WALDORF CURRICULUM STUDIES – VOLUME I

SCIENCE IN EDUCATION

the lanthorn press

Science in Education

Preface

Out of print reference books are often difficult to locate. Through the foresight and support of the Waldorf Curriculum Fund, this title has been resurrected and is now available gratis in an electronic version on www.waldorflibrary.org, one of the websites of the Research Institute for Waldorf Education. We hope you will find this resource valuable. Please contact us if you have other books that you would like to see posted.

– David Mitchell
Research Institute for
Waldorf Education
Boulder, CO
August 2008

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VOLUME I

SCIENCE IN EDUCATION

Introduced and Edited by BRIEN MASTERS

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Cover drawing from the main lesson book of a thirteen-year-old Waldorf student

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Upper School Sciences

Foreword

Constantly heard coming from the classroom is the call for more resource material. To respond to this call was one of the aims that resulted from a discussion at the Steiner Schools Fellowship Council meeting of 22nd/23rd November 1991. This response is finding expression in several ways. The present one is to reprint material from *Child and Man*, the publishing organ of the Steiner Schools Fellowship. Articles have been selected whose relevance for teaching remains pertinent and stimulating. *Science in Education* is the chosen theme for the first volume in the series. The series is entitled *Child and Man Resources*.

Child and Man is the longest established educational journal within the anthroposophical movement. Articles, therefore, date back to the early 1930s. They appear here mainly grouped according to age, together with a newly written introductory article that reconnoiters the field.

Some overlap is inevitable—as are also gaps. Yet the overlap shows how Waldorf teachers share a common inspirative source, which at the same time spurs them on in different directions. Nowhere is this better demonstrated than in the articles on Class 6 acoustics: one author is drawn to the mathematical proportions to be found underlying the diatonic scale; another relates everything to 'Nature'; a third revels in jam-jars, tin foil and the like (n.b., the percussion section in an orchestra is often endearingly referred to as the 'kitchen department'); a fourth links everything strongly with literature, and so on. But the reader must bear in mind that each writer is obliged, in keeping within the limits of an article, to emphasize his or her particular slant; in a main lesson block, several different approaches are not mutually exclusive. Indeed, given the truly comprehensive composition of a class of pupils in a Steiner school, a range of approaches becomes one of the necessary techniques in one's style of teaching. The 'gaps' have been bridged to some extent through the inclusion of the article "Science in Waldorf Education: General Survey," specially written for this publication.

Waldorf education is not achieved, however, merely by ticking down the checklist of curriculum content. Hence the inclusion of articles that dwell on *methodology*, or—better still, in some ways—include the methodology in their handling of the material, whether this be done implicitly or explicitly.

In view of the modern trend to insist on 'science education' right from school entry to school leaving, the list of articles liberally includes those that show how what is done in the Waldorf Kindergarten and in the Lower School is an integral part of science education. The Waldorf approach is deemed to be not only suited to the younger child's consciousness, abilities and attitudes but also a preferable and more efficient foundation for later scientific expertise, taking all aspects of professional life into consideration.

Brien Masters
Michael Hall, July 1992

Science in Waldorf Education: General Survey
by BRIEN MASTERS

Since the inauguration of Rudolf Steiner Waldorf education in 1919, discoveries in science have made unanticipated advances. At that point, developments in astrophysics, genetics, aerodynamics, nuclear science, space exploration, computer science and many other highly specialized branches were a thing of the future. Moreover we can only assume that scientific research will go on delving more deeply into matter, widening (and narrowing) fields of knowledge in the years to come. The question that everyone teaching science in a Waldorf school has to live with, therefore, is bound to be: Was what Steiner gave us as a foundation of science sufficient? The science teacher needs to be fully conscious why it is so, if it is, and at the same time, needs to develop the capacity for knowing *how* and *when* to introduce recent developments in an appropriate way.

The Historic Background to Modern Scientific Consciousness

Today we speak glibly of the Third World, often without stopping to think critically what we mean by the term. It is as if someone had provided us, as far as our conceptual life is concerned, with a vast self-adhesive label that we can conveniently stick to the atlas in our mind, thereby covering a large portion of the earth. And what is left? That part of the world consisting of states that are rapidly going down the road to realizing their full scientific-technological potential. A fundamental course for this 'advance,' in the scientifically orientated culture that has arisen, is the change in world outlook that came about at the turn of the seventeenth century.

The plays of William Shakespeare reflect this changing consciousness quite dramatically. In those plays that were written in the sixteenth century (as far as *Henry V*, *As You Like It* and *Julius Caesar*), there is much reference to the medieval world outlook, even in the way the author plays to the gallery—or the pit, as it was in the Globe Theatre. However, already in 1601 and 1602, we feel the chilly breath of the new consciousness blowing through the text. In *Twelfth Night*, a novel but rather supercilious strain of humor is exhibited; and in *Hamlet,* Hamlet struggles scene after scene with a new self-consciousness—on the one hand, it raises him head and shoulders above other characters in the play (in a sublimely tragic way), but on the other, it inhibits his will to act. The changing consciousness is manifest in an *artistic* form in Shakespeare's plays; in someone like Bacon of Verulam, we meet one of its strongest adherents in the *political* and *technological-scientific* life of the times; and through Amos Commenius we meet an example of how it seeps into men's thinking through a new approach to *education*.

Studying the teaching of science in schools within this context, we see that, in the twentieth century, one of the most influential factors has been the jockeying of world powers for supremacy in space exploration. "We are racing along the Baconian autobahn—not yet necessarily in the fastest lane. Many would say that we engaged overdrive with the launching of Sputnik I. Not unpredictable among the reactions to it was John F. Kennedy's broadcast commitment to a manned moon landing in the 1960s. Equally predictable was the ricochet felt in education: the United States' immediate upgrading of its technical syllabi; the Soviet Union's more than doubled budget in the 1960s alone; the British government's schemes launched to 'increase annual production of professionally qualified scientists and technologists.'" [1]

What is the context of science teaching in Waldorf education in view of this? Science 'proper' could be said to begin in Class 6 (ages 11–12). The Waldorf science program continues from this point without break for the last seven years of the Waldorf student's school career. At the point of commencement, the child is recapitulating, in many respects, the very change of consciousness which was referred to above. Students of this age are less dreamy, less preoccupied with imaginative forms of thinking, and more directed towards earthly affairs. They pay more attention to precise forms of thought. It is in order to meet these changes that woodwork, for example, with its sharp tools and demanding precision in both thought and action, is introduced into the craft program; that exchange rates and conversion are practiced in foreign currency problems in arithmetic; and that geography—though still presented in a vividly graphic way—is structured more *systematically*. Interfaced with these subjects, physics is introduced and is invariably welcomed by the students with enthusiasm.

Lest the enquirer into the Waldorf approach to education consider this to be too late in the contemporary scene, it will be advisable at this point to refer to the foundations that have been laid in the first five classes—and even earlier. In that science may broadly be said to concern itself with the material world, we see that in the natural course of the school curriculum, the child before the age of 11–12 years undergoes a sequence of different relationships to this material world. The way these relationships are taken into account in education forms an integral part of any educational science program.

Pre-Science: Preliminary Explorations into the Created World

The preschool child experiences the world through a condition of dreamy but devoted exploration. Experiences of the natural world are usually on a small and intimate scale at this stage, yet they are nonetheless all-engaging. One bright star shines out in the heavens and catches the attention of the child, who may be otherwise oblivious to the star-studded canopy of the complete firmament. A walk by a stream will be 'memorable' because of the shallows by the shore in which the child could paddle for a moment or because of a gnarled stick that was picked up from beneath an alder tree and thrown in, to be carried floating away on the stream's current, or because of a white marble pebble that is discovered beneath the rippling water surface and carried home like a little treasure; the topographical beauty created by the stream's course through its valley or the special flora that seeks and thrives in the moist atmosphere that continuously prevails there, all pass seemingly unnoticed. Something from this walk will almost inevitably find its way to the Kindergarten nature table. The methodology that Steiner laid such emphasis upon for the older students is already inherent in the process of the child's picking up a cone from the ground and bringing it to school so that his/her teacher and the others in the class can share in the joy and admiration it calls forth.

So the scientist, far from despising the naïve enthusiasm of the four-year-old, recognizes in it that which will eventually grow into the attitude of inquiry upon which all scientific investigation is founded. Keeping to the phenomena preserves the freedom of the student to make his/her own deductions without recourse to existing theories. The section on science teaching in Frans Carlgren's *Education Towards Freedom* (Lanthorn Press: East Grinstead, 1972) brings over this point very strongly. A finely detailed example of this approach, which is so central to Waldorf school science teaching at all levels, is also set out by Hans Gebert to show how it can be used to demonstrate the production of an electric current in an Upper School main lesson (see: "Science in the Upper School" this publication). Hence the importance of the Kindergarten with its specially cared for nook, covered with folds of muslin (plant-dyed in colors according to the season of the year), and its posies of spring vetch and primulas, or its glare of dandelions, its summer burst of sweetpeas and roses, or its rich tones of Michaelmas daises and blazoning maple leaves draped in dying splendor. The emphasis is not on knowledge with labels attached: pine bark, amethyst, sunflower seed, corncob, abalone, wren's nest ... The emphasis is on joy of discovery, beauty of form, play of light on color, love of the world "and all that therein is."

In the main lesson period, this classroom activity, for such it is, may well become less important, waxing at festivals, when the young child's link with nature is particularly intimate, waning in between. At times it will have special features, reflecting the content of certain 'nature' lessons (these will be described presently). Or there will be sudden surprises: one child brings in an off-cut of yew with a particularly striking grain; another brings in a sprig of berries; a third is excited about a solidified chunk of volcanic lava; a fourth comes in hugging a basket full of newborn kittens.

In the inner city situation, where opportunities are few, this side of classroom life might need considerable input from the teacher; but it will still remain part of the child's connection with the world of nature, at this early stage, living entirely in the sphere of *will* and *feeling*. Around this activity (the caring for the class 'nature corner'), the germ of a 'ritual' may be born: the lighting of a candle before story time, or before the cutting of the birthday cake. At the same time, the teacher will seek to extend the child's connection with the created world through an interesting form of narrative: the so-called *nature story*.

Nature Stories

Through the nature story the teacher is able to widen the connections the child has with the immediate environment. It may be the sprouting of a seed when the earth is warmed by spring sunshine; or the first flowers that appear following the thaw—snowdrops or aconites; or the polar opposite movement of the radical, seeking not the light but the darkness of earth; or the migration of birds; or the hovering dance of a dragonfly by the rushes. In an imaginative way, the children are told of such happenings in nature which are part and parcel of everyday life. For the little child, all things that comprise the world of nature—including clouds, sun, moon, stars and meteors—are able to converse with one another as characters or beings who act together.

The making of such stories is usually original, though this does not prevent teachers from borrowing and lending their ideas. The stories may be premeditated or the spontaneous result of the flush of reciprocal joy one feels as the child walks in with the first pot of this season's honey or a molted peacock's feather or a yard-long piece of sea-wrack, beach-combed over the weekend. Whether premeditated or spontaneous, a common experience of the storyteller is that, while the making of the story is in progress, some aspect of nature (which before had lain hidden) reveals itself as if by special dispensation. An attitude is cultivated whereby nature begins to 'speak,' awakening further observation, so that one begins to understand more of the inner nature of those cumulus clouds when they next sail overhead, or more of the quality of those aspen leaves as they flutter in the June breeze, or more of the rhythmic life of the ocean itself as one hears the shingle grinding on the Atlantic shore and the breakers swirling with glee. Through this kind of story, the involvement of the child in the wonders of nature at the level of *will* becomes transformed into *feeling*, while at the same time a more subtle sense of observation is awakened.

The following short extract from a nature story by a Waldorf parent demonstrates the above well. "Not long after, a porcupine ambled up. 'Um' he thought, 'this is a nice, fat nut—just right for my dinner.' He put walnut between his strong teeth and made a loud crunch. 'Ow!' he exclaimed, letting go of walnut. 'This nut is so hard it's given me a jaw-ache.' "[2] Such dialogues as these help children of this age to enter into the properties of the inanimate, material world as well as the qualities of the living world of nature.

Ages 9–10

This mode of nature study, however, would be inappropriate for the consciousness that children achieve through their next stage of development at ages 9–10. At this stage, the world of nature is presented purely through its sense appearance (though the children still *respond* with their full feeling life). To this end, in Class 4, a series of *nature lessons* is started which forms an important part of the curriculum and is the third and last stepping stone that leads towards the study of natural science itself. The three kingdoms of nature—animal, plant and mineral—comprise the focus of study for Classes 4, 5 and 6 respectively, at least three or four weeks being given over to these subjects each year as a main lesson block. Moreover, the sequence tallies with the natural development of children from the younger stage, when their participation in the world is by nature more active and lively, to the threshold of adolescence, when they gradually become happy with more sedentary occupations and more engrossed with thought.

What is stressed in the Class 4 main lesson is the threefold form of the human being: head, trunk and limbs, though at this stage, the consideration of the bony structure as such does not come into question. It is the *whole* head, the *whole* trunk, the *whole* limbs that concern us. Later, in Class 8, when the skeleton is studied, the form of each bone can be observed with the 'sculptural' eye that will have been developed by then. At that later stage the students will be able to discern the 3x3 subdivisions within the skeleton:

Within the *skull*: The cranium above leads over to the occipital region. Below is the lower jaw, somewhat pointed by comparison. This is the only combination of bones within the head that moves. In between these two are the nasal cavity and cheekbones. In this part of the head, not the bones, but the muscles move when we show facial expression.

In the *thorax*: the predominant feature is not above but in the middle. This is the ribcage, formed in such a way as to be capable of continuous, tireless movement. Above it, the shoulder blades reveal a protective quality, reminiscent of the cranium. Below are the 'floating' ribs.

Thirdly, the *limbs*: above the legs is the pelvic girdle, round now in the horizontal plane and protective. At the extremities are the limbs proper, radial and possessing through their joint structure the maximum possibility for movement. In their whole configuration the strength of their load-bearing capacity is evident. In between pelvic girdle and limbs are the *os pubis* and the *os ischium*.

The more general approach to the human form undertaken in Class 4 is followed by and contrasted with the *form* of each animal, in connection with habitat and movement. In different ways these express what lies in the animal's instinct, the form being the more outwardly observable. Drawing on the children's own observations of animals as well as on the descriptions that they bring forward, the teacher helps the children to experience how and in what way one aspect of bodily form is developed in each animal in a specialized way. There are, for example, the kangaroo's hind legs, the cuttlefish's 'ink'cloud spurting device, the elephant's proboscis, the moose's antlers, and many other examples to choose from. Each one selected is then compared with the human equivalent.

A sprinter, even before the race has begun, is up on his toes, having very little use (except in a passive sense) for his heels until the race is over and he reverts to normal walking. As the horse gallops by, churning up turf after turf in parabolic flight, the hoof, for all its thundering power, seems to be 'toe' to perfection. Even when standing still, the noble creature can be seen with 'toe' deliberately poised, be it working Percheron, thoroughbred Arab, snorting Mustang or jogging Palomino. To sit on horseback is to experience how this thrust thrills through the whole creature's legs and body at the merest touch of the rein or stirrup. What a contrast we have in the pig whose entire sensitivity seems concentrated on its sturdy snout, snuffling, rooting, foraging and grubbing around continually in mud and mire. We could equally well characterize the parrot with its built-in nutcracker of a beak, or a rabbit with its burrow-digging paws, or the mouse with its incessantly active incisors.

In such ways, the students experience the quality of each form and movement in the animal world as being superbly adapted to the species' needs. The human form, preeminently illustrated by the hands, retains something of an embryonic reticence so that development may take place in an infinitude of freely chosen directions.

It is interesting to note that Steiner did not shrink from suggesting that children, even at this early age, should learn about creatures of which first hand observation and experience would be unlikely. Hence, the children are made dependent upon the teacher's power of description which stimulates their own inner power of visualization. The following may help the reader enter into this process. It is a passage in which a Waldorf class teacher records something of the conversation which he had with his class during an animal main lesson in the fourth grade. "... [B]elow the surface of the water, far from the air and the light, there lives a creature called the cuttlefish. This creature has a rounded, hollow body. The walls of this body are like a shell. One end is closed and round, like the back of the head. The other end is like a big open mouth ... " [3] Needless to say, the teacher is entirely free to decide which animals to describe, wild or domestic, known or unknown.

Ages 10–11

Though Steiner indicates that the form of the animals selected should be compared with the *human form*, with regard to the Class 5 main lesson on plants he suggests a comparison with *human progress* from birth onwards.[4] In the seminar that he led with the group of teachers-elect prior to opening the first Waldorf school, he evolved a method of teaching this subject to children of this age, relating the plants to certain notable points in the development of the human being in an intriguing way. In the discussions that took place, he pointed out how the various categories of plants: fungi, algae, gymnosperms, monocotyledons, and so forth, achieve more and more of the full nature of the plant—ability to absorb the light, erectness and so on.

Alongside these stages of plant evolution, the comparison is made of the human being's achievements through childhood. For instance, as we watch the baby develop from its sleeping state to a more wakeful participation in life, we see its primary urges towards uprightness: the head is lifted; the whole trunk is moved;

crawling of some kind begins; it pulls itself up onto chubby little feet and stamps or bounces gleefully up and down; until finally those first unaided steps are taken. However faltering or uncertain at a physical level they may be, we also perceive the triumphant expression of achievement that radiates from the baby at this moment. It is an expression of human fulfillment. Along this route the fine motor coordination will have been concentrated in the hands and fingers. Once the gross motor coordination has become strong and rhythmic, the finer movements start to enter the realm of the speech organs. Finally they may be traced imaginatively into what is necessary for the human being to *think*. This, of course, can only be observed outwardly—in the child's power of comprehension and ability to ask questions and form sentences that have a *train* of thought.

These abilities are ultimately those by which the human being becomes independent. In this way we move to the ripening fruit of each human biography. Within the human being a *time process* is involved. In the plant world, as one moves 'up' through the different plant families, from the elementary fungus to the highly evolved rose, the same route of development is paralleled, and we see it spread out in our environment.

In the following conversation, recollected by a class teacher, an example is given of the comparison of the early fungi stage of plant life with the very first days of childhood. "Children! Before the time which any of you can remember, you used to lie in your cradle for hours on end—a hardly noticeable mound beneath neat white cotton sheets, surrounded by a veil of colored silk through which the sunlight softly filtered ... After feeding, you would gaze dreamily around or suck your toes or gurgle with pleasure ... When you walk in the woods at this time of year, with the fading light sifting through the canopy of russet and gold, or the morning mist lingering in the hollows and swathed around the ferns, you will come across plants that remind you of what you were like then ... They are the toadstools, the fly algaric, the boletus, deadcaps and truffles, or in the fields, the field mushrooms ..." [5]

Vitally important also, from an educational point of view, is the temporal nature of the plant. This may not seem to coincide with one's impression of a stand of sequoia. It is nevertheless true. Groundsel or goat's beard gives a clearer example, however. For the whole plant is never visible; we see only part of it at one time. First cotyledons, then leaves and stem unfold; then the flower and seed develop; and finally (not only with annuals) it disappears into the soil. In deciduous trees and shrubs, the woody part of the plant becomes the equivalent of the earth-soil.

Eagle, Lion and Bull

A further study of animals is pursued in Class 5, in which the three categories, epitomized by the apocalyptic beasts—eagle, lion, bull—provide the focus of the main lesson. Through this study the children are led into a more intimate understanding and inner perception of the three soul qualities: thinking, feeling and willing. This appeals particularly to the developing sense of inwardness that children experience as they step from Class 4 to Class 5, which is a prelude to the full independence of the inner life that comes about with such strength and clarity at puberty.

In this context, the eagle represents the entire bird kingdom. In folklore it is the king of this kingdom just as the lion is regarded as the king of beasts. In birds there is a remarkable freedom from earthly gravity through the extraordinary configuration of air within the creatures' bones. This, together with the graceful lift of their wings, presents a powerful image of the quality of human thinking. For through thought we can survey the facts, as it were from the heights of objectivity (the bird's eye view). In the case of a jury, objectivity is raised to the *n*th degree through the striving for unanimity and because of the deeply ingrained effect that the decision may have on a particular human destiny. In thought, we transport ourselves into other places or situations: to a lonely ice flow in Antarctica surrounded by penguins; to the banks of the Ganges with its teeming thousands; or, equally, back through the years to the moment when we rode our first bike, or walked over our first suspension bridge. With still more powerful flight (imagination) we can enter the Forum of Imperial Rome or embark upon the fearful westward trek of the slave trader. When faced with a seemingly insoluble problem, we can be reminded of the eagle's proverbial ability to gaze unflinchingly into the blinding glare of the sun itself or the buzzard's incredible command of the air currents—as we find at last a point of departure or sift through endless statistical information and facts and then wing our way to a solution.

In a similar way, but pondering on the characteristics of the lion pride, we will be able to understand, appreciate and gain our bearings in the life of feeling. Bull and cow reveal the complexity, the attributes, the virtues (and dangers) of the will forces within the soul.

Mineralogy

In Class 6 the descent is made into the mineral kingdom, which the class teacher will describe more from a topographical point of view than from a geological. The latter forms the approach to mineralogy in a later class (9) in the Upper School. On the one hand the mineral structures are shown to be the basis of a whole continental mass, such as North America or Europe; on the other hand detailed structure and scenery associated with the landscape characteristic with each mineral on the earth's surface is studied. In mountainous areas these two features unite. The Armorican folding of the Alps gives rise to the rugged and virile skyscape formed by chain after chain of Alpine peaks. This stands in stark contrast to the round-weathered ice-sculpted form of granitic Finland. Yet purely structurally we find the older rocks as well as the younger forming the skeletal framework of areas as contrasted as the Scottish Grampians or the Cordillera of the Ukon.

On the slowest of time-scales we can also find ways in which the rocks relate to different parts of the human body. The experience of youthfulness in the human limbs helps the students' understanding of the more recent, tertiary deposits such as are found in alluvial river basins and flood plains. Interestingly enough, it is these arable areas, being rich in fertility, that provide food for the human being, through the digestive system.

The breathing and blood circulation within the human body finds its parallel in the vast cycle that limestone goes through. Its rich fossil content serves as a reminder of the time when, on expansive stretches of the seabed, belonging to oceans that have long since disappeared, the thick layers of calciferous rock were being built up by the bodily remains of billions upon billions of crustaceans. This process is recapitulated, as it were, in the dissolved minerals that are washed into the ocean by rivers that have their source in limestone/chalk country. Though shorter in duration, a similar cycle is gone through: water is evaporated through the action of sun on ocean; cooling, it condenses into rain and falls upon the land masses; during the process it becomes acidic, and therefore able to dissolve the calcite as it permeates through. Some of the calcite is deposited as stalactite and stalagmite, while the rest is taken in fine solution and disgorged by the river into the ocean where the process recommences. At this point it may be an opportune moment to draw the students' attention to the impressive fact that the blood has a very similar composition to that of seawater, also to note that the function of the cells in the blood, which is to 'extract' those substance that are needed for the formation of the bones. In this way one can see how a wonderful *correspondence*—in the medieval sense of the word—exists between the rugged limestone mountain ranges, that bring the skeletal structure of the earth to such lofty expression, and the calcium in the human body, calcified and formed with such wisdom into the bones.

By contrast, the crystalline rocks seem much more static, hardy, impervious, resistant, unweatherable. These, in their unchangeably, can be likened to the form of the human cranium, particularly of the delicate nerve/brain substance within, but at the same time cooler than the rest of the organism. These are only broad divisions and others may occur to teachers, but they serve to bring the point home and help the student, through comparison and contrast, to observe the characteristics of the minerals, in the first place in their surroundings, and thereafter in the wider world.

This approach to natural history, as taken in Waldorf schools, is therefore doubly beneficial. The fact that the teacher is constantly relating the three kingdoms of nature to one aspect or other of the human being enables the younger students to find a bridge from themselves to those levels of existence which would otherwise contain no 'human interest.' Reciprocally, those perspectives of the natural world that are brought into the lessons in the ways outlined above, present the students with images of their own nature at physiological and psychological levels appropriate to their age and understanding. Thus the *last* branch of 'nature study' is placed in the same class as the *first* study in 'natural science.'

Observation of Phenomena: Cause and Effect

To understand science and scientific law, the human being needs to be able to apply that form of intelligence which can grasp the logical connection between cause and effect. With this type of intelligence the world is reduced, as it were, to that which is purely material—hence the focus in the sixth grade on the mineral world, from which any form of life that may be connected with its origin (as in limestone) has long since withdrawn and can therefore be discounted. The hardness and the composition of the skeleton within the human being is that component within us which is nearest to the mineral world. Ernst Lehrs, author of *Man or Matter* (London: Rudolf Steiner Press, 1958), connects all three phenomena: the *mineral* world, the *skeleton,* and the *human intellect*. "The intellect, therefore, can most easily grasp that which is dead in the world. In outer nature this is the mineral world, in the human being, his skeleton. Both are governed by the laws of mechanics."[6] Thus, it is this type of intelligence, applied to the phenomena around us, that plays an important role in the students' further study of science.

But this is not all. Phenomena are not perceived by the intellect: they are perceived by the senses. It is not surprising, therefore, that also in this sixth grade, the senses receive specific training, to heighten the act of perception. Two examples will be given.

Perspective

The first of these relates to how the world appears through the laws of perspective. In earlier classes, a feeling for perspective will have been gained through color. This can be done in two ways. The first is through intensifying a particular color to bring it into the 'foreground' of the picture that is being painted or drawn. As long as the picture is in monochrome, this applies to any color. The second way is through using the range of colors themselves to suggest perspective. The colors at the 'warm' end of the spectrum appear to come towards the viewer, while those at the 'cool' end of the spectrum recede. An example of this is seen in Van Gogh's well-known *Cornfield with Cypresses* (Rijksmuseum, Amsterdam). This picture, familiar to most people through reproductions, uses four basic colors: blue, green, yellow and red. The color composition is such that the blues are used for the sky and the background of the hills. Greens predominate in the middle distance, and in the foreground is the yellow of the ripening cornfield. Finally the painter puts the finishing touches to the color composition with groups of bright red poppies (alongside blotches of white chamomile and blue cornflowers, both common 'weeds' in an arable landscape of this kind). In addition to this general color composition, Van Gogh painted a sky, characteristically full of life and movement in the brush strokes, in different *shades* of blue, all overlaid with billowing white forms that are inspired by clouds. In this upper part of the picture, the darker blues are in the foreground (overhead) and the paler blues, fading eventually into delicate cerulean, disappear beyond the distant hills.

Historically, perspective enters into the world of art as more precise 'law' (where space is experienced more exclusively in its material dimension) simultaneously with the moment when spiritual beings, which the ancients experienced as qualitatively filling space, are 'vanishing.' Hence the viewer is left looking into space with *spiritually void* consciousness, the corollary being an *enhanced physical* perception. A class teacher, in commenting upon this, emphasizes how apposite it is, therefore, for children at this age to study the laws of perspective, taking them into account in drawing exercises. "In these centuries began that intrepid adventuring into all unknowns which is the truly progressive characteristic of our modern age. [It is the] epoch in which men for the first time see the world clearly as an outer thing ... The new experience of the death of three-dimensional space into the distant vanishing point ... is the hallmark of our modern centuries. [The students] begin in a sense to come level in awareness with the civilization in which they are growing up; they begin really to be our younger contemporaries in consciousness as well as in life." [7]

Shadow Drawing

The second training of the senses in which the students participate at this time is through shadow drawing. Steiner pointed out that in nature there are no outlines. Lines *seem* to appear where one color meets another. For example, the ridge of a roof is seen as a straight line because the two slopes that meet at the ridge are different colors by virtue of fact that the light strikes them in different ways; or the ridge stands out against the contrasting color of the sky or of the surrounding foliage in the treetops.

In an artistic way, children in Waldorf schools have been brought up to draw the world in this fashion, i.e., with color meeting color. This artistic approach can now take a step in a scientific direction through a close observation—and portrayal—of the way that light falls onto surfaces. To begin with, exercises are set up with objects that have planar faces such as a cube or a tetrahedron. The exercise is twofold: more than one face of the object itself will be shaded in contrasted depths of tone according to the illumination. In addition, the shadow of the object which the light projects will also be drawn. Over the forthcoming years, such simple beginnings can then be developed in various ways. The objects chosen can become more complex; curved surfaces can be included; shadows can be arranged to fall on non-planar surfaces, such as on planes meeting at an angle, or on curved or corrugated surfaces; until finally, in the Upper School, the wonderful intricacies that are to be discovered in nature itself can be drawn *in situ*.

Through shadow drawing, the teenager can also experience at first hand different degrees of reality within the physical world. The shadow itself is a reality, the object that casts the shadow is a reality, and the source of light that projects the shadow is a reality. All three are related in different ways, and may be seen as having different *degrees* of reality. *En passent*, it is interesting to note how these experiences, awakened through a more scientifically directed observation of the world, feed back into the world of art and provide the student-artist with an added dimension of expression. A teacher once expressed it in this way: "Colors must meet each other and converse; light and shade must battle with each other for mastery; and none of this could happen if color and light and shade were tamely confined within the well-guarded frontiers of a line!" [8]

Class 6 Physics

Knowing that the above is taking place in the life of the student through other lessons, that the powers of observation are becoming more acute simultaneously with the very first ripening of abstract thinking, the science teacher in Class 6 can embark confidently on the method of teaching science that Steiner recommended. An outline of this method, commonly referred to as *Goethean*, follows.

The students' attention is drawn towards phenomena of nature. Their already awakening powers of observation are further intensified through this. General experiences are referred to and the memory of them kindled. The experience of *light* at sunrise before color becomes discernible; the different *tone* of a mountain stream, soothing and soft and low-pitched as it trickles and burbles through the summer months—pounding and tense and high-pitched when it is in full spate after the thaw or after heavy rain; the appearance of the rainbow colors, either arched and glowing in the sky after a passing spring shower or hovering in the poised mist of a waterfall...

All children will have vivid memories of such natural events, but these are not enough on their own: the teacher will want to bring phenomenological experiences and evidence of a comparable nature into the classroom for the whole class to be able to observe at one and the same time. Why is it that these same phenomena are to be seen again and again? The scientific laws living within the phenomena can be 'discovered' by the students. To do this, observation is not enough. Now they will need to apply their sharpening power of intellect. Awakened observation must now be penetrated by equally awakening causal thinking. Only then will the mind *reach* the 'laws.' Thus from day one, a certain mode of scientific training is established. Scientific law arises from, and the understanding of it is stimulated by, observable reality. In later years there will be time and occasion for entering into hypotheses. However, a scientist who is grounded in a certain scientific discipline will confront a hypothesis differently from one who has not trodden such a disciplinary path.

In the physics lessons of Classes 6, 7 and 8 (ages 11–14), six branches of the subject are studied: sound, light, color, heat, magnetism and electricity (usually in that order). In addition, mechanics is taken in Class 7.

An example of this, from *sound*, follows: a flat metal bar (such as is used in a metalaphone) is struck and the tone it produces either noted or, preferably, matched with a bar of identical proportions so that exact comparisons can be made with the 'standard.' The first bar is then filed in the middle so that a groove of metal is removed from across the back of the bar. It is struck again, at which it is noted how much (approximately—this is not an occasion to measure sound waves) the tone produced has *fallen*. A third, identical, bar is taken, leaving the 'standard' one still of the original pitch for the sake of further comparison. This time some metal is filed away, not from the middle but from one end, making the bar slightly shorter. When the shorter bar is struck and the tone compared with the 'standard,' it is noticed that now it has *risen*. Finally, contemplation of these phenomena leads to laws being deducted in explanation of what has been experienced.

This example is not necessarily one that would form part of the very first main lesson block of science. It is often an advantage in the early stages to make the experiment as life-size as possible so that the whole class can experience the same phenomenon together. An example in the color section of the block would be as follows.

(i) The students collect wood to make a bonfire out of doors.

(ii) When the fire has been lit, they arrange themselves so that they can look into the smoke with the sunlight coming directly from behind.

(iii) They move round to the other side of the fire exactly 180 degrees and note the difference in the color of the smoke.

(iv) An extension of this is to allow half the class to view the smoke from one side and the other half to look from the opposite.

Then (v) all change.

(vi) Back in the classroom the next day, it would be revealing to recount the events and so arrive at the law: light observed through darkness is reddened, i.e., is dulled by the darkness into the red end of the spectrum; while darkness observed with light illuminating from behind the observer becomes 'blued,' i.e., is raised into the color of the blue-violet end of the spectrum. Using a bonfire as a medium to arrive at this law will not give the glowing colors obtained by looking through a prism at a window frame. The bonfire smoke's colors, though much more murky, will, however, have a subtlety and sense of surprise that is awakening for the observation and for the powers of perception, both important elements at this age, elements that can be addressed ideally in this, the science lesson. Discussion that follows will disclose which are those students who have noticed similar phenomena in the environment and which are those students who also realize that it is the same law 'at work.' The everyday occurrence of sunsets, though it may never cease to cause lifelong wonder, will furnish us with one such example; whereas the (rarer) glowing pink/apricot clouds that also appear as part of the splendor on this, nature's most awe-inspiring canvas, will need more intricate reasoning.

These examples do not call for anything out of the ordinary. We have not at this stage stepped into a physics lab. Nor have we purchased any specialized equipment. As each branch of physics goes on, however, more apparatus becomes necessary. This could be demonstrated by following the first example through more stages. (Actually, already at the metalaphone stage, we require some material, though it may well be that a piece of scrap keel brass or something even less elaborate will be hauled into service.) The study of pitch can be furthered with the help of a monochord. Length and tension can be varied according to exact measurements and the resulting differences in tone-heights noted. The monochord is not an everyday object and will normally be housed in the physics lab and either used there or, in the case of main lesson science blocks, brought into the classroom for experiment purposes. Its use, however, sheds light on everyday phenomena. We understand the principles involved in the tuning of guitar strings and the placing of the frets where we want to stop the strings; also the use of thicker strings for the bass notes in each instrument. How dramatic these differences are when we open up the lid of a (grand) piano and look at the strings used for the lower notes as compared with those used for the notes of the very top of the register!

The third stage might be left until the following class. This would take the study into the determination of frequencies. Mersenne's experiment might be described, and indeed repeated, in which he obtained the laws of the transverse vibrations of strings. Experiments in this domain might include a sonometer, a siren, an electric oscillator. Further research might well take the student into Upper School physics, branching off into fascinating phenomena such as vibrato analysis, audible frequency range, the 'wolf-note,' absolute pitch, the 'standard temperature' for organ tuning, the history of Mean Pitch, simulated sound, and so on. This very wide range of subjects within a comparatively narrow and specialized branch of acoustics leads us to consider the two ways in common practice of distributing the physics curriculum between the three Classes 6, 7 and 8.

The first manner is to work one's way through each branch of physics, starting with sound in Class 6 and ending with electricity in Class 8, taking approximately two topics per annum. If this method is adopted, it is helpful to bear in mind the general principle described here of graduating from the more natural or everyday phenomena to those that depend on scientific apparatus. This largely explains the order in which the subjects are taken, as the last three, and particularly electricity, require an increasing amount of more sophisticated equipment.

The second method in use in Waldorf schools is to range through each of the six topics each year, placing greater emphasis on the first two (sound and light) in Class 6 and the second two (color and heat) in Class 7, and then the last two (magnetism and electricity) in Class 8, each year adjusting the amount of time that is spent on the remaining four. Thus a sample curriculum for Class 6 could be:

Sound: Sounds of nature; simple studies in pitch, dynamics, resonance, echoes.

Light: Sun and moon as sources of light; contrasts; stages in the increase of light, e.g. sunrise; reflections, sun refraction.

Color: Primary and secondary color phenomena in pigment (darknesses); primary and secondary color phenomena in light; stage lighting; colored shadows; complementary and image colors.

Heat: Natural manifestations of heat and their effect; expansion and contraction of heat in solids, liquids, gasses; conduction, and convection.

Magnetism: Natural occurrences of magnetism as in the lodestone and the earth's magnetic field; magnetic North; general use of the compass.

Electricity: Static.

Reserved for Class 7 is the study of elementary mechanics (with, at this stage, only limited mathematical application). The reasons for extracting this branch of physics and reserving it for this age in Waldorf education are connected closely with the developmental stage that the students are going through as part of the onset of puberty. At this time, one observes how the quality of the child's movement changes, in some cases quite dramatically. The buoyancy of the younger child disappears and is replaced by a heavier form of movement. Earlier, the child's movements were naturally graceful as if the physical body was of secondary importance; now the movement gives the impression of being initiated by the bone/cartilage structure. In drawing the teacher's observation to this, Steiner indicated that, as a result of this change, the students are particularly ready for learning about mechanics. As the bodily movement finds its source of support in leverage, so the inner attention of the student is drawn to this principle (and other simple machines such as the wheel, the inclined plane and the pulley) in the physical world. Studying these mechanical principles gives a basis for understanding numerous inventions. Finding the principle incorporated in machinery, gadgets and appliances (both ancient and modern) is also an important and attractive aspect of this and other scientific studies. It satisfies that side of the student's nature which becomes more absorbed by and seizes on the practical application of knowledge in the realm of matter.

Tools, invented and constructed by the human being, may be seen as *extensions* of the limb system, and an interest in the mechanical advantage to be gained can easily be aroused at this age. Thus the study of mechanics brings the students' awareness closer to those forces that prevail in the world of matter, so that they may gain mastery over it while at the same time producing an awakening effect through discovering that these forces 'obey' laws that can be stated in terms apprehensible to ordinary logic.

The principle of the lever as applied in the simple crowbar with its fulcrum, load and effort, is found again in a different guise in the claw hammer. With nutcrackers and the wheelbarrow there is a different relationship, the load being *between* fulcrum and effort. The students also observe that the two inventions employ additional devices in connection with the fulcrum: the wheelbarrow has a wheel and axle, the nutcrackers are hinged. With sugar tongs the relationship of the three mechanical elements has to be thought out anew. Further mechanical principles will be studied. That of the inclined plane will be one that the students have experienced all their lives, finding it applied in airport ramps and the like. They will have met the principle of the screw, generally in nuts and bolts, but more especially in the vice, which they are accustomed to using every week when they work at the bench in the woodwork shop—they may well also have helped turn the tommy bar when the jack was used for changing a tire on the family car or for steadying the chassis of the family caravan. They will also be familiar with the devices which incorporate the wheel and axle principle, not only the wheelbarrow, but also the box spanner, the brace and bit, and maybe even the windlass. Gear wheels make for fascinating study, usually invisible in any domestic setting; it would be important, when the subject is taken up again in a later class, to enter the industrial scene and to extend the study to Pascal's principle, for instance, and its application in the hydraulic press and hydraulic brakes.

This 'descent' into matter and into the forces that operate there, is balanced in Class 7 with a study of astronomy and the first introductions to chemistry and human science; the latter is usually entitled "Health, Hygiene and Nutrition," the starting point being that of personal care. This aspect of human science can hardly be overemphasized these days—and in fact, can be seen in the urgency accorded to environmental issues the world over. All three (human science, chemistry and astronomy) offer widening horizons of knowledge toward which the thirteen-year-old is eager to set sail in the spirit of discovery which is surging within each of them.

Astronomy Class 7

Teaching astronomy challenges any teacher, whether working in a Waldorf school or not, to make a firm and independent stand on the approach to the subject. It is difficult enough in other scientific subjects because popular literature does not always make clear—however clear it may be to the 'professional'—which 'facts' that are being presented are proven and which are still entangled in theory. In astronomy this is even more complex. Later, when astronomy is taken up again in the Upper School, it is appropriate to examine the different approaches there have been—not only Ptolemy's and Copernicus'. The thinking of a normal thirteen-year-old is hardly advanced enough to enter into the intricacies of many astronomical systems, though teachers may feel that they would like their students to have at least a taste of geocentricity and heliocentricity. All the more necessity to take observation as a starting point: *observing* the sun, *observing* the moon, and so on. To start from what the eye can see and to enter into the vast dimensions of space is an extremely satisfying and stimulating experience for the seventh grader's inquiring mind. [In this respect, two particularly helpful publications are *Movement and Rhythms of the Stars* by Joachim Schultz (New York: Anthroposophic Press, 1986) and *Astronomy and the Imagination* by Norman Davidson (New York: Routlege, 1985). Both these books are guides to 'naked-eye' observation of sun, moon and planets.]

This pursuit of phenomenology presents an interesting situation in the case of astronomy. For a student of 12–13 years, the 'turning heavens' can still be a phenomenon full of wonder, indeed, this can remain so for much longer. At this age, in Class 7, the wonder is enhanced through knowledge. At the same time, it is usually the case that most students have met—and will have questions about—views of the universe based essentially on that of Copernicus, and modern phenomena that tend towards the sensational, like black holes and UFOs. These, however, hardly form more than a veneer covering the underlying interest in what is actually *visible* nightly. And it is on this interest, and the mood of awe that the vastness of the universe evokes, that further inquiry is best based. A class teacher, reflecting on an astronomy main lesson, captures both these elements in these few words: "This wonder of discovery in the special characteristic of learning in the main lesson period and, for these thirteen-year-olds, poised between childhood and youth, the starry worlds can speak a special language of hope and challenge that can sound through the years of their development towards adulthood." [9]

In the Upper School block(s) on astronomy, the new powers of abstract thinking, which the student is fast taking hold of, can be both applied to the phenomena of the firmament visible to the naked eye and also stimulated by consideration of it with the help of modern astronomy. "An appropriate stepping-off point for this [Upper School study] ... is a comparison of the old earth-centered and the new sun-centered planetary systems ... In Ptolemy's system ... the order is according to the *observer's* experience of the planets' speeds of movement against the fixed star background ... The moon moves fastest. Mercury is next in average swiftness. Venus follows a little slower, and so on. One feels what is fastest is to be nearest to oneself. It is an ordering in one's personal experience and justified on that account ... Copernicus transferred this into an external, physical space which can only be reached by abstract thinking ... In terms of physical space his system is once again justified." [10]

Chemistry: Class 7

While astronomy takes us into a world of space and movement, to comprehend which may force us to stretch to the very boundary of thinking, chemistry enables us to enter a world of different relationships and reactions, a world in which substances are constantly undergoing transformation and working upon each other. This aspect of chemistry, which is its essence, has a strong affinity with what one might aptly describe as the more 'alchemical' ingredient in puberty. It is the age at which greater inner changes overcome the student more than any other. The thinking comes consciously into sharp focus. The feelings expand, even beyond comprehension, so that the student is constantly having to cope with inner situations that are entirely new, often—mostly, in fact—at the same time not wishing to reveal that this is the case. While struggling to remain above water in the feeling life, the student is also having to contend with the psychological consequences of accelerating physical maturation. Simultaneously there is much growth, particularly in the region of the limbs, giving rise to lack of energy—though the opposite can also be seen in adolescents' sudden outbursts, which are frequently followed by periods when they crawl back into their shells again, overcome by a feeling of depleted will-forces. In view of this a new source of inspiration is needed. The teacher can often succeed in bringing this about if the student's newly born *idealism* can be touched. The confluence of all the above can result in inner turmoil and uncertainty, interspersed, fortunately, with spurts of forthrightness, drive, enthusiasm and exceptional (even if bordering on the excessive) activity. Add to this, the impulsive need to find new heroes, to find changed relationships, to find the inner voice of authority despite the as yet far off maturity of the ego, and the often emotional imbalance, and one gains an impression of a kind of psychological chemical ferment, boiling over one moment 'out of the frying pan into the fire' and as hastily solidifying in the next. Chemistry lessons at the approach of puberty, as well as during and after, are therefore ideally placed. They can give rise to impressions that can reassure the adolescent that the world is a place where processes of change—sometimes extreme—are in order, even essential. But equally essential, the human being needs to remain in control. When the control is there, the human soul is enabled to cross the frontiers of development in a natural, balanced, dignified and productive way. In her dissertation on the teaching of chemistry at this age, Eileen Hutchins ("A Religious Background to the Teaching of Chemistry," this publication) shows how the teacher can lead into the main lesson material through a skillfully guided conversation—itself an art requiring what might almost be described as a chemically linguistic interaction between teacher and class.

