Portmann (1897–1982). The work of the Swiss biologist and anthropologist directly refers to Goethe's research while also using his methods. Portmann brings Goethe's science of nature into a modern context. By emphasizing organic qualities as irreducible to mechanistic and molecular ("reductive") explanation, and by using teleology of the type employed in explaining the ontogenesis of the human being, Portmann's biology and anthropology are based on principles and methods of Goethe's science.
- ⁵ Adolf Portmann. *An den Grenzen des Wissens*. The author is unaware of an English translation.
- ⁶ Johann Wolfgang von Goethe. Born in Frankfurt A.M., August 28, 1749. Poet, dramatist, scientist, traveler, state minister, etc., author of *Faust*, *Wilhelm Meisler*, and many other works. Died in Weimar, March 22, 1832.
- ⁷ Johann Wolfgang von Goethe, *Metamorphosis of Plants*, (Bio-dynamic Literature, Wyoming, Rhode Island 1978)
- ⁸ *Goethe: Scientific Studies*, edited and translated by Douglas Miller (Suhkamp Publishers, New York, 1988). The passage is from "The Purpose Set Forth (From On Morphology), page 63, third paragraph.
- ⁹ Hermann Poppelbaum scientifically developed some of Rudolf Steiner's spiritual research in two books: *Man and Animal* and *A New Zoology*.
- ¹⁰ Rudolf Steiner (1861–1925) was born in Austria, and grew up with the clairvoyant certainty of a spiritual world. Recognizing the need to reconcile the experience of supersensible realities with that of the material world, he schooled himself in modern science and developed anthroposophy as a phenomenological approach to the spirit. Starting with our capacity for thinking, anthroposophy leads to an experience of the spirit in each human soul who would follow the path. Rudolf Steiner shared the results of his spiritual research in 40 books, and in approximately 6,000 lectures now available in 300 volumes. He is increasingly recognized as a seminal thinker of the 20th century and one of humanity's great spiritual teachers.
- ¹¹ Rudolf Steiner *Boundaries of Natural Science*, Eight lectures given in Dornach, Switzerland September 27 – October 3, 1920, (Anthroposophic Press, Spring Valley, New York 1983).
- ¹² Guido Gezelle (1830–1899) was a Roman Catholic priest and teacher and a highly regarded 19th-century Flemish poet. Independent of all literary movements, he ushered in a rebirth of Flemish poetry with his volume "Kerkhofblommen" (Graveyard Flowers, 1858). His poetry was a unique mixture of traditional literary Dutch with the dialect of his own West Flanders. His passionate literary and nationalistic beliefs led to conflicts with ecclesiastical and educational authorities, which caused him to stop writing poetry between 1870 and 1875. During this time he wrote essays and translations. But Gezelle returned to the brilliance of his earlier poetry in "Tijdkrans" (Time's Garland, 1893) and "Rijmsnoer" (String of Rhymes, 1897). Typically, the poems in these volumes deal with nature, religion, and Flemish nationalism and display an original use of rhyme, metaphor, and sound.
- ¹³ Rudolf Steiner *The Philosophy of Freedom* (Rudolf Steiner Press, London 1964).
- ¹⁴ Konrad Zacharias Lorenz (November 7 1903–February 27, 1989) was an Austrian zoologist and ornithologist and founder of modern ethology. He studied instinctive behavior in animals, especially in grey geese. He discovered the principle of imprinting in psychology.
- ¹⁵ "Jackdaw" is a crow like black bird (*Corvus monedula*) with a gray nape and pearly eyes. About 13 in. (33 cm) long, jackdaws breed in colonies in tree holes and on cliffs and tall buildings; their flocks fly in formation around the site. Their cry sounds like their name: "chak." The species ranges from the British Isles to central Asia.
- ¹⁶ Konrad Lorenz *Er redete mit dem Vieh, den Vogel und den Fischen*. (Vienna: Borotha Schoeler 1949).
- ¹⁷ Ibid.
- ¹⁸ Hermann Poppelbaum, *Man and Animal: Their Essential Difference* (Anthroposophical Publishing Co., 1960)
- ¹⁹ Adolf Naef Zur Morphologie und Stammesgeschichte des Affenschadels, (1926) *Naturwiss* 14: 89–97.
- ²⁰ Ibid.
- ²¹ Goethe, Johann Wolfgang (1783) "The Divine."