Begun in Class 7, the teaching of chemistry continues throughout the second half of the student's school career. Examples of experiments undertaken in Waldorf schools to bring this work of chemical change fully before the adolescent are as follows:

Class 7: Combustion and its polar opposite process, deposition; properties of oxygen and carbon dioxide; special characteristics of the combustion of phosphorous, sulphur and carbon—their distribution in the natural world; acid and base; the slaking of lime and quick-lime.

Class 8: The chemistry of foodstuffs, cooking processes; chemistry in industrial processes such as papermaking, candles, matches, smelting, the extraction of salt; the seven chief metals.

Class 9: Plant chemistry, cambium, photosynthesis; different types of sugar in the plant; starches, cellulose, albumen, fats and oils; a study of celluloid cellophane, pulps, fibers, byproducts of coal; the chemistry taking place in the cambial girdle of the plant where the products of photosynthesis and the refined salt in the rising sap are combined. The 'magic' of *apical meristems* is an important experience for the adolescent who feels him/herself in many respects also as being a growing point.

Class 10: Descending into mineral chemistry, the curriculum should link with the history curriculum in this year through following transitions such as: from honey to cane sugar (introduced by the Arabs) and beet sugar in modern time; or from the earlier animal and plant clothing, with natural dyes, to synthetic (mineralized) fibers such as rayon, nylon, polyester, acrilon, fiberglass, and so forth.

The foundations of the Waldorf chemistry curriculum were written by Eugen Kolisko in collaboration with Steiner. *The World of Matter and the Education of Man* by Frits Julius is also indispensable. Steiner indicated that, on the basis of the earlier years' lessons, by the age of about eighteen years an understanding would become possible for the three different organic realms. "A chemist with [no more than] an ordinary education cannot understand Kolisko's chemistry. He has not developed the necessary concepts for it. [Kolisko was also the school doctor with an intimate knowledge of the human organism, something more than one would expect the average school chemistry teacher to have.] It would be good to aim at making this possible for our students." [11]

Chemistry offers a particularly illuminating example of there being more than one reason for teaching a particular subject. "Then there can come as [a] surprise the miraculous result when two powerful extremes meet; when the fiery hydrochloric acid and the caustic soda, that rots whatever it touches, come together ... the new substance is ... common salt." [12] The author goes on to point out how, that when this phenomenon is being reflected upon during a lesson subsequent to that in which the first experiment was conducted, it is a golden opportunity to point to the parallel traits in human character, i.e., the two extremes and the need for the individual to exercise sufficient control to keep them in check. In such educational processes more than chemistry is learnt: personality and character are formed. It could be argued that this is the *main* point on any educational agenda, though this is not to detract from the learning process itself which is, if anything, enhanced through such methodology.

Because the natural laws that operate in the realm of chemistry are more elusive than those discussed in connection with physics, it will be necessary for the chemistry teacher from the outset to stimulate the students' imagination for what is hardly visible: the inner processes at work. It is possible to see this from the simple example of the extinguishing of a candle by placing it beneath an upturned jam-jar. Firstly we have the clearly burning flame; then, when the jam-jar is placed over it, we see the flame 'die.' The composition of the 'air' within the jar is not visible. This must be distinguished from the trail of smoke that rises from the smoldering wick. Through further experiment the composition of the gas (before and after the extinguishing of the flame) can be discovered. Through an inner effort, the process taking place in this change of substance can be 'followed' in the imagination. This inner involvement is an important adjunct to each experiment which the students need to experience through the lead given by the teacher who makes the necessary effort to verbalize what is happening.

Or, take examples from the Class 9 material: in this year the chemist can do with something of the artist's eye as well as his/her technical skill. With it the teacher will be able to bring the students powerful images that arise from the nature of the plant and its task in transforming substance. There is, for example, the air 'polluted' through human and animal breathing which is then refreshed through the respiratory system of the plant. In the realm of water we find how, from the stench of decay at the bottom of a lake, such exquisite plants arise such as water crowfoot or the water lily itself. And in the mountain heights, above the treeline, we find healing herbs growing in great abundance—arnica, aconite and many species of *labiatae*, all of which are able to extract from the rare quality of light that which is needed for medicinal value.

In the earlier approach to natural science in Classes 4, 5 and 6, it was shown what relevance Steiner attached to the method of relating outer nature—macrocosm—to the inner (and bodily) nature of the human being—microcosm. As a method, this will be found still to be helpful in all scientific subjects. It also helps cultivate an attitude to science that includes the human being. Many disasters in the world have been the result of an advance in scientific knowledge being applied in a way that is oblivious to the consequences for humanity. It needs to be emphasized that this is usually not the fault of the scientists involved. When the account of the development of the atomic bomb was made known in *Brighter Than a Thousand Suns* by Robert Jungk (New York: Harcourt, 1958), the dilemma that the research scientists were in formed one of the most poignant parts of the book. Clearly what is needed is a deep humanitarian outlook in general. Here one can see how pertinent Steiner's suggestions are. Even so, these oblique references are not sufficient from Class 6 onwards, however deep-sighted they may be. The students now need to get a completely holistic view of the human organism.

This begins with a main lesson entitled "Health, Hygiene and Nutrition." In it, the emphasis is on care. Care of the body, care of the environment in which people live, work and play, care of the food that is grown and prepared for human consumption, care of the air we breathe, care of the plant world covering the earth upon which we are interdependent, care of the human being also in sickness and in sorrow, care of people's working conditions *including those at school—students and staff,* care of places with specialized communal uses such as kitchens, dining rooms, toilets, bathrooms, as well as their public equivalents—restaurants, hospitals, food stores, and so forth. A generally caring attitude for all the above will have been cultivated in the school from Kindergarten upwards. Hitherto, it has been in practice and in the feeling life. At this stage, these attitudes need raising to clearer consciousness, with the consequences of this or that practice scientifically described. The lesson also offers opportunities for important side issues to come to the surface (*side* issues, that is, from a scientific standpoint). The benefit of grace before meals, for example, is considered alongside the excretion of the digestive enzymes. Such correlations will show that although the body has its clinically factual needs, soul hygiene is an equally important dimension of modern life and not merely something that people were obsessed with in a former age before modern research had striven ahead to where it is now.

In Class 8, human biology enters the sphere of anatomy. The skeleton is studied and the anatomy of the eye and the ear. In Class 9 the study of anatomy is taken into the neurological and muscular systems. Embryology follows in the next year, the most all-embracing setting for sex education plus physiology and elementary anthropology. These are important years in which the bodily form, constitution and function described are in the very process of reaching the climax of their maturation.

Non-abusive attitudes towards the human organism are essential if the physical frame is to serve the soul and spirit of both woman and man. Without this, healthy psychological and spiritual development (neither of which cease when bodily growth ceases) would be impaired.

Sex education, as one of the most topical issues, deserves some special mention. Obviously the full context of embryology must form part of the child's education. In accordance with Steiner's whole educational approach, this would be regarded as inappropriate if embarked upon before the age at which the *physiological* basis for the human being's reproducing its own kind has been arrived at. Without belittling this in the slightest, however, Steiner points towards an accompanying need of the adolescent of still farther-reaching significance. Qualities in adolescence that the psychological attitude matures in each girl and boy, not only to love the opposite sex, but also love in a more altruistic sense the wider needs of humanity and with them the needs of the planet earth. This is not to imply that the broader aspect of love for humanity forms part of the main lesson block on embryology in the same sense, but it was recommended that the inner (microcosmic) equivalent of the outer (macrocosmic) chemical processes could be approached educationally in a mutually supportive way.

At the same time, it would be well to point out another aspect of Waldorf education that supports the teaching of science. This applies to all science teaching to some extent, but is chosen here because of its special relevance to the present topic. It concerns the life of feeling and will. These provide the focus of education for the first two seven-year periods and continue as an integral part of the Waldorf method. Even if sex education is introduced with careful regard to the adolescent's maturity, there still remains the fact that the human being is constituted in such a way that the field of *knowledge* is not something that can go on being cultivated forever entirely on its own. "For the facts of sexual life are not confined with our desire to know ... and feelings and will are more active in them than our thinking; and only an education which gives as much place to the education of the feeling and will can help here ... Through an artistic, imaginative approach to knowledge, we can educate feelings; through a religious and moral approach to knowledge, we can educate the will." [13]

The Upper School

In the first part of this article it was shown how *nature study* formed an essential, preliminary stage to the teaching of sciences such as physics, chemistry and biology. We saw how the three stages of animal, plant and mineral followed a *descent* from the animate world to inanimate; this sequence is reversed in the Upper School. First, in Class 9, geology is the object of study; in Class 11 it is botany, and finally in Class 12 zoology is taken up. In each case the earth as a totality is considered. To complete the sequence, as it were, a period on oceanography and meteorological phenomena is sometimes taken in the intervening Class 10. Through these phenomena, the student experiences a realm that is closer to life than the merely mineral (of Class 9), yet not as close as the plant itself (of Class 11).

One can hardly overemphasize the importance of a global consciousness today, and it is vital that this be developed during the years at school. In his ecological study *Dying Forests, A Crisis in Consciousness*, Jochen Bockemühl traces the course of the planetary problems we have to live with to attitudes that have arisen as a result of the human being's direct relationship—or, one might say, lack of it—with living nature. "Our modern forms of life and thought have given rise to consequences whose destructive influence on the forest and on ourselves has assumed the dimensions of an elemental power ... It is not enough to look for the outer symptoms in exploitation or false economic thinking." [14] The author goes on to point out that, although one can modify technology and adjust one's energy needs, in the long run only a radical *change in outlook* will suffice to change the downhill direction in which we are rapidly slipping.

School lessons cannot be divorced from this outlook. Indeed, in the early years, a healthy foundation can already be laid. Attitudes towards ecological issues that are expressed by the students in the Upper School often have their origin in some activity that has taken place in earlier years. One class teacher referred to two connected incidents that were clearly in this category. She had been on a morning walk with her class of six- to seven-year-olds, having told nature stories about the early spring and the signs of life that were to be seen all around. "Look," said one of the children, not directly to her. "Look at the gold, the gnomes have brought it there." [15] She went on to describe how she was able to take these experiences further, resulting in a simple enactment that evolved into a play. "It was not written as a play, but the possibility of acting it suddenly occurred to me. The class knew it by heart by this time. Now they spoke it in parts and I realized how deeply the children had experienced it ... The children did not act; they *were* the gnomes, the flowers and the animals." [16] Identifying with nature in some such way as this is an important stage for the younger children to absorb. In the Upper School such experiences must be transformed so that the students can look freely at the facts, directing their awakening thinking towards the *whole* situation and thereby taking the entire planet (and its feature) into account.

Science Education and a Fully Integrated Curriculum

One of the objections that might be raised to the fully comprehensive aims of Waldorf education is that all students cannot be 'good' at everything, and it is therefore more economical in terms of educational time to concentrate on those areas in which they show some aptitude, those subjects they probably enjoy the most and in which they are likely to make some contribution to life, eventually as specialists. Those who would support this approach might even grant that a little general knowledge is a good thing, but that, particularly in science, specialists should be allowed to—indeed urged to—'get on with it' as early as possible. Some of the arguments against this—and in support of the policy of teaching science to *all* students in Waldorf schools—will therefore be put forward, though the National Curriculum in operation in the maintained sector in the UK as a result of the 1989 Education Act, which stipulates a comprehensive approach to science, puts its emphasis more on 'an early start' rather than a mature continuation into the eleventh and twelfth grades, where specialization for A-level examinations (1992) rules out the broader approach to science that Waldorf offers for any students other than those specializing in the sciences.

There can be no doubt that the general awareness of people today includes the world of science. When a plane crashes there is deep human concern, and there is usually political concern; but there is also a good deal of emphasis on the scientific significance of such a disaster: the likely causes are immediately speculated, forensic reports are relayed, questions asked in Parliament are given publicity, and the media keep the public informed (assumedly) of the major details that come to light in the course of the ensuing inquiry. Such an example is symptomatic of the inherent interest in science that everyone today maintains. As early as 1919 Steiner acknowledged this general scientific awareness by *including* a wide range of sciences—which become fairly advanced in the Upper School—in the Waldorf main lesson curriculum, taught to all students. One might consider it almost as the right of the modern child to receive such a broad scientific education. It would be difficult to make a meaningful contribution to modern life, in any field, unless this general awareness has been cultivated.

In earlier times the same claim could not be made. *Knowledge* of scientific facts has increased rapidly, as has been mentioned already, particularly over the last four centuries, but until the present century *awareness* of that knowledge was confined to a few. Dr. Walter Heitler, the Bristol physicist who is engaged in the study of cosmic radiation and the technical problems arising from it in the 1950s, makes the following comment: "The eighteenth century had all the mathematical and mechanical knowledge necessary, e.g., to develop water power and could have transformed the ancient water wheel into a more efficient water turbine. This, however, did not happen." [17] He goes on to discuss the science of thermodynamics, showing how it had to wait for a certain condition of soul before it was applied to technology, indicating that it is not a 'chicken and egg' situation but that the technical developments have to wait until inner changes in the human being take place and give rise to the corresponding outer research and invention. "... The science of thermodynamics took its origin from a peculiarity of the human organism. Only when we are aware of the new relationship between the thought-permeated will and technical achievements will these facts become more than a curiosity. They point indeed to a new stage of soul development in the human being." [18] That stage of soul development is something that evolution has now achieved and to which we are all heirs. It is this—and all related stages of development—that prompts the science teaching in Waldorf schools, rather than the 'need' for more scientists in a particular country for sake of prestige or standard of living or military supremacy. At the same time, it should be submitted that better scientists will result from such an all-round approach.

Naturally this poses a challenge for the science teacher. For each branch of science these days, a whole technical library may be consulted, probably growing at a voluminously faster rate than even the specialist can read. It is therefore for the science teacher to decide: What are the essential phenomena that will give the student an entree into and a grasp of the subject. What? Alan Hall, an experienced physics teacher in the Upper School, maintains that this can indeed be done in the context of an integrated main lesson: "... by using such fairly simple means it is possible to *go to the heart of the complex technical apparatus and understand the basic processes* without getting lost and bogged down in highly technical language and detail ..." [19]

Acquaintance with Scientific Principles as a Basis for Modern Life

The great virtue of the above approach is that those students who wish to go further in the study of electromagnetic fields will be thoroughly equipped to do so, while those who need only to grasp the essentials—simply as part of modern life—will have been provided with the means, even if they would not boast of an advanced scientific understanding. Precisely for the latter group, however, Steiner emphasized the necessity for all students to comprehend—in broad outline at the very least—the basic scientific principles of those things that are used in everyday life. If this is done, it gives the user a degree of inner certainty. It seems obvious that a person needs to be able to handle a car if he/she is to drive it safely. Steiner meant more than that. He referred to the *understanding* of how the internal combustion engine operates. Whether one drives one or not, one could hardly lead a normal life in today's world without making use of a car or a diesel-engine bus; it is the understanding of what is being used that brings the inner certainty to which Steiner referred. This is a certainty that is not confined to the single sphere of technology, but fans out into the whole of life, giving weight to the purposefulness with which the students, later as adults, want to bring forward their own contributions. Where a foreign element exists, he suggests, it is bound to cause a degree of undue reticence in the soul. As modern people, in a world seething with crises at every level, we cannot afford this.

In the days of user-friendly machines—and these are mostly the ones in question, those that find their way into house and home as labor-savers and mod-cons, sales of which are backed up by colossal advertisement campaigns, this has far-reaching implications. Automatic carwash, traffic indicator, antifreeze, carjack, cassette player and a dozen other accessories come to mind. So do dish washer, television screen, calculator and computer, washing up liquid/powder and gloss paint, fluorescent lighting and front door bell, vacuum cleaner and telephone, refrigerator and chainsaw, all before one has stepped out of the house into the street. Add to this automatic doors, elevators, jet planes, hovercraft, and other commonly used public services, and a wide array of technology spreads itself out. Chemical technology, in particular, should not be overlooked.

A healthy adolescent will be borne along on a tidal wave of inquiry. The 'movement' of this tidal wave derives from this science education that has preceded this stage of child development, the experience in the preschool years and in the main lesson periods outlined above. Those three earlier stages of nature *experienc*e, nature *story* and nature *study* have been referred to in the present context as 'pre-science.' But they have enormous significance—as have other life experiences—for the adolescent's awakening mental powers. The science lessons are inserted into this awakening process as well as further stimulating it, which thus stands as a foundation for the *understanding* of what comes to meet the adult in life itself. Steiner attributes the inner unfolding of freedom partly to this process. "If during his early school years [the student] has stored up an inner treasury of riches, ... then at puberty these inner riches can be transmuted into intellectual content. You will now be faced with the task of thinking what up to now he has willed and felt ... [A] human being can only come to the experience of freedom if the intellectuality awakens within him of itself. But it must not awaken in poverty of soul." [20] Thus a rich store of earlier educational experiences leads into a richness of thought-life in the adolescent and in the adult. But the store must be allowed time to build up. Premature causal-type thinking undermines this, hence the commencement of that mode of science education based on causal-type thinking only at age 11–12 years (Class 6).

Science in Its Social Setting

In the Upper School a further interest awakens: What are the social consequences of the application of technology? From Class 7 onwards the students gain strong impressions of these from their history lessons. The medieval craftsmen formed associative brotherhoods known as 'guilds,' which were an inspiring and morally wholesome influence upon social life. What a contrast this presents with the social circumstances which became spawn of egotistically acquisitive attitudes typical of the extreme capitalist at the time of the Industrial Revolution, which epoch is studied in the eighth grade. Seen historically, the social significance of applied science becomes more important than the scientific advance itself. In Class 9 (14–15 years) a timely opportunity presents itself to show this *socio-historic dimension of modern science*. All updating of the Waldorf science curriculum in the Upper School is embedded in this way in a human context. The thirst to be contemporary, which all teenagers naturally have thrust upon them, is thereby somewhat quenched without frustration or delay, and the scientific content of recent developments can follow at different grades of the Upper School, whenever the students are able to encompass the accompanying mathematical or scientific concepts.

Computer Science

Computer science furnishes a good example. In the ninth grade history curriculum, the social and economic consequences of the computer and of information technology can be studied even though the algebraic and electronic aspects of the computer need more advanced understanding, which comes with the years. This approach has been advocated and endorsed by no less prominent a figure than Joseph Weizenbaum, professor of computer science at the Massachusetts Institute of Technology. Moreover, physicists and mathematicians are pointing out the advantage of waiting until late adolescence (or even until adulthood) before learning to program, due to the rapid change in 'languages' and the subsequent slowing down that results when having to relearn. It would seem that the so-called languages that serve information technology work in the opposite way to foreign languages where it is a well-known fact that expertise accelerates in proportion to one's ability to become fluent. Primary educationists have now joined the cause of caution, pointing out that premature use of devices such as calculators can easily erode a child's mental capacities, nurtured by results from straightforward mathematical disciplines like learning the multiplication tables or long division. All in all, teachers in Waldorf education have been encouraged that their well-considered approach to computers is proving educationally advantageous to the student as well as being 'recognized' in ever-widening circles of academics, medical practitioners and industrialists as providing a firm basis for taking computer science further, as and when required.

Science and Technology

To conclude this reconnoiter, two colorful aspects of Waldorf education will be mentioned that place science education in the broad context of life as a whole, rather than confining it to an academic straightjacket. They are the 'technical workshop' and the 'industrial tour'; the latter is fairly widely put into practice, the former has been slow to root itself. "According to Steiner's basic concept of education, practical activity ranks as a par with academic learning and artistic work. He regarded *practical work* as being of very great educational value. But in the first Waldorf school in Stuttgart he could only partially implement these principles." [21] In this article the author describes how a certain stalemate was overcome by the initiative of those who founded the Hibernia School in the Ruhr industrial district of (what was then Western) Germany. The excellent work done there broke new ground in such a way as to attract the attention of the UNESCO Institute for Education. In the Institute's case study, emphasis was given to the "exemplary way in which ... [the] artistic, practical and academic [components of] education are articulated ... with the result that ... every student is potentially qualified to enter either University or skilled technical employment." [22]

Such a program—and the importance of it is now being acknowledged—has to be spread, of course, over all classes in the Upper School. Although Hibernia is a special case, it is widely acknowledged that there is much room for development in technology within Waldorf education. However, it deserves a separate volume in the present series.

In the eleventh grade it is customary to make a tour of industries. The selection will depend very much on what is available for each school within comparably easy reach. It is good to include contrasts of course, such as iron smelting and cut glass manufacture, or ophthalmic lens making and going down a mine, or open cast quarrying and musical instrument making. The purpose of such a tour is to add a third dimension to the students' study of science—an awareness of those who are the skilled technicians and laborers on the production line. This is an invaluable experience for the adolescent and is to be seen in conjunction with the other aspects of the curriculum discussed here. Two illuminating descriptions of such tours are to be found in L.F. Edmunds' *Rudolf Steiner Education* (London: Rudolf Steiner Press, 1962) and Alan Hall's "A Visit to a Steel Plant" (reprinted in this publication).

The industrial tour, despite the increasing popularity of *work experience*, is a one-off experience. Apart from visiting manufacturers, such as has been mentioned above, it is not uncommon also to visit an institution en route, caring for the elderly or handicapped—institutional life of this kind has come about, after all, as a byproduct of the society that has resulted from the technically advanced civilization of our age.

The young people are therefore able to see the actual effects of applied technology, the work conditions that people enjoy or have to contend with, their dwelling places (a particularly important aspect in the UK where so many Waldorf schools are some distance from urban conurbations), and the types of products produced. The place given to design is an important factor to include in such a visit, as is also the opportunity to meet and talk to those involved with production, both at management and shop-floor level. Through such experiences the students are able to stand at the threshold of life as before a fully opened gateway, yet well before they have to pass that gateway to shoulder responsibility for the world and for the direction in which civilization is going.

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What Makes a Good Scientist?

by DR. HANS HEITLER

It may seem to many that this question can find a comparatively straightforward answer. A good scientist will have to know his subject thoroughly; he will have to be well acquainted with all the work done in his particular line; he has to master the techniques required if he deals with experiments and also the theories and mathematical formulae. All these requisites, to which, of course, may be added others, demand certain intellectual abilities; and therefore, in the first instance, he must be an individual who knows what to think and observe. Further, it is demanded that he has initiative and an urge for knowledge, impulses which grow out of his will or moral nature. And finally, it is considered advantageous if he has imagination and the faculty of grasping intuitively the solution of a problem, to be confirmed later through experiment or other proof. Such gifts come out of the feeling. It seems as if thus the demand is already fulfilled which Rudolf Steiner constantly made, namely, that the whole human being will have to enter once more into the problems, scientific or otherwise, with which he is confronted when facing the world. But the picture of such a human being contains nothing beyond rather commonplace trivialities, and is therefore far from what Steiner could have meant.

When we look at the history of science, we notice that at the beginning of its era a certain universality of knowledge was prevalent. The whole of nature was looked upon and taken into account, and no pronouncement about its laws or its relation to man did not also involve philosophy and with it religion too. When Johannes Kepler found the laws of the planetary movements, he was satisfied not only because he found a simple solution to a complex problem but also, because in this grandiose simplicity, as a philosophical *sine qua non*, harmony was reflected, and through it the divine creative powers expressed themselves. How different is the position today. The worldwide outlook has contracted more and more. Science and philosophy have separated; science is split up into numerous branches; and specialization into smaller and smaller fields has taken place. For example, a physicist today is not expected to be familiar with all that physics has achieved. He will have to be a specialist in radio, in nuclear physics or part of it, in x-ray studies, in optics, heat or acoustics, and so on. His attention, and often his whole life, is focused on a small section of the whole. This process of specialization is still on the increase and one could foresee that eventually every scientist will be his own specialist. Seen from a bird's eye view scientists may appear bent intently over patches of ground digging holes which get smaller in size but deeper, and hardly aware of what the neighbors do. "They are getting to know more and more about less and less until they know everything about nothing," to quote the wistful remark of one of the great scientists of our times.

It is easy to criticize these modern tendencies and to point to their fallacies and pitfalls. Yet, if mankind were to repeat its scientific evolution, even with the full knowledge of where it has come to, would it arrive at something different? Are there any apparent turning points at which one could say that if only science had gone in another direction, it would have avoided the predicament in which it finds itself now? The answer is no, or at least nothing obvious. Science has had to go the way it went, and only now we begin to realize that we have achieved an extraordinary dispersion into cells, the occupants of which hardly know of their origin. We feel strongly that the walls have to be broken down and that every single cell will have to find itself in the context of the whole. There is, however, nothing in the content of the cell which could initiate such a process. We feel, however, that the human being is an individual and complete being in himself and that society and all that grows out of it is not a complex machine with the human beings forming only the cogs, but that society in its innumerable aspects should reflect man in his totality.

At all times it was known that nature held deep and wonderful secrets which were revealed to the human being according to his capabilities, among which particularly in early times the intellect, was by no means a predominant one. When about four hundred years ago this intellect began to be the most predominant part of the human being's soul, it was only natural that he approached nature with this new faculty. He experienced the joy of finding that this new power led also into the spirituality of what is outside of the human being. Kepler was still aware that in the concept of the planetary movements, that is, in their human intellectual form, was reflected the harmonies of the heavens. This awareness disappeared with the progress of time until today it has been completely lost. At the end of the nineteenth century, during the so-called classical period of science, the human intellect had become almost incapable of being active in any other way but in the strictest sequences of cause and effect, and therefore of nature's many secrets only those of a rigid pattern could be apprehended. Of the totality of nature, only that was allowed to penetrate into our knowledge which had been retained by the rigid mesh of our intellect. All else was either rejected completely, or allocated to a region outside the realm of objective science and to the reaction of our subjective personality.

A typical example is the scientific treatment of light and colors. In the pure phenomena there is nothing, to start with, which could be grasped by our intellect. All the sense impressions of the world of color escape its grip and are therefore ascribed to a subjective reaction to something, whose 'real nature' we do not know. Only when light is passed through certain artificial arrangements in our optical experiments, which of course are the result of intellectual deliberations, then, eventually, we obtain something which can be measured and in general treated with our analytical mind. In this way we obtain all the manifold optical instruments like telescopes, microscopes, interferometers, and so forth, which in turn reveal to our senses detail of the heavens and earth which otherwise would not be known. But the color as such has disappeared into the realms of psychology. The scientist has become colorblind, as Ernst Lehrs points out in his *Man or Matter*, or, to put it the other way round, as far as the human being experiences color he is not a scientist. This is acknowledged every now and then, but very rarely the conclusion is drawn that in the allocation of one part of a phenomenon to objectivity and the other to subjectivity, the scientist acts quite arbitrarily. He imposes upon nature his own temporary intellectual limitations. Instead of confessing to these limitations that, e.g. the experience of colors is at present on a different level of consciousness from that of the intellect and that therefore the methods of the latter are not readily acceptable to the former, he maintains that the objectivity goes exactly only as far as his own scientific intellect can reach. True, this intellect is not at the end of its possibilities yet, but to return to the picture above, it digs deeper and deeper into its own hole, making it at the same time more difficult to find an exit.

Nobody would blame a person who is not able to give an answer to a problem because he knows that his faculties are not developed enough. On the contrary, we would respect him as an honest individual and perhaps even as a wise one, because through the knowledge of his limitations he knows that there is something beyond his reach at the moment. Do we not deride as foolish the 'proofs' of eminent scientists of their times, not so long ago, that no machine heavier than air can ever hope to fly? They did not realize that their thinking was not developed enough to contemplate such a possibility and they therefore decreed that it was impossible. But is the scientist of today not in the same position who declares that the wave nature of light deduced from experiments is the objective reality whereas the colors he sees are only the result of the impact of the waves upon the nervous system? He cannot imagine that such and similar sense impressions may in future time be the elements of a science in the same way as length, weight and time are those of our sciences today. It may well be that our present-day scientific thinking is inadequate for such a task and a new quality will have to be developed. We may not yet have a clear notion what form this new quality will take, but the very fact that on innumerable points of our sciences of today we touch on the borders of our capabilities should certainly awaken the awareness of new realms of consciousness waiting at the threshold.

This becomes even more obvious when we consider the field of electricity. We should be quite clear that here we are dealing with something which is completely removed from any immediate experience. Electricity nowhere touches directly any of our sense organs. Only its effects show themselves as mechanical power, heat, light, sound, chemical influences, and so forth. This makes it almost impossible to ask the question: What is electricity? Even if the question is asked, we would not know what sort of an answer we would expect. An unknown quality has permeated our civilization to an overwhelming degree, yet rarely do we stop and reflect upon the fact that there is so to speak an invisible servant who performs his tasks as from behind a curtain. It may be for psychological reasons that we do not like to look too closely at this ghost-like acting from behind an impenetrable veil, and that we accept the services, pretending that as long as we get the quantitative results there is no need to puzzle what is at work, if it is at all sensible to do so. But it is also a fact that half-solved problems, unanswered questions cannot be put aside forever. They live in the subconscious of the human soul and will make themselves felt sooner or later. It is almost common knowledge today that unsolved conflicts below the surface of our consciousness have very often detrimental effects. There is no reason to assume that a 'scientific subconsciousness' should form scientific thinking itself. Indeed, one can sometimes wonder when statements or proposals of an amazing logic appear in print and are taken seriously if this very process of deterioration has not already gone underway.

A great deal more could be said and many examples cited where, in our scientific civilization, the human mind goes so far and no further. It does not look at the frontiers consciously but turns round and says: That is all there is. It is the refusal to face the question which is perhaps the most serious symptom of our time. Races, empires, nations have fallen and vanished again and again in history because they refused to 'face the question,' that is, to see what the future demanded as a new impulse, a new evolution. Of course, most of the aspects of our civilization find themselves today in this position, but in science, which is undoubtedly the most influential activity of our time, it has become the most urgent problem. The scientist will have to become fully aware of the borders to which his particular field leads him, borders which are neither imposed by nature nor by himself, but which appear as such by the way in which he establishes the relationship between himself and nature. In this, experience will then live, and, instead of the inner cowardice which refuses to acknowledge the passing character of the borders and the consequent dishonesty which declares that there is nothing further, the courage to approach the unknown and the selfless honesty concerning the temporal quality of achievements.

An event of times long past seems to put into picture form the task of the scientist today. Moses led his people out of Egypt towards the Promised Land, and when the time came he was allowed to see the goal of forty years of wandering in the desert although destiny did not permit him to enter it himself. The scientist of today should be aware of the existence of a 'promised land,' and this knowledge should live in his research and his teaching. Then, and only then, has he fulfilled what has been put before him as a task in the relationship between nature and his own being. Then the path is shown, and in this lies the promise that sooner or later, in this generation or in some to come, it will lead over the border of today.

And so the border experience shows itself to be not the limits of cognition in the Kantian sense from which we have to turn back with resignation, but a new beginning. It opens up the possibility of a wider and deeper knowledge of nature, unfolding at the same time the cognitive powers of the human being. Once more, the way is opened for the whole human being to enter into harmony with the totality of nature. The necessity of our age to approach her scientifically only through the narrow faculties of our intellect will be recognized as a passing phase. The cognitive faculties of the future, though dim and dormant at present, appear as inherent possibilities as real as is the plant an inherent possibility in the seed. When the scientist carries this consciousness into his work, it will be permeated with a new spirit. Then, even the layperson will recognize that not only a thinking machine, to which he has hardly any relationship, produces all these incomprehensible ideas, but that a full human being is engaged in the solving of the riddles which the relationship of the human being and nature present. When he lets it flow into the teaching of the young, then he plants into their souls this living seed, which will be nurtured and cared for until its time for fruition has arrived. And what could be of greater value for the future than to give our young people bread and not only stones?

Goetheanism and the Scientific Method

by MICHAEL WILSON

In the remarkable essay "The Experiment as Mediator between Object and Subject" which he wrote in 1792, Goethe described, gently and with great modesty, the principles which he believed should apply to any work of scientific investigation. First and foremost is the quality we now call objectivity. The pleasure or pain, attraction or repulsion, the use or harm which in the first place relate the human being to the things of nature, must be allowed no influence upon his judgment. The responsibility for the steps he takes is entirely his own, for he will not, as in ordinary life, find that a false step soon meets with its own correction. The very solution which an artist requires for bringing forth his best creations is a hindrance for the scientist, who should work in a team and never withhold his results from others. He should not draw premature conclusions from experiment, and should emulate the mathematician in the rigor of his procedure. Objectivity, meticulous judgment, rigorous procedure, exchange of ideas and disclosure of results—these belong by any standards to the best precepts of Scientific Method. Where, then, does Goethe's method differ, and why should it have been so completely neglected, even denied, by all the scientists of fame who followed him?

The success of the scientific method which had begun with Galileo two centuries earlier was that the phenomena of nature, particularly those of the inorganic world, were beginning to be described in terms of relationships of number and measure, relationships which could be expressed as Natural Law, accessible to reason, and independent of authority. Movements of bodies—falling, rolling, swinging, rotating, and so forth—could be expressed and predicted in terms of distance, time and mass. Musical sounds were found to have measurable vibrations as their basis. Expansion and contraction became a relationship of temperature, pressure and volume. Colors became measurable components of white light, and so on. These claims could be verified by experiment, and experimenting was open to anyone. The universe came to be thought of as a vast machine, and the human being was discovering that he could begin to take it to pieces and find out how it worked. What could be more natural than to conclude that here was the kind of thinking that would unlock the secrets of the world, and what more tempting than to want to take nature to pieces down to the very last cog? Might it not well happen that the human being eventually succeed in getting down to the smallest, the ultimate cog, the universal atom, out of which the whole world was built?

For Goethe this attitude had no attraction. He had his own kind of acquaintance with nature. He, too, saw that all the elements of nature are related, but he saw it in quite a different way. For him nature was a unity, a oneness in which everything had its place. He did not look for the smallest unit out of which everything else was built up, but for the way in which everything was related to the highest, the ultimate all-embracing unity. He saw moreover that the only way in which the human being can comprehend this unity is by first separating, differentiating, defining. Separating is the work of the Intellect, whereas reassembling is the work of the Intelligence, the Reason.

The realization of this last point leads us to the heart of the matter. The discovery that we can take nature to pieces and find the most wonderful and beautiful relationships and proportions between the various parts is no evidence at all that the completed works of creation were put together from the elementary parts in the first place. In the world of living things, we have only to follow the successive stages from seed to flower, from egg to chicken, to see that the reverse is indeed the case. Nature proceeds by processes of differentiation and selection. It is only the human being who must construct from the parts to the whole. Let us look at this more closely. The architect, the engineer, and to some extent the industrial designer too, if embarking upon a new design must start from the most general conception of the finished creation and the roughest freehand sketches, putting in first the main features, then gradually working down to the separate details. The builder and the manufacturer on the other hand, who have to execute the plans, must do the reverse, namely, first make the parts and then assemble them, and only as the final step, put the whole into working order.

As earthly beings we are so constituted that anything which we create out of our own forces cannot be translated from idea to reality without going through the stage of being 'broken down' (a popular expression nowadays) into elements of manageable size. It is the same with our knowledge. We cannot create the great edifice of Science directly out of the Unity of Nature. We must first break down the vast natural events into separate processes, principles and definitions which have been sufficiently 'abstracted' for our intellect to be able to grasp them. Only when we have been able to reassemble them into their appropriate places and connections can we infuse them with the breath of life and begin to feel that we understand the workings of nature as she is.

The almost universal failure, against which Goethe protested with such vehemence, has been the failure to recognize that it is we who have made the separate pieces, whereas in nature everything is part of the unity, the totality. We have broken nature into pieces, and have then pretended that the pieces, as pieces, have been there all the time. All the single concepts which constitute our scientific language, such as distance, time, mass, temperature, wavelength, frequency and the like, are concepts which we have created in order to be able to describe and to predict with accuracy the behavior of the things around us. And now we have got into the habit of talking about the world as if it really had been built up from these separate elements. The great and thoughtful scientists have not been blind to this state of affairs, but I speak from my own experience when I say that the small boy entering his first lesson in Mechanics rightly feels that he has been cheated when he is fed only the indigestible abstractions of statistics which simply do not have any existence in the real world around him.

For Goethe it appeared highly unscientific and quite unforgivable to pretend to 'explain' something that one could see and experience, by means of something that one could not experience. The idea that behind the curtain of our often unreliable sense impressions lies the 'reality' of the objective mechanical processes which can be measured and calculated was foreign and repulsive to him. His method was to use all his senses and all his presence of mind to observe, in patience and humility, the things he was interested in, and from the things themselves to learn the kind of thinking which was appropriate to the study of them. He would experiment, observe, and modify the experiment into all possible forms and variations in order to perceive the kind of relationship which existed between the various elements and the phenomenon. He would never forget that the experiment itself was his own deliberate creation, and not nature's deed at all. He would find out which conditions were essential to the appearance of the phenomenon and which could be discarded. The relationships as such were perceptible to his thinking, though not to his senses. But the relationships were certainly not arbitrary. They originated in the things themselves even though they had to be formulated in terms of human thought and speech. Therefore if he arrayed before his mind's eye all possible instances of the same phenomenon, it should eventually be possible for the essential nature of the phenomenon, the very kernel of it, to present itself to his consciousness. The form in which he experienced this he called the *Urphenomenon*. It was an almost direct inner perception, which he called 'higher experience.' His Urphenomenon was the same thing that the intellect would formulate as a Law of Nature; but by refraining from making this formulation, and by allowing the Urphenomenon to speak for itself, he avoided the danger of arbitrarily importing a type of thinking, a theory, which might not be in conformity with the nature of the phenomenon itself.

Let us try to follow the method in the study of *Light and Color*, wherein Goethe's approach has been thrown into such sharp relief. At Cambridge nearly three hundred years ago, Isaac Newton made his famous experiment with a prism. He made a small hole in his window shutters and allowed the narrow shaft of sunlight to pass through a glass prism so that an elongated blurred image of the sun, a 'spectrum' of colors, was formed upon the opposite wall. He found that if he made the colored rays to converge again exactly into one place, then the colors disappeared and formed a colorless white light once more. His conclusion was that the colors had really been present in the original light of the sun, and that all that the prism had done was to analyze the white light into its component parts, and then reunite them, much as a cake can be cut into slices and the slices then put together again to form the whole cake.

It is a simple matter to repeat this experiment, and the results appear just as Newton described them. It is a very convincing experiment and should be done by all those who think that Newton was as dishonest an experimenter as Goethe made him out to be. Newton already knew that without the prism, he would get just a colorless image of the sun; with the prism the image appeared stretched out in length, the ends looking as though they were parts of successive images in different colors. I believe that anyone with any enthusiasm for describing an experiment in terms of neat mechanical concepts would at once come to the same conclusions that Newton did, namely, that he was dealing with a small patch of light in the form of an image, and that this was first broken up into colors and then reassembled to its original condition. But that for two and a half centuries it should have been generally accepted that all the colors are in fact present in the white light, when the eye sees that they are all absent, is a remarkable indication of the greater faith that was put into mechanistic interpretations than in the direct evidence of the senses.

If we proceed on Goethean lines we shall be unable to start from the image of the sun upon the wall without asking how it got there in the first place. We soon find that in order to have an image at all, even the hint of an image, some shutters or window frames are essential. By itself the sun simply does not produce images of itself. Therefore the hole in the shutter has played an important part and must be taken into account. But now comes the classical question as to whether the hole itself is the frame around or the space inside. Evidently Newton, like the architect in Christian Morgenstern's poem about the lattice fence, took out the space from inside the hole and built a great theory about it. Our method does not allow this. We make the image of the sun by putting up a dark frame and leaving only a small hole, so we must not pretend that the image was there from the outset as part of the light. Also we see that the bright colors which appear when the prism is put in the way of the light always stick rigidly to the edges of the image. Whatever we do we can never separate them from it, and they always occur in the same order red-orange-yellow, turquoise-blue-violet. One set belongs to one edge, and the other set to the other edge. If the sun's disc becomes obscured by light clouds, we get an indistinct patch of light with no outline, no edges and with indefinite colors. We can modify the experiment in any way we like, we may define darkness as the mere absence of light if we wish to, but the pure fact which presents itself to our observation is that both image and colors appear only where there is an element of darkness meeting the light. Furthermore, in any given experimental arrangement, we find that if the red-yellow colors appear with one orientation of light and dark, then with the opposite orientation we are certain to get the blue colors. We are compelled to think in terms of polarities, the first polarity being that of light and darkness.

In the type of experiments that Goethe made, it is not difficult to convince oneself that the fullest and most beautiful appearances of color are where the light and the darkness are meeting each other on nearly equal terms, that is, where there is the fullest mutual interplay between the polarities. It would be hard to find a clearer exposition and application of these principles than in the modern processes of color photography. It has been my personal experience that once this Urphenomenon of the polar interplay of light and darkness has been seen and grasped, further and hitherto unthought-of experiments suggest themselves in a surprising and fascinating way. Moreover the basic experimental facts, all of which have been known and published for many years, rearrange themselves quite naturally into a system, a plan, from which not only the practical laws of color mixture and manipulation can be read off, but even the moral qualities of the colors as well. From this it becomes abundantly clear that the standard experiments which are used to illustrate the behavior of light and color are only those which arise from the school of thinking which Newton initiated.

But when we come to the exact quantitative experiments which gave rise to the wave theory of light, experiments which were only beginning when Goethe was writing his "Farbenlehre," we have to be careful not to be swept off our feet by the beautiful mathematical processes and proportions which are associated with the appearance of the colors. It is, of course, not possible to go into any of the technical details in a short article of this kind, and I can only say that if we remain true to our first Goethean principles, trying to read from a multitude of experiments and phenomena, the intrinsic nature of the relationship of darkness to light, never losing sight of the experimental conditions which we have imposed, then we can come to only one possible conclusion, and that is that the mechanical-electrical properties and the mathematical forms which are usually attributed to light as such, are in truth properties of darkness, of matter, which are impressed upon the light and revealed by it.

To some readers this may seem but a change of name, and without significance in practice. But it is a great deal more than this. Firstly, it is entirely in accord with the fact that the logical development of Newton's conclusions—the use of the spectrum as a means of investigation and measurement—has given us an immense amount of valuable information about the nature of matter, but practically nothing at all about the nature of color. Secondly, it puts the study of color into the place where it belongs, namely, the subtle interplay of light and darkness, in the region midway between the two extremes, and, what is most important, into the realm where we experience it every day in the colors of nature. Thirdly, and this points more to the future, it gives us an indication of the kind of thinking which will be necessary if we are one day to grasp the nature of light itself. In making these statements I am not speaking in a vague and qualitative way, for I see that the kind of approach which I am trying to describe will involve the transformations of the very mathematics itself, so that it can become livingly orientated to the world of spiritual principles on one hand and material principles on the other. The transformation will require tremendous labor, and will not be achieved overnight. But if we start with the simple principles which Goethe enunciated in his essay, and follow them up along the comprehensive path of knowledge which Rudolf Steiner has built upon them, developing a new power of selfless perception and a new power of inner wrestling with our thinking, then we may hope that Goetheanism will give us a science that touches the real problems of human existence, and a technology which heals and does not destroy.

Finding Truth in Art, Beauty in Science

by EILEEN HUTCHINS

The attitude towards painting and rhythmical movement as school subjects has very much changed during the last fifty years. A few decades ago these were not part of the normal curriculum but were extras for students particularly gifted or for those not capable of academic work. Today most educationalists have come to the view that the arts play an essential part in education. But they are now too often regarded as opportunities for self-expression rather than as studies with their own necessary disciplines. And in general there is little connection between them and the standard school subjects.

In a Waldorf school all branches of knowledge are regarded as different aspects of one essential theme—the relationship of the human as a spiritual being with the surrounding world. History, geography, physics, maths, chemistry, and so on, are all studies in pursuit of this basic understanding. Literature, music and art cannot be kept in separate compartments. Children need to express their thoughts and feelings about history through drama and pictorial art; arithmetic and geometry are essentially related to rhythm and form; chemistry requires an imaginative observation comparable to that of a poet. But if these relationships are to be truly developed, then the arts cannot be regarded merely as safety valves for students to express their subjective feelings.

There are laws of color as objective as those of mathematics. Early in their school life children begin to realize the qualities of color. A red snake upon a green field leaps into life, while a blue one almost disappears. A yellow flower shines against a blue sky, but loses its brilliance among green leaves.

In physics lessons, when students are about twelve, they learn to observe complementary colors. It is for them an almost magical experience when, after looking intently at a bright scarlet disc, they turn their gaze to a white background and become aware of the delicate jade-green afterimage. Later, in the Upper School, their attention is drawn to the way in which leading artists use complementary colors. Exercises in copying some of the paintings of Turner or the Impressionists can alter with their own experiences on color contrasts.

Forms and patterns also have their objective qualities. In the younger grades a great deal of attention is given to movement. Marching in a straight line has a different effect upon children than making circles or moving through spirals and lemniscates. The regular performing of certain patterns has a harmonizing influence on those who are restless and unfocused; walking backwards and becoming aware of dimensions in space strengthen the will and the memory. Drawing of forms and completing of symmetrical designs and mirror pictures are also of value. For the slow, dreamy child, sharp, angular figures awaken consciousness; for the precocious one, flowing, rounded forms have a tranquilizing effect.

These exercises lay the foundation for a sound understanding of geometry. What children have experienced in their limbs comes to consciousness in their thoughts in later years.

The gift of expression in language is no less an art than music or painting. But now that the teaching of English is becoming freer from the formal disciplines of grammar and sentence construction, there is a general uncertainty about how it should be taught. It is taken for granted that children should learn to express themselves, but the teacher is warned against providing the material to be expressed, for this would be preconditioning the minds of the students. A good example of the general bewilderment is illustrated in "The Uses of English," Herbert Muller's report of the Anglo-American conference at Dartmouth College, 1966.

One possible approach is the interrelating of the teaching of English language with other subjects. In their scientific studies students are taught to observe accurately. This training can be further developed in their exercises in writing. They can be led to describe the scenes and activities around them. The first essential is that details should be accurately recorded. Vague descriptions can be shown as of no value. Clearly observed characteristics of individual plants, animals or scenes are required.

The second stage in the art of describing is the inter-relating of details around a central motive, such as the mood of a particular autumn day, the impression of a storm, the way in which the outer characteristics of an animal reveal its nature, and so on. The subject matter of botany and zoology lessons is approached from another angle. Students can at the same time be introduced to the works of authors who have written on similar themes. In this connection the poems of Robert Frost are especially suitable, as his faithful observations can lead to a heightened sensitivity and awareness of the relationship between the human being and nature.

As it is often a hard struggle to get students to be willing to express themselves, teachers are sometimes led to encourage the writing of horror stories and science fiction, or to arrange debates in which personal views are aired. Though these methods may be justified as a first stage, there is a danger of establishing the assumption that language exists merely to express one's own opinions. We need to confirm that language is a medium of understanding and that this is impossible without a regard for the truth.

A sense for the right use of words can be awakened by connecting language with history. Students are interested to discover the different qualities of words of Old English origin from those of French or Latin. They enjoy finding expressions which English pioneers have borrowed from countries all over the world. They can appreciate searching for synonyms and sensing the varied shades of meaning in their use.

Speech exercises can bring awareness of the qualities of sound. Alliterative phrases using 's' and 'r' are stimulating and invigorating; those with 'm' and '1' are calming and lulling. Students find pleasure in making their own examples and trying these out in various rhythms. They can be brought to realize that deep feeling lifts language to another level than that of our everyday commonplace conversation. The expressions of blessing and cursing, of prayer and of grief have their own grandeur.

Today a sense for the truth of imaginative knowledge has to a great extent been lost. Yet it is only in this light that the value of legend and literature can be known. They reveal more profoundly than history the aims and ideals of a race or civilization. Pre-Christian myths resemble the stories of the Old Testament; they tell in imaginative form of the human being's loss of an ancient wisdom and union with nature and his development of independent consciousness.

Children themselves go through a similar stage and, if the stories are brought to them at the right age, they derive strength from the tragedy and courage of the human being's struggle to find his true being. In the Upper School they learn to relate these great themes to the changing consciousness of the human being through the ages and to follow his development from a narrow tribal religious life to the Christian conception of world brotherhood, and his emergence from the guidance of a priestly cult to the sense of individual responsibility.

Today the teaching of scientific subjects has tended to become abstract and divorced from human values; the arts have become experimental and chaotic. They need to be reunited in the light of a truer understanding of the human being.

Teaching Science Humanely
by HANS GEBERT

A great deal is being written and spoken about the gap between scientists and humanists, and many schemes are being worked out designed to bridge it, at both school and university level. Most of the innovators seem to pin their faith on the introduction of additional subjects into the curriculum of the sixth forms or the syllabuses of the universities. Such suggestions lead not only to the vexed question where time is to be found in already overcrowded timetables for these additional subjects, but it is also doubtful whether the problem can really be solved in this way. If these subjects are still to be taught by specialists as more or less closed subjects, there is the great danger that the gap will merely be transferred from society to the individual. This danger is indeed realized by many people. The demand, then, is for a more humane teaching of science and for a consciousness of the impact of scientific thought on the culture of our day when the humanities are being taught. Attempts to do just this have been made in Waldorf schools since they first began. What follows is based on the experience of one science teacher in such a school, who has been privileged to share in these experiences for twelve years, after teaching for some time in a state grammar school. I rather think that success in the attempt to teach science humanely will also go a long way to solving the ever-present problem of the short supply of scientists and technicians.

The question of time is, of course, also an important one in a Waldorf school. In fact I am convinced that nothing really satisfactory can be done in humanizing science teaching without severely pruning the traditional syllabus. In doing so it is most important to keep constantly in mind that one is trying to select those parts of a subject which are important for every educated person to know, or which will convey experiences or develop faculties which it is desirable for such people to have. The danger is always that the specialists consider, instead, what they regard as important from the point of view of their science, and the result is a school syllabus which is really the beginning of specialized training in different sciences. Most ordinary level syllabuses of the G.C.E. [state examinations] are rightly criticized on just this count. Even many curicula for general science cannot be excepted: they stop at far too elementary a level.

A great deal of the research techniques and of the problem solving which these syllabuses contain is not necessary for a general education. The students must, of course, learn about the methods employed by scientists, and they should also carry out experiments themselves. They should have experienced what it feels like to be faced with a scientific problem and what it means to make an accurate experiment These aims can, however, be achieved much more economically than is done usually. At present the students are required to learn experimental methods in every part of their work. A great deal could be gained by a judicious selection of a few typical experiments or, even better, small research projects, if the facilities permit this. It would then be possible to deal with these much more thoroughly, and the students would gain a much deeper experience from them.

Problems are, of course, largely introduced because they are supposed to test whether the student really understands the subject. Now, it is certainly true in general, although not invariably, that a candidate who can solve a problem has also understood the subject. It does not follow, however, that a student who cannot solve a problem has not understood the subject. Faculties, especially that of translating a concrete situation into mathematical symbolism, are required for solving problems which have nothing to do with an understanding of the concrete situation. Problem solving is, of course, a good training for the intellect and as such must not be entirely neglected. It is, however, practiced in the mathematics lessons, and facility in it develops slowly in many children. There is no reason why difficulties in problem solving should impede the teaching of science as a cultural subject.

What should then be done with the time saved by putting less stress on problem solving and on learning many different research techniques? A good deal of it should be devoted to teaching the history of science. Most teachers now seem to agree that this is a most important part of the science syllabus, but it is doubtful whether under present conditions many can do more than make short historical references here and there. It is not a question of introducing a connected course in the history of science. This is mainly because the subject has two different aspects which are suitable for children at different ages.

There are first of all the practical applications of science in technology, medicine and hygiene. These have affected our whole mode of living. This is very obvious to us adults and we often forget that it is not equally plain to the children. After all, many of the younger ones can hardly remember a time without a television set. I have found that students from about 12+ to 14+ are particularly interested in the way in which the modern inventions have developed and how they work. They are also interested to learn how this development has affected the routine of daily life. They seem to ask *how* and not yet *why*. In answering this question a great deal of useful scientific knowledge can be imparted. If one takes, for example, the development of the heat engine from Thomas Newcomen to jet propulsion, one sees how every new advance was likened to quite fundamental scientific discoveries. The course can be planned so that the most important laws and experiments are selected as a hard core which is treated in great detail, while the whole historical development has to be presented more in outline. Such a course can give the students the feeling that science is everybody's concern.

Only at a later age, at the earliest from sixteen onwards, are the students (in my experience) able to appreciate the second aspect, namely science as a chapter in the development of human thought. All the same, it is essential that as many of our students as possible are brought to such an experience. Such a course has to be rather comprehensive if it is to be really effective. One cannot appreciate the novelty of modern scientific thought unless one knows what has preceded it. It is therefore necessary to deal fairly fully with Aristotelian ideas in both their original form and in their medieval modifications.

Both in Greek and in medieval cosmology all sciences are really included. After this they diverge, and the story of the divergence can be linked with the teaching of scientific facts in many different ways. One scheme which I have used with some success can be given as an example. In this story it was shown how chemistry and astronomy first gradually separated and became sciences on their own, without the obvious connection which they shared in alchemy. The development of chemistry was taken up to the atomic theory and the periodic table, and astronomy up to Isaac Newton. Such a treatment shows how the awakening interest in numerical relationships leads to quite a new view of the world; the students can see how fresh vistas open up, but also how the essential unity of the universe disappears. We continue the story in lessons on electricity, up to the end of the nineteenth century and the dissolution of the simple concept of the atom. We reference earlier studies in elementary electricity and the development of the telegraph and telephone, just as in the chemistry course many illustrations are taken from the previous year's work on acid, base and salt and on some of the most important elements. A study of optics in the last year led to a unification of all the previous work and brought the story up to date. Since the students were all in their seventeenth or eighteenth year, and since problem solving was only required from those who were also budding scientists, little difficulty was experienced in introducing material usually classed as advanced. The aim was to give a qualitative treatment of as many of the results of modern research as possible and of the problems raised by them.

Such a course stimulates the interest of the more philosophically inclined students. They see that science nowadays gives the philosopher the hardest nuts to crack and that scientific thought in its turn is very much in need of philosophical elucidation. Some of them may experience the present view of the physical world as philosophically unsatisfying. Even the modern youngster is still sufficiently self confident to expect to do better than his elders, and this may well result in students choosing science as a study who otherwise would have taken up the humanities. But the course is also of greatest value for the future scientist. A concentrated experience of the way in which theories and modes of thought change gives him a healthy skepticism in the matter of theories, and should make it much easier for him to break new ground later. Our present mode of teaching makes our future scientists far too hidebound. When they leave school they are already indoctrinated with the currently accepted views; it would be much better for them and for the future of science if they had more of Michael Faraday's cautious attitude toward theories. In any case no one should leave our schools at age eighteen without having some idea about the philosophical implications of modern scientific thought. Too many people are still living in a comfortable nineteenth century universe; if he is to play his part in our cultural life, modern man must truly face the challenges presented with more up-to-date views. This challenge would, I am confident, bring many more students to the science faculties in our universities.

If the interest of the students is to be aroused, the way in which the picture of nature develops is also most important. It should take shape gradually over the school years and at every stage account must be taken of the maturity of the child and his interests. At an early age the eagerness of the children to learn facts, to know what is the biggest of this and the fattest of that, can, for example, be used to teach a great deal about the variations in the physical properties of different materials. Even if they bore the teacher, tables of expansion coefficients and of specific heats of refractive indices have, in my experience, a fascination for the youngsters and arouse questions in their minds. Subconsciously at least they ask how these properties are related to the chemical behaviors of the same substances and to the uses which plants and animals make of them. Later on comes the stage in which each teacher must know something about electricity in the human organism and in electric fish. Only indications are necessary because the biologist and the chemist will take up the work in more detail in their subjects. In this way wonder is aroused. As questions are answered at one level, they give birth to new and more profound ones, which are not immediately answered, but allowed to rest in the mind. If many remain still unanswered when the young men and women leave school, all the better. Wonder is the beginning of all scientific quest. At present we tend to send the students away with the illusion that they have learned most of the answers, at least in their specialist studies, and that those which they have not learned somebody else knows and they can simply look them up in the library. Can we be surprised, then, that they show the lack of interest and initiative of which many employers complain today? On the other hand, a wide knowledge of facts and phenomena always raises questions about their connections. If this unites with a healthy skepticism about theories, which should be imparted by the historic approach, the students will be prepared to enter their university courses with eagerness and expectation if they choose to become scientists, and, if they enter other walks of life, they should at least have a responsible and informed attitude about science.

From what has been said above, it is clear that there are two different aspects to the 'humane' teaching of science. First, we must take the word 'humane' really seriously and adjust our teaching so that we impart the knowledge and the experiences which our students should have in virtue of the fact that they are human beings and not because they may take up this or that as a profession. As human beings they must have the right relationship both to society and to nature. We may hope to have done something for the former if we have taught the historical aspects of the subjects correctly and have thereby introduced the students to the technical achievements of modern science and to scientific thought as a chapter in the spiritual development of humanity. Whether we establish a right relationship to nature will depend at least as much on the mode of our teaching as on its content. Paradoxical as it may seem, I am convinced that an attempt to be too scientific at too early an age can do more harm than good. After all, there are two parts to the scientific method. Science starts by induction. Slowly the manifold phenomena of nature group themselves and reveal an underlying harmony, a logically connected body of scientific law, from which we can then proceed to deduction, and thus verification appears only later. In the day-to-day working of the scientist, the two go, of course, hand in hand, but in the development of science teaching, they should be consecutive.

This brings us to the second aspect of 'humane' science teaching. We must take into account the facts of human development. In my experience of secondary school science teaching I have experienced two quite distinct stages of development, which I should like to call the 'how-stage' and the 'why-stage.' The two, as always in natural development, have no absolute hard and fast boundary, but age fifteen is perhaps a good average. Before that age children seem mainly interested in *how* things work and *how* they were discovered. Despite some attempts in this direction, I have never succeeded in arousing the interest of more than a small minority of a class of fourteen-year-olds in the question *why* the steam engine was developed just at the time and in the country where it was in fact first used; but I found a great deal of interest in *how* this happened. When the question *why* arises at this age, the children are usually satisfied by the most immediate explanations, which really describe only *how* a thing happens. This is the inductive stage and theories have no place in it. If one tries to impose one's own desire for more fundamental explanations at this age, I think the response is the often all too familiar experience of science teachers that a considerable number of the students decide that science is an esoteric study which can be understood only by a few, "of whom I am not one." There are, of course, always a number of students who are intellectually inclined, and who can be drilled even at this stage to ask the questions which we want them to ask, but this procedure leads to a loss of many potential scientists and is not healthy for those who can be so drilled. This is the stage when many facts can be learned, and they should be drawn from all the sciences, provided it is done in a way which arouses wonder.

The work so done provides the necessary broad basis for the second stage, that of presenting science as a logically connected system. This study can be brought to a proper conclusion only if the children stay until they are eighteen. One of the greatest menaces to good science teaching is the ever-growing volume of even elementary textbooks of chemistry and physics which start with the atomic or electric theories.

Two consequences are apparent from the above. First, the time required for teaching all the sciences in the way outlined—and they must all be taught if it is our aim to establish a true relationship to nature—does not permit the high degree of specialization practiced in most grammar schools at present. Secondly, it presupposes some form of education up to the age of eighteen. The latter is in any case provided for in the Education Act, and it only remains to implement its provisions. That this can only be done gradually goes without saying. As far as specialization is concerned and some vocational or pre-vocational training, we have found in the Waldorf schools that this is not incompatible with general educational courses as outlined above which do, of course, include the humanities as well as the sciences. Boys and girls capable of a university education can, by age eighteen, be brought to the standard of the G.C.E. advanced level in three specialist subjects in addition to the necessary ordinary level. If we also take into account that the necessity of advanced level work for university entrance is only a comparatively recent innovation, and that it is only in England that a degree can be obtained after so short a time as a three-year university course, the solution to our educational problem lies probably in an extension of the latter to at least four years. The advanced-level courses could then be remodeled so that they provide only the real essential fundamental knowledge, which is much less than the present content of the syllabuses, and an opportunity for the candidate to show in a restricted field that he or she is able to do work of university standard. The universities and employers would then get generally educated people who could specialize against a wide background of knowledge and experience.

In conclusion it should be emphasized that the work described above represents developments of Rudolf Steiner's pedagogical indications by one science teacher only and that they owe a great deal also to the work done by colleagues in this and other countries. I have also only written about the task of the *teacher* in humanizing the material available in present day science. There is a similar task for the *scientist*. The high degree of specialization in the sciences has led to the disintegration of the picture of the universe. Our knowledge of the human being especially, and of his place in nature, is only a very fragmentary one. A great deal of work is therefore required in the sciences themselves to make them into a truly humane discipline. It may be hoped that students who have gone through an education such as that described above will be better fitted to carry out this task than our own generation.

Science and Technology

by DR HANS HEITLER

Science is understood in general to be an intellectual activity concerned with the various aspects of the world and the human being insofar as such are accessible to the human mental powers. The scientist endeavors to find the laws of nature, to understand the underlying principles in various phenomena and to come to some generalization, looking for the common factor in the chaos of the bewildering multitude of our sense impressions or scientific observations and finding satisfaction when such a common factor emerges. For example, it is a matter of observation that coal-gas, oil and wood burn when ignited. Although one is gas, one is liquid and one is solid, all are combustible. When on investigation it is found that in all these cases of combustion the combining of the carbon with the oxygen of the air takes place, the general scientific principle then emerges that substances containing carbon burn if oxygen of the air—or from other sources —has access to them.

Here is a comprehensive scientific principle applicable to practically all forms of combustion. But the principle alone can never build an actual oven or furnace. When we want to make a fire we must apply something fundamentally different. Our physical organization, in other words, our will, must take part. We have to get bricks, we have to set them in a proper form, we have to fetch wood and finally light it, and only then have we made a fire. The technique of burning involves the activity of our physical organization, whereas the science of combustion requires the activity of our thinking. It is true, of course, that the technician does not act blindly, but is the more successful the more he observes in his furnace construction the corresponding scientific principles; it is equally true that his scientific knowledge alone is of little avail if he cannot use his hands properly.

The word *technology* in itself means knowledge of execution—the skill of doing. It has always to do with the shaping, molding, working and forming of material substances. From this it might seem that the ancient skill of craftsmanship, evidence of which archeology is constantly bringing to light, should fall under the category of technology. But this conclusion would overlook the important difference, that the soul force which flowed into the will of the artisan of the past was not thinking, but feeling. It was in his feeling that the craftsman experienced the image of what he wanted to create with his hands.

Contemporary with our modern civilization, however, came the development of technology, a development dependent upon the intimate intercourse of thinking and will in the human being. When we consider the three human soul qualities—thinking, feeling and willing—thinking and willing form naturally two opposite poles. In thinking we separate ourselves from the world. We think about an object and we are immediately aware that we and the object are two separate entities. Nothing must go over from one into the other. Indeed it is one of the fundamental requirements of thinking that the thinker should not interfere in any way with the object of his thoughts. Objectivity, the strictest reticence, is absolutely essential, and it is therefore perfectly correctly assumed that it is quite immaterial to the object whether the human being thinks about it or not. With regards to the will, the exact opposite is the case. Not the slightest will activity can take place without having an immediate effect in the surrounding world. We cannot take a step without altering the balance between ourselves and the ground, we cannot take a breath of air without changing its chemical balance. Through the will the human being is part and parcel of the world and influences it directly and inevitably.

With the birth of technology—that is, the will mainly directed through the thinking—the human being and the world entered into a new relationship. A great deal is known about thinking. No other activity has been subjected to such intense study throughout the ages since Aristotle established the principles of logic. But little is known about the human will. In fact, the most essential parts of it disappear entirely into the darkness of the subconscious. What we can observe consciously in our minds when we, for instance, lift an arm is the intention to do so; but intention alone will never result in any movement. Another element enters which evades our conscious grasp altogether. Only when this unknown has acted can we observe the performed movement. The vital link—the act of will, as such—is unobservable.

In a technology which is fundamentally the forming and shaping of material objects, we shall have to look for the will element and from what part of the human soul it emerges as impulse for action. With the evolution of mankind as a whole, new soul forces gradually unfold themselves, and we can therefore expect that these are reflected in the thinking and actions of the time. History shows also that the three soul forces in the human being do not always develop together, and that the predominance of one or the other gives the period of civilization its characteristic feature.

Let us now consider our modern technical age which came into being with the invention of the steam engine and which, with the creation of innumerable machines since then, has been able to transform more earth substance into technical aids than any other age. We may well ask whence this ability originated and what new impulse began to reveal itself in the will-organization of the human being.

The end of the eighteenth century saw an already highly developed general science. More than two centuries earlier Kepler, Galileo and others had presented mankind with a new picture of the heavens. Newton had established the laws of gravity for the earth, eventually extending their validity into the universe. He also evolved principles of optics which are fundamental to this day. He and Leibnitz, quite independent of each other, invented a new calculus dealing with the infinitely small and large. The mathematical edifice grew rapidly after Newton's days, and reached by the end of the eighteenth century a standard comparing well with that demanded from a modern university graduate in mathematics. The eighteenth century had all the mathematical and mechanical knowledge necessary, e.g., to develop water power, and could have transformed the ancient water wheel into a more efficient water turbine. This, however, did not happen. When the desire for a more concentrated force of power of a mechanical kind arose, the steam engine was invented. Now, nothing was known at that time about the behavior of steam; nothing in the way of a theory of heat existed from which the steam engine could have been the immediate logical offspring. There is the story that Watt saw the lid of a kettle being lifted by the steam of the boiling water, and it is supposed that this observation gave him the idea of the steam engine. But he did not use the steam pressure as would have been the logical conclusion from his observation. Instead, he used the negative pressure, the vacuum which is created by the condensing steam.

The laws of thermodynamics which express the relation between heat and mechanical energy were discovered about eighty years later by Julius Robert Mayer. He was a doctor, and he observed that the blood of people living in the tropics was of a lighter color than that of those living in temperate climates. He concluded that in the hotter countries, owing to the constant blood temperature, less inner combustion is necessary to produce the same amount of energy. The laws of thermodynamics which Mayer deduced from this observation have now worldwide significance and are considered to govern all processes of heat.

Now the outstanding facts to consider here are that at the beginning of our technical era, heat for the first time in human history was used to provide mechanical energy, and that the science of thermodynamics took its origin from a peculiarity of the human organism. Only when we are aware of the new relationship between the thought-permeated will and the technical achievements will these facts become more than a curiosity. They point indeed to a new stage of soul development in the human being.

What then is this new quality which began to appear less than two hundred years ago? Mankind had already been living for about three hundred years under the impact of the growing ego-consciousness. The new outlook into the world, the Newton–Kepler universe, was becoming common property. In the new scientific concepts the universe was emptied of living forces and was becoming rapidly a mechanism of huge dimensions. In the field of philosophy Kant had thrown down the challenge of the categorical imperative, thus leading to the denial of freedom in the realm of ideas. To a large extent the mechanization of the human being went parallel with that of nature and the cosmos. The heart became a pump, the lungs a means of exchanging oxygen and carbon dioxide. The digestive organs were pictured as a chemical laboratory, and the nervous system with the brain and other centers, a telephone exchange. It is as if a kind of phantom man, a ghostly specter, was put over the living human being. But all this would not have been possible if the human thinking had not become independent of cosmic guidance. It is an astounding paradox that Kant and most of the following philosophers would not have been able to deny freedom if they had not been in possession of a thinking freed of previous bondage.

The freedom has so far opened up and conquered a mathematical-mechanical world and our concepts are perfectly adequate for this particular region. It is not surprising, therefore, that practically the whole of life is being fitted into this world conception. We speak, for instance of the 'mechanism' of democracy, of the 'machinery' of reconciliation, and there is no end to the intrusion of statistics into our everyday lives.

When we now try and follow this ego-development, not towards the outer world as it shows itself in thinking, but along the inner path into the will, then we meet it again in the blood, and in particular in the warmth of the blood. Rudolf Steiner pointed out in various connections that this is indeed an indication of the ego nature of the human being. Only in him is the blood temperature constant to such a degree that it makes him independent of his surrounding environment Although, of course, nothing in the nature of a proof can be attached to such an observation, it may, nevertheless, appear feasible if we try and put before our mind's eye a picture of the human being as a whole. We can see how he has become independent and separated from the world, not only through the thought-permeated senses, which make him into an observer, but also through his blood which makes each individuality into a self-contained center of constant warmth, independent of the seasons of the year and of the region of the earth he happens to inhabit. Only a being endowed with an ego, that is, a spiritual entity, can be imagined to occupy such a unique position.

It is the ego which expresses itself through the observer in the mechanical-logical world picture, and it is the same ego which links the constancy of the blood temperature and the consequent differences in the metabolic rate with the universal laws of thermodynamics. The one path is going through the senses, the other through the metabolism. It was at this juncture that the ego, in its constantly progressing evolution, could find, for the first time in human history, external expression through the thought-permeated will in the form of the steam engine, and in the discovery of universal laws through the conditions of the blood, that the industrial revolution started and technology was added to science.

When we now look once more over the intricate interweaving of the forces which formed and molded our scientific and technical age, we can discern a pattern which involves the human being and nature both in their twofold aspects: the human being as a thinking and willing being, nature as a provider of material substances and forces like heat. But it was Watt, the energetic technician, who gave physical-material expression to the mechanical conceptions through his action, whereas Mayer, the thinker, was inspired from the realm of the dynamic, the will, and brought it into conceptual form in the mechanical heat theory. It can thus be observed that polaric inspirations—will and thinking, find their meeting place in the human being, and then cross over into polaric manifestations—science and technology.

It can be seen in the above example how intricately and intimately the human being is involved in the evolution of the outward civilization, that indeed soul and world development go hand in hand, and that in particular in our technical age, will and thinking are involved. Another aspect of the will extends, however, into the moral forces. Today the question stands urgently before our mind whether man or machine will be master in future, clearly a moral issue. The answer will depend on the recognition of those interconnections which have been touched upon tentatively here.

The Goethean Approach to Science

Coping with Change

by MICHAEL WILSON

It has always been far easier for artists and poets to feel sympathetic towards Goethe's scientific ideas than it has been for scientists. Today it is still difficult for someone with a strict scientific training, particularly in the field of physics, to take Goethe seriously as a scientist. The conventional physicist will only accept causes which can be measured, formulated and depended upon to produce the corresponding effects exactly, whenever they are allowed to operate under the appropriate conditions.

For Goethe this limitation of allowable causes was much too narrow. He was a person for whom the laws of nature were still connected with the divine forces that had created nature in the first place, and for him the idea that these universal laws should be no more than expressions of the functions of matter was quite unacceptable. I believe that had he had a little more understanding for the methods of the physicist, he could have found a physical basis for his theory of colors which would have earned the respect, instead of the scorn, of contemporary scientists.

It has to be admitted that there are many assertions in his theory of colors which, if taken as statements of physical fact, simply do not make sense. On the other hand there are grandiose and sweeping pronouncements—such as "colors are the deeds and the sufferings of light" and his characterization of the formation of green and magenta in the spectrum as "the earthly and the heavenly offspring of the Elohim"—which in their nature seem far removed from scientific statements, and yet when seen in the perspective of his whole attitude to nature are found to be fully supported by modern technical knowledge.

I stress these points because for a long time Goethe's ideas about color have been set up in opposition to the generally accepted line of scientific thinking as represented by Isaac Newton, and this has been made into a controversial issue that has consumed much time and energy without making the situation any clearer. No one has in fact been able to show that Newton's experimental work was other than scrupulously correct, although the interpretation put upon some of it, partly by Newton himself and partly by others, is very much open to argument.

Here we should remember Goethe's own words: "The senses do not deceive; it is our judgment that deceives. … It will therefore be best if in our observing we are as conscious as possible of the objects, and in our thinking about them as conscious as possible of ourselves."

Like all great pioneers of human thought, Goethe had the kind of insight into the relation of the human being to the world which was in the first place a direct perception into the depths of existence rather than a synthesis of laboriously collected facts. If we do not understand this, then we cannot understand his science at all. For him it was a matter of actual perception that the separate existence of single objects at any one moment was only part of the truth. The 'process of becoming' was part and parcel of the things themselves.

He saw that just as in the human sphere all intelligent action proceeds from an underlying idea in the mind of man, so in nature all the wonders of creation proceed from a higher kind of intelligence which he calls 'idea' and which does not proceed from the mind of man, although the human being can find access to it.

It is in the inorganic realm that we face the greatest difficulties, for here the living process of 'becoming' is at an end. The idea now takes the form of what we call natural law and stands in the background. Our conquest of nature consists of making these inorganic laws obey our own will, and very often the process can be made to work equally well in either direction (such as changing the white light into colors or the colors into white light), so that at this level it is impossible to say which is the original cause and which the original effect. Nevertheless Goethe saw these phenomena always in relation to the world processes through which they have become what they are. How are we to picture these?

Here we come to the point where Goethe's own approach is unable to answer the kind of questions which arise from our present state of knowledge. Rudolf Steiner made it clear that his own work was a continuation of what Goethe had begun. Only in the light of Steiner's own work shall we be able to find a 'Goethean approach to science' which makes sense in the light of modern technical knowledge. During the last six months of his life, when his final illness had brought his lecturing activity to an end, Steiner wrote a new chapter of anthroposophy in the form of "Letters to the Members." In the course of these (October 1924), he summarized the evolutionary process and showed that the gods have come to the end of their work of creating the world of outer nature and have retired, leaving the whole machine of natural processes to run by itself.

When we look at this world of outer nature, we can and must continue to see it as divine handiwork, but we must have no illusion that the gods themselves are still in control of the machine. The place where they are now to be found at work is not outer nature, but the region of the human soul, and it is in this region that the future of our life on earth will be determined.

Again and again Steiner impresses upon us, in this final message, the need to discriminate between the working of the existing world of nature, the "world of finished work," on the one hand and, on the other, the workings of our own soul life, our life of inner activity which for better or worse will determine the kind of life that can be lived on earth in the future. With Steiner's own description of world evolution in mind, let us look once more at nature and the human being in the 'process of becoming' and see where Goethe's 'idea' leads us.

The mineral world, the world of inorganic processes, has the longest history, the oldest memory, and embodies the divine will and wisdom at the deepest level. It has undergone the greatest number of transformations, and now runs by itself. For us its laws are given, immutable. But the human being is free to manipulate them as he will.

The plant world also can run by itself. Its wisdom, too, is very old, and is a constant source of inspiration for the human being. He can manipulate it to nourish and to surround himself with greater beauty. Only to a small extent can he use his own growth powers to influence the growth of the plants.

The animals are closer to humankind and their history is shorter. In them, the human being finds memories of part of himself. He can make some of them serve him, breed them and change some of their habits. He can find his own moods and feelings reflected in them.

The individual human being is the youngest member of creation, with a memory that is short compared to world memory, but a freedom to penetrate the world with his thinking, a freedom that exists nowhere else. His ideas are still at the visible level and he can always change them. His habits and instincts take longer to change, and his body is such that he cannot add one cubit to his stature. But he stands at a turning point in time, where the gods have retired from the outer scene, leaving the future in his hands.

The Goetheanist will recognize all the facts and processes of the finished world of creation whether they be comfortable or not. He will revere them as divine handiwork at their different levels and will be grateful that they are put into his hands to control and to use for his own needs. He will still see them against the background of their own cosmic memory but will not try to populate them with a spirituality which has long since retired. On the contrary, he will study how the gods did their work in the past, and from this he will learn how they are ready to do their work in his own soul life, once he has made the necessary decisions. Here he meets darkness and light in their full reality.

In observing nature he will not try to make the facts fit any theory, but with patience and humility will array all the aspects before his mind's eye, training his outer and his inner senses and awaiting the moment when the unifying idea behind the phenomena will speak to him. When this happens, then every scientific fact falls into its place in perspective and the experience of beauty is such that any deliberate adornment is mere insult. He will never fear the evidence of his senses, remembering with Goethe that it is not our senses, it is our judgment that deceives.

On the other side of the picture he will ask himself: What ideas am I putting into the world when I bend the laws of nature to my own purposes? What sort of a world am I helping to create with my newfound freedom? How can I become a channel through which the gods can bring new life into a dying universe?

Steiner summed up Goethe's whole approach in a single sentence: "In our knowledge, the idea; in our action, love. This must be our guiding star."

A New Way of Knowing
The Goethean Approach to Science
by DAVID LANNING

Bernard Levin, writing in the *London Times* recently, was asking the question why the film *Star Wars*, which to him seemed to be singularly lacking in merit, should nonetheless attract such large audiences. He came to the conclusion that what really struck a chord in the hearts of the cinema-goers was the fact that, at the very end of the film, at the most critical point, when it was a question whether the evil empire would triumph or be destroyed, the hero achieved his ends by abandoning all the advanced technology which was at his disposal, and obeying the 'force' that was within him. The idea of an advanced technology creating a soulless and spiritless world is one which probably lives, at least subconsciously, in most of us, and the present image of science is that which is the basis of such a technology. This is one of the problems for a teacher of science.

Another is that in the scientific world picture there seems to be no particular place for the human being. The whole process would go on just as well without him, in fact rather better if we consider how we are at present destroying our environment. Values such as truth, beauty and goodness become merely relative, and in the end just a byproduct of certain molecular aggregates. If we are of a religious disposition, we might wonder how it is when Christ said, "By their works shall ye know them," that by knowing His work we do not come to know Him. There are really only two conclusions—either He is not, or we are not knowing in the right way. This, too, is the business of the science teacher.

It was not always so. The interest in science at the time of Charles Darwin's *Origin of the Species* was tremendous, and in fact, the book itself, although rather heavy and cumbersome in style, was a bestseller, and soon went into several editions. Vast crowds would line the streets to watch the professors arriving for their scientific congresses, and much of the adulation now reserved for pop stars and footballers was then the lot of professors of zoology. (Let pop stars and footballers take note!) The feeling was strong in the nineteenth century that science had the key to unlock the problems of the world and that scientific knowledge would show the way to a new and better time. The hope was high, and the confidence in science was great.

The authority of science was also great, and continues so even now, having entirely replaced the authority of the church. This is largely the church's own fault. When they denied the spirit and advanced the dogma of the human being as body and soul alone, they did not foresee that the soul would slip into the domain of science along with the body. Otherwise they might have kept the spirit. When they warned the early scientists to keep off the major questions of life, on which the church alone would pronounce judgment, and confine their efforts to weighing and measuring on pain of burning at the stake, they did not foresee that ultimately this would prove so successful in giving birth to an almighty technology that the time would come when the scientists would set the same limits by their own volition. We have consequently achieved a way of knowing the world which has given us a mastery over nature, but it is questionable whether it has given us an equivalent understanding of nature. And the authority of science is still almost absolute. A television program a little while ago featured a spiritualist medium who claimed to be in communication with extraterrestrial beings in flying saucers, whom he said came from Venus. The interviewer, a psychologist, asked him to describe conditions on Venus, and then terminated the interview by sending for a physicist to describe what the conditions on Venus were really like. It never occurred to him to subject the physicist to the same critical questioning as he did the medium. If he could have foreseen the subsequent Venus space probe, he might well have done so!

The young child has a strong connection with animals, but he needs to be about ten years of age before he can look at them with some detachment. Previous to that he so identifies himself with them that stories such as Aesop's fables are the best material. But at age ten something like an objective study can be made. Even then it needs to be very strongly connected with the entelechy of the human being, e.g. those animals which swim around like disembodied heads, such as cuttlefish and other cephalopods, can be likened to the human being's sense activity, ruminants can be related to his digestion, and so forth. There is, in fact, considerable truth in the idea of the human being as a compendium of animal forms, and one animal type developing a certain part of the human anatomy predominantly. For the child of a year or so later, this idea can be extended to the characteristics or soul life of animals, and perhaps something of the feeling can arise of the tremendous debt the human being owes to the animal world which, in taking over the extreme manifestations of certain instincts, allowed mankind to continue the evolution of his balanced development. At this time plants too are studied, and it is also the period of Greek history. The Greeks, with the possible exception of Archimedes, had more connection with the living sciences than with the physical sciences.

It is not, in fact, until Class 6 that a child can really come to grips with cause and effect, and so come to appreciate the physical sciences. Rudolf Steiner was quite specific about linking intellectual and emotional readiness with physical growth. In this case the pre-puberty spurt in skeletal growth—the skeleton being one part of the body which works by mechanical principles—is accompanied by a growing intellectual ability to grasp mechanical principles. This is not to say that it is impossible to teach such things before, just as one can teach reading before the change of teeth, but it is usually at a cost elsewhere. If you want to buy something before you can afford it, you have to get a loan, which must be repaid later with interest. It can be like this, too, in education.

Physics in Class 6 deals principally with acoustics, heat and optics. Acoustics starts with music and may lead into the forms created on a Chladni plate, and optics starts with the observation of light and darkness. Chemistry is perhaps the most material of all sciences and it comes the latest, not until Class 7. It starts with burning, which is a chemical reaction of common experience. What is burnt are leaves, just as one might in a bonfire. Then these are compared with the burning of other parts of the plant and with other natural substances. This provides an opportunity for the exercise of careful observation—what color flame, how fast the burning, how much ash, and so forth. Strict objectivity should be insisted upon—'pretty' colors or 'nasty' smells will not do as descriptions. It can then be shown that the vapors given off when something burns are usually acidic, and the ash alkaline.

This leads to the burning of limestone and the subsequent slaking of lime. The latter is a key experiment, and it is worthwhile taking trouble in its execution. If a large lump of marble, best obtained from a stonemason, is used, the final effect can be quite dramatic. It is best placed in a solid fuel boiler for at least forty-eight hours. It is then removed and allowed to cool, and brought into the classroom. Differences in consistency can be pointed out, but usually the form of the original piece of marble is retained. Then water is added. At first nothing happens. Maybe for quite a time nothing happens. This is excellent if properly treated, as suspense can be built up. I have known class teachers to go away at this stage, writing it off as another failure; and certainly the class will be ready to dismiss it as (possibly another) experiment which has not worked. But they will all be wrong. Cracks, reminiscent of primeval geological upheavals, appear in the lime, which puffs itself up to several times its original size. Tremendous heat is evolved, and clouds of steam are given off. But what is perhaps most fascinating of all is that, with a really decent sized lump of lime, one can add up to about a pint of water, and the lime is still as dry as it was before. The difference between chemical combination and merely wetting becomes a matter of experience, as does the terrific heat change which is also a feature of chemical reaction. It is not so easy to find a solid fuel furnace for such a demonstration, and if this is not feasible it is still possible to carry out this experiment on a smaller scale with some firebricks, a steel pipe and a Bunsen burner.