GLOBAL PERSPECTIVE

If we could shrink the earth's population to a village of precisely 100 people with all the existing human ratios remaining the same, it would look like the following.

There would be:

57 Asians

21 Europeans

14 from the Western Hemispheres, both
North and South

8 Africans

52 would be female

48 would be male

70 would be non-white

30 would be white

70 would be non-Christian

30 would be Christian

89 would be heterosexual

11 would be homosexual

6 people would possess 59% of the entire
world's wealth, and all 6 would be from the
United States

80 would live in substandard housing

70 would be unable to read

50 would suffer from malnutrition

1 would be near death

1 would be near birth

1 (yes, only 1) would have a college
education

1 would own a computer

When one considers our world from such a
compressed perspective, the need for acceptance,
understanding, and education becomes glaringly
apparent.

DSM

Points to Consider in Science Teaching

1. Did I arouse the interest of the children?
2. Was there "soul breathing" in the class? Did they laugh and also feel deep introspection? (A lesson without a laugh is a lost opportunity.)
3. What real images were brought as opposed to judgments or pre-formed concepts
4. Were different senses of the children properly stimulated?
5. Was the experiment clear and phenomenological?
6. Was the recapitulation without equipment successful?
7. Was a concept arrived at by the class?
8. Did I prepare the children properly for the night? Were the questions that arose from the morning lesson stimulating? Did they give back through the will today what went through the senses yesterday?
9. What new skill or knowledge did the children receive today?
10. Was every child acknowledged, and did they each produce effort?
11. What was done to get the children moving in some way?
12. How can you better apply all of the above tomorrow?

DSM

Deconstructing Black Box Aspects of a Computerized Physics Lab

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Introductory physics labs increasingly incorporate computers as powerful systems for logging, graphing, and analyzing data (Fig. 1). Situated both physically and conceptually between the external physics experiment and ideas about physics in the mind of the student, such digital systems, composed of electrical technology largely not comprehended by the student, mediate the laboratory process and may function inadvertently to inject an element of unreality and mystery into an otherwise straightforward but challenging experience. The level of mystery can be greatly reduced by briefly postponing the first physics experiment and devoting an entire lab session to a series of guided discussions and simple exercises using the computerized system in conjunction with voltage probes, batteries, and simple transducers to introduce the main features of the digital oscilloscope and establish a simple but workable understanding of the concepts *voltage*, *analog/digital*, and *sampled data*. Figure 1.

BACKGROUND

Relatively recent advances in computing technology have put small but powerful computers on the benches of many high school and university introductory physics laboratories, often as part of an integrated probe/computer/software system (PCS).^{1,2} The associated computer-based lab projects³ impress both teachers and students but not always for the same reasons. Teachers regard the remarkable automated data-logging and real-time data-graphing features as tools that permit elaborate investigations of phenomena and make physics more accessible and fun. In contrast, students may perceive this same system as just another manifestation of their easy push-button lives, where conceptually fuzzy or procedurally tedious tasks get accomplished quickly without significant investment of personal energy or much comprehension of what happened. Much in the same way, many people at the societal level respond to advanced consumer technologies with a mixture of satisfaction (the convenience of a cell phone) and bewilderment (the difficulty for the nonprofessional mechanic to repair a car laden with integrated circuits). This juxtaposition of utility and mystery, the essence of a *black box* (Appendix A), engenders a mentally passive state described by Pirsig⁴ as the *spectator attitude* wherein people are:

*"... living with technology without really having anything to do with it. Or rather they had something to do with it, but their own selves were outside of it, detached, removed. They were involved in it but not in such a way as to care."*⁴

In practice, the black boxes we encounter in modern life are often interlinked, and the "overall name of these interrelated structures, the genus of which the hierarchy of containment and structure of causation are just species, is system. The motorcycle is a system."⁵

Indeed, in the minds of many students beginning their study of physics, the increasingly popular PCS, with its probes, analog-to-digital (A/D) converter, computer and logging/graphing/analysis software, functions as an intricate black box system, as poorly understood as the electromechanical workings of the modern motorcycle.