When the students are fourteen to fifteen years old, the chemistry centers around photosynthesis. This again is key knowledge. The chlorophyll of the plant is the gateway through which the sun's energy keeps the earth alive. All the energy we use in coal, wood, petrol and our own food, comes from it. One cannot live in the world today and have no knowledge or interest in this. Steiner warned that making use of scientific energies and processes without any knowledge or interest in what lay behind them, would lead to a severe weakness of will.

In the Upper School, in Class 9 the organic products of photosynthesis, and the substances that can be obtained from them, are studied. The chemistry is seen here to have rather more of an organic slant at the beginning than is usual. The way things are first presented is very important, and the conventional method of the building up of compounds from simple elements suggests that more complicated molecules and eventually life itself arose in this way, which at least is non-proven. Similarly in arithmetic, building up the sum from the parts can lead to acquisitiveness. But organic chemistry can be complicated, and the emphasis here is on qualities. For instance, if we ferment sugar to make alcohol, we can see that if the sugar loses its qualities of carbon dioxide, something which has the qualities of alcohol will remain. This is different from breaking up a molecule of sugar much as one might break up a jigsaw puzzle or meccano model into smaller molecules, which is what is suggested by the chemical equation.

In physiology, the blood is described as creating the pattern of veins and arteries, including the heart, rather like a river creates its path across a landscape. This, it is gradually becoming apparent, is much closer to the truth than the easy image of the human being as a mechanical model, with the heart as a pump, the liver as a chemical factory and the brain as the control center. Elementary textbooks do not always reflect the insights of leading scientists, for they cannot go into the whole story. But for those who are not going to go further, this may be the only picture they will get. Again, for instance, has Darwinism completely explained the mechanism of evolution, or should we still keep our minds open? Are we merely higher animals or machines? Perhaps mankind will act in the future according to how men believe themselves to be.

The pattern of science teaching in the Waldorf curriculum is remarkably symmetrical and the concept that it contains is clear, the being of the child incarnates on a descending and then re-ascending path. At the lower end of the school we find the introductory sequence: the human being, animal, plant, mineral. At the upper end we have the sequence: mineralogy, botany, zoology. In Class 12 (at the age of eighteen), a review is made of all the main animal phyla. In seeing how one animal form develops into another one, *imaginative thinking* can be developed, which is as much a demand of the present age as the *logical thought* developed by a classical education was a demand of the previous one. In his work of education a teacher must always have in mind the development of faculties as much as the acquisition of knowledge.

It is the task of the science teacher at least to keep the doors of the mind open. It is generally agreed that the more one knows, the more one realizes how little one knows, and the reverse is also true, for in the realm of science it is easy to think that all is explained by a superficial, mechanistic approach. But a little knowledge need not always be a dangerous thing if it is based on a true experience of the subject, accurate observation and thinking, and keeps abstractions and theories to a minimum. It can then be a springboard for the radical and flexible thinking which made science great.

Hugh St Victor
The Pursuit of Wisdom in Science
by MARTYN RAWSON

In the history of science Hugh St Victor does not figure prominently. And yet it is from this rather obscure voice belonging to the twelfth century that we can find guidance in our search for a new relationship to science and technology. We cannot here examine the whole of Hugh's philosophy which concerns itself with metaphor, analogy, mystical knowledge and love, but two rather minor aspects of his work can give us an historical perspective on some of the problems we encounter with science and technology today.

We find that Hugh viewed science as a path of self-development, as a means of developing wisdom and as a means of healing the suffering brought by the human being's estrangement from nature. Looked at in detail we find accord with more modern ecological and spiritual approaches to science. As to technology, Hugh had another significant contribution to make to our understanding. He recommended what we call technology as a challenge to create works of art which imitate nature (or express natural forces) and which serve people as tools to raise our level of humanity nearer to our true spiritual condition.

However, before pursing these two themes, let us put Hugh into some kind of historical perspective. He was born in Ypres, probably around 1096, and grew up in Saxony. He was known as Master Hugo, Venerabilis Hugo, Hugo the Saxon, or simply Hugh St Victor to his own century. As a young man he joined an unusual community known as the Canons Regular of Hammersleben. Rather than follow the strict monastic isolation of most Orders at that time, the Canons of Hammersleben established themselves in busy towns and committed themselves to a life of "exemplary virtue for the edification of the Christian population."

He then joined the Augustinian cloister of St Victor near Paris, a city at that time teeming with spiritual debates. Peter Abelard, the brilliant cleric, outshone most of the brighter lights of the day. In an age of faith he taught the value of methodical doubt and emphasized the role of reason—ideas vital to the rebirth of science. Abelard's great rival was the mystic Bernard of Clairvaux, reformer of Benedictine monasticism. For St Bernard philosophy (science) and the humanities should strictly serve the scholarly monk's better understanding of holy Writ (see Fig. 1).

Abelard's notorious relationship with Heloise brought about his downfall and temporary supremacy for the opponents of mankind's search into matter. At that time the scientific and metaphysical works of Aristotle and their many Arab commentaries were not known in Paris. Hugo, Abelard and St Bernard stood at the end of a cultural epoch; they stood in the light of Romanesque architectural, in the earliest strivings towards the ideals of the Gothic.

Little is known of Hugh's personality other than that his detractors noted that he took the eccentric step of teaching his students that serious matters are more easily understood by the soul if presented artistically and enjoyed. His two major works *Didascalion* and the *Dialogue of Dindimus on Philosophy*, however, remained in use as textbooks up until the sixteenth century.

Hugh defined science as that part of philosophy which studies remedies for weakness, when that weakness derives from human disruptions in the world. Since all suffering and ignorance derive from the original sin in Eden, then science is the pursuit of redemption. The human being's estrangement from nature and the spiritual world may, perhaps, be healed by re-establishing that harmony between the human being and nature. In other words Hugh expressed the fundamental approach of ecology.

This view is very much the polarity of the view expressed later by Francis Bacon, which has more or less been the outlook ever since, that "the progress of arts and sciences is to achieve mastery over Nature." Bacon taught that science "in very truth leads you to Nature with all her children, to bind her to your service and make her your slave." The search for balance and harmony with nature, for science as a healing process is clearly expressed by Hugh.

In Hugh's view, when Mankind caused the Light of God to be dimmed within men's hearts, it was not totally extinguished—a spark remained. That spark kindles in us surprise, curiosity and admiration—the starting point of scientific inquiry. And for Hugh the pursuit of scientific research had an individual threefold significance, or threefold goal: "Wisdom, virtue and competence to face needs. Wisdom is the understanding of things as they are. Virtue is a habit of the heart, a habit which establishes harmony with reason in the way of Nature. *Necessitas* (competence in the face of need?) is something without which we cannot live, but without which we could live more happily. These things are as many remedies against the three evils to which human life is subject: wisdom against ignorance, virtue against vice, and competence against the body's weakness. In order to do away with the three evils, men have sought these remedies, and in order to reach them, art and discipline were discovered. For wisdom, the theoretical arts were discovered; for virtue the practical arts; for needs, the mechanical arts."

Here we see science relating to our individual spiritual development. Theoretical science which requires clarity of thought and imagination and objectivity in perception may lead to wisdom. Virtue, I think, we must understand as an awakening to responsibility in the life of the soul. And finally Hugh urges us to carry through this wisdom and responsibility in our deeds.

In an age when most research and development (R&D) is carried out by professional scientists on behalf of governments, the military, industry and large academic or medical institutions, what meaning can that research have in a direct human way to the people who are paid to do it? Does it matter that a scientist is not personally or inwardly involved in the work—whether it be on missile systems, cancer or seed technology? Can science in this context be a response to human needs, let alone a path of wisdom?

On technology or the mechanical arts (*scientiae mechanicae*) Hugh revealed: "All living beings were born with the armor which befits them. Only the human being comes unarmed and naked into this world. What was given to others by birth he must invent. Imitating nature and outfitting himself through reason. He shines forth more brightly than if he had been born with the equipment to cope with his environment."

He recommended meditation on the practical arts—each art is an expression of wisdom whether it be *lanificium* (weaving), *armatura* (metal work), *navigatio* (trade and transport), *agricultura venatio* (basic raw material industry), *medicina* or, significantly, *theatrica*. The emphasis on the seven arts is their relation to wisdom and the elevation of the human experience. Technology, if we may update Hugh's terminology, mirrors both nature and the human soul and faculties. The pursuit of technology is an exploration of both nature and the human soul. Goethe maintained: "Every recognition is only possible through self recognition." I feel that Hugh St Victor would have agreed.

As a Waldorf teacher I am concerned that science and technology be human-centered and that scientific inquiry help us realize the true nature of our relationship to nature. In Waldorf education scientific discovery is also a process of self-discovery for teacher and student.

Fig. 1 *A seventeen-year-old's impression of "The Mystic Mill"—an image taken from the early development of technology to depict the mystery of spiritual transformation—from the Romanesque basilica at Vezelay*

LAYING THE FOUNDATIONS IN THE KINDERGARTEN AND LOWER SCHOOL

Welcoming the Young Child into the World of Matter
by BRIEN MASTERS

In an old stable two children were playing together, a girl of twenty-two months and a boy three years older. It was summer and the stable door let in flowing veils of afternoon sunlight; the tiny windows hardly got a look-in and, in any case, there the light had to battle through a Methuselah of tangled cobwebs. The rickety staircase—little more than ancient woodgrain, packed together like a first-day queue at the sales and patched like a crew of half-blind pirates—led to the hayloft, now the boy's father's workshop, sweet with rare sawdust. Beneath the staircase was an old biscuit tin, lidless and inches deep in discarded gearbox oil—a reminder that horse and cart and bridle had all been sucked into the sump of modern technology.

Filthy, dilapidated and no place for children? On the contrary, they were in their element. Off-cuts from upstairs had provided a store of fabric for the grand castle they had built in one corner—not to mention its sprawling kingdom. Wood shavings dangled decoratively from the maze of old nailheads and hooks that bristled from walls, beams and newel-post. Hours went by—eons for them no doubt—until one parent set out to 'go and find them.' As he approached, he heard the boy presenting the girl with a six-inch nail (already powdered with its first rash of rust) that he had unearthed triumphantly from a drawer of oddments—a huge object in his tiny hand. He presented it awesomely as if it were a mixture between some holy relic and a sword poised for a knight's accolade he was about to confer. The sun went on playing in the girl's golden hair, she took the nail (being a visitor from a town flat, she had probably never seen one of that size before) with a gracious smile, reached out dreamily for an oily paper bag that had been scrumpled beside the secateurs into a garden trug, and, as if she were gently putting her favorite doll into its cradle, said in that singsong way that only children are capable of: "First we must put the nail into its cozy little paper bag house ..."

Children of course also need more organized environments in which to play and, of course, such a setting as described above could certainly not be part of any *official* playgroup premises. Nonetheless, of paramount importance is it that children should experience matter—Creator-made and humanly-formed—in such a way that they can pour all their hearts' (and limbs') devotion into it. The British government would probably not have to budget £60mpa for vandalism in schools if the *cultivation of such attitudes* formed part of the education of the young child. Yes, *education!*

How easy it is to tread—unwittingly and well-meaning, of course—on the child's profoundly deep, yet tissue-delicate, feelings of reverence. "Look, darling, at this end of the nail; see these crisscross marks? That helps the hammer not to slip when we knock the nail in ...” We wade in with our clumsy-footed intellects, pouncing on every opportunity for ‘learning,’ oblivious of the age child we are dealing with.

Experience within matter (the *Mater* of the human race)—this is what the education of the young child is about—from conception onwards, one might say, at every level. In the Lower and Upper Schools a second and third opportunity to ‘enter’ the material realm follow. Research into it, an understanding of what is contained within matter, can then plumb the depths—but the depths have first to be created within and through such ‘creative play’ as here described. Indeed, when children are engaged in this way, it would not be too much to say that they are in communion with the Creator.

In this way, the home first and foremost and then the Kindergarten prepare for the rest of education as well as for a richness of life, a satisfaction in what life brings, and an element of service and gratitude for the gifts of the earth and humanity. Miss out on this, and the cost will not be only £60; it will be ‘missing out’ on life itself—no longer a mere bill, but a serious *price to pay*. A proportion of vandalism is almost certainly anger in disguise—anger at the vandalizing of the childhood that has just gone.

No wonder Rudolf Steiner deplored the then current practice of relegating (even in terms of salary) the educational status of the Kindergarten teacher, and that he brought about a different order in the Waldorf schools. For upon the foundation of these years is built the whole of education, the *academic* successes which are so important, *holistic attitudes* to life, and much else besides.

Alas, not every home has a rickety old staircase leading to a stable loft—or other forms of material and human environment that are specially suitable for early childhood. The pace and demands—and hence the style—of modern life usually prevent this. However, where such a gap occurs, the Waldorf Kindergarten is there to serve.

"The Walnut"
A Nature Story for Classes 1 and 2
by DOLORES GRAHAM

Rudolf Steiner consistently recommended an imaginative, pictorial presentation of material for children in the lower classes. Teachers who practice it discover how akin such a presentation is to the life-giving nature of a young child's creative consciousness. In this issue we are concerned with its application to 'nature study' (though it applies equally well to the introduction of letters and writing, the learning of musical notation, and to disciplinary matters). The following is an example of a so-called 'Nature Story.'

Through such stories the children of Classes 1 and 2 are introduced to some of the natural processes in their environment What they receive in this way may then flow on as an undercurrent of deeply-felt interest in the natural world. Such a stream may well be joined by tributaries of wonder or reverence in a soul in which such qualities abound. Where they do not, it may well lave the thirsty land precisely with those qualities. Moreover, in the later part of a school career, when the stream passes through landscapes of more conceptual activity, of natural scientific modes of thought, and of precise observation and analysis, it will have more chance of imbuing the necessary precision and exactness of the scientist with life. [This was published as the editorial introduction to the 'article' when it first appeared. – Ed.]

In the forest under a large nut tree sat a walnut. He hadn't always been sitting on the ground. Once he had lived high, high up on the very tip of one of the tallest branches with the blue sky smiling at him, the sun warming him and the wind rocking him. The birds sang to him. He had been a very happy, little green walnut until one day something happened to make him very afraid—and this is what it was.

Early on a summer morning a black crow landed on the walnut's branch and began pecking at the nut next to the walnut. He pecked and pecked until he made a large hole in the nut's side. Then the crow put his beak into the hole and began eating. "Oh!" shuddered the walnut, "I don't want that to happen to me," and he pulled the two halves of his shell tightly together and tried to make himself very, very hard. From then on, day after day, he practiced making himself as hard as he could. Summer passed and walnut's color began to change from green to pale brown, but indeed, he scarcely noticed this for he only thought about making his outside shell harder and harder.

One day a dark shadow fell on walnut. Startled, he looked up—straight into the black beady eyes of the largest crow he had ever seen. The crow began fiercely pecking at the walnut's side; he pecked and pecked and pecked. Little walnut could do nothing but quiver inside and shudder and pull his shell tight. But, do you know: no matter how hard that crow pecked, he could not make a hole in the walnut's shell. Finally the crow gave up and flew away.

How proud walnut felt. How happy he was that he had practiced becoming hard during the long summer days. “Why, I am stronger than crow!” he exclaimed. “I am a hard nut indeed!” It wasn’t long before all the nuts heard about walnut’s hardness. They gazed at him respectfully and whispered to each other that he must be the hardest nut on the whole tree. Walnut puffed his chest out with pride and kept on practicing to become harder.

The days went by until one afternoon with a big huff and a puff the wind came and blew walnut right off his branch. “What’s this?” cried walnut as he felt himself falling. “What will happen to me now?” He kept on falling faster and faster. With a loud ‘geplunk’ he landed right on a large stone at the base of the tree. Walnut looked around. Scattered about the stone were bits and pieces of other walnuts that had fallen and cracked as they bounced off the stone. “Ha!” said walnut as he saw this. “I’ve nothing to be afraid of down here. Why, I’m even stronger than this stone. I really am a tough nut to crack!” and there he sat proudly on the forest floor.

A squirrel came by collecting nuts for his winter store. He tried to bite into walnut “Ouch!” cried squirrel. “Why, this nut is so hard it hurt my tooth.”

“That’s right,” retorted walnut. “I’m a hard nut to crack—much too hard for you, squirrel!”

Not long after a porcupine ambled up. “Hm,” he thought. “This is a nice fat nut, just right for my dinner.” He put walnut between his strong teeth and made a loud crunch. “Ow!” he exclaimed, letting go of walnut. “This nut is so hard it’s given me jaw ache.”

“That’s right,” piped walnut. “I’m a hard, hard nut. Nobody’s harder than I am!” So it was with all the forest animals. They took turns trying to open walnut but he was too hard and tough for them. “No one is going to crack me,” he said, “not ever!”

After that the creatures of the forest left walnut alone. There he sat for the rest of the autumn and the long winter until one day he awoke to find that the spring rain had come. “Splash, splash, splash,” went the raindrops against his shell. “Tap, tap, tap,” like a quiet knocking.

“Hello, rain,” said walnut. “I’m walnut and if you haven’t heard by now, I’m a hard nut to crack.” The gentle spring rain didn’t say anything but only sent another soft drop of water rolling down walnut’s cheek, then another soft drop, then another. “Hymph!” continued walnut. “I can see I have nothing to fear from you. Why, you’re so soft you couldn’t even crack a peanut!” He went on, “I’ve been pecked by a crow but I was too strong for him. I fell all the way from the top of the tree onto a stone and I still didn’t crack. Nearly all the creatures have tried to break my shell, but I’m too hard for them. The truth is, I’m probably the hardest nut in this forest,” he exclaimed loudly, swelling with pride so that his chest looked as if it might burst. But, the rain didn’t say anything. It just kept falling gently, ever so gently, and soon walnut became drowsy and fell asleep.

He awoke with a start to find the rain had stopped and he was quite dry. He thought of the rain and he felt a tender stirring in his heart, and he could not help but wonder if she would come again. Then he suddenly remembered that he ought to be practicing to become harder, and all the rest of the day he pulled his shell tight … except now and again he stopped and thought of the rain, and each time he felt a gentle stirring in his heart.

The next day the spring rain came again. "Hymph!" he greeted her as the soft drops began to fall. "Er ... ah, I mean hello." The rain didn't reply but she stayed a little longer this time, and walnut felt the gentle stirring in his heart grow stronger and stronger.

On the following day walnut didn't even feel like practicing. His whole heart was filled with tenderness. All he could think about was the rain and if she would come. "I wonder if she has a heart," he thought. "I will ask her." The rain didn't come that day but she came the next.

"Do you have a heart?" he called to her as soon as the first drop touched his cheek.

"My heart lies hidden in the clouds," replied the rain.

"Ah," sighed walnut, "then I must somehow reach the clouds." He sat very quiet for a while thinking. Then he realized that in order to reach up for the heart of the rain, he would have to open his shell.

At this thought walnut began to tremble. He was very afraid. "If I open my shell, crow may peck me or some creature eat me, and then I will never reach the heart of the rain." But all the time that he was thinking, the fresh, soft rain was falling, and the heart of the walnut filled with such tenderness that it pressed against the sides of his shell. Suddenly, with one mighty swell of courage, the little walnut cast his hard shell aside and the two halves fell to the ground.

But crow didn't come to peck him and the forest animals didn't eat him. Instead, out of the heart of the walnut a little green shoot sprang, its tiny green arms stretching up to touch the clouds. As the days passed, it grew taller and taller, nearer and nearer to the clouds, and the tenderness of the walnut's heart changed into a mighty strength. Still the walnut tree kept growing, closer and closer to the clouds, never forgetting the rain.

If you get out into the forest today, you will see him there. Always he is reaching out with his strong arms, reaching higher and higher, so that one day he may hold the heart of the rain close to his own.

“I Look into the World ... ”
The Student’s Life Experience as a Prerequisite for the Science Teacher (Extract)
by BRIEN MASTERS

On the edge of the stubble field, a few wisps of wheat are left growing among the last shriveled poppy petals, some marjoram, meadow fescue and hawkweed. The corn stalks are heavily laden with full-corned ears, dry and surprisingly hard. Gathering them are children from the nearby village school. The friendly farmer invites them back to his farm. There, in the barn, sitting on hay bales,they drink juice; they chatter excitedly about the forthcoming harvest meal which is to be adorned with corn dollies, still being made from their gleanings.

In the farmhouse, the farmer’s wife shows them an ancient and long respected sample of a Wedmore wheel which has pride of place over the kitchen mantelpiece. It was made by her great-grandmother who farmed in Cheddar, Somerset. She remembers carrying it in harvest processions as a child, clad in white, with a crown of blue cornflowers circling her flaxen head of hair. Now she is white-haired; but her deep, heaven-blue eyes sparkle with a flaxen light as she shares her vivid memories with the children.

On the way home a boy pauses. He glances at the summer sky. He was thrilled by the agricultural machinery in the farmyard which the farmer had so proudly shown the class. But despite this, the abiding impression is of cornflower-blue eyes twinkling as the story of the past unfolded: the Wedmore wheel in the harvest procession, the wheels of the haywain rumbling along the track home carrying the last load of the year.

Such may well be the scene of a Class 3 in a Waldorf school if the environment is rural enough. The nine-year-old is becoming aware of world and self as two distinct entities, both capable of infinite exploration. Behind him, as he pauses, the very sunlight seeming to ruffle his hair, lies the experience of the world. Before him lie the pathways leading towards an understanding of this experience. How does the great combine harvester work? How does the seed become wheat, the wheat become bread, and the bread become human nourishment? How does the light, as the sun sets over the stubble field, become so golden-hued; and how do the fleecy clouds turn pink, a pink that seems to be absent from anything that the human hand can hold?

Any given situation may furnish sufficient questions for a lifetime’s scientific study, if one cares to take them far enough. However, science teaching in Waldorf education is preceded by a sequence of closely related work in earlier classes. In Kindergarten, feelings of gratitude and wonder accompany and enrich being in and surrounded by Nature. In the younger classes in the Lower School, ‘Nature Stories’ are told, presenting the world imaginatively to the students’ picture-filled consciousness. Nature study comes next: the forms and configurations of the animal world, the plant world and the mineral world, each with their particular relationship to the human being, are vividly characterized by the teacher, thereby awakening more conscious powers of observation. Such observation is nourished in the previous two stages of experience and leads the way to the final stage: natural science.

If scientific knowledge is like a mountain range that the mind has to cross via the pass of Chemistry, the pass of Biology or Physics, and so forth, one can visualize the experience of the younger children as routes coming from great distances of the lowlands of childhood consciousness and converging at the foot of each pass. Following this, an intense interest in the phenomena themselves characterizes the adolescent's climb into the highlands of scientific discovery.

Equally important as the subject matter itself are the implications as to how science is taught in Waldorf schools. And most important of all, perhaps, is the relevance of each topic for its respective age group. This is the starting point for Rudolf Steiner's approach to all subjects within the curriculum and is itself based on an educational principle, the scientific integrity of which he never compromises: an understanding of the developmental stages of the child—collectively and individually.

Science Teaching in a Rudolf Steiner School
The Task and the Method
by ERNST LEHRS

Among the great advances made in the nineteenth century in the understanding of nature, there is the realization that every organism, including the human being, repeats at the embryonic level the evolution through which it had to pass to reach its present stage of development. Expressed scientifically: *phylogenesis is repeated in ontogenesis*.

This discovery has thrown new light on the position of the human being in the kingdom of nature. But while certain long-established illusions have become dispelled by this knowledge, it did not bring forth a new picture of the human being's own true being. The picture that had been arrived at on the path of external observation was only a half-truth.

It remained for Rudolf Steiner to complete this picture by showing that what was true for the human being's bodily development was also valid for his spiritual. Every individual in his early years passes through a development of consciousness which, though shortened in time, is analogous to the development of consciousness of the whole of mankind. Only to understand this properly one must not imagine that human consciousness was ever in any way similar to that of present-day animals.

While the human being today experiences himself as standing opposite his surroundings as an independent and individualized being, there was a time when he knew himself equally surely as being one with his surroundings. A similar experience that we have today, and then only partly, is our relationship to our own bodies. In this state of consciousness the soul of man was poured out, as it were, over the whole world. He was in the world and the world was in him. Ancient Indian writers describe this condition clearly in the portrayal of Atma and Brahma. Many thousands of years had to elapse before the other state of consciousness was reached, which marked the beginning of our modern 'scientific' age. Before that time it was natural for the human being to experience nature as he experienced himself, that is, as being endowed with soul and spirit. In order to understand nature he looked first of all at himself, since he experienced himself as that being in whom all nature forces were revealed as a totality. Then from the standpoint of his own being, he looked out upon the animals, the plants, and the stones as forms revealing in an ever-decreasing degree the spirit which he knew to be living within himself. For his way of comprehending nature, he himself was the most easily understood and the stone the most difficult to grasp.

This changed radically when the human being awoke to that form of consciousness which we call the *intellectual*. When possessed of this, he experienced himself as being absolutely enclosed within himself, and nature as completely without. The first philosopher to express this form of consciousness was the Frenchman, René Descartes (1596–1650), who said: "I think, therefore I am." (Had an individual even in Greek times sought to express himself similarly, he would have had to say: "The spirit of the world is in me, therefore I think.")

Intellectual consciousness is bound to the brain, that is, to an organ which does not serve the organism insofar as it lives, but insofar as it dies. This is why the American physiologist, Alexis Carrel, says in his book *Man the Unknown*: "Death is the price man has to pay for his brain and his personality." The intellect, therefore, can most easily grasp that which is dead in the world. In outer nature, this is the mineral world; in the human being, his skeleton. Both are governed by the laws of mechanics. Thus the beginning of the modern age is marked by the intense study of anatomy, by Galileo's investigation into the behavior of freely falling, inert masses, and by the statement by Marcello Malpighi, one of the first botanists, that every true investigation must begin with the mineral kingdom and seek to reach the human being by passing through the kingdoms of the plant and animal. This procedure has been adopted by natural science ever since.

To present a child in the lower classes of a school with natural phenomena in Malpighi's order and with the help of mechanical explanations could be to outrage his psycho-physical organism. For at this time the child is only making his way towards that condition of soul and body which the human being had reached between the fifteenth and seventeenth centuries. Only at about the fourteenth year does the child reach this point of development. The toddler and the very young child live in a condition of oneness with the world, which recapitulates earlier stages in human evolution, although naturally this experience is modified by the conditions existing in our times. It is well known that little children will hit an object which they have knocked against. The psychological reasoning of adults, based as it is on the experience of the intellect, seeks to explain this by saying that the child endows the outer objects 'animalistically' with souls, similar to the soul he experiences within himself. Nothing can be further from the truth. At this age the young human being does not distinguish soul from body, nor does he distinguish his own body as bearer of his soul from any other physical object in his surroundings. Subject and object are as yet in no way distinguished. Put in other words, the child experiences the objects in his surroundings as subjectively as he does himself, and equally he experiences himself as objectively as he does his surroundings. Thus a little child will hit his own hand, when he has done something with it which he knows to be wrong. Another example is furnished by the following little event witnessed by the writer.

A mother entered a grocer's shop with her five-year-old son, greeted the assistant standing behind the counter, and told the child to do the same. This the boy refused to do. The mother repeated: "Say how do you do to Mr. X." The boy shook his head and remained silent. Further repetitions were of no avail, until finally the grocer, speaking kindly to the boy, told him he would like to say how do you do to him, but could only do so after the boy had said it first. Whereupon the child was heard to say softly, but quite clearly to himself: "Head, say how do you do!" Then he repeated the greeting to the grocer aloud and joyfully.

The condition of the child before school age and in the first school years demands that the individual animals, plants, stones, clouds, moon and stars are brought to his consciousness as Beings who act and converse together as separate personalities. A mechanically conceived nexus of dead causes and effects will have as yet no meaning for the child. Everything is rather the immediate result of the deeds of beings. When Steiner spoke before the opening of the Waldorf school to those who gathered round him in Stuttgart as the future teachers of the school, he gave many an elucidating example of possible conversations between objects of nature. We need not describe them here in detail. Similar examples are to be found in fairy tales known to all. When such tales are invented by the teacher, however, they must never be sentimental, nor must they attempt to use nature as a cloak for moral precepts. Whatever tales are composed by the teacher, they must always be drawn from the characteristics of the actual plants, stones, and so on.

The way of describing nature here presented, however, would remain utterly ineffective if the adult were to feel secretly that 'in reality' the matter was quite different, and he had to present it to the child in this form only because the child was as yet too stupid to understand the 'real' state of affairs. To find the proper standpoint, let us consider for a moment what is the place in natural phenomena of the mechanical connection between cause and effect, the only one accessible to the human being's intellect. Here we shall find useful an analogy which Steiner occasionally used to stress a similar point.

In the mud of a cart track we notice certain impressions running more or less parallel to one another. We investigate their cause and discover that they were made by the wheels of a cart. We push our investigations further and inquire into the cause of the movement of the cart. This we find in the limb movement of the horses pulling it. The physical causes of these movements we are able trace to certain energy processes in the bodies of the animals. To push our investigations further in this direction, however, has obviously no point whatever. For what really set the energy of the horses in motion, giving rise to all the phenomena we have hitherto investigated, was, say, the intention of the farmer to drive his cart to market to sell his produce. Here we find ourselves in the realm of an individual will, governed by a definite thought content. It is obviously senseless to inquire further along these lines of purely mechanical cause and effect.

Our example quickly led us away from the realm of mechanical causation into quite a different nexus of causes. But such are, indeed, the origins of all seemingly mechanically-caused events in nature. Only, the span of time is much greater here and it increases with each lower natural kingdom. Let us be clear about the fact that to speak of cause and effect we must observe certain changes in our surroundings. For instance, when we say that a stone becomes warm because the sun shines upon it, we call the sunshine the cause and the warming of the stone the effect. If some objects were always to remain warm, because they were irradiated by the sun, and others always remained cooler, because they were never met by the sun's rays (for the sake of the example, let us ignore all other possible causes of temperature), we would not form the concept of causation as we did a moment ago. In order to become the subject of our observation and judgment, two objects must come into a relationship with each other, which results in a change of state in one (or both). Following our example, we would have next to consider the motion of earth and sun and investigate its cause. This leads us into regions where, indeed, the human intellect has tried to form all kinds of mechanical theories. In reality we are led here to a realm of causation fundamentally similar to that of our first example: namely, into the region of purposeful will of individual beings (though of an order higher than the human being's).

It is by no means to be denied that science is justified in selecting isolated events such as the change of temperature of an object and in considering them as the results of certain energy processes, without pressing the inquiry further into realms of whence and whither. This procedure has led to illusion, only because we have been tempted to regard this as sufficient for 'explaining' the world. And in education, it becomes a sin against the living spirit in the child to present the world to him in this way. The little child is one with time just as he is one with space. For the child, therefore, we must never divorce the farmer going to market from the ruts of his cartwheels on the track. Indeed, we present him with truth when we reveal to him something of the Mind and Will of the Creator while describing His Creation. To recognize both as well as one may in outer nature, and to clothe one's understanding in words warmed by feeling, is the task of anyone who teaches children of this age in the sense of Steiner pedagogy. The indications which Steiner has given can be a guide in this task.

When the child has reached the ninth year, a new task presents itself to the teacher. At this point in the child's life something occurs which, at a different level, appears in early childhood when the child first says, 'I' to himself. This word 'I' is the only word of his language which the child does not learn by way of imitation. (If he did so, he would—as is sometimes the case with some handicapped children—call other people 'I' and himself 'you.') A sudden lighting up of the experience of the difference between the child's own individuality and that of another must underlie the appearance of the use of the first person in relation to the child's self. But however strongly this is felt, it remains a deeply subconscious experience.

About seven years later the same experience occurs again (at the 9th/10th year), but this time far more consciously, distinguished moreover from the former, in that the child begins to experience himself as divided off from the whole world. He begins to be aware that the world, as mere sense perception, conceals something. At the same time he begins to feel the boundless immensity of the world and his own smallness. This calls forth a feeling of impotence in the face of the world, of other people and even of God, a feeling hitherto quite foreign to him.

At this moment it is of decisive importance for the healthy further development of the young person, that he is in touch with adults who can build a bridge of confidence between himself and the world. This, however, can be done only by someone who is able to describe to him, by means of the spoken word, those connections with the world which once lived in the child unconsciously, but now no longer do so. Just because this need in the child has to be met, a proper teaching of nature observation is so important at this age.

Steiner once said of this 9th/10th year: "Now the force of the human being's ego-nature begins to stir. As a result of this, a question arises deep in the soul of the growing child. This question can assume one form in one child, another in another. But woe if this question is not answered correctly by an older person!" What is here referred to may best be illustrated by a conversation, which once occurred between a teacher in the Waldorf school and a nine-year-old boy, who boarded with him, as the two were walking through a little copse at sunset:

BOY: Do grownups know everything?
ADULT: Why do you ask that?
BOY: Grownups ought to know everything.
ADULT: If you really think this, why do you ask me?
BOY: There are grownups who do not know everything.
ADULT: Who, for example?
BOY: Mrs. X. I asked her: If God made everything, who made Him? She said she didn't know.
ADULT: Do you know anyone who you think knows everything?
BOY: Yes, Miss Y [his class teacher]. She told us this morning in class that heaven is not only up there far away from us, where we see the sky, but

everywhere [pointing to a bush beside the path], in every leaf. And [with great emphasis] that is true! [short pause, then suddenly turning to his companion]: Do you know who made God?
ADULT [who had been expecting this question]: Do you know everything that God has made?
BOY: No.
ADULT: Do you think you will know everything one day?
BOY: Yes.
ADULT: When?
BOY [with great conviction]: When I have been right through the school.
ADULT: Oh! That would be awful! Then you would have nothing left to learn for the rest of your life! No, the school wants to teach you just enough for you to be able to learn more and more after you have left school. It is in your life after you have left school that you will learn so much. And it will take you a long, long time to know everything that God has made. But how can anyone know who made God before he knows all the things He has made? I know you will understand that a person must know all the things God has made before he can know who made God. You must go on learning more and more in school and later on in life, so that you can know more and more of God's creations. When at last the time comes when you know them all, then you will be able to have the answer to your question.

To this the boy replied nothing. But his expression showed well enough that he was satisfied. He never put this question again. He had his answer, an answer which directed him to his own powers of will.

A few indications may be given here as to how the teaching of natural science is approached at this age. For reasons which have already been stated, the teaching starts with the human being and only reaches the mineral by way of the animal and plant.

In the teaching concerning the human being, the child's attention is drawn to the outer form of the human body. This is shown to consist of three parts: head, trunk and limbs. All three are formed by the same principle, the spherical form, but this principle does not come to expression equally clearly in each case. Only the head expresses this form completely. Even this is not uniformly round, but slightly flattened where it rests on the trunk. (One may bring to the child a strong experience of the dynamic relationships which are at work here by using a ball of wax.) In comparison, the trunk represents only part of a sphere (see Fig. 2, which is a copy of a blackboard drawing Steiner made when he first described this subject to the Waldorf school teachers).

The greater part is not visible. The teacher prepares another ball of wax and cuts of part of it with a knife. He shows the children the portion cut off and points out how the rest of the sphere is now invisible. He then reminds the children that

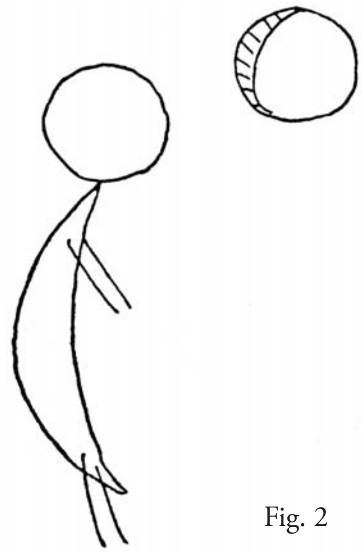


Fig. 2

they have often seen a similar shape—when they have looked up at the moon which is sometimes a full disc, but at others only a portion of it.

This indication must not be misunderstood. It is not the intention to suggest a kind of mystical, cosmic relationship between the trunk, with its heart, lungs and other organs, and the moon. Rather the intention is to show the child in a visual and convincing way that there are things which are greater than their visible parts, and that to this category belongs a part of his own body. In the earlier years of his life the child was instinctively aware of this. Now he is brought to the point of winning this knowledge once again by observation wisely guided by the teacher. The human being belongs with part of his being not to himself but to the outer world. The knowledge of this fact will be of the utmost importance in the future life of the child and is called into his newly awakened consciousness by the teacher when he shows him the morphological secret of the structure of the middle part of his body. This the teacher makes understandable by his demonstration with the small wax ball and by pointing to a phenomenon observable in the far spaces of the heavens.

This experience is strengthened by a discussion of the third part of the body: the limbs. Here the sphere, which is the basis of the human form, is not visible at all, because it is as large as the universe itself. The only part of the sphere that is visible in the human form are the four radii, which ray down from the circumference to the center (not the other way round), and of these, only the ends are visible. Of this, at this point, no more is said, for the child at this age could not understand more, being at this time not sufficiently conscious in his limbs. The teacher points the child to a future time, when he will be advanced enough to understand more. (This is a principle of method which is of pedagogical value, especially at this age.)

Instead of further elaboration of this point, the child is made conscious, with all the emphasis at the teacher's command, of the different tasks of the limbs on earth, by being shown the clear differentiation between the arms and legs, a fact which distinguishes the human being from the animals. Animals use their limbs only to serve their own bodily needs—theirs are 'selfish' limbs. Only his legs does the human being use in this way. For with his arms he can work for his fellows. In this way the transition is made from the external observation of the head to the inward experience of the volitional activity of the soul of the limbs. The child is first shown what he is as the wrought work of his Maker and is then led to a realization of that part of himself which he can use for its own activity.

About the teaching of the animal kingdom which follows, only a few things can be said in the compass of this article. A number of animals are described in such a way that it becomes clear to the child that they represent merely one or another part of the human form. This theme is followed up through the other families of animals, so that it becomes obvious to the child what Goethe expressed so pertinently by saying that the animal kingdom was the human form spread out over the world. Naturally, such a thought must not be presented to the children in an abstract form. Rather, the various kinds of animals are to be shown to him in such a manner that a strong intuitive feeling is evoked of their bodily construction and their habits, and of how much these two things belong together. In this way the child learns to know both the parts of his own body and his true relationship to the animal kingdom. He understands that he is the only being who contains within himself all the possibilities of a physical body, which appear in nature as divided out into separate beings.

It will not be difficult to understand what Steiner meant when he said that through such teaching of zoology the child is helped to develop a sense of moral responsibility which will be very fruitful in later life. Steiner's other remark will not be so readily understood at first sight: Through a rightly conducted teaching of the plant kingdom, a healthy faculty of judgment will be inculcated. The following example may make this clear.

When Steiner was discussing with the teachers the introduction to the beginnings of the teaching of botany, he showed how he would do it. He chose the dandelion as his example and, without naming the plant, began to describe the various stages of its development, beginning with the last: the round ball of seeds. With a series of simple descriptions, always calling upon the children's own recollections of what they had seen, he took them back through all the stages of the plant. After thus having evoked a picture of the entire plant by passing through its various stages in time, he concluded by saying (now naming the flower for the first time): "Children, this is the dandelion."

We cannot here attempt to bring forward other examples from the wise suggestions which Steiner made. It must suffice to explain that the plant is always treated first as an organism in time, and secondly as standing in relationship with all the surrounding elements: earth, water, air and fire. Each is shown as having its own peculiar part to play in the forming of the plant. Thus the child is brought to the experience that anything which appears in a transitory form in space presents a riddle which can be solved only if one extends one's observation out into space and time. How sorely needed is this very faculty in life, if one is to judge events healthily!

This is not the place to describe the whole Waldorf curriculum of natural science as it stretches through twelve classes. Our aim is to give only some impression of how the curriculum, in this as in all other subjects, is conceived in the light of the developing child. When the mineral kingdom is reached, the minerals are so presented that they appear in their relationship with the whole earth, her mountain formations and so on. At this point the child is introduced to that realm where nature's purely physical forces hold sway. Here the teachings of physics and chemistry begin. After that the path is retraced through the natural kingdoms, beginning with the mineral kingdom in the sixteenth year, followed by the plant world and finally the animal. These are now treated in a more 'scientific' way. Still, natural details are never brought forward in such a way that only abstract knowledge is communicated to the student, but always so that his powers of thinking, feeling and willing are called upon in a harmonious way. At this stage of school life, it is the aim to implant into the young man or woman, standing on the threshold of adulthood, the conviction, which Goethe once put as follows: "If in the moral sphere we are to rise by faith in God, virtue and immortality into an upper realm, so drawing nearer to the Primal Being, why should it not be likewise in the intellectual? By the contemplation of an ever-creative Nature, may we not make ourselves worthy to be spiritual sharers in her production?"

Learning to Read from the Book of Nature

An Exploration into the Plant World with Eleven-Year-Olds

by BRIEN MASTERS

How evocative the plant world is: ferns clinging to a stalagmite cave entrance; sunflowers beaming from a cottage garden; a Scots pine triumphantly breaking a gaunt granite skyline; a laden rowan merged in the spray of a mountain torrent; sainfoin, a robed pink of a Fra Angelico annunciation angel, bedewed amongst the grasses near Stonehenge at sunrise. Every petal, every leaf, every stamen a source of wonder, a nature story,[1] or the object of intense observation and discovery.

How often are we reminded of the plant's and the human being's interdependence: the crown of summer blossoms bobbing on the brim of the Morris dancers' boaters; the threatening red of the lentil jar, barking but not biting, on the kitchen dresser; the alpine enthusiast groping in plus-fours round the peak of Ben Lawers; mother-in-law's tongue, as symbol status, dressing the local Building Society's street front; a whiff of garlic during the first interval of The Master-Singers; or the hint of valerian, high above the clerestory, a dab of rouge on the grey visage of an abbey ruin.

Plants adorn our whole lives, from the vase by the font to the last visible deed of one heart for another, the red rose being covered by the soil of solemn burial. We make daisy chains; we squeeze our tubes of plant dental cream; we steep conkers in vinegar; we rasp away at our first wooden darning egg; we savor our first curry; we carry our first bouquet; we measure our longest kidney bean; we drive along our 'scenic routes'; we 'say it with flowers'; we hang our Dürers and Constables over the mantelpiece; and we replace the rubber ferrules on our walking sticks.