After several years of using the PCS in a range of introductory physics laboratories, I have concluded that a preliminary introduction to its workings, prior to performing any

computer-aided physics experiments, qualifies as time well spent. Otherwise the system itself, by inadvertently imposing extraneous mystery on the discovery process, may also function as a silicon veil (Fig. 2), distancing the physical experiment from the abstractions of it in the mind of the experimenter, thus weakening the impact of *experience*⁶ in the learning process. Figure 2.

This paper presents a sequence of simple exercises and discussions designed to help students

- 1) form unsophisticated introductory ideas about electricity and concepts related to the PCS, and
- 2) develop facility in collecting and visualizing data using a single voltage probe.

DEMISTIFICATION OBJECTIVES

The PCS is entirely electrical in nature, and students need to have some idea right away about how it works even though the study of electricity generally comes later in the course. Therefore, our students go through a sequence of PCS-based activities using 1.5-V batteries and flashlight bulbs, zero-center dc analog voltmeters, small dc toy motors, audio speakers, voltage probes, and microphones whereby they appreciate the voltmeter function of the PCS; then comprehend its oscilloscope function, where the voltage generated by a probe is displayed as a function of time; then see the inherent graininess of sampled-data (discrete) representations of continuous functions of time; and finally learn the practical button-pushing basics of the system, undistracted by a formal physics learning objective.

MINI-TUTORIALS FOR THE PCS

1. VOLTS AND SCOPES

Beginning the first lab session with a class discussion about electricity enables the instructor to discover and then reinforce and expand on whatever correct notions the students may already have on the subject. After all, they have successfully dealt with electricity since childhood and have knowingly or unknowingly made functional (but not always correct) models of what goes on with batteries and wall sockets, voltage and current, ac and dc. At a minimum, some audience-appropriate idea of *voltage* should be established, even though students do not yet have a rigorous vocabulary of physics concepts. Examples include the tautological but useful "voltage is what a voltmeter measures," voltage as a measure of the capacity for doing electrical work, and the analogy between voltage and water pressure. This discussion attempts to bring some order to a few of the students' fuzzy concepts, starting right where they are.

Then students go through a sequence of short activities, first attaching a small battery to a flashlight bulb (then to a small dc motor) to become familiar with assembling a simple circuit and seeing that voltage is somehow related to useful work. Next, they measure the battery voltage with a zero-center analog voltmeter and note how the polarity of the connection determines the deflection direction of the meter.

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Fig. 1. A PCS-enabled study of the waveform and harmonic structure of a tone produced by a clarinet. The microphone (A) converts the sound sample to a weak voltage signal, which is digitized (B), amplified, recorded, and plotted in real time on the computer screen (C; see inset) along with its fast Fourier transform (FFT) showing the tone's harmonic content (timbre). Note the predominance of odd harmonics, indicating that the clarinet behaves much like a closed pipe.

Finally, attaching the PCS voltage probe leads to the battery, they discover the system to be a graphing voltmeter with voltage plotted against time. An electromechanical transducer is a device that converts mechanical motion into a time-varying voltage and vice versa. Examples of transducers include such familiar items as an inexpensive audio speaker, a small dc motor, and a piezoelectric buzzer (all available at electronics hobby shops). Normally, these devices are used to convert an applied voltage to some type of motion, but they are also reversible in the sense that each will produce a voltage in response to applied mechanical motion. In the exercises below (using first a speaker and then a motor), students apply a voltage to the device and observe the resulting motion. They then supply motion to the device and observe the generated voltage. The PCS monitors and graphs the voltage in each instance. This gives students a working familiarity with the PCS while at the same time dramatically introducing them to basic ideas about currents, the forces on a current-carrying wire in a magnetic field, and Faraday's law of induction.

Many of the various commercially available PCS probes are transducers of a more general sort, which create a time-varying voltage in response to changes in some physical parameter such as sound level (microphone; Fig. 1), temperature (thermometer), position in space (motion detector), acceleration (accelerometer), air pressure (barometer), voltage (voltmeter), current (ammeter), magnetic field (magnetometer), force, light level, or pH. The output voltage of any such probe can be recorded, graphed, and analyzed with the PCS. Students will likely use a variety of probes in various experiments over the course of a semester.