These and a thousand other impressions of the plant world slumber in the twenty or thirty odd souls of every class of eleven-year-olds, like the sleeping forests and groves, hedges and lawns that may pass through the seedsman's hand any day of the week.[2] During the conversations in their plant lessons, such experiences awaken, like the face of the desert after rain, helping form the humus into which the teacher can plant the pedagogical substance he had been cultivating for this particular moment.

Obviously this is not the first classroom encounter with the life of plants. The earlier years have seen such activities as bulb planting; the collecting of Turkish oak acorns, maple or poppy seed heads, and tulip tree leaves for pressing; conifer bark, and so forth, for collage plaques and calendars; and the ubiquitous *objets trouvées* brought by any class of younger children, a kind of still-hope Still Life, rich in gnarled roots, stattice, speckled fungus on a birch twig, honesty or newly sprouting bracken fronds. There will have been[3] a wholehearted entry into the farming practices of an age before labor—the true and living echo of the redemptive labor of the Middle Ages—was usurped by leisure; followed, the next year, by the stepping out from this more archetypal picture into the local environment, entering into a full and active appreciation of the barley growing in one district, the A to Z of besom-making or the trug-trade in another, forest conservation in a third, or the joys and vagaries of fruit farming somewhere else; while in the background there has been the ever-increasing fertility of the mother tongue, itself revealing, through words and phrases stemming from the plant world, how close to the heart of the people the heart of the land can be.

Yet, vital though all this has been in cherishing and nurturing the children's connection with the earth, as far as the plant itself is concerned, these are, as it were, still only side-shoots. Now that the children are developing—and need help in developing—a certain delicacy of outer and inner perception, the time is ripe to come nearer to the 'growing point'—the plant kingdom itself.[4]

The awareness of the seasons deepens. Autumn ripening takes place in the abundance of reflected rather than direct warmth, right up to the oncoming of the first frosts. The ecstatic growth through Ascensiontide to the Summer Solstice is like the midsummer night's dream of earth itself. A wax-crayon sketch of the stark blue branches of winter surrounded by, but not penetrated by, a pale, slightly acid-yellow, engenders a mood not merely of outer death, but of inner awakening and expectancy. Still in color, such a contrast is transformed in the spring with the lighting from above of apple-blossom hues, pressing before them, as it were, the yellow into the blue, to bring the first tender greens into play. The children have no difficulty in deciding, through the coldness in color, whether Sophie's drawing of the season is earlier or not than Rupert's, sometimes discriminating even by a day or two. Having spent a week, perhaps, sharing through word and color the cycle of the year (in India how different that would be!), it will be fruitful to work systematically through the plant families, seeking a satisfying qualitative classification.

It is Monday. The class have changed from their Wellingtons in which they have waded through the falling lime leaves, or which show signs of the manner in which a choleric tackles a muddy cart-track well impregnated with sodden beechmast. Sweet chestnuts have been exchanged, a bunch of late marigolds presented, the last hazelnut cracked and swallowed with the shells fished out of the inkwell, the effects of a holly leaf gleefully explored, and a few treasures added to the individual jam-jars of twigs, grasses and flowers. When at last the moment comes, some have the expression: Will he do it now? Others look very vague when reminded that on Friday last they were told that … we would be going on to fungi.

"Children! ... Before the time which any of you can remember[5] you used to lie in your cradle for hours on end—a hardly noticeable mound beneath neat white cotton sheets, surrounded by a veil of colored silk through which the sunlight softly filtered ... After feeds you would gaze dreamily around, or suck your toes, or gurgle with pleasure ... When you walk in the woods at this time of year, with the fading light sifting through the canopy of russet and gold, or the morning mist lingering in the hollows or swathed around the ferns, you will come across plants that will remind you of what you were like then ... they are the toadstools: the flyalgaric, the boletus, death caps and truffles—or in the fields, the field mushrooms ... They have no green, the color of more advanced life ... The younger they are, the more rounded. Their appearance is as brief as a babe's awakening. They can hardly lift their soft-skinned heads from the pillow of the earth ..."

The response is remarkable! To mention only one side of it: rural children bring so many samples from their gardens and escapades that the classroom needs extra airing before school each morning. One spare trestle is not enough as one moves 'up' the plant scale and has to accommodate liverwort, lichen, moss, ferns, cones, pampas grass and so on. The news gets around. A colleague brings in a spray of spindle[6] from a downland walk; Deborah turns up with some splendid teasel; Dani finds some Jack-in-the-pulpit and discovers that her mother calls it by another name. A crop of hitherto unmentioned observations springs up. Golden opportunities occur for the teacher to bring home the importance, through rarity, of preservation; to inculcate the respect for nature—one of the desperate needs in an epoch of vandalism; to recall a verse written for a foreign student, who has meanwhile returned to her native land, about a transplanted seedling which, through all the care and help given, was able to send down its taproot and thrive in its new situation. Through the plant study a big stride can be made towards satisfying the healthy yearning that children have to enter into their surroundings stage by stage. This is not merely of parochial significance. It symbolizes the need for the human being today to reconnect with the whole of his earth environment

Many people in our time are afraid of the 'fall into matter.' One so often wonders what has happened when one sees the matted manes of today's journeymen which have so painfully obliterated the sun-dangling curls of childhood. The jostling tonnage of the Waldorf Niagara is not designed to turn into thistledown as it reaches the brink, thence to float aimlessly away at the first prevailing puff of wind, and eventually to take shallow root in the dirtless earth of an oasis where no telephone is heard. But neither is it designed to become a scurrying congestion, rat-racing through the humdrum debris of bourgeoisie.

Children of this age are still some way off from the fall into puberty—though not all of them the same. They are gathering their last strength. They too are to become citizens of earth.

But earth needs *balanced* citizens. The indigenous plant is an image of balance to perfection: it mirrors the cosmic seasonal influences perfectly as well as those of altitude, geology, latitude and so on. A freeman must move from perfect balance to imbalance, and on to a new self-restored balance. The secret of the twentieth century Humpty Dumpty is that, although indeed the king's horses and the king's men can do nothing, he can pull himself together. Until he has done so, he is as adolescent as the rest of us. But he is not destined to do this groveling in terrestrial forces alone. Even the biggest and most complacent of turnips has *leaves*.[7]

Amongst the Archangels, Michael holds the balance. When the Michaelmas Daisies are in bloom—mauve, magenta or violet but gold-centered—we turn to his inspiring leadership. The eleven-year-old is a young Discobolus springing free from all marble impediment, a Caryatid visibly moving along the school corridors. Yet he/she will have to say adieu to the fair summer of balance and follow the Fall in Nature. Without this, the possibilities of his own freedom will never widen into the full horizon of a new heaven and a new earth. A full experience of spirit in the early years can become strength which casts away the fear of the fall, which prevents the sleep in and through matter, and which culminates in a willingness and ability to take the task to hand firmly in hand. Such an Athenian will return triumphantly from the labyrinth, however scathed.

Endnotes:

1. "The Violet," in *The Kingdom of Childhood* by Rudolf Steiner, is a 'classical' example of a so-called nature story.
2. An idea which is poetically incorporated in *The Seed Shop* by Muriel Stuart, used for class recitation by this author during botany main lessons.
3. In Class 3 (age 9/10).
4. There are, of course, many approaches to this kingdom at this age (not to mention the more senior approach discussed by Frances Woolls in "Child and Man," Vol. 12, No. 2, in which there is also a helpful list of reference books). This article is limited to only a few.
5. See *Discussions with Teachers* by Rudolf Steiner, Discussion XI (London: Rudolf Steiner Press, 1967).
6. See the poem at the end of the original article, verse 2.
7. Leo Tolstoy, "The Turnip," and elsewhere in folktale collections.

A Class Poem Is Born
by ROLAND EVERETT

Most children have an inborn love for animals and also a natural feeling for poetry. What better way than of concluding a study of the whale than by trying to make a class poem about this lovable and largest of all mammals? Descriptions of its features and its way of living had been written by the ten-year-olds in their compositions. Illustrations had been drawn in colored pencils, showing huge 'breathing fountains' in arctic seas. Watercolor paintings of whales, leaping through the air or diving to the bottom of the ocean, were hanging around the classroom. A poem would be just the right way of rounding off this subject before leaving it *to mature in mellow forgetfulness*. But what if inspiration should fail to turn up at the appointed hour? A cautious teacher, realizing that true creativity needs seclusion and the maturity of an older age than that of his class, thought it wise to be prepared 'just in case' by concocting his own version, observing carefully the process of his own poem making.

Next morning the students were asked to "paint the whale with spoken words," and the most suitable of these were written on the blackboard. In this way, what emerged from the twilight world of the children's feelings became lifted a little more into the sphere of consciousness, the white chalk literally lighting up the words on the dark background. But now these disjointed words had to be linked together into a living flow of rhythm which could only arise from the dark world of the will-sphere below. A critical moment had come, for the first few words would set the pattern for the whole poem. After a somewhat hesitant silence, the following words tumbled out, "Great is the whale." Catching this phrase we spoke it out together several times, while clapping its rhythm, as if to anchor it. Suddenly from somewhere, like the answering call, the words rang out: "The giant of the ocean," thus completing the first line.

Now ideas came pouring out in quick succession and presence of mind was needed for necessary guidance and for sorting out the grain from the chaff. There was no time for anyone to feel hurt when suggestions were not taken up, but great was the joy when new jingles or word pictures were allowed to carry the evolving poem forward. Some of the children's imaginative and charming metaphors were breathtaking.

When at last the class poem had been born, each line was scrutinized. Which was better: "With skin like oily silk" or "With oily skin like silk"? 'Oily silk' sounded unclean, messy, but "Oily skin like silk," yes, that sounded right for the whale. But we had forgotten the title! Should we just call it "The Whale"? "The Ways of the Whale," retorted a boy from the back, quite unaware that with one stroke he had improved both the sound and scope of the poem, apart from introducing an alliterative effect, adding weight and style.

For several days we began the morning lessons by reciting 'our' poem with great relish and joy. At home again, the teacher could safely entrust his own efforts to the discretion of the wastepaper basket.

Man and Animal in the Dark and Middle Ages
by BOETHIUS

Sixth century Christian philosopher and poet, Anicius Manlius Severinus Boethius, was a great influence in the 'Dark' and Middle Ages. His book *Consolations of Philosophy*, from which the following passage was taken, was translated into Anglo Saxon by Alfred the Great and into English by the poet Chaucer. The version below is Chaucer's, somewhat modernized.

"The beestes passen on the earth by ful diverse figures. For som of them have their bodies straight and creepen in the dust, and drawen after them a continuous trace or furrow; that is to say, as adders or snakes. And other beestes, by the wandringe lightnesse of their wings, beaten the windes, and overswimmen the spaces of the longe air by moist flying. And other beestes gladen them-selves to diggen their trace or their steppes in the earth with their goings or with their feet, and to go either by the grene feldes or else to walken under the woodes. And al-be-it thou seest that they all discorden by diverse formes, their heavy heads, inclined downwards, make heavy also their dulle wittes. Only the linage of man heaveth highest his high head, and stondeth light with his up-right body, and beholdest the earth under him. But if thou, earthly man, waxest evil out of thy wit, this figure warneth thee, whose face lies in the axis between heaven and earth and who hast raised up a-high thy courage; so that thy thought be not made heavy nor put lowe under foot, since that thy body is so high raised."

On the Animal Teaching in the Fourth and Fifth Classes
by L. FRANCIS EDMUNDS

It is our object, in the present article, to show how we may lead children of the same age along their first steps towards the observation of nature. It will not yet be a scientific approach in the modern sense. Our task will be to present nature to the children in such a way that we may call forth in them feelings of wonder, sympathy, reverence, enthusiasm; we wish to bring into play their own powers of fantasy. Such feelings, experienced in a right relationship to facts, and such activity of soul, will later be transformed, with the growing life of thought, into a true scientific interest in the world—a warm, searching interest, that will not stop short at cold, surface objectivity, but that will lead the thoughtful student to enter also into a moralistic relationship with the phenomena of life. Observation reveals the facts, thought can penetrate to the laws, the artist in the human being can lead us to the creative source, and religion unites us with that creative source: All these together make up a knowledge of Life, and we must pay attention to all these in our lessons.

The mythologies could awaken in the children a feeling for the moral-creative forces in the soul of man. Now, in looking at the forms of nature, they can learn to feel that these are life-filled images of the creative powers of heaven. In the fourth class we consider the kingdom nearest to the human being, the animal kingdom.

How shall we begin our approach to the animals? Our starting point must be the human being himself—man who alone in all nature has been raised to a free, upright position. Around the human being we see how the animals, in successive stages from the apes downwards, fall away from this free, independent uprightness, to ever humbler conditions of earthbound existence. Of the animal it is possible to say that what we perceive of its bodily form and processes marks the limit of all its possible experiences. With the human being, this can never be the case: The bodily form and processes are, at most, but the groundwork for what is truly human. The most trivial conversation is proof of this. The life of thought, of feeling and of will carry us completely beyond the bodily as such.

We will begin, then, by speaking quite simply about the human being himself. What follows in inverted commas may be regarded as a summary of lessons given to the class.

"Look children! Here is the head. It is like a ball—the roundest part of the human body. How different it is from the long arms and legs, the limbs! They are as different as can be—and between them is the trunk, which is different again. So we can see three parts, the head, the trunk and the limbs.

"What do we do with the head? In the head we have eyes with which to see the things around us; we have ears with which to hear; we can smell with the nose; we can taste with the tongue. Without the head the world would be quite dark; no sound could reach us; there would be no scents and odors; there could be no taste.

"Last year you learned about chaos, and how, out of chaos, God created the world. Without the head, the world would be chaos for us. With the head we learn about the world. We not only learn, but we think about the world, and so we can come to understand all the many things around us. When we think, the light of God shines in us and lights up all things.

"The head is the roundest part of the body. And what is the roundest thing in the world? It is the sun! The sun in the heavens is quite round. The sun lights up all the world. The head of the human being is like the sun whose light fills all the world.

"The sun does not live only for itself. It hides nothing. It holds nothing back. It sends its light to the moon, to the earth, to all the world. It sends its powers to the earth so that all things may grow. Without the sun nothing could live, could it? All things that live owe their life to the sun.

"The head, too, does not live only for itself. It takes in food. It breathes in air. Whatever it takes in it passes on to the trunk so that the whole body may grow and be strong. What it learns of the world, what it takes in through eyes and ears, what it thinks, it also sends down to the body so that we can act and do things. The more we learn, the more we are able to do. The head helps us to know about the world. Then we can learn to love the world.

"The trunk is not round. The head is always the same shape, but the trunk never is. It changes its shape with every breath. It is always changing. What do you know that is always changing its shape, now being fuller and now thinner, always waxing and waning? The moon! The trunk is not round like a ball; it is more like part of a ball, like a crescent moon.

"In the trunk we have the lungs with which we breathe, and as we breathe in and out, the chest rises and falls. So, too, as the moon waxes and wanes, the great tides of the earth rise and fall, like a mighty breathing. Mariners must watch the rise and fall of the waters very carefully. They are always looking to the moon. Remember your farmer of last year. Farmers also watch the moon, for they know that the rains come with the moon. The moon helps all things to grow. The trunk, too, works for the whole body so that the body may grow.

"And now think of the limbs. With our arms we can stretch out in all directions; we can reach out towards the farthest things, towards the stars even. Indeed, when we stretch out our fingers wide, our hands are themselves like stars. We can point to the heaven from which we are born. Our feet point to the earth below us that supports us. Heaven and earth have built our limbs.

"So, when we look at a human being, we can think of sun and moon and stars, of the whole heavenly world, and of our mother earth.

"And now, let us think of the limbs again. What can you do with your legs and feet? And what can you do with your arms and hands? How much more you can do with the arms and hands! What do you do chiefly with your legs? They carry the trunk from place to place over the earth. They are the bearers of the trunk, and they also belong very much to the earth.

"But the arms and hands are quite free from the earth. We can lift them to the heavens, we can fold them in prayer, we can also till the earth, we can write, we can paint and model, we can play music, we can do a thousand things. The legs serve the trunk. With our hands we can serve one another."

It is important for children to be taught in such a way that when they look at a human being, they may feel that there is much more than they can see—in the human being are assembled all the powers of worlds visible and invisible. His form is not earthly, but is born of heaven. What the sun does for plants, lifting them away from the earth, that, the spirit of man does for the human being, raising him to the free upright position.

After such an introduction, extended over several days and interspersed with much conversation, we can proceed to select characteristic types of animals. The descriptions must be vivid, accurate, dramatic, and filled with contrasts; our aim is to give living characterizations. The children must feel: We enter a magic world. The word 'magic' is connected with the word 'Magi'—with an entry into the deep wisdom of the world, a wisdom that is beyond ordinary sense and reason, that is quite beyond mere logical cause and effect. The various animals are living images of divine thoughts. When men think, they have ideas. With these ideas they direct their conduct and achieve results in the world.

When the Lords of Creation think, they engender beings, for so has the world been made and all that is in it. The thoughts of the human being are the reflections of the deeds of Heaven. To the human being is given a life in ideas because he is himself the central Idea in all the created universe. To speak in terms of the Gospels, he is the expressed image of the living Word, the Word that became flesh. In the human being alone does the God 'I AM' find immediate utterance. Looking from the human being to the kingdoms of nature, we perceive there the dismembered parts of all that in the human being has been brought to the perfection of harmony. We can perceive in the separate animals, one-sided developments of particular parts of the human being. Looking at the human form, it is comparatively easy to recognize the origins of the different animal creations. For such a view, we are indebted to Rudolf Steiner. It is a view that does not divorce us from the fruits of scientific observation; on the contrary, it makes full and adequate use of them. It is a view that would teach us to look at nature from above downwards rather than from below upwards. Stage by stage we can descend from the heights and, having grasped the depths, re-ascend to the heights. Merely to build from below upwards is to construct, in modern terms, a Tower of Babel that must surely end in confusion. The human being, who stands at the pinnacle of earthly creation, is at once the central edifice and the key to the understanding of the creatures around him.

Having formed thoughts about the human being, we can now turn to the animals. Our first approach will be from the aspect of form—what can the form teach us? To this end, we have selected certain animal types whose forms can be specially suggestive. Steiner recommends especially the cuttlefish, the mouse and the horse.

"Children, deep below the surface of the water, far from the air and the light, there lives a creature called a cuttlefish. This creature has a rounded, hollow body. The walls of this body are like a shell. One end is closed and round like the back of the head. The other end is like a big open mouth. With this mouth it takes in food. It also takes in water and so it breathes. The food we take into the mouth we send to our stomach. The air we breathe through our noses we send to our lungs. In the cuttlefish, mouth and stomach, nose and lungs are all one, and all this is inside the head, for it has no separate body or trunk. It has two big eyes, one on either side of its head, just behind the mouth. It has no ordinary lips, but its lips are drawn out into eight long feelers, which are forever moving this way and that. Sometimes they open out wide like the petals of a flower, and other times they draw close together. These drawn-out lips, or feelers, take the place of arms and legs. They help to direct it from place to place. It also has two long suckers. Perhaps these take the place of a tongue. With these it can seize hold of its food and draw it into its hungry mouth. When it is not using its suckers, it carries them folded back in little pockets on either side of its mouth.

"It also has something else. Do you know what *Tinte* means in German? It means 'ink.' In German the cuttlefish is called a *Tintefisch*, an Ink Fish. It has a little pouch reaching up somewhat like a nozzle. When it meets something it doesn't like, something that makes it afraid, it suddenly spurts out, through this nozzle, a dark, inky fluid. The inky fluid spreads out like a dark cloud making a screen which hides it and so it can get away more easily. This is really very clever, though I do not suppose the cuttlefish knows that.

"Think of the cuttlefish in the water. It has no trunk, no real limbs. It is really just a head, and it has made for itself just what a head would need if it had no trunk and limbs to help it. What the cuttlefish does with its feelers and suckers and opening and shutting mouth, we do with our heads when we watch and listen and take in the things we wish to learn. And sometimes I have noticed even this—that when you do not wish to learn something, you do very much what the cuttlefish does when it hides itself behind a cloud of inky fluid. It really does happen sometimes that when I think you are in the class listening to me, with your heads you are very far away, and I have to call you back.

"Remember this then, the cuttlefish is a head animal—it is really all head. It does not think as we do. Its life there below the water is like a kind of dream.

"Of course, there are many other head animals [One little boy: "The octopus!" Another child: "The jellyfish!"] Yes, and there are still other animals that are really head animals. Think of the head, it is all hard outside. Do you suppose it is hard right through? What animals are there that are hard outside and soft inside? Do you know the mussel? It has a shell outside and is soft inside, and it is always opening and shutting like a mouth. Then there is the crab, the lobster and others. They are all hard outside and soft inside like the head; and even the limbs are not at all like our limbs—they too are hard outside and soft inside as though they have just grown out of the head body—all such animals are really head animals. We will speak more about these animals later.

"Today we will think of the fish, an ordinary fish. It really has no head to speak of but only a kind of head end to its body with eyes and a big mouth in it. It has no real limbs but only fins and a tail. The fish is really all trunk from beginning to end. That is why it has so many bones, like little straight ribs, running all the way down its body.

"How gracefully the fish can bend its body this way and that. As it dives and darts and curves in the water, it seems to speak to us with its trunk. And how hungry this trunk can be sometimes! With a lash of its tail, it leaps forward and just snaps with its head at anything it sees to eat, just as you might leap forward with your legs and take hold of something eagerly with your hands, and then the trunk is quite happy and can remain still for quite a long time. So the head and the tail and also the fins are all like special limbs serving the trunk. The fish is really a trunk animal. It is altogether different from the cuttlefish.

"Now let us think about quite another creature, the mouse. You have all seen a mouse, I expect. You cannot say the mouse has a head resting on its shoulders. It looks much more as though the trunk grew on into a head, and this head part narrows down quite to a point, a very inquisitive little point that is always busily sniffing at everything. And then, just at this point, you know how it has long trembling whiskers growing out on either side; the whole mouse seems to follow what these trembling whiskers tell it; the whiskers know at once when a cat is near. And now, inside the mouth there are sharp pointed little teeth. How busily the mouse works with them, nibbling and nibbling; not only does it nibble at food very, very quickly, but it can nibble a hole or even a tunnel for the whole trunk to go through. A mouse's teeth never stop growing; they must always be kept strong and sharp. It has quite tiny little beady eyes, but very large ears that stand out from its head like sentinels. Altogether the head is a very useful tool for the trunk, or rather, a whole set of little tools working together for Master Trunk.

"The tail of the mouse is quite special, too. It is long and thin but very strong. It has little rings running down it almost to the very tip, and a mouse can really stand on its tail when it is trying to climb up the side of something.

"So what is the mouse really? It has quite a long trunk, and the head is a kind of limb, and the tail is a kind of limb, and then it has its four little legs which carry the trunk along. The mouse, too, is just a trunk, and everything else serves this trunk.

"Think of our friend the pig; there is another famous creature for you. It is really very difficult, isn't it, to know just when the trunk begins to be head. In the pig, too, this trunk-head tapers down, this time to the hard, horny snout. What does it do with its head-snout? It is always working away with it, digging and turning up the earth or the rubbish heap, looking for something to eat; how it snorts and grunts as it works; how eagerly it swallows, swallows, all it can to feed its great, big, heavy trunk. Its eyes are quite buried in flesh. Its large ears flap lazily down. The snout is the chief instrument, and the greedy mouth just below it. Its four legs just trot about, pigs trotters, carrying its heavy trunk from place to place; that is all they can do. You can see, in the pig, that what matters is the trunk. The pig also is a trunk animal.

"Let us think of the noble horse. What graceful legs it has! How it beats the ground with its hoofs and sends the turf flying when it is impatient to be off! How beautiful it is to watch a horse galloping across a green meadow or along the ridge of the hill! Have you ever sat on a horse in full gallop? It is the nearest thing to flying. This graceful, certain movement, this lightness and speed, making it the swiftest of creatures, the horse owes to its legs. And in the carthorse, how strong and sturdy the legs are!

"These wonderful legs all serve the trunk to carry it about. That is their only work. Now watch a horse walking. For example, watch a horse pulling a plough or a cart. Look at the head as it does so. The head moves up and down with every step. The head is not free as in the human being; it is much more like a part of the trunk made into a head. When it is grazing, with its long neck stretched to the ground, and its strong teeth tearing at the grass, the head of the horse is just like another limb serving the trunk.

"Let us think too, of the humble cousin of the horse, the ass! The ass is certainly not graceful. It does not move easily as you know, and sometimes it refuses to move altogether. Have you ever seen an ass gallop? And if it does move more quickly than usual, it is awkward and bumpety. But now try to go up a stony path on a mountainside. How wonderfully sure-footed it is, as it picks its way step by step over boulders and stones. The path may be ever so narrow, and the mountainside very steep, but leave the ass to pick its way and do not hurry, and it will prove a very good ass indeed, and will bring you quite safely to the end of your journey. So the ass may be obstinate and stupid in some ways, but it is very, very wise in its legs.

"When the horse neighs it is like a champion calling to his mates, but when the ass brays, it is telling a sad, sad story of all the burdens it must bear on its shaggy back, and of the road that is always too long. Wonderful in their different ways as are their legs, the horse and the ass are still trunk animals. It is the trunk that is all-important, and all else serves the trunk."

The above are naturally but sketchy descriptions. In Class 1 the teacher can enlarge on all this. The children draw pictures of the animals. It is important to describe the environment characteristic of each animal. One can tell animal stories, can recall fables they know and add less familiar ones from different cultures.

With reference to the last group of animals, the mammals, different though they may be in shape, size, appearance, habits of life, environment, nevertheless, one principle clearly prevails—they are, one and all, essentially trunk animals, with head, legs and tail as particular appendages. There is no real threefold division as with the human being.

We have spoken to the children of head and trunk animals. The question naturally arises, are there also limb animals, i.e., creatures whose essential nature is vested in the limbs? We discover the remarkable fact that, emphasized by Steiner, there are not. This can come to the children as a great wonder, and it leads us back once more to the human being. As Steiner pointed out, the human being is the only being who has real limbs—limbs that have a life of their own quite apart from their service to the body. It is the limbs that make him truly a human being. We can compare the human head to the cuttlefish. We can compare the human trunk to other animals, but in all nature, there is nothing to compare with the human limbs. There the human being is unique!

What a miracle are the human hands! Let us think of them, for example as in Dürer's picture, folded in prayer. How much individual life and expression there is there! A whole soul dwells in those hands. Let us think of the hands of a musician—in every movement of the fingers there is a world of expression; the careful, precise hands of a mathematician; the fine, disciplined hands of a surgeon; the skilled hands of a laborer; the hands of an actor, that almost speak to us; or just hands, any human hands—what wisdom, spirituality, variety, is contained in them! How loving they can be, or how cruel! They are indeed not merely tools of the body but something in themselves, real limbs, the bearers of the will of man, the agents of destiny.

What the hands have gained in freedom, the legs have sacrificed. They are much more limited in function, much more bound to the earth—yet they, too, show, in their uprightness, in the straight line with the kneecap characteristic only of the human being, a degree of emancipation from the earthly, from the all-binding force of gravity, possessed by no other creature. The legs, too, in their expressiveness, completely transcend their merely functional nature. The walk of a human being is quite individual. In their own particular way even the legs are not merely servants and agents of the spirit. The human limbs are indeed a wonder of creation, and this all-important fact we can bring home to the children.

We are, after all, at this stage in the education, concerned only with broad and fundamental facts. As a seed for their future, the children can receive the thought that the animal world finds its meaning only in relation to the human being; that the animal kingdom finds its syntheses and higher unity in the being of man. Without the human being, nature would be meaningless. Such a thought is, as yet, but little acknowledged. Yet without this thought, life is lacking in all real purposefulness: We are merely plunged into materialistic utilitarianism and a Darwinist blind struggle for existence. We must rescue the human being from a point of view that would deprive him of all dignity, and ultimately of all humanity.

We can remind the children of the story they heard in the previous year, of Adam naming the beasts. He surveys them with a Godlike eye; he alone knows them in their innermost nature, and he pronounces this knowledge in the name. We can remind them, too, of the farming main lesson they had: of the farmer, the husbandman, the being who can care for all nature around him. These are real pictures of the human being.

It is always valuable in education to describe the same thing to the children from different points of view. This stirs the will and the imagination, whereas mere definition cramps and limits them.

Having described such animals to the children, we can*, in the following year*, i.e., Class 5, make quite another approach. So far we have dealt principally with the *forms* of the human being and the animals. Now the children are old enough for us to take the three contrasting types of animals, the eagle, the lion and the bull, in relation to the *functions* of head, heart and limbs in the human being. The traditions of wisdom have always grouped these together around the being of man. Zarathustra, in his first vision of the Sun-Spirit, Ahura Mazda, perceived Him in human form, seated on a throne supported by a lion, an eagle and a bull, with three hierarchies of Angelic Beings ranged above Him. In the Sphinx, we have a human face, the wings of an eagle, the chest of a lion and the lower trunk of a bull. We are reminded, too, of the Vision of the Apocalypse with the eagle, the lion, the bull and the human form. There is a great truth contained in this symbolism. At the present stage we can discuss these three types quite simply.

"Children, let us think now of the King of the Birds, the Eagle. Where does he live? All alone, in high, rocky places. His fierce eyes seem to pierce every distance, as, from his aerie high above, he surveys the world below him. His long, strong beak is like an iron limb of terrible power and strength. When he is not in his stronghold, you see him hovering high in the heavens, on wide, outstretched wings. Suddenly he swoops down to the world below; he has seen a lamb, maybe. And now with his iron beak or his strong talons he has gripped the lamb, and with rapid strokes, his wings carry him back to his lofty home, to consume his prey in solitude.

"If we wished to compare the eagle with some part of the human being, which part do you think he resembles? See the head. The shoulders of the human being are themselves like rocky crags, and on these the head rests, looking out over the world. The head itself does not fly off, of course, but our thoughts do, and we think with our heads. We may seem to be resting, but our thoughts can be far away; they can carry us everywhere in an instant. Our thoughts can fly to the heavens, they can descend to the depths. We can look back in our thoughts to the past, and we can look forward to the future. We seize hold of what we see and hear, whatever we take hold of with our thoughts, we make our own. We carry it off, like the eagle, to the lonely fastness where we live in our heads, and there we devour it.

"How different is the eagle in its airy heights, from the cuttlefish living below in the dark waters; yet they both remind us of the head we carry on our shoulders.

"Think, too, of the shrill, piercing cry of the eagle. I expect you have never heard it. You know that when you make a squeaky sound, which some of you are fond of doing sometimes, it seems to come from high up in the head. Perhaps you have been to the zoo and visited the bird houses. When you hear the very high twittering sounds of some of the little birds, and watch them fly swiftly from perch to perch, they are like a cloud of gaily-dressed little thoughts, like a lot of feathery heads flying about.

"The shrill eagle's cry is a head cry; compare this sound with the deep soft mooing of a cow or with the deep bellow of the bull; these sounds are not at all head sounds—they come from much deeper down.

"Now think of cows in a meadow. Here they love to rest comfortably on the rich green earth. How quietly and contentedly they chew the grass. Can you imagine a cow taking a flying leap at a tuft of grass and carrying it off at a gallop to a corner of the field to devour it greedily! The cow, with its great heavy body, is so very different from the eagle—the broad mouth with the thick soft lips, so very different from the horny pointed beak! And what do they do, these cows? They change blades of green grass into white flowing milk—and this milk is not at all for themselves; they give it all away. What can the cow teach us as it changes grass into milk that it gives away? It teaches us that what we learn is not just for ourselves; what we learn we shall change into powers to help our fellow men. We take in what we learn and we change it into ways of working for others. This is not at all easy. You know that a cow has four stomachs. You have watched a cow chewing the cud; it does not chew the grass just once, but many, many times. It goes over the same food again and again—and only in years to come shall we be really ready to use it.

"And think of the angry, stormy bull, charging across a meadow. He holds his head down like a battering ram, and charges forward as though he would move mountains from his path. Where does the might of the bull chiefly live? Is it in the head? No, he uses his head merely as a weapon. The mighty drive of the bull comes from behind, where he beats against the earth with his hind legs, hurling himself forward. What can the bull teach us?

"Think of the human being at work. Think of him driving the spade into the earth, turning wild places into fertile fields. Think of him digging rocks and stones out of the mountains to make his great buildings. Think of him seeking out the heavy iron to make his vast engines and machinery. Think of all the many hard things men must do. It is the bull in the human being that gives him the strength to do all this. In your morning verse you speak of 'the strength of human limbs.' It is the hidden bull in the human being that gives him this strength.

"We can now think of the lion, the King of Beasts. The roar of the lion certainly does not come from the head; nor is it like the deep bellow of the bull; it comes from his mighty chest, crowned with noble mane and head. With his roar he commands the forest. We can think of the lion, first crouching, very still, all drawn together, and then making a great and sudden spring through the air. He is so strong, the lion—stronger than the huge elephant, and yet he can move so gently and quietly through the grass, or jungle that there is not the faintest sound. The eagle carries the lightness of the air, the bull, the heaviness of the earth; the lion comes between. The eagle swoops; the bull charges; the lion leaps, and in his leap through the air he is the most graceful of all animals, for he is at the same time light and strong. The crouch and spring of the lion, the drawing together and the leaping forward, remind us of the heart we carry in our breasts; the heart of the human being does this always—that is the beating of the heart we hear. We carry a lion in our heart; that is why, when a man is very courageous and also gracious and gentle, we say he is lion-hearted. There was an English king who was like this. He was called Richard the Lionhearted.

"When we listen to the beating heart of the human being, it is as though we could hear, in this beating, the footsteps of God.

"Now we know that the eagle rules in the head of the human being, the lion in the heart and the bull in the limbs. But in the human being, too, there dwells an angel, and this angel changes the fierceness of the beasts so that in head, heart and limb there can live the love of God. So we can be swift and brave and strong, quick to learn and understand, gentle and loving, and eager to serve.

"My dear children, all the beasts of the world can teach the human being something, for every beast carries the secret of God. When we learn to understand these secrets, we are also learning about God.

"Now you will understand why the ox and ass were also present at the Christmas Crib. Not only did kings and shepherds seek the Child, but the ox and ass were also there to protect Him with their warm breath. Why the ox and ass? They are called beasts of burden; they are the servants of man. Behind them we may think of the whole animal kingdom waiting on man. The patient ox, the lowly ass, the gentle sheep, stand very close to us. One day they will be followed by all the other creatures—but first, we must learn to understand them."

We owe much to the science of our times, but, just as Shylock in demanding his pound of flesh forgot the blood, so does modern science, in dealing with nature, forget the spirit. Such a science can never nourish the deeper forces of the human soul. An unspiritual science that leaves the heart cold, that makes demands on the intelligence but has nothing to say to the moral being of the human, can never be a basis for true education. It separates the human being from the world and makes him an unsocial spectator. An imaginative, perceptial view of life such as has been indicated here, a view to which we have been led by Steiner, releases the heart forces, brings warmth, enthusiasm, and purpose into life, penetrates beneath the surface of the senses to the moral grounds of all existence, and unites the being of humanity with nature. What the children have enjoyed through such a method of teaching becomes the driving force in their own endeavors in later years.

First Lessons about Plants

by E.G. WILSON

Flowers play their part in the very earliest stories told to the youngest children as the hiding place and the cradle of fairies; but they are flowers which are naturally invested with all the varied qualities of human beings. Children look up to the proud hollyhock, are shy with the timid violet, laugh at the 'saucy little redcaps' and the mischievous poppy, and welcome the brave buttercups and daisies when they come in field and meadow to tell of the approach of summer. From Norse mythology they hear of Frigga enticing the hardworking shepherd over the rugged, dangerous rocks in order that she may give him the seed of the little blue flax to be woven later into linen. From Greece they hear the story of Mercury directing Ulysses to the magic flower which will destroy the power of Circe. So that in many ways flowers have been present in their lessons before the age of ten or eleven, when they begin to learn what they are proud to call botany. A child, especially a melancholic child, loves to make use of new words and to turn the meaning of them over in his mind.

Now comes the joy of 'looking at' the many plant growths in their various homes, of discovering the varying degrees in which they are dependent on their 'Mother Earth,' on the sun, the rain and the wind. It is often astonishing to see how much has been noticed, even by children brought up in towns, of the homes, needs and ways of many growing things. But it is most important that children shall preserve that truly human relationship to the plants which they felt instinctively at an early age—that they shall not come to look on flowers as 'objects.' A beautiful and living way of introducing to young children the development of plant life through its various stages is suggested by Rudolf Steiner in his course *Discussions with Teachers*.

Take first the *fungus* with its helpless, dependent habits, unable to gather its own food from the air around it, relying entirely upon the tree or stump on which it grows. The children will delight in comparing it with the baby at home, unable to fend for itself, waiting for its mother to bring it all its needs. One little girl, after learning about these babies amongst the plants, in illustrating her botany book, painted two pictures side by side, a number of fungi growing under a tree and a cradle with the curtains drawn that the baby might be in the dark, for she had noticed that fungi frequently grew in the woods, away from the bright light of the sun.

And now the baby begins to grow and we go on to the *algae* and make delightful excursions into rock pools and deep seas, finding seaweeds of many kinds and colors, often holding on to the rocks while they peer all round them, a little older in their habits than the mushroom, but still very young. And the children are very happy in telling of their experiences by the sea and of the various places where they have found seaweeds for themselves.

Mosses and ferns then have their turn, mosses showing by their green color that they are in advance of the mushroom, and ferns still loving shade, but spreading out their beautiful leaves with a certain gentle mischief and letting themselves be seen and loved like little children of three making lovely shadows as they dance over the lawn. What a different feeling comes when the next step it taken, the step that leads from ferns to cone-bearing trees, to the *conifers*—the pine, straight and strong with its far reaching root enabling it to stand against the buffeting of wind and weather. Here is the picture of the child away from the protection of home, standing up in a world from which he/she is learning his/her own lessons. But there is another aspect of the cone-bearing trees, an aspect to which children of this age are very responsive—they listen eagerly, and with the reverence that the story brings with it, to the "Legend of the Cedar Tree." The Tree of Life, standing on the border of Paradise, watched with sorrow when Adam and Eve were driven forth. Later when Seth found his way back to the Tree, one of its seeds was given to him, a seed which, planted on Adam's grave, grew into a magnificent cedar. Long, long ages after, this tree was felled at Solomon's command for use in the Temple at Jerusalem, and again, after the passage of long ages, wood from the cedar had its share in the Cross on Golgotha. Of itself, too, there comes to the children's minds all that they connect with the Christmas Tree, and they find themselves with joy led by their botany lesson to the thought of Christmas.

I once saw a picture in colored chalks drawn by a very thoughtful boy after he had been learning about conifers. It was of a forest of pines, very dark (for a boy of his age, he was unusually aware of the darkness in life), and through it there went a path of gold right up to the sun, a marvelous revelation of the understanding that comes through a child's feeling.

After the conifers come the *monocotyledons* and the *dicotyledons*, fine words again for children to munch and crunch. They are eager to tell of the many sword-shaped leaves they have noticed, and they love to distinguish between the straight, parallel veins of these leaves and the network of the veins in the dicotyledons. Many botanical terms become familiar during the first main lesson of botany, while some are left until later. The calyx (chalice), with its sepals forming first a protective covering and then a cup to hold the flower, is a beautiful study within the reach of children from ten to twelve, whereas the work of the pollen, and the germinating seeds, fascinating as they have been made by innumerable teachers, really belong to the understanding of older children. Before fourteen they need to think of the plants and trees in connection with the earth, influenced by rain, winds and heat, or by dry stillness and cold. Indeed, children should always be led to think of the whole plant—root, leaf and flower—to see in imagination the roots spreading under the ground and the halo of perfume and color which surrounds the blossom.

One way to help the children to feel how the plant belongs to the earth, after the first introduction of familiar plants compared to the growing child, is to give a picture in words (which the children will quickly translate into a picture in colors) of the tundra, with its stunted trees spreading outwards instead of upwards, as though held down to the earth by a mighty magnet, willows big enough to bear only two catkins, and other trees in similar proportions. Let the next picture be of a tropical forest where the growth is rampant and luxurious, where seeds vie with each other to find a place where they may grow high in the air on branch or tree trunk, a little plant, maybe, flowering high up on a hospitable tree, scattering its petals into the dank dark of the forest below. At once the children will feel the effect of the heat and the damp on plant growth, and they will be prepared for the magnificent forests of the temperate zone, where trees are neither held down too much by a magnet from within nor too much drawn up by that mysterious outer force which works in the tropics.

This change in the vegetation spread over the surface of the earth can also be observed by ascending some great mountain such as Mount Kilimanjaro, where the whole story from tropics to Pole is seen in miniature. For, starting from the tropical growth of Africa, the climber passes through a temperate zone and finally meets with the dwarf-like plants which belong to the cold regions near the Poles.

There are many legends about flowers and many stories telling of their healing properties, and it is good that these should form part of the botany lessons, preparing the children for the wonderful relationships between plant and human being of which they will learn later. What a marvelous picture Goethe gives in his *Faust* of the magic of the rose. Faust is dying. All around him are devils, ready at the command of Mephistopheles to seize the soul of Faust as soon as it leaves his body. They are surprised by a shower of rose petals so potent in their effect that they all creep back to Hell, scared and miserable; and while Mephistopheles is impotently raging, the soul of Faust is borne away by a company of angels.

There is no need to show pictures of flowers to children or to place the blossoms in the schoolroom that they may be able to copy them. If they are taught about plants as they grow, dependent on what they draw from the earth, and what is brought them by wind, rain and sun, they will make most beautiful pictures of their own, in which the flower is no isolated flower, but part of all the world of nature that surrounds it.

SCIENCE IN THE MIDDLE SCHOOL

Child-Centered Science

Reverence Instead of Vandalism

by ROLAND EVERETT

When entering the sanctuary of modern science, the would-be student has to leave behind his personal life. As he dons his white lab coat, he seems to deposit his individuality in a kind of cloakroom, to redeem it only when returning to private life again. It is due to such boffin-like isolation and self discipline that the work of the scientist can flourish.

But here, right at the beginning of our story, the teacher, wishing to introduce science to younger students, is faced with a problem: His twelve-year-olds are too young to have developed their individuality, and hence they are unable to be scientifically objective and humanly neutral.

Teachers in a Waldorf school not only allow their students a direct and personal approach to science but they even place the human being right in the center of it. Naturally this invisible, but ever present, guest in the classroom is above the personal level. He is the link between student and subject and encourages objective assessment of observations.

The unspoken motif of the twelve-year-old could be epitomized in the following words:

Through all my days there was Nature and I,
The playground where my life began.
But now I ask the question "Why?"
And try to find the hidden plan.

How can the teacher help to bring this about? We began our first science lesson by remembering an evening at the seaside. Each student contributed characteristic features, such as the color of the sea or of the setting sun, the sound of the waves, the clouds drifting in the sea breeze, and so forth. From the totality of such a picture we concentrated first on the color of the sun, which is the earth's main source of light. When is the sun red? Why should it change its color? To find the answers, we blackened bits of glass by holding them over a candle flame. Looking through the darkening film of soot at the candle flame, at a naked bulb, or at the sun itself, we discovered that the light source always changed to orange-red. This, and similar homemade experiments showed us that when light is struggling through a darkening medium, its color changes towards orange and red. In this way we had artificially produced the very processes which were taking place as the sun was descending on that memorable summer evening at the seaside.

But how can we understand the ethereal blue of an open sky? Why do mountains look blue from a distance? With a little guidance and more homemade experiments (such as jam-jars filled with soapy water and held against the blackboard) the emergence of blue was recognized as the consequence of our looking at darkness (e.g. the mountains) through the intervening lit-up space. This helped us to realize that, when seeing the blue sky, we were looking into interstellar darkness, but through the earth's light-filled atmosphere. The remote and peaceful mood of blue, in contrast to the dramatic and ever-aggressive quality of a flaming red could now not only be felt artistically but even understood logically.

Whereas ordinary textbooks on light and color translate everything the eye can see into terms of waves and vibrations, which are unrelated to our sense experiences, it was the human eye itself which revealed to our youngsters the very secret of color. As light and darkness interact, the whole rainbow bridge of color springs into being. Between the white of the eye (and white is the color nearest to light) and the black of the eye's pupil, we see the colors of the iris spreading in a circular band. And 'iris' is the Greek word for 'rainbow'!

Returning to our scene at the seaside, we now described in detail all the sounds we could hear: the angry roar of the stormy waves followed by the hissing of the backwash, or the dreamy lapping of the ripples on a very calm day. We compared the cruel cry of the seagulls with the limpid warbling of a robin. Back in the classroom, identifying with blindfolded eyes different objects as they were being struck, knocked or tapped, we discovered that in each object a characteristic sound was hidden which could tell us something about the object's quality. Thus noble metals had a different ring from that of base metals. Past observations of railway men tapping carriage wheels with a hammer, or shopkeepers tapping crockery for 'soundness' before selling it, now assumed new significance. Outwardly produced sounds of inanimate objects told us something about their quality, but animals' voices, produced internally, also transmitted feelings (e.g. the bleating of a lamb, the bark of an angry dog, and so forth). The human voice, on the other hand, conveyed thought content as well as emotional undertone and the individual timbre of the speaker's voice which is so characteristic of each person's nature.

Returning once more to the seaside, we watched the drifting clouds, and, like the Brothers Montgolfier, we "caught a cloud in a paper bag and let it fly." As our hot air balloons rose into the air, we could experience how heat, through the expansion it caused, was freeing matter from the pull of gravity. The flames, suspended below the balloons, were looking smaller and smaller as they were rising rapidly, seemingly returning to their original home, the realm of the sun. Many other simple experiments showed how heat sets up movements and currents, winds and storms, which give to the earth the very breath of life and without which the earth would have been poisoned to death long ago.

Such an ecological approach to physics not only involves each student quite personally, whatever his gifts or limitations may be, but it also offers practice in accurate observation and scientific thinking. Looking at the world in the way outlined, the young student may gain the experience of discovering the very fingerprints of the Creator's hands. Trying to read and understand these, he will feel inspired by the great wisdom pervading all natural processes and phenomena, big or small. His reverence for all created things, in contrast to the ever-increasing vandalism of our times, may foster a sense of responsibility towards the earth and its inhabitants, and initiative to do something about the serious dangers besetting it.

Science in the Middle School

by LAWRENCE EDWARDS

Science today has assumed so large an influence over our lives that the class teacher must feel a sense of very special responsibility when he comes to present this subject to his class for the first time. How can he present the world to the students as a subject of thoughtful study without portraying it as some vast machine, grinding slowly and relentlessly to some conclusion at which we can only dimly guess, ruled by the inexorable laws of cause and effect, heartless, soulless and utterly indifferent to the race of human ants which have somehow been thrown up in the course of its development? How, above all, can he preserve a sense of primal wonder, while passing on the legacy of accurate and precise thinking which is ours from the struggles and labors of the last four centuries?

These, I think, are the two problems which face us above all. The modern attitude to science has led us to a view of a mechanically driven universe in which the human being and the activity of the free human spirit have no real place, and the sense of wonder, of religious awe even, which impelled the earlier scientists to their search for truth, seems almost to have departed. It has been explained away by the abstract explanations of an arid intellectualism. Much might be written, but one small concrete example is worth more than reams of paper covered in abstract generalizations—so away with them!

Let us start with the simplest of matters: Let us consider an equilateral triangle. We can contemplate its beautiful threefold symmetry, and in so doing we are led to the idea of bisecting its three sides. If now we join up the midpoints we obtain another triangle, half as big in the length of its sides but a quarter as big as regards its area, apparently upside down as compared with the first one, but still equilateral. We can repeat this process with ever smaller and smaller triangles, until the thickness of our pencil lead prevents us going any further. It is such a simple exercise, and it can be done at the very beginning of the first geometry main lesson in a child's school career, yet there are contained within it mysteries untold.

Let us consider what we have really done. We have made a family of triangles related to one another in such a way that each is exactly half the size of the one outside it. If we were to start with one of the inner triangles and move outwards we should have to double our size with every step we took; it would be times two, and times two, and times two and times two again. We have made a picture of multiplication!

When we multiply we manipulate an abstract process in our minds, based largely on memory and habitual methods of working, and the true nature of the process never enters our consciousness. Yet this process in its reality is wonderful beyond our imagining; it contains the secrets of life and of all living things. And now we have made a picture of this process.

Let us examine it more carefully. We would continue our journey outwards, doubling our size from triangle to triangle, and there is clearly no limit to the distance we could go. We follow our triangles outwards into the far reaches of space until our imagination reels as they melt into the infinite distance. But suppose we were to turn and go inwards; how far could we go? It is lovely to watch a class of twelve- or thirteen-year-olds wrestling with this problem. Some think a dozen steps, others, more adventurous, guess at a hundred or more, before the center will be reached. Then one of them suddenly realizes that here too one could go on forever. No matter how small the triangle one has reached, there is always another one within it. Just as before one had looked at an infinitude without, so now one gazes down an infinite vista toward an infinite center within. Qualitatively the journey towards the center is as long and as rich with form as that to the infinite periphery (see Fig. 3, a family of triangles forming a picture of the process of multiplication by two).

Thus we begin to see the process of multiplication in a new light; it is a process of transformation bounded by two infinitudes, working between an infinitely distant center within and a finitely distant periphery without. In contradistinction the process of addition is one which is bounded by only one infinitude, in this lies the true nature of the basic difference between these two very different processes.

Now we can take another step, let us repeat this diagram, subtracting this time from each side not one half of its length as before, but a smaller fraction, say one tenth. Immediately the drawing springs into life. Where before we had only a jerky jumping from triangle to triangle, we now see the tendency to form three beautiful logarithmic spirals. These are the curves of multiplication *par excellence*; they sweep away into infinite distances, but they also coil inwards, towards the center, wrapping endlessly round one another, but never touching and never reaching their destination (see Fig. 4, a family of triangles where the multiplicative factor is smaller, approximately 1/10, in which three beautiful logarithmic spirals begin to make their appearance, formed solely out of the

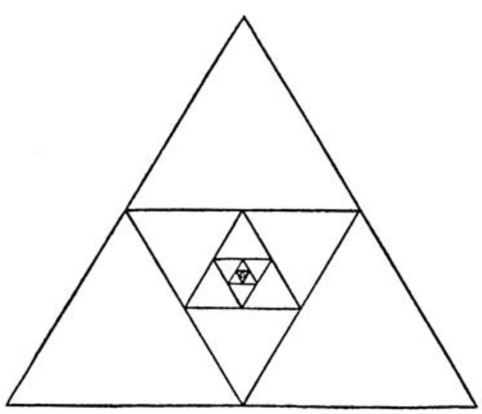


Fig. 3

sides of the triangle; and Fig. 5, the curve of organic growth, the law of multiplication).

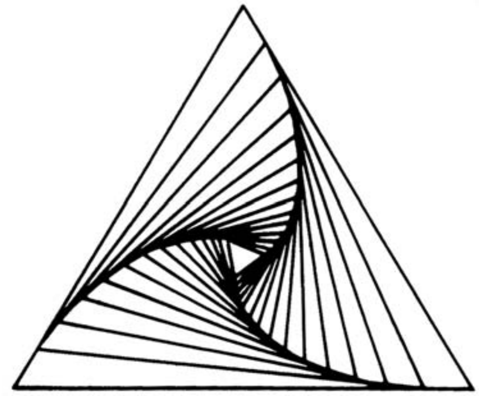


Fig. 4

Of course we could make a spiral which went outwards in even, instead of muliplicative steps; then it forms a picture which gives a very different impression. It is called sometimes the Spiral of Archimedes. It coils endlessly away with dull and even steps, which gives an impression of apathy and boredom, while the logarithmic spiral flings outward into space with a dynamic urge which is beautiful to contemplate. The Spiral of Archimedes bears within a sort of poverty; it winds inwards and reaches its center in a finite number of steps; it has only one infinity, that of the periphery. The logarithmic spiral moves between two infinitudes, for it has an inexhaustible center! What far secrets we touch whenever we add or multiply! (see Fig. 6, the curve of mechanical increase, the law of addition).

But what has this to do with our picture of the universe? Let us go back through the history of the earth. As age precedes age in our backward review, we find the earth originating more and more from a fluidic, living state. Rightly has the mighty ocean, with the ceaseless flow and rhythm of its tides, been called the great mother of all that is. We can look back to a time when in a sense the earth was all sea. And this sea is not just water and salt. We know today that it is filled, permeated, with the very stuff of life.

Fig. 5

Fig. 6

Once we were in the sea! And its rhythms flowed in us and through us. And now we are on the dry land, but the rhythms of the water of life continue in us as the pulse and flow of our blood. It is a significant fact that the chemical constitution of our blood very closely resembles that of seawater. Probably the students one is speaking to are twelve or thirteen years old, and the bones in their bodies are already fairly firmly formed, but it is possible to look back to the time when they were tiny babies and had practically no bones in their bodies at all. In a way one could say that then they were all blood. It is not a fanciful comparison one is drawing; the human being is a part of the world, and its very nature flows through his being too.

But what goes on in this living texture of the ocean? The students will not know of the countless millions of microorganisms which form an inexhaustible reservoir of life; they can hear a little about it from their teacher, but they will know many of the forms of seashells, and will have recognized them in the logarithmic spirals which they have already drawn in another lesson. Now they learn that this is a form of life for vast quantities of minute creatures as well. While they have been laboriously learning their multiplication tables in class, all these little organisms have been doing theirs under the sea! The mysteries concealed in the process of multiplication are so profound that we are most of us only able to glimpse their possibilities, but the ocean is permeated with this, through and through, as with a living wisdom.

Now what happens to the shells of all those little creatures? Well, they fall to the bed of the sea, and there they get pressed together in great layers until they become limestone. And many of the greatest mountain ranges of the earth are limestone. And so, through the ages we see the bones of the earth gradually forming out of the living ocean.

But how do the bones form in our bodies? In our blood there are millions of little cells whose function it is to crystallize the calcium out of the blood (which is really lime!) and lay it down as the substance of our bones. And thus through the years, out of the living blood, the rugged mountains of our frame are built (see Fig. 7, diagrammatic sketch of the back of the humerus).

And now let us take one of these bones in our hand, perhaps one of the long bones of the limbs or a rib. Let us admire its superb artistry, its subtlety of form and line. As we examine it we will begin to perceive that in the most subtle way possible the spiral principle is in evidence here too. Examine the bones not just according to their outline shape, as it were, but according to the planes which would be tangent to their surfaces, and again and again, in all sorts of unexpected places one finds the spiral principal leaping into life before one's eyes. Look at an x-ray of the femur and one finds that this spiral form is built into the inner structure of the bones as well. This great weight-bearing shaft of the body is formed of little laths of bone lying side by side. These laths form two families of spiral curves which run crisscross, left hand and right hand, forming a column that is a truly wonderful engineering structure. But as one gazes at it one sees more than an engineering structure—a fountain of life, leaping spirally, frozen (see Fig. 8, diagrammatic sketch of the spiral formation of the head of the femur, as shown in an x-ray photo).

Thus can we look into our bodies and find the secrets of the greater outer world at work there. But first of all we find the spiral in another place—in our minds! And it is as real there as it is on the seashore. Thus we learn to see the world as permeated by a living spirit of wisdom which is as real as any substance which we could hold in our hand. How else could the world have become such a

Fig. 7

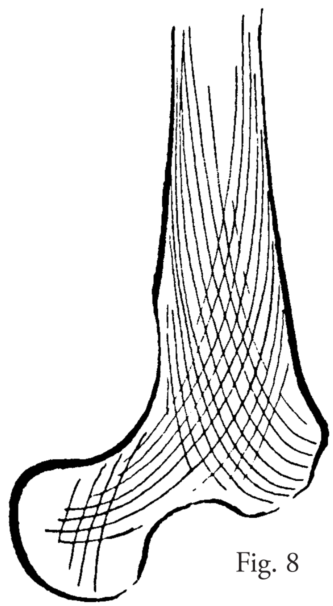


Fig. 8

wonderful place? And when we look into the secrets of our own thinking, we find there the same spiritual realities which have built the world. Thus can we come to confidence in life.

In the course of a short article it has been possible to show, by means of an example, only something of the sort of attitude which I believe the class teacher needs to bring to his science teaching. This attitude has to be varied and adapted to the needs of the different aspects of science which the class teacher needs to touch upon, and to the different situations which meet him in the classroom. The students will learn much else of detailed knowledge besides, of course. I have been concerned to picture the basic attitude which the teacher brings to the task.

Introducing Physics: Color

by HANS GEBERT

Physics is first introduced to Waldorf students in Class 6. Usually all branches are started except mechanics, in each case the point of departure some familiar phenomenon, familiar from everyday life or from previous work at school. Each branch is developed until some regularity or conceptual pattern appears which is part of accepted scientific knowledge. If it has practical application, so much the better. In the process, students should experience the joy and aesthetic satisfaction which accompany deepened insight and understanding.

I shall describe a possible introduction to light and color. The example shows clearly all aspects of early physics teaching mentioned above. Naturally, many other introductions to this branch of physics are possible.

From the time they start attending school, Waldorf school students learn painting. They are therefore familiar with the way in which mixing paints produces new colors: yellow and blue produce green; red and yellow produce orange; red, blue and yellow make some kind of brown. The children have experienced also that some colors are good neighbors and others are not. Red comes naturally between violet and orange, while it has no neighborly relationship to green. If children have not already painted a color circle, in which good neighbors are next to each other, they can now do so. Starting with red and going round the circle we get orange, yellow, green, turquoise, blue, purple, and we end up with violet on the other side of red. In each section there is a graduation. The green section, for instance, starts very yellowish and ends nearly turquoise.

So far the color circle simply shows neighborly relations. The space occupied by each color section is arbitrary. The following experiments show that the circle can be arranged so that opposite colors are also significantly related.

Paint a strong patch of color near one edge of a white sheet of paper. Gaze at it until a luminous halo appears around it. Then shift your gaze to another part of the paper. A luminous patch of color, the so-called *after-image,* appears. It is lighter than the paper to the same degree to which the original color patch is darker than the paper. If the original color patch is, let us say, red, the after-image is bluish-green. Now try to paint the hue of the after-image. It is, of course, impossible to capture its luminosity and brightness because all pigments *darken* the paper. If you have succeeded reasonably well, the after-image of the second patch of color will have a hue very similar to that of the original one. This experiment should be repeated with several colors. The color pairs thus obtained are *physiological complementary* colors. (The term 'physiological' is necessary because slightly different color pairs derived from the spectrum are called 'spectral' complementaries.)

Perhaps some students have experienced a similar pairing of colors when observing shadows. The phenomenon is particularly pronounced in snowy landscapes just before sunset. When the setting sun tinges the snow yellow to pink, the shadows appear violet to green respectively.

The phenomenon of color shadows can be produced artificially if two similar light sources are available, one colored, the other white. It helps to fit dimmer switches so that the brightness can be adjusted. With the *colored* light source, cast the shadow of a simple object onto a screen. If the light source is red, the screen appears red also and the shadow is black or slightly tinged green. Arrange the other light source so that it does not throw a shadow on the screen but just illuminates it with ordinary, white light.

Gradually increasing the brightness will lighten the red color of the screen as the shadow illuminated with the white light becomes unmistakably green or turquoise. If possible, continue the experiment by shifting the non-colored light source until it also casts a shadow of the simple object onto the screen. This new shadow is illuminated by the red light only and therefore appears red. The two shadows are colored in physiologically complementary hues while the background is pink.

It is now possible to arrange the color circle so that good neighbors are next to each other and complementary colors opposite to each other. The students can show the arrangement by drawing a diagram in which arrows indicate pairs of complementaries. Cyan is the technical name for a light, icy blue, while magenta is a bluish pink; the latter is the color which Goethe sometimes called peach blossom.

The color circle or a similar scheme is used in very many applications of color technology: in television, photography and interior design. It is an aspect of all color specification methods. In the continuation of the lessons it is exciting to show how it applies to color mixing. In this way the work can be led back artistically to its starting point.

We continue by showing how colors mix when they are produced on a screen by colored lights rather than by paints. Produce two partially overlapping light patches on a screen which can be colored independently of each other. This is most easily done with two projectors, each fitted with one opaque slide with a central hole. The light patches produced on the screen by the projectors can be colored by filters.

Make one projector light yellow and the other blue and show each patch of color alone. When both are then shown partially overlapping, there is no trace of the green which most people would expect. The area of overlap is a light grey. However, when the patches are green and red the overlap is yellow. Most students will gasp with surprise when they first see this.

Different color pairs can now be tried out, to show that saturated green, red and blue hues are best for producing new colors in this way. If three projectors are available, green, red and blue patches can be produced, arranged so that there are some areas on the screen illuminated by one color only, other areas on which pairs of colors overlap, and one other area illuminated by all three colors together. A surprisingly large gamut of color is seen as the brightness of the three so-called primary colors is varied. Examining a color television screen, it is often possible to see the separate green, red and blue dots which make up the picture. This is particularly easy if the set has separate controls for the brightness of each color. (Warning: readjusting the set after such an experiment may be difficult!)

It is clear that color mixing by *lightening,* which has just been described, follows quite different laws from those governing the mixing of pigments. Adding paints to any colored patch always *darkens* the color. The color mixing at the beginning of this article is, therefore, an example of color mixing by *darkening*. Mixing by lightening is scientifically called *additive mixing* because light is subtracted; this is to say, every new pigment absorbs its share of light.

Subtractive mixing can also be demonstrated with a projector. Use the projector to produce a red spot on the screen. Now use an additional green filter in front of the same projector. The green filter darkens the light patch produced by the red one. Far from being yellow, the resulting color is nearly black. However, if yellow and blue filters are used in a similar way, the result is green. Further experimenting with the one projector shows that the best filters for producing new colors by darkening are magenta, cyan and yellow, i.e., the complementaries of green, red and blue. Magenta, cyan and yellow are called the *subtractive primaries.* Printers use these colors together with black for producing relatively inexpensive color prints. For really good prints more colors are used. Older physics books and encyclopedias sometimes show what prints look like when only two of the primaries are used. If a school parent is connected with a print shop, she or he may be able to provide similar examples which are intermediate products in producing the final color print. The subtractive primaries are also used in color photography. We can sum up the whole main lesson block by superimposing on the color circle the triangles corresponding to the primaries for mixing by lightening and by darkening.

The question arises: Which of the many reds, blues and greens are the correct primaries? Actually there is a reasonably wide choice. Colors from the spectrum are often chosen. No three colors, however carefully chosen, give all other colors; arrangements too complicated to describe here have to be used.

Let us review what has been accomplished. The starting point of the work was two well-known experiences, in our case the results of mixing paints and the neighborly relations between colors. Next we discovered conceptual, almost mathematical, relations; in our case the polar relations shown by pairs of complementary colors. Next we saw how color responds differently to polarized processes, such as darkening and lightening, in polarized ways; we showed that the primaries for the two processes are complementary to each other. Finally we arrived at a geometrical pattern illustrating the laws used in all color mixing. *The fact that the conceptual scheme, beautiful as it is, fits reality only approximately shows an important feature of all physical law.* In branches like mechanics and electromagnetism the fit is very good; when it comes to color and sound, reality is too complicated to fit exactly into the simple mathematical laws.

Similarly, familiar starting points can be found for other branches of physics. Acoustics, for instance, can be started by studying the well-known family of stringed instruments or of recorders of various sizes. It can then be shown how pitch, loudness (dynamics) and quality of notes (timbre) relate to properties of the instruments and the way in which they are played. The study of heat could begin with the well-known air movements (draughts and winds) produced by temperature differences and could continue by showing their effects on motion, size, density and pressure of different substances. A little thought and imagination will yield a number of different points of departure for each branch of physics.

Some First Approaches to Science

by L. FRANCIS EDMUNDS

In a Waldorf school any approach to nature finds its starting point in the human being. Thus, in the first animal main lesson in the fourth grade, we can show how the various animal types that surround the human being present one-sided aspects of his total being. A young child whose imagination has not been spoiled can have a vivid enjoyment of the picture forms which the animals present so expressively, and can, in that way, come to a feeling of understanding sympathy for the animals which goes deeper than words, and which will only later flower into thoughts. From the 'form' of the human being we pass to the particularized 'forms' of the animal world. These animal forms are like single letters. The human being, however, as he stands before us, is a revelation of the 'word'; he alone, therefore, carries within him the seed of fully conscious experience.

In the fifth grade (age 11) we come to that kingdom that reaches up towards the animal world. In the plant kingdom it is not the isolated 'forms,' but the *progress* of form that is most important. In the plant we behold the 'unfolding' of life; that which the single plant achieves as it progresses from seed to shoot, to leaf, to blossom, is also the achievement of the plant kingdom in its entirety. Thus the mosses and lichens are plants which have remained at the first stages only. The ferns are leaf from end to end. In the dandelion the ring of leaves that spreads humbly on the ground surrounds the single stem that grows up from their midst to be crowned at last with the golden flower. In later plants, we see the leaves winding their way up the stem, growing ever more delicate and refined, to pour their secret striving into the fast-shut bud, the magic casket from which, like a second birth, there is to come the crowning glory of the whole plant. The glory we see passes away into the hidden powers of the waiting seeds, that must bide their time in the darkness of 'Mother Earth' until a new season of sun-filled light and warmth shall call them forth to light and being. That which is 'unfolding life' in the plant, Rudolf Steiner relates in its progressive stages to the "unfolding life of the soul" in the human being. As the child is led from stage to stage of plant life, he may come to feel how, in his own soul life, he too passes from stage to stage of knowing, feeling, understanding. And thus the higher plants and all that is the seed process itself is left until he has passed through puberty to a greater maturity of soul and being. Then what he has learned to feel in a childlike way will flash up within him as inner power of understanding.

It is not until the children have reached the age of twelve, the age which is like an early or false dawn of the rise of intellectual consciousness, when feeling perception passes over to a life in ideas—it is not until then that the child is introduced to the mineral kingdom and to the 'pure' sciences so-called. The first of these is physics.

It is tacitly assumed that science deals with reality. Well, a shadow is a reality. In our ordinary scientific thinking it is just this higher reality, the human being himself, that is designedly left out of account. It is this that has made science as we have it—a spiritless, god-void, shadow of reality. The truth of this is slowly dawning on the modern mind. Human existence is something incalculable, and a kind of science that limits itself on purpose to the calculable only can never grasp it. We, however, have to educate human beings and not merely clever, calculating minds. Science, therefore, if it is to help human beings to grow and develop, must learn to include the human being in its statements of nature, and not exclude him. Steiner put it forward as a fundamental point in practice in his art of education that the human being should always stand centrally within the subject taught, no matter what the subject may be. Science in our schools should bring the human being closer to an understanding of his own humanity. A child of twelve is still sufficiently alive in his experience to want to clothe every concept brought to him with flesh and blood. He can, if forced to it, mechanically learn by heart bare concepts and definitions. He can also, for example, learn to build pretence structures with meccano sets, and he may even derive pleasure from doing so. This alone, however, will merely train him to develop a kind of thinking which will come to pieces before the realities of life like the meccano set itself. It will never enable him to enter into the nature of things. As human beings, however, we long to enter into the nature of things—that is the driving force of our being and of all human ideals. We need to transcend the obvious; not to do so is to perish as regards our pure humanity, and that is what the world is in danger of doing. Again and again, by present standards, we seek to apply 'obvious means' for solving the problems that meet us, and we fail, because we miss the underlying realities within these problems.

How then are we to educate human beings to a deeper grasp of the realities? The answer is that we must restore to science that which was arbitrarily cast out at the dawn of our modern age—we must introduce qualitative values into science while paying due regard to the quantitative. We must include in our scientific data "the redness of the rose" and not talk merely of wavelengths that produce an impression of red on the human retina. 'Wavelength' is not a reality, but only a hypothetical notion which provides a useful basis for calculation. From such calculation we arrive at number relationships between unknowables. Such statements are not infrequent today. Science, however, is destined to lead men to insight, to 'knowing,' and not merely to calculations about unknowables. The fact that these calculations, when applied to practice in limited spheres, often lead to predictable results, still leaves the human being out of account. They still leave him gambling away his manhood for doubtful gains. If we are to enable him to strengthen his manhood, to heighten his power of consciousness, to enliven his being, making him more capable to cope with himself and life in general, we must evolve a scientific method which holds fast to the human sense of reality and does not skirt around it. The younger the child, the more is this vitally necessary. Physics for our twelve-year-old must mean an enhancement and not a deadening of experience. It must fill him with awe and wonder and joy at the grandeur of God's plan in big and in small. If we start from 'quality,' we shall also find the right place for 'quantity.' If, however, we follow the way of the modern textbook, building only on the notions of quantity to the exclusion of quality in human experience, we are lost.

By way of illustration, we will give in what follows an introduction to the world of sound for students in the sixth grade. The language used for the students would naturally be different and the descriptions greatly enlarged. Moreover, the subject would be presented so as to evoke questions and answers from the students themselves. We detect sounds in nature with definite organs, the ears. These organs are not there apart from the world of sound. They have been evolved and created according to the laws that prevail in the realm of sound to be in harmony with those laws. Therefore, if we look at the human ear, and if we later study the whole structure of the ear, outer, middle and inner, we have visibly before us an expression of the hidden powers of the world of sound working formatively in nature. The ears are themselves the creations of the world of sound.

We do not merely detect sounds with our ears; we are affected by the sounds we hear. There are sounds that are soothing and harmonizing, sounds that please us, and there are sounds which grate on us and disturb us. Our feelings are directly taken hold of by what we hear. Our ears therefore are intermediaries between a creative world outside and our own hidden life of soul.

We ourselves are largely created by the sounds that surround us from birth. The different languages, by their sounds, have a very definite influence on the way human beings grow up. For example, a child of Russian parents brought up on the English language will become very much 'Englished' in the process. So too, refined speech or coarse speech has a determining effect on child development even down to the bodily appearance. Coarse language will tend to coarsen the appearance of the child as it grows, refined language will have a refining effect. We can also quote the remarkable instance of a child born of dumb parents and therefore deprived of the influence of coherent language in his early stages of development. The child in his demeanor was vague, loose, unformed, incoherent, weak in character, lacking in will and self-determination.

What are the sounds we hear around us? There are the sounds of wind and wave, the rustling of leaves, the babbling of the brook, the rolling of a dislodged rock, the patter of raindrops, the sharp tapping of hailstones, the rumbling of thunder. This is a language that takes hold of the outside things—it is a world of inanimate sound. Mingling with it are the sounds of the hammer, the saw, the hum of a wheel, the sound of tools, instruments, engines, plied or driven by the power of the human being. The kingdom of the plants, unless moved from outside, is a world as silent as that of the minerals. We may hear a branch snap, a tree crash down—these are still mechanical sounds caused from outside. Closely associated with the plant kingdom, however, is the world of the insects. Here, in the hum and buzz and flutter of the insect world, a new world of sound bears in on the first. The insects produce their characteristic sounds. Even these, however, on examination, prove to be mechanical in their nature. The world of sound has here gripped the living world, but still only from the outside.

It is only when we come to the higher animals, the vertebrates—beginning with the croak of the frog, the hiss of the serpent, the song of the bird, and the various calls and cries of the mammalian creatures—that we encounter for the first time a world of sound born from within—sounds of joy, of pain, of fear, of the call for companionship, the ewe bleating for her lamb, and so on. Here, for the first time, we meet sound as a language of soul, sound formed from inner, non-spatial realms. We soon come to see how each type of organism is fashioned for the sound it emits. Out of the silent world of the invertebrates, we come to the sounding world of the vertebrates. When we hear the bursting into song of the birds, it is as though nature herself were bursting into song, rejoicing at her great achievement. We may begin to see that all the sounds that we have heard before are mere reflections, echoes, of the inwardness of sound: thus, even the wind and the waves and the babbling brook may appear to us to be 'ensouled.'

But now into this miraculous world of sound, sound born of the invisible world of soul—doleful sounds, eerie sounds, hungry sounds, angry sounds, joyous sounds, the sound of the lover calling to his mate, the dam calling to her young—into this world of single cries and utterances emitted by the several creatures, there enters the kingdom of the meaningful word, the shining through of reason, of the human spirit, the language of conscious endeavor, of human intercourse, of revelation from being to being. It is a language of communion in higher spheres of experience. The Word more than anything else declares the human being to be a member of a kingdom of his own within the rest of nature. Whereas the animal in its cry is given over to the particular emotion that fills it, language is that which informs the soul, which rules and directs the soul from still greater depths of being.

As surely as language is infinitely more than the sum total of the natural cries of animals, so surely is the music composed by the human being something immeasurably greater than the loveliest singing of the birds. It is born from another source, and evolves from stage to stage with the evolving nature of the human being. We think of "Orpheus with his lute" singing to the accompaniment of his own music, singing of the mysteries of world-creation and world-event. Who but a mind deadened to dust by materialistic theories can fail to see in the human being an order of being standing within nature, and yet distinct from all that surrounds him, singing immortal songs, despite his mortal frame.

Returning to the animals, we can discriminate between the different kinds of sounds. The cry of the eagle, the king of the birds, appears to us as a shrill, piercing head-cry; the roar of the lion with its rumbling breath proceeds from its mighty chest; the bellow of the bull filled with inner fire bursts forth from deep below the diaphragm. We can thus begin to locate the sounds and to appreciate their quality according to their place of origin. In this way we are led over to a first consideration of the nature of 'pitch' in sounds.

To begin with, the tiny child makes marvelously high sounds; as it grows more and more into its bodily nature, as the body increases in size, so the sounds become deeper, more earthy. The sounds appear to descend gradually from higher spheres; as the body increases, the pitch falls. In human beings, many other factors play in. The simplicity of the law is revealed in a visit to the organ of the nearest church. Here we see at a glance the relationship between pitch and physical dimension—the bigger the pipe the lower the pitch. In the violin the strings are the same length, but they differ in thickness—it is the same law of matter in another form. As matter increases, so the pitch falls, until, to return to the organ again, musical tone fades off into what is little more than physical vibration. In the piano, we can see the combination of length and thickness as the physical basis for varying pitch.

We can advance now to the study of the musical scale. We can, for example, take vessels of the same height, and by filling them with water to different levels, examine the pitch produced by the different vibrating air columns. We can examine the stops of a musical pipe and see how this principle of the length of the air column determines the position of the different holes.

We can next proceed by making use of the monochord, and discover how the different intervals in music are related to the numerical ratios in the length of the vibrating chords. We can show also what we mean by the vibrations of strings. For example, with the help of little riders placed along a vibrating string, we can soon discover the nodes or points of rest and the points of greatest amplitude; at the former, the rider remains on the string, at the latter it is immediately shot off.

Thus we come down eventually to number relationships; simple ratios produce harmonious intervals, complicated ratios express disharmonies. We discover that music, the most intangible of the human experiences that reach us through the senses, must conform to exact mathematical laws of ratio if it is to find expression in the realm of matter. We have thus 'come to earth' with our subject.

It makes all the difference to a growing child, as indeed it does to all of us, whether we say that sounds are produced by vibrating strings or columns of air, or whether we say that sound manifests wherever the laws of its being are reflected in the mathematical ratios that govern the vibrations of physical objects. The former statement closes the way to further inquiry—it shuts the door on the spirit. The latter opens ways of further investigation, ways that led Pythagoras to his teaching of the music of the spheres.

Here, then, is an example of the way in which physics may first be introduced to young children. Beginning with the qualitative experiences in which the human being exists, we can lead to an even more alive grasp of the quantitative laws expressed in mathematical ratios bound to matter. It opens the way to a study of number ratios as reflections of heavenly events. It places the human being centrally between the world of matter and the mysteries that rule his being, so that he can look up from the earth to the world of the stars and the circling planets and see creation as an outer manifestation of the divine spirit. This stirs the imagination and fortifies the will. Nothing has been lost of the exactitude of discovered law, but immeasurably much has been gained for the growth of human experience. In this way science can provide a means for the education of the human being and not merely an exercise for the frozen intellect. Whoever has had the experience of teaching young children in the way here indicated will know how it can engender strength and courage and enthusiasm for life in contrast to the nightmare of universal fear, distrust and frustration that fills the columns of every daily newspaper throughout the world today. We have to educate so that we may free the human spirit from its bondage to matter.

The physics of the sixth grade includes a similar study of light, of heat and of static electricity. All these subjects are extended through the seventh and eighth grades, and to them are added current electricity, mechanics, and the growth of industry with the development of power machines. The children are not left in fairyland, but are led to the workshops, the station-yards and the factories. In the

Upper School all this is carried a good deal further. Nevertheless, the character of the teaching remains the same. Only a science that does not shrink from including in its data the qualitative experiences of the human soul can advance to modes of thought, perception and discovery that can bring the healing of the spirit to a harassed mankind.

First Experience of Science
The Art of Introducing 'The Essence'
by ROLAND EVERETT

My heart leaps up when I behold
A rainbow in the sky:
So was it when my life began;
So is it now I am a man;
So be it when I shall grow old,
Or let me die!
The Child is father of the Man;
And I could wish my days to be
Bound each to each by natural piety.
– W. Wordsworth

Does your heart still miss a beat when you see a rainbow in the sky? Or, as the years are slipping by, has it become dulled by habitual sense perceptions? How easy it is to take the phenomena of nature for granted. And yet, each phenomenon is a kind of question, silently waiting to be answered or, as with Goethe, "an open secret" whose discovery can renew the links with the powers of creation, with the divine world itself. Wonder at the wisdom and beauty of the world sets the mood for the first science lessons given to twelve-year-olds.

Several years ago I was asked by a parent during an exhibition of young children's paintings at Elmfield School, "What is the significance of all these rainbows hanging on the wall?" If only I had had the presence of mind to answer him, "Children paint rainbows simply because they love them." For the young, the world retains the freshness of a spring day; it remains as new as at Creation's Day. Who does not feel that no apple can match the taste of those savored in early childhood? Which summer can be as glorious, which winter as bright and exhilarating as those of the good 'old' days? Children today still look at the rainbow with the eyes of Noah after God had put it there into the sky as His sign. And it is the same rainbow which still hides the secrets of light and darkness and their interactions, quite apart from a host of other questions, such as: Where is its exact position in the sky? Can we pass under its arch? If not, why not? Which color is uppermost and in which sequence are the colors arranged? What makes a double rainbow appear in the sky and how are the two sets of colors related to each other? Can we ever see a complete rainbow circle? If so, what must our position be? and so forth.

The teacher, entering this situation in his Class 6, now has the task of leading his students into observing the world in quite a practical and 'down to earth' way, while at the same time fostering their natural piety in the sense of Wordsworth's lines. Accurate observations of simple and homely experiments made in the classroom now become a kind of whetting stone upon which the emerging powers of thinking can be sharpened. If, for instance, a rosined violin bow is drawn across the rim of a glass bowl until a clear note rings out, and then water is poured into the bowl, the pitch of the note will become lower and lower as the water level rises. Why should this be? To discover such underlying causes, the young scientist must become a kind of detective who, when following his clues, will not be led to the customary criminal at all, but to a pattern of law and wisdom, comparable to the very fingerprints of what we conveniently call God. But how difficult it is to learn to look and observe, not to be misled into ready-made answers or preconceived and vague ideas which can be completely off the mark! (Example: When, in a lesson on Heat, the expansion of water inside a bottle was shown, a student who was asked to think of other examples in everyday life wrote: In a similar way rivers rise in summer until they burst their banks with a flood.)

First only the phenomenon, i.e., the experiment, must 'speak' while the young observers must try to develop an inner silence—and this is very hard at the age of twelve! Then, one or two days later, the exact recounting of the relevant sequence of events may lead to an understanding of underlying causes. Finally—and this is the hardest step of all—these findings have to be put down clearly in writing without unnecessary repetitions or padding, while at the same time no leading point must be overlooked. One girl began her 'scientific' account of the string telephone experiment with: "Yesterday it was a gorgeously sunny day, just right for doing our experiment with the string telephone outside." A boy, following the exhortations to be exact, began his composition about how students could identify objects by the sound made when knocked or tapped, with quite ominous sounding words: "On Wednesday, 26 April 1978, at 9.45 am, Mr. E. blindfolded a student who had to guess what was knocked because sound tells you exactly what things are."

Another girl described how sound can reveal symptoms of illness by writing: "If you go to the doctor's, he always knocks your chest to make sure you're all right." In a description about how smoke appeared blue when seen against the dark background of the blackboard, one boy found it necessary to justify his teacher's action with the words: "But Mr. E. only smoked a cigarette to show us how blue comes about. He would never have done it otherwise." Other descriptions showed a delightfully imaginative approach. When, for instance, strips of glass were held over a burning candle flame in order to allow a layer of soot to form on the underside, students were asked to make one part of the glass opaque and another translucent, leaving one small area clear or transparent. Several of them described it thus: "One part of the glass we made into night, another into twilight and the rest was left daylight. And when we looked at the sun through the twilight part, it looked orange. We had made an artificial sunset at midday!"

Which adult has the heart to interfere with such innocent charm? And yet, just as the young child learning to speak eventually has to be weaned from making its own quaint words, these children now have to learn to lift their own rich feeling-life into the clearer mountain air of thinking. This means hard work which cannot be achieved from one day to another. Alongside dreamy approaches towards observing experiments, instant comprehension and pure logic can also be witnessed. Thus, while blacking his glass strip over the candle flame, a boy shouted excitedly, "I can see myself in it—that's how mirrors work!" In a flash he had recognized the principle of the mirror, viz. light being reflected from a smooth surface with an opaque background. Another boy, after having been shown some days previously in several experiments how light itself is invisible, challenged me with the following words, "Why do you draw sunrays on the blackboard if they are invisible?" I asked him. "What about your thoughts, are they visible?" He realized that writing was a means of conveying invisible thoughts. I continued, "In a similar way a diagram can make light visible, so that we may understand better how it spreads and what it does." In this way the differences between drawing a picture, a geographical map and a scientific diagram were made clear. However, despite such an unusually logical attitude, any direct appeal to the intellectual grasp of scientific phenomena would be completely meaningless to most children of about twelve, because their as yet latent thinking capacity needs to be gradually awakened from below upward.

Fig. 9

One begins with where they are in their present stage of development They respond to the world mainly with physical activity directed strongly by inner feelings, rather than with logical thinking. This poses quite a few problems. We held a vibrating tuning fork closer and closer towards the opening of a seashell until suddenly the volume of the tuning fork's sound increased many times. How could one explain this principle of resonance in a 'feeling' way? A long- forgotten episode came to the rescue: A colleague who had lived in Africa once described how one evening in a native Kraal he heard ringing laughter coming from one of the many huts. This laughter appeared so infectious that ripples of it spread from hut to hut until the whole village was full of laughter. Then the chief of the tribe announced to the white man with a beaming face, "The compound is happy, Sir." Well, that vibrating tuning fork 'laughed' in its own way. Its laughter was so contagious that all the air inside the shell, inside the compound, joined in with it, thus swelling the sound. Is such a picture an unforgivable sin in the eyes of a real scientist, I wonder? It certainly helped to convey some meaning to what is generally referred to as 'vibrations in sympathy.'

When studying the laws of Pythagoras in acoustics, a good opportunity offered itself to link up again with a past main lesson of Greek History. The cultural life which blossomed on so many Aegean islands was recalled, especially that on Samos, where Pythagoras had his famous school. One day, while walking through the beautiful Mediterranean landscape, his curiosity was evoked by the sounds issuing from a nearby smithy. Thousands of other Greeks had heard these same musical sounds of hammers striking hot pieces of iron on anvils before, but to the searching mind of Pythagoras they were like questions knocking at his door. "What is the difference between a musical sound and mere noise?" he asked himself, and in time discovered the laws governing the number relationships of harmonious and discordant intervals (a subject as yet too advanced for students of this class). In what way does the particular pitch of a note arise? he wondered, and experimented with metal plates, making the first glockenspiel. He found out which characteristics determine the pitch of a plucked string, and this the students can easily discover for themselves by plucking ordinary household strings of varying length and thickness. They can also play melodies on one and the same length of string, simply by changing its tension, i.e., by pulling and releasing the string. Every time we play a violin, we apply these three laws of the pitch depending on length, thickness and tension of strings: the tuning pegs alter the tension, the lower strings are thicker than the higher strings, and to produce a melody, the string is shortened or lengthened by the playing fingers of the left hand.

Pythagoras continued in his search: There are innumerable sounds in the world. In how many ways can all these sounds differ from each other? Through his thinking he reduced them to only three ways: volume, pitch and quality or *timbre* (the latter caused by overtones, another subject best kept for later study). Yet, how could one explain the quality of a note? Two girls were asked to come out and sing the same note with their backs turned to the class, one girl singing at a time. To discerning ears it was quite easy to identify each voice, for each sound had its own and quite individual 'voice,' and this is called its quality. We can always distinguish which particular instrument is playing a note by its quality or timbre.