Speaker

Students attach a 1.5-V battery directly to the terminals of a speaker (8-impedance) and note that the cone moves abruptly in one direction. When the battery leads are reversed, the cone moves in the opposite direction. They then connect a PCS voltage probe to the speaker terminals to display on the computer screen the voltage pattern associated with the connections and polarity reversals.

Next, students connect the speaker (with voltage probe still attached) to the output of an audio oscillator producing a 1-Hz square wave. As they slowly increase the frequency from 1 Hz through several hundred Hz and watch the graph change accordingly, they discover that the sound associated with the back-and-forth motion of the cone begins to seem like a tone at frequencies above about 60 Hz. In some classes, it may be appropriate to ask students to pick a frequency (such as A 440 Hz) and change the oscillator output from square wave to sine wave to saw-tooth wave so that they both hear and see that the sensation of tone depends on wave shape as well as frequency.

Finally, with only the PCS voltage probe attached to the speaker terminals, students wiggle the speaker cone directly with their fingers and note the resulting time-varying voltage signal created on the screen. They conclude that the cone motion somehow generates a voltage and that the speaker thus functions as a small electrical generator. The instructor points out the tiny coil of wire (with leads to the speaker terminals) attached to the cone and explains that the voltage is created by the motion of that coil in the proximity of a nearby magnet. A shout directed into the speaker causes the speaker to function as a (rather inefficient) microphone and produces a voice waveform on the screen. The instructor can make a few audience-appropriate comments during these exercises about Faraday and electromagnetism.

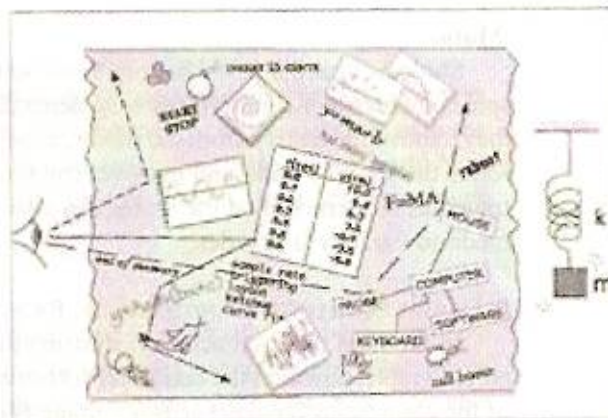


Fig. 2. Through a glass darkly. Student perception (eye) of a physics experiment (mass oscillating on a spring) through the intervening computerized data gathering and processing system.

Motor

Students attach a 1.5-V battery to the terminals of a small motor and note that the shaft spins clockwise or counterclockwise depending upon the polarity of the connection. Next, they remove the battery from the motor, attach the PCS voltage probe to the motor terminals, rotate the shaft by hand, and discover (by observing the resulting oscillating voltage record traced on the screen) that the motor can also function as a small electric generator. Again, credit to Faraday is in order.

3. DIGITAL OSCILLOSCOPE AND SAMPLING RATE

In the final directed activity, students turn off the *LINES* format option for the most recent graph shown on the computer screen and immediately see that the wiggly line record of the continuous (analog) sensor voltage is in fact a sequence of equally spaced dots, each representing the value of the probe voltage sampled at a specific sequential moment by the analog-to-digital (A/D) circuitry of the system. Turning *LINES* on and off repeatedly reveals the seemingly continuous line on the screen to be a primitive dot-to-dot interpolation of the discrete (digital) voltage sequence automatically recorded in a data file as an experiment proceeds. The uniform dot-to-dot time interval (the sample interval) is the inverse of the sample rate (number of samples/s), a parameter adjustable over a wide range of values according to the needs of the experiment.

With advanced classes, it may be appropriate to discuss various good characteristics (such as the increased dynamic range of music recorded on a digital CD versus analog audio tape) and bad characteristics (such as digital artifacts) associated with *digital* representations of the *analog* world and to mention the Nyquist sampling criterion (requiring a minimum of two samples per period of the highest-frequency signal component to be resolved). Deliberately under-sampling the known output of a signal generator creates dramatic examples of spurious (*alias*) signals.