These studies quite naturally led to the three kinds of instruments of the orchestra: instruments that are blown (wind), or bowed and plucked (strings), or knocked and struck (percussion). The following remarks may be touched upon if the right moment offers itself during class conversations, for children at this age are too young for conceptualized or philosophical ideas. However, if they live in the teacher's mind, they may nevertheless set the mood of what he has to say: With which part of our body do we blow a musical instrument? With the mouth, the breath being lifted up into the region of the head. With which part do we knock or hammer? With our limbs. What is the characteristic movement of bowing a string instrument? A forward-backward movement, just as we make with our lungs and rib cage when breathing. And so, within the head, chest and limb instruments of the orchestra, the familiar picture of a hidden human being appears. (Let anyone who disagrees with the comparison of bowing a string instrument with breathing observe his own breathing when he has not enough bow left to sustain a long note! The bow makes the string vibrate in a very similar way in which the breath activates the vocal

Fig. 10

chords. Bowing is very akin to breathing, while in speaking and singing we produce sounds only on the outgoing breath. When plucking strings, we already approach a sublimated percussive quality. Plucked stringed instruments, such as the harp and the harpsichord, were the forerunners of the piano, where hammers hit strings.)

All instruments of the three sections must play together, just as our thinking (head), feeling (breath) and our doing (limbs) always have to work together, although usually one or the other predominates. As with people in life, some instruments will come more to the fore, while others may have to play 'second fiddle.' Some may have to wait patiently, but they must be awake at the crucial moment to deliver the one and all important sound that will release a buildup of tension in a climax of clashing cymbals or thundering kettledrums.

But among all these players there is one figure who stands erect, almost aloof from all the rest, right in the center, and who does not produce a single note: the conductor. With his baton, twice the extension of his pointed finger, he inscribes his musical inspirations into the plasticity of the air-space, communicating his ideas by means of gestures and by sheer telepathy. He is like the all-embracing 'I,' which impresses its individual seal upon the whole body of players.

And so, from the rainbow in the sky the teacher tries to lead his students down to earth, right down to the technicalities and natural laws governing musical instruments. The children help him to uplift his vision to those pristine and untainted regions where life began in childhood. At times, the roles of teacher and student become interchangeable in quite remarkable ways. The Child becomes "father of the Man" (see figs. 9 and 10).

The Shortest Way Home

Physiology in Class 7

by ROLAND EVERETT

Few students leave school nowadays without having learned Euclid's often-quoted axiom: "The shortest distance between two points is a straight line." This curt sentence might well have been coined by a successful general. It smacks of efficiency; it is 'to the point' and suits our modern way of life.

Another axiom, less often quoted, is the proverb which tells us the very opposite: "The longest way round is the shortest way home." Which of the two statements is true? Can they both be true?

In their metaphorical value the two sayings can well be applied to two divergent approaches in teaching. We could compare the passing on of facts from teacher to student with following the shortcut route. Experience has shown that students tend to forget these facts or, worse still, they confuse them with the same efficiency with which they have 'learned' them. In order to engender interest in a subject and to make children experience enthusiasm for its grandeur—and this is the only right way of learning—I have always found it necessary to go the roundabout way; I have also found it essential to 'trespass' on to other subjects whenever they could contribute towards a deeper understanding of the one in hand.

It is obvious that in order to understand the history of a nation one also needs a sound knowledge of the geography and the climatic conditions of this country. How then can one hope to understand the manmade problems of the world today without first trying to gain an understanding of the human being himself? How can one learn to understand anything at all without going below the surface of outer appearances?

Teachers in our schools are fortunate in being encouraged and inspired to delve into the depths by the vast treasure which Rudolf Steiner has created for use in teaching. As an illustration I should like to offer one example given to Class 7 (age 14) from a course on the Study of Man, in which I have found it helpful to use music, botany and geometry for the understanding of Goethe's discovery of the metamorphosis of the bones. (This class on the Study of Man was one of the last which I was to give as class teacher to this particular group of adolescents before passing them on into the hands of specialist teachers in our Upper School.)

To go into details of the rather intricate class on the Study of Man would be beyond the scope of this article, and I can only mention in passing that we had been trying to build up a living picture of the human being from several different aspects until we finally reached the human skeleton right at the end of the course. Rudolf Steiner showed us how (and why), at this stage of puberty, boys and girls are experiencing the heaviness of their own bones which leads to the well-known 'gawky' stage of the early teenager, who has lost his hitherto natural grace and who tends to show a lack of coordination in his movements. Steiner therefore asked his teachers to awaken in children at this particular stage a feeling for the beauty that lives in the human skeleton. Yet this beauty is not at all self-evident to adolescents who would probably see 'nothing but bare bones' if merely put in front of a skeleton. They need to be guided step by step towards a recognition and appreciation for the wisdom, the rhythm and the purpose which live within the architecture of the bones. I therefore kept our (borrowed) skeleton safely locked in the classroom cupboard until the last few lessons, and began our study by asking the class to draw diagrams of their own skeleton on paper. As none of the students had ever looked properly at a skeleton before, my request did not receive a warm welcome, but I nevertheless persisted and persuaded them to use their imagination and, where necessary, to feel their own bones with their own hands. The comical situation which followed and the uproariously funny results of this first meeting with the 'living skeleton' will hardly ever be forgotten. Yet slowly we came to discover the threefold nature of the human skeleton (still refraining from using the skeleton in the cupboard!), and we found its three archetypal forms: the rounded form of the skull standing in opposition to the radial form of the limbs, and met halfway by the in-between stage of the thorax with its ribs.

We also learned to distinguish how arms, though principally of the same design as the legs, had been freed from the heaviness caused by the gravitational pull of the earth so that they could develop a much finer and lighter build to enable the human being to perform the intrinsically human actions. (Later on we exchanged the bones of one leg with those of one arm on the same side of the skeleton to show this contrast of 'above' and 'below' quite drastically.) When at last, after much preparatory work, the skeleton was shown to the class, a solemn and almost meditative mood pervaded the classroom, and further and deeper observations could now be made. For instance, we observed how the main function of the plate bones is to *protect from without* (e.g. in the skull), whereas the functions of the rod-like bones is to *support from within* (e.g. in the limbs). We also rediscovered the threefold nature of the skeleton, so apparent in head, chest and limbs, in each one of the three parts: so that each main part has again its subordinated head, chest and limb parts, but with one part dominating over the lesser two. Thus we arrived at the following arrangement:

1. HEAD	a) skull – dominant part (rounded plate bones protecting brain) b) cheek bones (curved, semi-open bones resembling ribs) c) jaw bones (like "little legs grown together under a Buddha statue sitting deep in meditation")
2. CHEST	a) shoulder blades (plate bones protecting, e.g. when warding off a blow from behind, thus functioning like the skull) b) ribs – dominant part (partly plate, partly rod-like bones; neither spherical nor radial in form; both protecting and supporting) c) last two ribs (standing separately like two little limbs, as they are not united to the sternum)
3. LIMBS	a) pelvic girdle (plate bones protecting inner organs, thus resembling the skull) b) pelvic bones meeting in front (*os pubis* and *os ischium*, imitating the form of the ribs) c) limbs – dominant part (strongest tubular bones, radial quality supporting from within)

The same can be simplified algebraically as follows:

A	A	b	c
B	a	B	c
C	a	b	C

We also learned that within the deadest part of the human being's body, within his bones, there lies a hidden source of life in the bone marrow, which creates new blood—a symbolic picture, forever pointing to the mystery of death and resurrection. This is expressed in the medieval alchemist's verse:

Behold the Man of Bone
And thou beholdest Death—
Behold within the bone
And thou beholdest the Awakener.

There was, however, one further idea which I felt unable to bring to my students at this stage, and this was the previously mentioned discovery of the metamorphosis of the bones. I therefore left it in abeyance for the time being, and began the next main lesson block in mathematics.

Fortunately we had a piano in our classroom and, as a reward for hard work, some fifteen minutes of each main lesson was devoted to music. During the first week I played a theme with variations by Beethoven until the class was thoroughly familiar with both the theme and every variation. (A simple set of variations found in Beethoven's collected variations is far more suitable for this purpose than the more complicated examples in his sonatas.) Soon the class could sing the theme while I played only the left-hand accompaniment; they could recognize the theme when it was 'hidden' in variations; they learned to describe the different moods living in each variation, such as a *playful,* a *wistful,* a *boastful* and a *sad* mood, and so forth.

During the second week I played another set of variations on an original theme, this time by Mozart, the first movement of the well-known *Sonata in A Major*, which the students already knew from previous eurythmy lessons.

When, after a fortnight, my class had really developed an experience of the meaning "Theme and Variations," we discovered this idea in many other examples, such as in the human being, the archetype or *theme,* and each human individual appears as a *variation*.

In a separate set of lessons I then asked the students to think of as many different parts of the plant as possible. (This brought back to mind a botany main lesson block, given some two years previously, on which foundation I could now build fairly rapidly.) These parts of plants were written on the blackboard in the order in which they were mentioned, and then we sorted them out into groups belonging together, such as: petals, stamens, pistils, sepals, carpels, fruit, seed, and so forth. Looking at the lists of the different parts of the plant, the students were asked whether they thought that each part was absolutely different from each other, or whether these parts somehow were mysteriously linked together by invisible bonds. The words 'theme' and 'variations' came out spontaneously from several students. It was now comparatively simple to find the theme hidden in the leaf which is the central part of the plant in general, so that we could make the following list. (Most examples in the plant world were supplied rather than 'discovered,' by the students themselves and doubtlessly countless other examples could be quoted. The original discovery was made and published by Goethe in his *Metamorphosis of the Plant.*)

THE LEAF AND ITS VARIATIONS

Variation I:	Roots resembling leaf in: all bulbs consisting of thick fleshy leaves
Variation II:	Stem resembling leaf in: all grasses, rushes, iris leaves
Variation III:	Bud resembling leaf in: tulip, the 'sticky buds' of the horse chestnut
Variation IV:	Sepals resembling leaf in: the rose, the bracts of the marigold
Variation V:	Blossom resembling leaf in: arum lily, Christmas rose
Variation VI:	Petals resembling leaf in: tulip (the petals are coarser and green before they reach their final color)
Variation VII:	Pistil resembling leaf in: the bluebell, peony
Variation VIII:	Stamens resembling leaf in: dahlia, chrysanthemum, double daisy (stamens reverted to petals)
Variation IX:	Carpels resembling leaf in: buttercup
Variation X:	Fruit resembling leaf in: peapods, lupin
Finale:	Seed resembling leaf in: 'flying seeds,' e.g. lime or ash trees, honesty seed

And so all plant parts were recognized as modifications of the original 'mother leaf.' They were found to have adapted themselves to special conditions of their environment (the tough roots to the earth, the tender blossoms to the light, and so forth), and in their specialization they revealed the wisdom of a divine plan which Goethe called the archetype of the plant (*Urpflanze*).

During the following week (now a month after the end of the Study of Man class) we looked again at the human skeleton and experienced once more the three archetypal forms: the sphere-like form of the skull, which is like the vault of the starry heaven above us; the rod-like form of the limbs, which the gravity powers of the earth have formed; and the looping movement of the ribs, which reminds us of the "looping movements of the planets" (Goethe).

We then observed separate bones, modeling and drawing them, and noticed the three fundamental forms in each individual bone, in a similar way to that in which we had found the threefold nature of the whole skeleton revealed in each of its three main parts. Thus in the femur we found a sphere-like shape at the top, a looping movement in the 'twist' of the bone and, dominating the other two, the main rod-like bone. After looking at many different bones in this way we tried to find the least specialized kind, the one which would show the three forms in the most balanced way, and so, at long last, the vertebra with its spherical, radial and looping form was discovered to be the underlying theme of the many beautiful variations in this 'frozen music,' our skeleton.*

The straight line or the longest way round—which? We believe that in educating children today a teacher needs to bear in mind two quite different aims, of which the first is the generally accepted attainment of knowledge, whereas the second is the fulfillment of the children's needs in their different stages of development. Teaching can thus become a healing, or at least a strengthening and developing of latent capacities. This second way can never be the short way which brings quick results, but it leads us beyond the world of matter into realms where forces are at work which we can trace in the wisdom of outer objects. Thus the longest way round can lead us back to the world of the spirit, to our true home.

*There is one flaw in this method of exposition of which I am well aware, and this is the fact that there it a definite difference in the meaning of the words 'variation' and 'metamorphosis.' A *variation* is a more superficial change, whereas *metamorphosis* means a breaking through to something new, not unlike a musical fugue, which grows and goes through different keys during its development while the 'round' or 'catch' always remains at the original level. Nevertheless, it seemed justified to use the example of 'theme and variation' to illustrate Goethe's *Metamorphosis of the Bones* because many musical variations are really metamorphoses (especially if they have been created by a genius like Mozart or Beethoven) and because the concept of 'variation' could thus become a bridge leading over to the more subtle concept of 'metamorphosis.'

First Lessons in Physiology
by M. SERGEANT

In the Nature Study of their early school years, the children hear much about the kingdoms of nature, but in a certain definite order. First, at about the age of nine, begins the study of the human being, in connection with the forms of the animal kingdom. Then the children hear about the animals themselves, then the plant kingdom, and finally the minerals. The reason for this development of the subjects is that the growing child is connected differently with his body processes at different ages, and there should always be a correspondence between the subjects a child is taught and the state of his development. After birth the child's soul and spirit descend further and further into connection with his body, until at about the age of twelve his life unites itself firmly with the hardest part of the body—the skeleton. It is at this time that the mineral world is introduced into the lessons, because the minerals on the earth's crust correspond to the bones in our body.

But after studying various minerals, the children return again in their Nature Study to the consideration of the human being, for it is very beneficial to bring before them the certain facts of physiology and hygiene at this stage. If what they are thinking about consciously in their lessons corresponds to what they are experiencing subconsciously in a dream-like way, they will be helped to unite more surely and firmly with the body that is the foundation for their physical life.

There is another advantage in introducing the subject at this age. Before they have reached puberty, children are less self-conscious and can regard the facts of hygiene and physiology from a more objective standpoint. Before puberty the soul of the child is still closely involved in the physiological processes of its own body, whereas afterwards it is, in a sense, released and the child becomes more self-conscious about them. It can be of the greatest service to children to learn a little physiology while they can still treat the subject quite objectively.

What will help them, however, is not a mass of physiological and anatomical detail, but a living picture of the harmonic interplay of forces in the human body: not a heap of building stones, but a building plan. They should come to look upon the body as a work of art, the expression of the human being's spiritual faculties.

One approach to such a course of physiology is to lead the thoughts of the children back to their very earliest recollections, and thence to a realization that twelve or thirteen years ago they were not in the world at all. No doubt they were 'looking down' on the earth to which they were soon to descend, looking especially to the parents who were to make it possible for them to have a physical body, for without one they could not live upon the earth. When the actual moment for birth into this world came, the soul and spirit entered into the little body it had been forming inside the mother organism, and the first thing that happened when the soul and spirit entered was that the body began to breathe. But the newly-arrived soul has to learn how to use its lungs, and the breathing is not very regular at first. It has to learn how to use the body, but at the same time it has to build it up to make it suit its needs. With a newborn baby, the movements of the limbs do not express its soul life. It moves its hands and feet indiscriminately, without definite purpose. Nor do the eyes focus properly at first. The children will think of many things that their little brothers and sisters had to learn to do. They had to raise themselves to the upright posture which the human being alone enjoys; they had to learn to walk, to speak, to think.

Before passing on to the manner in which the human soul builds up its body, the students must discover that the world around them consists of solids, fluids, gases and warmth (the Earth, Water, Air and Fire of the Ancients). These four elements are found again in their own bodies. The skeleton is the firm foundation, and is to the body what the rocks and the mountains are to the earth. These were the last to be formed in the development of the earth, and the bones are the last to form in the human body. A newborn baby has hardly any real bones, only cartilage that is later changed into bone. On the earth's surface there is more water than land, and in our bodies there is more fluid than solid. The air we breathe, filled with sunlight and sun-warmth, is taken to every part of our bodies. Our bodily warmth depends upon the stream of our blood. Thus the substances of our human body may be shown to resemble the substances found in the outer world.

What of its form? The human spirit thinks, feels and acts; therefore the body is also of a threefold nature. For thinking, quiet is necessary, and our thinking instrument, the brain, is enclosed in a bony casket where it is at rest. All rigid forms and hard substances belong to the head system. In great contrast to this head system is the digestive tract and the limbs, for here there is continual movement and changing of form. But between the head and the abdomen is another system of organs, and in the thorax we find neither the immobile and rigid nature of the head system, nor the dynamic energy and turmoil of the metabolic and limb system. There is, instead, the rhythmic breathing in and out of the lungs and the steady beat of the heart. This rhythmic system keeps a balance between the other two, and it is interesting for the students to discover some of the ways in which this balance shows itself. The metabolic system, which is nearest to the earth, takes in solids and liquids; the rhythmic system air, the head system light, sound and color.

This threefold nature of the body is an expression of the threefold nature of the soul. The head allows itself to be carried tranquilly through the world, for quiet is necessary for thinking. In the breast is the feeling heart, and it is here also that we free ourselves of the oppressive air coming from the rest of the body and refresh ourselves with fresh air from the atmosphere. Our will expresses itself through our muscles and our limbs; our feet must carry us over the world, and with our hands we must transform the world. The organs of digestion, which are closely allied to the limb system, break down and build up anew the substances we take in from the outer world.

When turning from the general pictures of the human being's bodily relation to the earth on which he lives, to describe the structure of the body in more detail, it is well to avoid showing children of this age pictures from physiological plates and atlases, because it is above all the living processes they should grasp. Instead of fixing the attention on the actual visible organs, a conception of the interplay of forces concentrated behind each organ should be aimed at. Pictures of the heart, lungs, stomach and so forth, give an impression of something static, with a fixed form, whereas in reality the organs are pulsating with life and movement. Only the bones have sharply defined contours, and during life these are clothed with muscle. Therefore it is more helpful to show the students some simple sketch or diagram rather than a beautifully prepared color plate of the internal organs.

When describing the various stages of digestion, the students cannot fail to be impressed by a description of the manifold processes that each piece of food must undergo before it can be turned into flesh and blood. Not until the substance we take in from the outer world has been utterly deprived of its own properties can it receive the impress of the human Ego and be incorporated. The fruit that has ripened in the light and warmth of the sun serves as nourishment for the human being. As he breaks down the material substance of the fruit, the forces of heat and light are released again and enter into the human being. Only substances that have these life forces* in them can serve as nourishment to man or beast. Light and heat are cosmic forces coming from the sun, and the students should feel reverence for the forces that come to them with their food. Meals could be veritable 'Festivals of Incorporation.'

When speaking of the body, generally we regard blood as a fluid, but when looking at it closer we find that it is composed of all the elements of Earth, Water, Air and Fire. The corpuscles are the solid constituents; the plasma the fluid; it carries the fresh air to the rest of the body from the lungs and bears away waste gases; the warmth of the blood maintains an almost even temperature in the body, whether we are at the North Pole or the Equator. Our blood is only really alive while it is flowing in our bodies; when it flows out of our bodies in wounds it changes immediately. But even in our bodies the blood is continually dying and being created anew. This 'very special fluid,' the blood, is so fine and delicate that it responds to our emotions. When we feel shame it rushes to the surface, and when we are excited it flows more quickly through our body. When we feel fear it withdraws to the deeper vessels, and shock can make it flow so slowly that the pulse will be imperceptible.

The blood flows into our muscles and the muscles respond, not to our feelings, but to our will. By controlling our wonderful system of muscles, we are enabled to work in the world, and to be of service to the world. We do not know how our muscles respond to our will; we cannot follow consciously the processes that result in the simplest movement even of our voluntary muscles, but we can study their structure and love them for the infinite variety of work of which they are capable. Through our muscles, invisible inner movement can become visible outer movement. Like the blood, the muscles are not overcome by earthly gravity, but help to raise the human being off the ground and keep him in his upright position.

With our bones it is otherwise; they are, in a sense, dead, and they can be moved only by muscles. Here gravity rules, for the bones have absorbed earthly mineral salts. But the students should be shown how beautifully formed and proportioned the skeleton is. Its architecture may well be called 'frozen music.' Compare the bones of the foot with those of the human hand, which is freed from the earth. The foot is perfectly constructed for its special requirements as a support for the body, but the bones of the hand are so made that the human being may become creative as an artist or technician in any field of work that will serve his fellow man. The threefold nature of the skeleton is very marked. The head is spherical, enclosing the organs within it. The ribs are rounded, forming a strong framework with the organs inside, but whereas those nearest the head meet, forming a circle, those nearest the metabolic system open out more and more, and the last two are too short to go right round. The bones of the limbs enclose nothing, but act as supports, and are surrounded by muscles.

Many practical details about diet and health can be brought to the students during this course of study which may have a very beneficial effect on their lives. But there is one other aspect of equal importance which may affect them even more profoundly. It was one of the great tasks of Rudolf Steiner to show in many detailed ways the connections which bind together the human being—in Body, Soul and Spirit—with the universe which surrounds him, so that a human being may need no longer feel himself alone in an alien and unfriendly universe, but rather that cosmic forces are at every moment sustaining and cherishing him. One such connection between the human being and the universe, which the students should know as one of the facts of experience, is a certain numerical correspondence between the rhythmical movements of the sun in the cosmos and of the breathing powers in the human being. The sun, in its yearly course through the circle of the Zodiac, is at the Vernal point on March 21st each year. The Vernal point, however, is not a fixed spot, but advances a little each year, and it actually takes the sun 25,920 years (a Platonic Year) to reach the same spot again on March 21st. The rate of healthy breathing in the human being (eighteen times a minute) is also 25,920 times in a single day. The same rhythmical law which covers such vast stretches of space and time in the relation of the sun to the fixed stars appears also in the daily life of the human being. It cannot fail to fill a person with awe and reverence to realize that the number that governs the movements of the heavenly bodies is the same as that which rules in every breath by which he or she lives.

* The name *vitamin* has been given by modern scientists to certain manifestations of the life forces.

The Teaching of Natural Science
by A.R. SHEEN

It is the task of the historian to allow the facts and personalities of history to tell him the story of the evolution of humanity. This story will be true insofar as the historian does not impose his own particular theories upon the phenomena of history. In the same way the educationalist must learn his art from an unprejudiced observation and study of the development of the growing child. Teaching and education must accord with the needs of the child at every moment of his life. Educational theory, however clever, which is not based on a deep insight into the child's nature—and how little the many complicated methods in use today are so founded!—can have only the most harmful effects.

The development of the child as he grows to personhood runs a parallel course with the evolution of mankind through the ages. The changing consciousness of every single child during his school years is a recapitulation in miniature of the changing consciousness of humanity from the earliest time until the present. Rudolf Steiner has shown us the truth of this in detail.

Our modern scientific age is the product of a certain way of looking at, and thinking about, the world, which is of comparatively recent origin. This kind of intellectual thinking, which is dependent on our sense impressions, and logically builds up one thought after another, really arose when men began to turn their attention to the world of external physical phenomena. We see this thinking first being applied in the study of the movement of the heavenly bodies made by Nicolaus Copernicus, who wrote his great work *De Revolutionibus Orbium Coelestium* in 1543. Since then this scientific thinking has striven to penetrate more and more into the realms of physical phenomena, and in this connection the names of such men as Galileo, Descartes and above all, Isaac Newton, come at once into our minds.

Now, in the soul life of the child, intellectualism has no place before about age fourteen. Previous to this there is very little understanding of the law of cause and effect which is the basis of all scientific theory. That kind of thinking, which is the way of thought of the physical sciences, begins to manifest itself at about the age of twelve and only comes fully to light after puberty. It is, therefore, just at this time that lessons in the physical sciences begin: Sound, Light, Heat, Magnetism and Electricity, Chemistry, and so forth. But it has been said that the thought structure on which our modern understanding of the phenomena of physics and chemistry rests is still foreign to the child at this early age, so that it is not the underlying Law which he needs to learn. If, however, we bring before students the pure phenomena themselves in descriptions and experiments, such a presentation entirely accords with their inner need. "Up to the age of puberty the nature of the human soul is such that it needs 'to behold'; whatever, therefore, we want to convey to the child—either for his upbringing in general, or with the purpose of increasing his knowledge in any special subject—we must make it highly imaginative and highly concrete." * Let us now consider a few examples taken from the early lessons in physics in illustration of what has been said.

Sound

At the age of twelve the students are introduced into the world of physical phenomena through lessons in Sound. The child's experience of music is the bridge across which the teacher leads him, for in such an artistic approach one is working with the whole nature of the child at this time. Among other things the students will be shown a monochord, i.e., a long gut or wire string stretched tightly over a hollow sounding-box. By moving a bridge along the length of the string, different musical notes may be obtained by plucking or bowing. The students will soon find that the note given out by a plucked or bowed string has some relation to its length, that the shorter the length of string used, the higher the note becomes.

Those who play the violin will know that the fingering depends on the same principle, that the length of the strings being altered by the position of the fingers gives rise to the different notes. In the piano the notes are ready-made by many strings of different lengths. Now one may proceed to show the students that there is a simple and definite numerical relationship between the note produced and the length of the string. If a string is sounded, and its length is then halved and again sounded, the first higher octave of the original note is obtained. If it is again halved this shorter length gives the second higher octave, and so on. Or if we take two lengths of string in the ratio of 3:2 (say, twelve inches and eight inches long) and sound these together,

Note	C	D	E	F	G	A	B	C
Interval from C		second	major third	fourth	fifth	major sixth	seventh	octave
String's length ratios...	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2

Fig. 11

we shall get the harmonious interval of the fifth. In the same way the lengths of string may be found for all the notes of the diatonic scale. The following are the ratios of the length of string corresponding to the different musical intervals (see fig. 11).

Now it will be noticed that the more harmonious the musical interval, the simpler is the ratio of the length of the strings giving the interval; the ratio corresponding to the octave is 2:1, to the fifth, 3:1. On the other hand the discordant intervals of the seventh and of the second have the least simple number relationships, 15:8 and 9:8 respectively. The relationship of the length of the string to the tone produced also provides a very good exercise for the students working with fractions.

Light and Color

There is no question of speaking of the wave theory and the like in the first lessons. Rather, one must again endeavor to treat this subject artistically. The teacher must appeal to the immediate experience of the child and let the phenomena speak for themselves. The naïve experience of the child in this sphere is the world of color, and in his painting lessons too he has learned how to use the different colors in an artistic way. He already has an inner experience of the qualities of yellow, of red, of blue, and now in the physics lessons one may build on this. There are many experiments one may put before the students. If we gaze for a moment at a bright red circle of color on a white background, then look away, we see a green circle. The eye has created this complementary color, as it is called. If we have a bright green before us the red is called forth. Similarly blue will create yellow, and violet, orange as their respective complementary colors (see fig. 12). This may be represented diagrammatically as shown, the opposite colors being complementary. Reading round the circle gives us the arrangement of colors in the rainbow: Red, Orange, Yellow, Green, Blue, Violet.

Again one may speak of how the eye reacts to a bright light on the one hand and to darkness on the other. When darkness is presented to the eye, it demands light, and vice versa. All this will give the students the feeling that the eye is

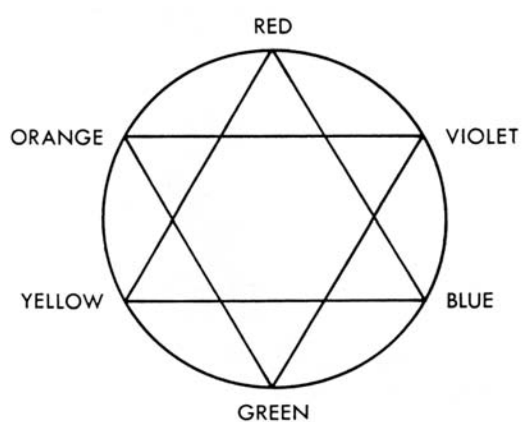


Fig. 12

not only a ‘camera’ which records impressions, but it is at the same time creative. In the words of an old mystic, “If the eye were not sunny, how could we perceive light? If God’s own strength lived not in us, how could we delight in divine things?”

Another important phenomenon in the sphere of color which the students have already experienced is the difference of the appearance of the sun at midday and at sunset or sunrise; and again, the more extreme contrast of the sun seen through a clear atmosphere and through a fog. The colorless light of the sun as seen through a clear atmosphere becomes yellow, red and even ruby red when observed through the misty air of evening or early morning or through a dense, fog-laden atmosphere. One may then do experiments to illustrate the same phenomenon. A beam of light seen through clear water becomes reddened if the water is made semitransparent by stirring lime into the water. The same effect may be obtained by passing a number of sheets of drawing paper in between the source of light and the observer.

The opposite phenomenon is observed when we are looking at a distant hill or mountain through a sun-filled atmosphere, for then this distant landscape appears a deep blue. Here we observe darkness through a light-filled transparent medium. The blueness of the sky is again due to the same cause, for we are gazing into the darkness of infinite space through an atmosphere illuminated by daylight. When this atmosphere is very clear or rarefied, the sky appears intensely blue (e.g. from a high mountain). From the valley the sky appears lighter owing to the greater density of atmospheric vapors nearer the earth. In their painting lessons the students will have experienced that the colors yellow and blue are polar opposite in all their qualities. Now they will understand how yellow is related to light and blue to darkness. Yellow is light slightly darkened down, blue is darkness irradiated by light. In green we have the balance between these two polar colors yellow and blue. Again, if yellow is enhanced or intensified, it goes to orange and then to red. If blue is enhanced it becomes indigo and then violet. The following table will illustrate further the qualitative nature of these two colors:

Yellow	*Blue*
Action	Negative
Light	Shadow
Brightness	Darkness
Strength	Weakness
Warmth	Coldness
Proximity	Distance
Repulsion	Attraction
Affinity with Acid	Affinity with Alkali

The examples taken from the teaching of Sound and Light may serve to illustrate the words of Rudolf Steiner quoted earlier in this article.

After the fourteenth or fifteenth year, the child’s relationship to the world around him undergoes a change. “To behold” the phenomena of the universe is no longer sufficient for his inner needs. He now wishes to reason about these things. The teacher should now approach the scientific subjects more and more from an intellectual point of view, studying cause and effect, bringing mathematics into relation with science, and so leading to the quantitative treatment of scientific phenomena as well as dealing with the qualitative aspect.

Steiner continues as follows: "But quite suddenly at the point of transition into the next phase of life (i.e., from the fourteenth/fifteenth to the twenty-first year), there arises in the human soul the urge to reason about the things with which it is faced; and the teacher—who should be well aware of this change—must try to satisfy this urge and, when speaking of these things, must show how each fact will increase in meaning in proportion as it is understood in its relation to other facts. On the whole one may say the following: It is necessary that at the moment when the child reaches puberty, we arouse in him a very great interest in the world around him. Our lessons, our education in general, must proceed in such a way that the growing child will recognize the laws and principles underlying the life that goes on around him, its causes and effects, its intentions and aims. Riddles must arise in the youthful, soul-riddles about the world and its phenomena. For with the setting free of the astral body, forces [thought and judgment] are set free for grappling with such riddles; and if such riddles do not arise, the forces will seek expression elsewhere—and that is what generally happens with the youth of today. They will reappear in the form of instincts—first the lust of power, and secondly, erotic instincts. Lack of interest in the world around him will turn the human being upon himself and make him brood about all sorts of things within him. Now, the age between the fourteenth/fifteenth and twenty-first years is the most unfavorable for such occupation with oneself, and therefore at this age the awakening faculty for reasoning—which, as has been said, is the true expression of these forces—should be directed towards a grasp of the connections and relations that hold everywhere in the world around us. Just let us observe the joy experienced by students of this age when we draw their attention to the why and the wherefore of things, when we widen their outlook in this or that direction, when we seek connections—when we take our start, for instance, from the smallest incident in their experience and relate it to occurrences in the widest spheres. Indeed every opportunity must be seized to do so; it can be done in any lesson, whether it be 'mathematics' or 'religion'—for it is by this means that the faculty of reasoning is roused and stimulated."

In this later period of school life, the teacher may bring before the students the theories of science, for, as we have seen, the consciousness of the child is now of such a kind that it can grasp and comprehend these things. The thinking faculty of the child is now related in an elementary way to the thought structure which is at the basis of our modern science.

Nowadays students have access to a great mass of popular scientific literature. Many so-called children's books give great prominence to modern scientific achievement and to the theories of science. But what to the real scientist is still only theory is, in these popular writings, put forward as fact. An example of this is the following extract taken from a *Children's Encyclopedia*: "We must understand that color is caused by waves of light of different lengths which can be taken up by certain structures in the eye … Light consists of waves of ether … And we have still, moreover, to study the great discovery of our time that light is really electric, which means that we cannot really understand it unless we study all kinds of electric waves."

Here the wave theory and the electric-magnetic theory of light are spoken of as though they were no longer theories, but proven facts, and, worse yet, beyond our understanding. This is typical of the quite erroneous ideas children can get. In our work as teachers we must take care to guard against this, and to discriminate in our teaching between fact and theory. Students who are taught such theories as facts in their younger years will never be free in their observations of life when they are older.

Thus we see that in the science lessons the students first 'behold' and experience the phenomena of the world around them, and that only later do they come to an *understanding* of these phenomena, through the study of cause and effect. Nowadays it is strongly the point of view of many parents and educators that everything must be explained and made reasonable for the young child, just as though he/she were an adult. But if we want to educate according to the needs of the child (and only such an education can be worth giving to body, soul and spirit), we must take as our general principle: *First experience, then understand.*

*Rudolf Steiner in a lecture on Education, June 1922.

Color in Art and Science
Interplay of Darkness and Light
by ROLAND EVERETT

Talking about his forthcoming summer holidays, a builder working in the same house remarked: "I like to take the lads for a walk. If you take the wife, it's nice all right. But if you take the children, you see so much more. They are always finding things—waterfalls behind some rocks, crystals, or a hawk's nest. Then I have to climb up the tree and see if there are any eggs in it. With them it gets real exciting."

This love of adventure, of seeing things for the first time, can be even more uplifting for adults than the healing atmosphere of nature itself. Yet how easily can such an attitude of wonder and enthusiasm in the young deteriorate into apathy and boredom in the classroom. Time and again the teacher must ask himself: "What must I do, how must I present my subjects, to keep alive this precious source of inspiration?"

At this point another danger looms, namely that of falling into the opposite error of making lessons too exciting and sensational, thus depriving students of finding the necessary solid ground into which to strike roots. How can the teacher be both 'child and father' in the sense of Wordsworth's well-known lines? Let me endeavor to give a few hints from the practice of a Waldorf school, by indicating three stages of development

All healthy children feel a natural connection with the world of color. They all love to draw and paint pictures—the adult can learn to read them like signatures of their different stages of development. If one tries to combine the child's inherent feeling for color with the understanding of a grownup, one can recognize that despite its infinite variety, color undergoes three main stages of development: (1) color as pure manifestation of light and darkness; (2) color as intrinsic feature of natural objects; (3) color 'trapped' into matter as a coloring agent.

Examples of the first stage are the changing colors during sunsets and the varying intensity of blue in the distant mountains or hills. Here one can experience color-in-the-making rather than finished colored objects, so that it becomes possible to speak of 'blueness' as a quality on its own and not merely as an attribute of mountains, seas or skies. This kind of evanescent, yet very real quality of color reaches a climax in the rainbow which shines in the distance, however near to the beholder its portal may appear.

In the second stage, color has become far more part of the earth but, nevertheless, it has retained something of matter's nascent state which can reveal inner qualities of substances. This fact is used in chemical analysis where colored flames indicate the presence of certain chemical elements (e.g. green flame = copper, deep blue flame = sulphur; yellow flame = sodium) and help to identify the "frozen flames of precious stones."*

Compare the ethereal quality of whites, pinks and yellows prevailing in spring flowers with the saturated and earthy quality of the sunflower, or of the autumn flowers which glow not only with the sun's heat but also with the warmth radiated back to them from the sun-soaked earth. Contrast blossoming trees in spring, verdant summer trees, golden autumn trees and the stark silhouettes of the trees in winter—all provide an ever-fertile theme for painting lessons.

Who has not felt the temptation to pick a bright red berry? an inner glow at the sight of a red rose after a storm? In this and many kindred ways does color in the second stage speak to us in its own inimitable language.

In the third stage, color appears torn from its natural surroundings, to be at the beck and call of the human being, for better or worse, in the form of pigments, paints and dyes. This final stage in color's descent into matter is both an end and a beginning, for the human being can now make use of it to create works of art or to express himself in his surroundings, but he is equally free to exploit its possibilities for more egotistic purposes, such as advertising or coloring food.

Color in Art

When observing growing children one can experience how they, too, undergo a gradual descent into the earthly realm from the stage of the baby in the cradle to the fully 'arrived' young person who is ready to take on responsibilities within his community. It therefore behooves the teacher to use color in lessons in accordance with his students' different stages of development.

To young children watercolors in dishes are hardly the same kind of stuff we grownups use, but rather some incredible magic and mysterious source of color. As the small child cleans his brush in the transparent water of a jam-jar, he will experience the 'waste' color floating downwards in the jar with the same enthusiasm with which he greets the color flowing on the damp paper before him. The result of his work, the finished picture, will mean less to him than the experience of color during the act of painting. At this early stage the teacher can approach color directly and not in terms of attribute. He can talk about "the cheeky little red chasing the gentle blue" or "the cheerful, spreading yellow waking up the sad blue."

At an age corresponding to the second stage of color (from about seven to twelve years old), color will set the mood of the picture to be painted. It will help to express the nature of plants, animals, people, scenes from stories, and so forth. As the child becomes more aware of the difference between his own inner life and the world surrounding him, his powers of observation will sharpen and lead him, under guidance, to color perspective and to the subtle changes between the lit-up and shadow-darkened surfaces of objects.

At the onset of puberty, roughly corresponding to the third stage of color mentioned above, most students (boys in particular) go through a critical period during which they seem to lose their innate love of and interest in pure color. Dark, heavy and often murky colors become the signal for the teacher to introduce an entirely new medium, namely charcoal. The once gentle colors of the rainbow now withdraw into the two opposing camps of darkness and light, bringing about a dramatic tension in the no-man's-land of their polarity. This time of losing touch with color in art lessons really represents a temporary 'hard-bud' stage before a renewed but more conscious and individual opening into the world of color can take place.

Color in Science

Caught in an apparent cul-de-sac, the adolescent student is introduced to color from a completely different aspect, not in art but in his first science lessons. Whereas previously color had been accepted unquestioned, its origin and causes now become the center of interest. The orange-red color of the setting sun is discovered to be the result of light penetrating and struggling through the darkening medium of a dust- and moisture-laden atmosphere. The blue of the sky is recognized as appearing when we look through the light-filled atmosphere into the darkness of space.

Then comes the fascinating moment when students can repeat, at will and in their own classroom, the same process taking place out there in the heavens, but on a minute scale. Simple experiments are made, such as holding jam-jars filled with translucent soapy water first against the light so that red tints begin to glow and then against the blackboard whereupon the same solution appears in shades of blue. Similar examples of color in its nascent state are discovered in ordinary life and it is as if the young scientist were allowed a glimpse into creation's workshop, thereby learning to understand the secrets of color in its first stage.

When contrasting the active quality of the sunset-red with the more passive mood of devotion of the sky's blue, old stories, told years ago, begin to reawaken. There was the Red Hunter, who dreamed that he was being hunted by the very animals he had killed, a story which illustrated the active and passive voices during early grammar lessons. Early mood paintings come back to mind, such as "The Wrath of Achilles" (painted in reds) and "The Sorrow of Demeter Seeking Her Lost Daughter Persephone" (painted in different shades of blue).

During history lessons on the Renaissance, students will meet again this contrast of struggle and surrender in the beautiful harmony of the Madonna's blue mantle enfolding a red gown. The polarity of blue and red will emerge again during physiology lessons, when the human being's red and blue bloods will be studies and when the 'muscle man' will be contrasted with the 'thinking man.' Like the story of the Red Hunter, this latter theme also has its roots in the very first grammar lessons learned some five years previously; verbs, the 'doing' words, were then underlined in red, while the nouns, the 'names' one so easily forgets, were marked in blue.

The climax of Goethe's work on light is his theory that colors are the result of the interaction between light and darkness, as exemplified in the rainbow. This theory will lead to the study of the human eye which mirrors this great secret, for between the white of the eye (white is the nearest color to light) and the black of the pupil, there spreads the colored band of the iris. And 'iris' is the Greek word for rainbow. Wordsworth's lines indeed assume a new dimension:

My heart leaps up when I behold
A rainbow in the sky.

*See *Man or Matter* by Ernst Lehrs.

Seeing Stars

A Brief Visit to a Class 7 Astronomy Main Lesson

by JOHN BURNETT

"Is there really a band that stretches round the earth with stars on it?" asks a Class 7 girl in the middle of an astronomy lesson.

"Of course not, silly!" replies one of the boys, "Can't you see it's just the way things appear to be?"

The class teacher has been trying to explain to the students the idea of the ecliptic, that imaginary line through the heavens on which the sun, moon and planets appear to move against a background of twelve constellations. The students are clearly fascinated by this—especially as they recognize the twelve groups of stars that comprise the zodiac. Hands shoot up when the class is asked which is *their* constellation. A thirteen-year-old experiences quite strongly his dawning individuality and is somehow touched by the fact that he has his own particular group of stars which are up there, objectively visible in the night sky. At this age the natural world is fascinating—a new country, still uncharted and unexplored, only yielding its secrets when the clear light of thinking is brought to bear on observable phenomena.

The night sky appears as a great star-filled dome revolving over our heads: our thinking explains the phenomenon through the idea of the earth's rotation. As the students absorb these ideas, one can see them moving between different pictures of the world. The ancient mythological imagery of the zodiac evokes the fairytale consciousness of bygone ages. The challenge of actually spotting Aries or Gemini in the night sky requires meticulous observation and careful thinking if the star-gazer is not to be left looking up at an indecipherable hieroglyph of confused patterns. "I saw Leo last night!" confides one of the students before the lesson begins. To actually recognize and identify night constellations can be a deeply moving experience and a discovery that becomes a key to an ever-deepening relationship to the starry worlds.