UNSTRUCTURED ACTIVITIES

After completing the tutorials and discussions described above, students use a probe of their (or the instructor's) choice with the PCS to follow their curiosity and collect whatever data they wish, thereby gaining confidence in their ability to operate the equipment.⁶ The probe could be a microphone (Appendix B and Fig. 1), ultrasonic ranging device, thermometer, or voltage or current sensor. If time permits, students try out the probe to be used with the PCS in the following week in their first "real physics" experiment, using it to collect and view a few data records of their own choosing.

During this time of student-initiated activities, the instructor should insist that each student in a group spend an equal amount of time at the computer keyboard so that the inherent variations of personality (aggressive/shy), motivation (curious/bored), or technical experience (savvy/nave) do not restrict the learning process for any particular student.

SUMMARY

With these introductory exercises and discussions, the instructor deconstructs certain opaque boundaries of the PCS black box and thereby attempts to build a bridge between Pirsig's *romantic understanding* (primarily experiential and appreciative of properly functioning technology such as riding a motorcycle or, as in our case, watching a red line move across the computer screen) and his *classical understanding*, which comprehends that "within the lines and shapes and symbols is a tremendous richness of underlying form"⁷ linking the external experimental apparatus on the bench to internal abstractions developed by the laboratory experience.

Henceforth, the lines students see on their computer screens will have a plausible experiential context, enabling them to concentrate more on physics principles and less on the novel and distracting complexities of the now-familiar investigative tool.

ACKNOWLEDGMENTS

I would like to thank Jennifer Wilhelm, Ron Wilhelm, and two anonymous reviewers for their thoughtful critiques of the manuscript, Deena Berg for her assistance with the figures, and our physics and musical acoustics students (including Sarah Raison and Neal Mann, Fig. 1) for their questions and observations in the lab as these exercises were developed.

APPENDIX A BLACK BOX

The *black box*, a very useful item in the reductionist toolbox of model-building, is a conceptual compartment for isolating, postulating, or summarizing a certain collection of physical behaviors with no concern about the inner workings of the box. The term also connotes an encapsulated region that is unknown and perhaps unknowable, an isolated packet of mystery and convenience that increasingly characterizes many facets of technologized "culture."

APPENDIX B MICROPHONE EXERCISES

A student whistling into the microphone generates on the computer screen a waveform of the pressure variations associated with the sound (using a typical setting of 10,000 samples/s for a 0.1-s data record), and from this record the period and hence frequency of the sound can be estimated. If a tuning fork is the sound source, the deduced frequency can be compared with its actual frequency. [With the fast Fourier transform (FFT) feature of the data analysis software, students can quickly find the spectral content (Fig. 1) of any sound sample.] As students investigate various other sounds (singing notes or sustained vowels, blowing across the end of a bottle, plucking a guitar string, humming into a kazoo, etc.) they learn (driven by their own curiosity) to make appropriate choices for experiment length, sample rate, triggering and various graph display options.

REFERENCES

1. LabPro interface and Logger Pro software by Vernier Software and Technology, Beaverton, OR (<http://www.vernier.com>) and Science Workshop 500 Interface and Data Studio software by PASCO, Roseville, CA (<http://www.pasco.com>).
2. Associated Colleges of the South Workshop on Microcomputer Based Introductory Physics Laboratories, Southwestern University, Summer 2000; <http://www.colleges.org/~physics>.
3. J. Gastineau, K. Appel, Clarence Bakken, Richard Sorensen, and D. Vernier, *Physics With Computers* (Vernier Software and Technology, Beaverton, OR, 2000) and *Explorations in Physics Lab Manual*, PASCO (PASCO, Roseville, CA).
4. R.M. Pirsig, *Zen and the Art of Motorcycle Maintenance* (Bantam, New York, 1974), p. 24.
5. Ibid, p. 87.
6. D. Kolb, *Experiential Learning: Experience as the Source of Learning and Development* (Prentice Hall, Englewood Cliffs, NJ, 1984).
7. Ref. 4, p. 61.