Every healthy thirteen-year-old has something of a Columbus within him. He is setting off from an Old World to discover a New World, full of riches and potential. Early childhood's dreamy consciousness is fast fading and the world of grownups and material civilization offers strong attractions. Just at this age, however, something of the pure spirit of childhood still lingers, holding back the egotism that can set in in later years. The child's gaze turns naturally earthwards and rightly so, but if, at this time, the teacher can point also to the heavens, it is possible that those natural forces of reverence which were abundant in earlier years can continue to flow in the awakening sphere of objective sense perception.

The immeasurable distances of stellar space, the beautiful, harmonic motion of the fixed stars in the rhythms of time, the 'dance' of the planets, and the mysteries of lunar and solar movement cannot but move the students if they can be led to make simple but precise observations. They have many questions. They ask about space travel, black holes, whether there is life on other planets, how far is the farthest star. If the teacher can answer these questions out of general knowledge and interest, the students are more than satisfied, but what he can also lead them to is the feeling of awe and wonder arising from their own actual observation.

I look into the World
Wherein there shines the Sun
Where glimmer all the Stars ...

Every day, at the start of their morning verse the students recite these words (in this or some other translation), which express so well the fundamental mood of the Middle and Upper Schools. They are learning to look at the world of the senses in a new way. Just as in the Hebrew Creation myth, the animal kingdom paraded before Adam, receiving from him their names as they passed him by, so too do the fabulous beasts and beings of the constellations pass by the gaze of these new-fledged astronomers.

"This is where we go to look at W!" two thirteen-year-old boys shyly announce on the occasion of their class teacher's visit to their boarding hostel. As he is led up to their rickety, rooftop observation post, he reflects that it doesn't really matter that they have forgotten the name of Cassiopeia as well as most of the other constellations. What is all-important is the enthusiasm and devotion they show as they lift their heads to gaze heavenwards—as countless others have done before them. The stars rise and set: the Celestial Dome, in eternal movement, arches over their heads, and both teacher and students are filled with wonder. This wonder of discovery is the special characteristic of learning in the main lesson and, for these thirteen-year-olds, poised between childhood and youth, the starry worlds can speak a special language of hope and challenge that can sound through the years of their development towards adulthood.

What Really Happens in Digestion and Nutrition?
A New Look at the Mysteries of Our Interior Processes
by L.F.C. MEES

For his life on earth, the human being needs to use his body. Activities force him to use up his reserves, which need constant rebuilding. This is done in the first place by nourishment, which generally means food and drink. In actual fact we ought to view the idea of nourishment in a much wider sense. Our respiration can, to a certain extent, be counted as nourishment because through it we also derive sustenance from our environment. Lastly we might argue that everything we imbibe with our senses can be counted as nourishment in the broadest sense of the word, because we cannot live without those impressions. How often do we hear expressions like: 'to feast one's eyes,' 'to thirst for knowledge,' 'to satisfy one's curiosity'? Something can be 'too much,' even 'indigestible.' In this article, however, we will restrict ourselves to the everyday notion of feeding, or partaking of food during meals, to what is generally described as the way we rebuild our body.

In modern dietetics the question of nutrition has yet another side to it: for his activities the human being needs energy. Only his body can give him this energy. Whether this is converted into physical or mental activity does not concern us for the moment. Putting it briefly: our food serves to rebuild our body and to provide us with energy.

During the last hundred years great strides have been made in the science of nutrition. Sometimes one is inclined to wonder how people in the 'olden days' managed to keep themselves alive without dietetics. At any rate they succeeded, and apparently quite well too. Only the names have changed. Previously one ate meat, fruit, vegetables and potatoes; nowadays one eats proteins, fats, carbohydrates and minerals—and, of course, vitamins. If one wants to follow this pattern even further, then the important thing is to get down sufficient 'building bricks,' because they are necessary for the rebuilding of the body. What is meant by building bricks is the products of the digested food. Only in the shape of amino acids, fatty acids, glycerine, glucose, and so on, can food be absorbed into our blood from the intestine and serve to rebuild our body.

One may ask: Why is all the fuss of digestion necessary when the aim is only the absorption of the said bricks? If they could be supplied directly we would be spared a lot of trouble.

Apart from the fact that this would mean the loss of much enjoyment (because feeding is related with enjoyment), it is well known that this is an erroneous thought. If our food consisted merely of such bricks, it would have no nutritional value, although the necessity to absorb those bricks cannot be denied. Every housewife is aware of this fact. She knows that food that is overcooked and therefore, as it were, half digested, loses some of its nutritional value. The loss of the so-called vitamins does not sufficiently explain this fact. Vitamins, after all, suffer the same fate as the rest of the food; they are broken down in digestion.

This observation leads finally to the conviction: the less food is 'prepared,' the higher its nutritional value. This has led many people to believe that undercooked food is the most nutritious. That is right up to a point, but it must be remembered that nourishment cannot be evaluated in theoretical terms only, and that much love was needed to achieve the present level of the art of cooking.

There is one conclusion that we can draw from all this: the digestion, that is to say the breaking down of our food, must take place inside our body. This leads to the surprising observation that the digestion (that is the 'destruction' of the food) mainly decides the nutritional value. It will not be easy, in contemporary dietetics, to understand this.

If, however, it is not the material result but the digestion itself that is the crux of the matter, then we must ask ourselves what digestion really is. Surely not only destruction. That would make it totally incomprehensible that this should necessarily take place within the body.

To find an answer to this question we will confine ourselves for the moment to vegetable foods and ask ourselves first: What does one eat when one partakes of a plant? Nowadays we say: a substance, matter. But one can equally say: *a shape.*

What is a shape? It is the result of an activity that has created it down to the smallest details. It is an organization, a structure that has emerged from a certain 'point of view.' For that reason, between the various parts of the shape, a connection exists that follows a strict law. Naturally we do not know the point of view that has been at work here. All we mean to say here is that at the basis of each form there is a unity that shows itself to us in its result. Here we must distinguish between the shape and the contour, which is merely the circumscription of the shape vis-a-vis the environment. In view of what follows it is very important to keep in mind the difference between shape and contour. What has all this got to do with the subject of digestion? The best way to discover this is to examine step by step what goes on during the various stages of feeding.

A little earlier we used another expression for eating, namely to *partake* of food. This phrase can make us aware of the fact that we can actually speak of feeding before there is any question of eating. When do we start partaking of something?

Let us imagine that somebody wants to eat a peach. He must first go and buy one. He goes to a greengrocer's. Let us say that he lives in a village, knows the owner of the shop, that there are several people waiting to be served and that there is, therefore, ample time to 'pick and choose.'

What is the first thing he must do? See if there are any peaches. That means that he must know what they look like to be able to recognize them. Let us suppose that there is a box of peaches in the shop. He goes towards it and takes the liberty of picking one up. What does he do then? Press very gently, move his fingers very carefully. Why does he do that? To examine the quality of the peach. He will also probably smell it, another way of judging the fruit. If it is too hard or has too little fragrance, he will put it back. If it is satisfactory, he will buy it.

Now he goes home and starts to eat it. What happens? He puts a piece of peach in his mouth and tastes it. This can only be done by moving the tongue and the rest of the mouth. One cannot taste without moving, in the case of solid food, not without chewing. That releases the flow of saliva (not to mention the fact that the mouth 'watered' already when he was smelling the peach); there the real digestion begins.

This is made possible by certain elements in the saliva called *enzymes,* which break down the food. Each part of our digestive tract has its own special enzymes that link themselves with the food. The marvel is that in this breaking-down process, which we call digestion, the enzymes themselves remain unchanged.

Something penetrates the food, causes a breaking-down and makes a closer judgment possible by means of tasting. If we try to conjure up a vivid picture of this occupation, tasting, and do not think in the first place of savoring, but rather of the question: What do I taste? (one often closes one's eyes when tasting attentively), then we can introduce new words for tasting—to probe, to investigate, to fathom, to indicate that here we are concerned with a closer acquaintance. Everything, therefore, is a continuation of what happened in the shop (movement—the light probing of the fruit with the fingers, whereby the fingers themselves do not change: smelling, evaluating, putting back or taking the fruit away).

In the mouth the sequence is: to take in, to move, to break down with the aid of enzymes that themselves undergo no change (one might call them biochemical fingers), to taste (i.e., to probe the specific form and structure—a peach tastes of peaches) and to evaluate. If one does not like it, one puts the peach back on the plate; if one finds it acceptable one continues to eat it. We have now passed the second stage of eating: our acquaintance with the fruit is now more intimate than it was in the shop.

What happens in the stomach? Again, movement is what we find first of all! The stomach does this even earlier, as though it is waiting for something to do. As soon as we think of food, as soon as we become hungry, even more so when we taste something in our mouth, our stomach becomes active. It begins already to secrete enzymes—we will not go further into the physiological details—and it is not difficult to think: Here is a continuation of the breaking-down process and a more intensive tasting. We often become aware of a tract of tasting in the stomach and this contributes to our sense of well-being. Enjoyment in the mouth, well-being in the stomach. If our stomach does not agree, it can rid itself of the food by vomiting. If the food is all right, it passes through the outlet of the stomach into the duodenum.

Again we get the process of *movement, digestion, evaluation.* If there is something wrong with the food this can cause a quicker elimination, diarrhea. Otherwise it will go into the small intestine, where the process is continued: movement, secretion of enzymes. Does yet another evaluation take place here? Would it be possible to continue the chain enjoyment–well-being? Can we really think that what happened in the mouth (and already began outside) continues inside during all further stages of the digestion? For that purpose we shall have to refresh and broaden our ideas of what happens in the alimentary canal, where all this takes place.

We observe the world around with our senses—sight, hearing, touch and so forth. These are located mainly on the outside of the body. This outside is called the skin. When asking if the human being also has an inside, we must think of the intestine, which can be compared with a tube that begins in the mouth and ends in the anus. In simple terms, the actual human body is between the intestine and the skin. In the intestine one is, therefore, not yet in the body itself. The French language expresses this very subtly. It speaks of a *milieu exterieur* (in the intestine), as opposed to a *milieu interieur* (between the wall of the intestine and the skin).

The intestine is an observing surface, just like the skin. That this is not usually mentioned is due to the fact that we refuse to accept a process of awareness in our body in which we do not actively and consciously participate. This is absolutely true: the 'self,' which in everyday life copes with the impressions of our senses, is excluded from the world of perception within. But we can say from the outset: thank goodness. If we tried to meddle in the incredibly wise activities of the inner person, it might have doubtful consequences. Our organs know better. When we speak here of our organs knowing, we mean a second person within us, who is dealing with everything that we mentioned in the beginning of this article about the rebuilding of our body.

If we consider the surface of the intestine to be an observing organ, then it is a short step towards the understanding that between mouth and stomach there is the transition between two worlds of observation. That which occurred outside our body (in the shop and then in the mouth) can be considered as continuing in the stomach and intestine and other digestive organs: a constantly more intimate knowledge of the secret of the 'shape' of our food, in this case the plant—which literally gets analyzed. In other words: one is dealing with a continuous and deepening acquaintance with the shape—first seeing, then tasting, and lastly digesting. The digestion is another form, a metamorphosis of tasting! This is a concise way of expressing it.

When we continue this reasoning in a logical way, starting from the viewpoint that the digestion is a continued, refined tasting and thus an ever more intimate acquaintance with the shape of the plant, the question arises: What interest does the body have in this continuously renewed acquaintance? We must not forget that this interest is at the same time related to the dietetic value of our food, as we have discovered in the beginning.

We must remember that the plant is not only matter, but at the same time that it represents a shape. The same could be said about the human body. We are dealing not only with matter that replaces loss of matter, but also with a shape (plant) that is being probed, analyzed by another shape (body).

We have given a certain definition of 'shape' and discussed the activity that brings it into being. An artist also creates shapes, forms, but this is a different kind of creation from that of the shapes in nature. The artist is himself a living being. As long as he is engaged in the creation of a work of art, his own life is indeed tied up with the form he is creating. When it is finished the form still carries the hallmark of that life, but it is no longer tied up with it. With the living shape, such as the plant and the body, this is different. 'Life' itself has created the form and remains linked with it until death. Then the form as such cannot be maintained any longer and disintegrates into the above-mentioned components of bricks.

We come again to the question: What significance is there for the living body in tasting plant-shapes, analyzing and probing them? To find the answer we must first reflect upon the quintessence of the shape of the plant. As we have already mentioned, this is not covered by the outline, which is only the limit of the plant as we see it. The shape is the result of a creative process that stops at a certain point that "congeals in an outline." Where do we find these forces, whence do they work? From within the *environment,* from the realm of earth, air, water, heat and light, all of which act directly upon the shape of the plant from without. To that extent, the plant is a completely open creature. In its original form it consists of stem and leaves, of lines and planes.

In the higher animals (and the human being, of course) we find exactly the opposite; they are constructed from the *inside,* from the intestine. Therefore animals have a content. Plants have no content, they have an 'out-tent,' i.e., their environment is part of their body, just as that which takes place in our intestine and lungs is part of us. In relation to the plant, the human being has directed his environment towards the inside.

Conversely one can say that what in the human being is inside is the environment for the plant, and as our skin is the boundary of that inside, so is the outline of the plant the boundary of the inside that surrounds the plant. That which acts from the air, the water, the soil and so forth, on the surface of the plant is therefore really part of the plant. We need to learn to view the plant in an entirely new way.

It's no use standing too close by; we must tackle it differently and study the plant in its environment from a distance. Normally we find that the plant is composed of roots, stems with leaves, and flowers (we use one of the 'higher' plants as an example).

To the question: How do we know that the plant has roots? the only answer is: We see them when we pull the plant out of the soil. Otherwise the plant is fastened to the earth, it is fused with the soil. From this point of view the whole earth belongs to the plant. It is preferable not to think of one plant on its own, but of the layer of plants inasmuch as it covers the earth. Thus the whole earth is the center in which the plants 'take root,' disappear. On the other side, where the flowers are, the plant also 'disappears' into an environment with which it is linked.

Where the flower appears, the plant stops growing. It is as if an entirely new influence comes into play here, curbing growth and making the plant produce flowers. Here a new world begins, in which the plant as flower begins to radiate with fragrance and color, in response to everything that comes its way from the environment, especially from the sun. In the flowering, plant and sun unite. Therefore the plant has in its flower the same link with the sun as the roots have with the earth.

Finally, even the middle part of the plant is not a closed, independent entity. The plant has a direct open link with that which the leaves absorb as light, air and water, and which causes the synthesis of the chlorophyll and the formation of *farina* (carbohydrates). One need only remember the stomata on the leaves where this direct contact with the environment takes place. Viewed in this way a plant in its totality is much bigger than one would suspect.

If we let our thoughts roam once more over the realm of plants, if we conjure up this realm from a great distance in our imagination, we find that the roots—round, calm and cool—are concentrated in the center, and that the part that is radiant, changeable and warm is on the periphery, while in the green middle area of the plant we find a structure in which the rhythmic repetition of a specific shape, the leaf, can be recognized.

Presently we will encounter something similar in the shape of the human being and it is important to state right now that we are dealing here with a primeval law: Wherever a rest-seeking tendency interacts with a tendency towards movement, there appears a rhythmic principle (trembling strings of a violin, leaves rustling in the wind, ripples in the sand).

In the middle part of the plant, in the area of the leaves, the atmosphere is the environment. It is no poetic fantasy, but a concrete fact, that the plant thus represents the link between two worlds—earth and sky. The ever-changing relationship of these worlds in summer and winter is directly reflected in the realm of the plants, because the plant is a seasonal creature. In this way the plant can be rightly described as a threefold organism: root, stem/leaf and flower are the visible writing in which we can read this.

In the human figure we can speak of the same phenomenon. The head is rounded, the elements of rest and coolness belong to the life of head and thought. In the lower part of the body, the area of limbs and metabolism, we find a radiating form, movement and warmth. It is not for nothing that somebody with a headache asks for a cold compress, and somebody with a stomachache asks for a hot water bottle. Between the two is the rhythmic system, where the principle of rhythm, of repetition, can be found in the functions of lungs and heart and in the structure of the spine and ribs. Much more can be said about this threefoldness (nowadays the term is triple articulation). The main thing for us is to look primarily for the similarity between the structure of the plant and the figure of the human being.

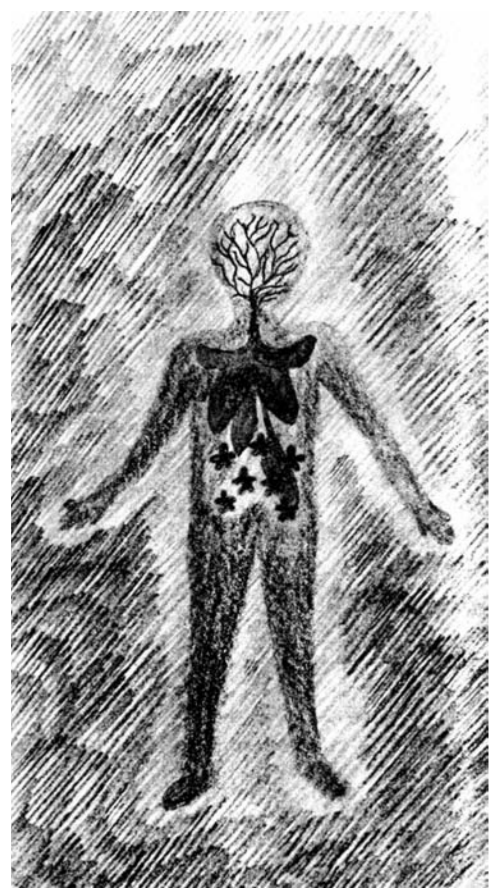


Fig. 12

From the broad description above we have seen that the shape of the plant and the human figure are the reverse of each other in their threefold structure: what the plant has below, the human being has above, and vice versa. When we take this comparison between the structure of the plants as a whole and the structure of the human form into consideration, we can also understand that it is not for nothing that it was known long before modern dietetics existed, that radicals (root vegetables including the potato) influence especially the head and its functions, leafy vegetables act on the middle part, while the connection between fruit and metabolism has been tested by long experience.

Something still remains to be said about the way in which our body can maintain itself with the aid of nourishment as described above. We have seen that there exists an affinity of shape between plant and the human being. (For the origin of this phenomenon we must refer to other literature on the subject, particularly Rudolf Steiner's *An Outline of Occult Science.*) In other words: What is the significance of our body being confronted regularly with plant shapes? A simple comparison will suffice to make clear whence comes the solution.

Let us suppose that I ask someone who knows nothing about the mechanics of clocks and watches to take a watch to pieces. The result may well be the end of the watch. But something else has happened. The person in question is enriched by the knowledge of the way the watch is constructed. This, as we have said, is but a comparison of what takes place inside the body, but now we can continue that train of thought as follows.

Not only do we have a physical life that contains the secret of our shape and maintains it (which we usually call 'to live'), but in addition we have a spiritual life, a life of the mind. It is not easy—nor is it appropriate at this point—to go further into the mystery of: What is life? a question that can lead to the deepest secrets of existence. All that can be said here is that life is life, in whatever form. Thus it is acceptable to think that we live somehow with our spiritual and intellectual life, or that we derive our vitality from our body. Our everyday experience tells us this anyhow.

What significance does the realm of plants have for us? To start with we can distinguish three kinds of plants: plants that feed us, plants that cure us, and plants to look at. It is no exaggeration to say that we cannot live unless we have all three. The 'beautiful plants' are as important as the others. It is moreover charming to think that every important event in our lives, every celebration—birth, engagements, weddings, anniversaries, jubilees and finally illness and death—is always accompanied by flowers.

But the role of the realm of plants is much wider. Our heating comes from the sun, from wood, coal, natural gas and oil—all ultimately derived from plants. One could call plants our sun-world on earth. Our respiration is made possible by the breathing in of oxygen, exhaled by plants.

If we have an inkling of geology we know that the soil would be swept away by rain and wind were it not for the roots of plants that provide it with the necessary support. Sand dunes, for instance, are held together only by the lyme grass that grows on them. Rivers and arable land are unthinkable without the plants that cover the earth. How often is a desert the result of deforestation?

It is therefore no fake mysticism to say that we owe our heat, air, water and earth to the plants. In other words, without the plants life would be impossible. The mineral world gives us our solid ground, our tools and our visible bodies; the plants give us life. As soon as we start eating the plant, however, the word 'life' acquires a special significance. By probing the plant, by tasting it, our body acquires the possibility to build up substances that correspond with the human form. The following brief explanation can clarify how we can pursue this train of thought in yet entirely different directions, whereby the connection between plant form and human form becomes ever clearer.

When the substances of our food have passed the intestinal wall, they arrive in the blood that, from the intestines, flows together into one great blood vessel, the portal vein. All the blood from the intestines flows through this vein to the liver. What happens in the liver can, up to a point, be followed and analyzed biochemically. The various functions of the liver, such as construction fission, accumulation, secretion and detoxification, to name but a few, form an important chapter in our physiology. The result is that from these building materials human substance is again constructed. In short, the organic substances of our body are proteins, carbohydrates and fats. The plant also consists of proteins (albeit vegetable proteins), carbohydrates and fats (especially oil). The question arises: If these substances are produced in the human body by the liver, what produces them in the plant, since it has no liver? True, the plant has no liver, but neither has it an inside, or contents in which there are working centers, as our organs might also be called. Instead of a content it has what we have called an 'out-tent,' to indicate how diagonally opposed the shapes of plant and the human being are, despite their profound affinity. What is *content* for us is *environment* for the plant. As already mentioned, this embraces the earth, the atmosphere and the cosmos.

The plant is an open being. We must seek the origin of the wisdom from which the plant has been built in the periphery, far away, just as in our liver we have the organ in which that wisdom manifests itself in a way we cannot comprehend. In contrast, the liver of the plant is to be found far outside it. Is it possible to follow this idea further? Not in the framework of exact science. But it is through these exact facts that the creative force, the in-act, ultimately manifests itself.

One is justified in saying that it will never be possible to explain the actions that take place in an organ like the liver with the aid of the characteristics of the substance; these actions, and the facts that result from them, lie on entirely different levels of consciousness. To these facts belong the shape of the plant and the structure of the substances of which it is composed. If we think that the origin of the viewpoint from which the shape of the plant as well as its biochemical structure have originated are to be sought somewhere 'far away,' our modern research methods lead us to an as yet unabridged gap.

If we then look back to bygone days, when the human being was still familiar with a world that our present-day consciousness cannot enter any more, and which was called "the world of the gods," we encounter something which points partly in the direction of an answer. In those days one spoke of the world of the gods as the creative world, but one distinguished various elements in this creative process, and attributed names to them. These names are closely connected with the present-day names of the planets.

The influence of the planets as we imagine it today has nothing in common with its counterpart of the past. Then planets were spheres of influence that acted directly upon the living nature of the plants out of the periphery of the earth. The planets as we see them now are but representative manifestations thereof. In those days there was never any question of material activity. One recognized various influences that play a part in the creation of the shape, a structure: the impulses of wisdom, movement, shaping forces, curbing influences, and so forth. One distinguished different influences and impulses and these were attributed to special beings, many of whose names still live in legends. Thus the beings that were felt to be the source of the wisdom that one recognized in everything were collectively called Jupiter, and because wisdom is an integral part of creation, Zeus/Jupiter was at the same time considered the most important of the gods. Hence the liver was the Jupiter-organ, because the consciousness of those times saw wisdom in the function of the liver. The other organs (centers of various activities) were also called after beings. Spleen and gall bladder (as a liquid organ) were seen as connected respectively with Saturn and Mars.

What does this mean? That the forces from which the plant is constructed and that must be looked for in the periphery are, in the human being, active in the organs. The plant is open towards earth, cosmos and environment; the human being carries his cosmos within himself; he has become independent vis-a-vis the earth; he has his own 'atmosphere,' i.e., his inner self, his spiritual life.

We have indicated here in a few words the direction that could alter our notion of the world and could lead us from the threat of stagnation, and therefore of the death of our knowledge, to a new development and therefore to a new life. In this way we can gradually develop new ideas about the human being and his environment that appeal to a completely different element in us. Contemporary thought addresses our intellect, our head. What has been said here may awaken 'something' that in the course of history has been drowned by the need of people to restrict their knowledge more and more to the exact. This 'something' resides in the heart, not in the head. There is a knowledge of the head and equally *a knowledge of the heart.*

Thus it can become understandable that our body has to be reminded constantly of its origin, so to speak. It would seem that the source of life through its metamorphosis in ever-changing fields undergoes something that we might call forgetting. Eating *refreshes.* (Do we not speak of refreshing one's memory?) If we say finally that the shape of the body, like all other shapes in nature, has been created from the Word, the various ideas we have developed become links in a chain. The saying: "In the beginning was the Word" begins to acquire a new meaning. This also sheds a different light on our food. Everything that has been said about food-plants and their cultivation, about tasting, digesting, the maintenance of our shape, even the use of expressions like forgetting, remembering, refreshing and of the source of life, begins to coalesce.

What is the advantage of contemplating the problem of our food in this way? Is our usual way of thinking not satisfactory? Do our dietetics need to be reviewed? I believe so. But first we must discuss the reason why. We live in a time of immeasurable technologic progress. This has been developed mainly in the West, in America. This technologic progress cannot be separated from an unbridled aspiring after material prosperity. We may watch the technologic achievements with the greatest admiration, but one consequence cannot be avoided, and it is expressed in the American slogan: "Prosperity breeds waste."

We know this to be all too true and have to accept it. But in one field this wasting throws a very dark shadow, and that is in the field of food and food production. Here we are concerned not only with the fact that things are wasted, but even more so with the indifference with which this is done. Anyone who has witnessed the callous way, devoid of the slightest feeling of remorse, with which food can be thrown into dustbins, finds it difficult to suppress a feeling of sadness, almost of shame. There is no trace of respect, let alone love, for our food. This can also be seen, on occasions, in the way that people behave at table.

Years ago I encountered this problem unexpectedly in my practice. A patient, a fishmonger, who cycled every day through the town selling his wares, came to me with a stomach complaint. A routine examination showed negative results. There was no ulcer, nothing. I considered how a man like that, who hardly allowed himself time for eating, would wolf down his food in order to continue his rounds. I pondered the proper way to approach a meal. One should not only look at what is on the table, but spare a thought for the way it has grown, the way it has been tended, transported and prepared. As a rule we ignore all the work that has gone into the provision of the meal. How much attention do we pay to our food, do we respect it, feel gratitude? When one stops to think what food really is, how much we owe to it, then the words attention, respect, gratitude, are not too big. Modern dietetics see food only as building bricks and fuel. Thoughts like the ones put down here are unlikely to be considered.

I debated with myself whether I should talk to my patient in this vein, and point out that we have a very selfish approach to our food, that we want to enjoy it, that we attack a meal. At the same time I hesitated, fearing that he would scoff at such notions. A matter-of-fact fellow, with two feet firmly on the ground, has no time for such sentimental thoughts. However, he came from a long line of fishermen, whose upbringing was very religious. So I said my piece and when I had finished, he said: "That is a beautiful thought, doctor. I liked listening to it, and I won't forget it."

There is another side to this approach. I said just now that we behave towards our food in a selfish manner. We want to take advantage of it, eat with pleasure, eat a lot. We ask what food means to us. We do not ask what the eating of food does to the plant.

I fully realize that people who hear this will only shrug. I do not want to go into this any further, but only ask: Is it not true that in the case of some people this notion appeals to something in them that has lain dormant up to now? Could this not be an inducement to start thinking in 'alternatives'?

In anthroposophy this thought is linked to the responsibility the human being has vis-a-vis evolution, not only of the realm of the plants, but also of the animals and minerals. The moral element that the human being develops in his actions, thoughts and feelings, is for the creatures of these realms, to a certain extent, as much a 'nourishment' as the plants are for us.

When the words attention, respect, love even, and gratitude, are more than hollow phrases, it becomes understandable how much one can value the saying of grace before a meal. In the olden days there was a custom, which is fortunately still fairly widely practiced, to say a prayer at table. When we talk about saying grace, we mean something that can replace the old form of prayer for those who have lost the traditional religious attitude towards life. Although we can fully appreciate that attitude, we think that to aim at a 'return to religion' is sterile. The point of the essay is to point the way to a new relationship with the spiritual world. But there is more to the saying of grace. If we say, for instance:

Earth that brings to us this food;
Sun, who made it ripe and good:
Dear earth, dear sun, by you we live;
To you our loving thanks we give.

it influences not only us, but also the plants. But of equal importance is the influence on the children who share the meal with us. The reverence "for the minute," that is exemplified here by the adults (educators) plays an important part in their upbringing. Precisely because an example is set in earliest youth, when a child still copies, the grace said at table has such great value. The fact that one waits a moment, restrains oneself, does not immediately 'grab,' influences our whole life in the long run.

I am often asked: In the present day one has to cope with problems like pressure cookers, mixers, deep freeze [and microwaves]. Are these good methods, do they make sense?

It has been proved by experience that people who treat their food in this way find their taste changing. A doctor friend of mine once said, "People always ask: How does it *taste*? They ought to ask: *How* does it taste?" By changing our attitude to food and nourishment, our taste changes, our judgment of food improves. Thus the difference in smell and taste in vegetables that have been treated with chemical fertilizers and those grown by the biological-dynamic method, becomes clearer all the time. This makes it possible to answer the questions we just put: If it smells good and it tastes good, there is no problem. But taste and smell must be cultivated, and this can be done by adopting the manner of eating we have described. People who already possessed a delicate sense of smell and taste felt clearly that 'violent methods'—chemical fertilizers, mixers, deep freeze and pressure cookers all act with 'violence'—have an adverse influence on taste. After such treatment the plant is no longer its original self. In other words: the plant no longer speaks its own language. There will gradually be other consequences of cultivating a sense of taste. People will stop smoking and drinking alcohol and eventually lose interest in meat. All this has been tested by the experience of many people. To my mind this is a healthier way of giving up habits than the 'thou shalt not' method applied by circles that are anti-something. It is, of course, undeniable that in some cases an urgent warning or piece of advice can be important. But on the whole it is more fruitful to obtain results by *educating the taste.*

It is to be expected that somebody will say that a large part of the world population still eats meat. You have only discussed plants as nourishment. What about meat, independent from possible abstinence based on ideals? The answer begins with a counter question. What is meat, where does it originate in the human being and animals? In the last resort meat also originates in the realm of the plants. Even the carnivore is, in the last resort, a herbivore. Meat can be characterized as a food with plant substances that have already been predigested. That is why meat is so quickly done and so easy to digest.

That does not mean that meat is good for us. Easy digestibility can be important, but for many constitutions it may be better to demand something of the body to spur it to greater activity. Yet, for thousands of years we have been omnivores and it would be unwise suddenly to want to put a stop to that for reasons of principle. Nourishment as described here will by itself lead to a different attitude to meat. The same goes for smoking and drinking.

To close, the following anecdote can show that there are still snakes in the grass. It happens occasionally that I go into health food shops. Forgive my plain-spokenness when I say that there I often meet people who, on the one hand, are convinced that God has predefined the length of their life, but who hope to sneak in a little extra time by 'healthy' nourishment. I sometimes say out loud: "Dear people, you must not chew your food." This usually causes a flutter. One hears whispers: "What's the matter with him? Has he turned against us?" I then continue: "You must taste!" To taste one must chew, of course, but the *aim* has been shifted. The one who chews thoroughly wants to profit as much as possible from his food. The one who tastes pays attention to the plant to which he owes his life.

Nutrition in Class 7
by DOROTHY SALTER

In the school year 1986–1987 my daughter was in Class 7 at the Holywood Rudolf Steiner School, and as a culmination of their Nutrition and Hygiene main lesson it was decided to prepare and serve a special meal for the parents. Helen Cremin, the class teacher, was fortunate in being able to enlist the help of Bartjan Brave, a friend of the school who had recently opened a French restaurant locally. He came to the school each morning for the last week of the main lesson and instructed the students in the art of food preparation and serving etiquette. The class learned such things as how to chop onions correctly (for this most members of the class came equipped with swimming goggles!) and how to remove the dirty plates from the table in the correct manner.

The school 'kitchen' fairly buzzed with activity. This was stoically borne by the rest of the staff as the kitchen is in fact the staff room and has extremely limited facilities for catering, viz. an ancient Aga, two sinks and a large table! However, undaunted by the lack of equipment, the preparations for the meal went on and the following menu was decided upon:

Starter: *Crepes stuffed with Spinach and tied with Leeks*
Main Course: *Millet with Vegetable Sauce*
Dessert: *Apple Pie with Ice Cream*
Drink: *Cranberry Juice with Water*

Class 1, whose room lies next to the kitchen, was persuaded to lend their room to Class 7 for the evening so that it could be converted to a restaurant. The invitations were sent out and accepted and the great day dawned.

The class spent the whole day chopping, cooking, moving desks and chairs out of Class 1 and tables and larger chairs in. The students were divided into three groups for the evening: one group would serve the food in the kitchen, another wash up in the pantry, and the third would wait on tables in the restaurant. This latter group had to wear black and white outfits. Since the class had to be at the school right through to the evening, sufficient food was prepared to provide them with a meal earlier in the evening; however, most declined and tucked into Pot Noodles from the corner shop nearby. (How healthy, hygienic or nutritious this was may be left to the imagination for the moment!)

The parents duly arrived and were led to the tables in the now transformed classroom. A humorous mood prevailed, especially when the menu was read (where was the meat and two veggies? The crack, as we say in Ireland, was great. (*Crack* means to have a good time!) Food began to arrive and, to the relief of many, was not all that bad. Efficient service removed the remains of the first course and the millet arrived. “Where is my perch?” quipped one parent to the waiter. “If I’m eating bird seed I ought to be suitably seated.” It was all taken in good part. However, there was a noticeable sigh of relief when the apple pie arrived. This was greeted like a long-lost friend, and several parents were seen eating with real enthusiasm for the first time that evening.

Thinking that was the end of the food, we all sat back but—surprise, surprise—in walked Bartjan with an extremely large cake—it was, that evening, the birthday of two of the parents present. So we all sang “Happy Birthday” twice and tucked into the cake.

It was a wonderful evening and warm thanks were given to the chef, the class and to Helen Cremin. The evening ended in a manner typical of events at the Holywood School—“Would some parents like to ‘volunteer’ to stay behind and move the tables and chairs out and desks back in?” The perfect end to the evening! The students went home exhausted but happy, especially as Helen had told them that they could have a half day the next day.

Since then it has become something of a tradition at the school that each Class 7 of parents is treated to a meal prepared and served for them by their children,

Class 7 Nutrition
by GORDON PURDY

The Clashing Rocks was an early hazard for Jason and the Argonauts on their journey, and in presenting aspects of Physiology to Class 7 it is all too easy, even for the teacher whose own education has not itself already been formed in the materialistic tradition, to be trapped in matter. The ‘particular thing’ can halt the proper description of the living process of which it is only a part, and the movement of the spirit somehow quickly crystallizes in mechanical technique. Main lesson books are at risk of becoming records of frozen events, and, for once, beautiful illustration serves less the desired mood than the glorification of intellectual knowledge.

For this reason I am hesitant to isolate one element from this four-week block, in which mood and movement must be so important. At most it should be only the pause of a heart beat in the exciting journey from the four elements through the life of the plant, through the human digestive and circulatory systems to their outcome as acts of the human will. For good reason the skeleton and the functions of the ear and eye are kept back that little longer to Class 8.

The working of the mouth should be considered as a whole, from the point where we take in food and begin its destruction to the moment when we lose consciousness of what is happening in this process. Teeth, tongue and saliva should be considered in movement together, chopping and dissolving and reducing the outer forms to a substance which our internal muscles can deal with; we can contrast the work of these solid and liquid tools and of the amazing mobile muscle which combines the nature of both. When discussion does focus on the teeth alone, the teacher can move from the recognition of the three different types of teeth we each possess to recall that lack of specialization, dealt with in Class 4, which distinguishes the Human Being from Animal.

As in so many areas these days, the teacher soon finds that the students are well-equipped with terminology they do not really understand, and which can work against the understanding we are trying to foster. Most will have sat in a dentist's chair, surrounded by illustrations deliberately designed to attract and distract, and almost as many will have had the working of natural processes halted or 'improved' by a combination of alien minerals and sophisticated technology. It is not surprising if they have come to regard the teeth we have produced ourselves as a rather unsatisfactory step towards something more efficient and less open to trouble, and are ready to offer themselves sooner to the impatience of the technicians than to the contemplation of the 'Sages.' A third of my class have suffered for some time now the real discomfort of orthodontic braces (I have at times wondered whether braces inserted for aesthetic effect are really worth the severe impediment to speech activity in these years), and in discussion it turned out that few had any appreciation of the need for it. In these circumstances it is a real challenge to a teacher to bring the students back to value their teeth as one of the jewels in, to use Traherne's phrase, this "Treasury of Wonders."

One of the aims of this main lesson must be to bring the students to undertake a conscious care for the bodily processes, which to this point in their lives has on the whole been managed on their behalf. Here, teeth can be an illustration most of them can easily appreciate. Students can be made aware of unconscious will at work, of the effects of so much activity and of neglect, and be led from a recognition of illness and its prevention in one area to the need for care in less easily observed processes. Teeth have for the teacher one very useful aspect; loss of the first teeth is still within easy reach of memory, and this loss is perhaps the most striking and easily perceivable example of the body's working at the constant replacement of itself. Much of my class's work at this point consisted of discussion, as they brought to consciousness their experience of tooth growth, repair or adjustment. This discussion produced one of the most awakening moments of the main lesson. When I asked the students what they remembered of the loss of the first milk tooth, one very solid lad blurted out, with a nervous laugh, "I was terrified!" As an instance of both the persistence of physical matter and the impermanence of our hold on it, they could hardly have lighted on a better.

A Religious Background for the Teaching of Chemistry

by EILEEN HUTCHINS

Many educationalists today realize that present methods do not meet the human needs of numbers of young people. There are countless books and articles on the subject. We need only think of such works as E.R. Braithwaite's *To Sir, with Love,* Margareta Berger-Hamerschlag's *Journey into a Fog* and Philip Toynbee's *Friends Apart*—all of which are written with sympathy and human appreciation—to become aware that the failure is not only in the secondary schools and youth clubs, in the public schools and universities, but in the very heart of our Western civilization.

In the Middle Ages from very early childhood a boy would gradually learn to take his share of the work done by his father. He would develop step by step until he acquired judgment and skill and could take pride in his craft, whether he worked in stone, metal or wood, or with plant, animal or human being. Book learning was not necessary; he learned through imitation and experience. At the same time he would share in the religious life of the community into which he was born and his daily work was strengthened by this bond. Every craft had its mysteries which were known to those who had mastered not only its techniques but its meaning and relationship to life.

For the few who became scholars, learning was regarded as the path to wisdom. The one who studied sought answers to the most profound problems of existence: of the human being's relationship to the spirit, of sin and atonement, of free will and destiny. There was no question of learning in order to gain power.

Today the situation is entirely different. Most crafts are no longer needed, for machines have taken their place; and learning has generally very little to do with the deepest questions of life. For nearly every branch of knowledge, handbooks can be found which make the chief themes easily accessible to the layman. A few chapters can give in outline what once took years to acquire; but this information has not the weight of a life's experience. On the one hand almost all our commodities are provided with no effort on our part; and on the other a great deal of what we are expected to know is a quick resumé of the hard-won attainments of others. It is not surprising that now, when education is compulsory, many students have no incentive to learn.

The men and women of the Middle Ages lived within the limits of their class distinctions; but they felt themselves as part of a divine world order—a world order, it is true, in which there was much that was tragic and inexplicable, but darkness and evil were part of a pattern of an existence which had its origin in God. Today young people are offered boundless opportunities, unhindered by their social status, but very few have confidence in the beneficent guiding powers of the human being's life. They need to rediscover the assurance that was once a common heritage.

Religion in its truest sense means a reuniting. It is a rediscovery of the spiritual in life and nature. Young children in a dreaming way are still aware of their origin, but all too soon they lose this feeling under the influence of their surroundings.

It is here that the educator can play his part, not by teaching religious dogmas or giving moral homilies, but by awakening in his students wonder and reverence for the beauty of the world. We can learn something from the thinkers of the Middle Ages. Although knowledge of what we call the sciences was then very limited, there was felt to be a relationship between the different realms of nature. The human being was the microcosm in whom were active the same powers that had created and inspired the surrounding universe. And the student knew that cleverness alone could not solve the problems of existence; only to the one who approached with humility and devotion would the secrets of the world be revealed.

Today when we teach about substances or processes, we tend to isolate our material from the world context. In the chemistry laboratory students learn the properties of many elements which have been abstracted from their compounds and which are never met in this isolation in the surrounding world. The tendency is to continue this abstraction into the realm of molecules and atoms, but rarely to show the relationship with processes in nature or in the human being himself. Yet it is the human being who stands as the observer and controller of this vast realm of hypothesis.

The first introduction to chemistry, when students are about twelve years old, could take place in the following way. The teacher could introduce the subject by speaking of processes which are to be observed in the world around. He could ask where fires are to be found—not fires that have been kindled by the human being, but fires that belong to the realm of nature.

The students will think of the sun and the stars, of the lightning and the meteor; and they will realize that these do not belong to the earth at all but to the far spaces. The only fire they will find on earth is the volcano—although they may also think of the hidden fires that live in flint and metal and flash forth when they are struck together. The conversation should then be led to the human being, and the students will find that the human being too has his fire, the warmth that lives in his blood; and it will seem a great miracle to them that he can pass through the coldest arctic nights and the hottest tropical noons, and yet his temperature will be unaffected by the extremes of the climate; for the human being controls his own inner warmth.

The teacher could then speak of the light. This too is sent from the far spaces. On earth there are only the inconstant lights, such as the wandering will-o'-the-wisps and the phosphorescent glow on fish or decaying wood. But the human being has his own radiance, the light that shines from his eyes.

The wind, on the other hand, belongs to the earth and envelopes it. We live in the continuous receiving and giving away of the air. How false a notion it is if the human being begins to imagine that he is independent of the earth. We could not live for a moment without the all-enfolding air.

The water passes through a perpetual cycle. It falls in dew and rain, it flows in streams and rivers to the sea and is drawn up once more into the vault of heaven. The students could be led to compare the stream of the blood which flows back through the veins to the heart with the earthly rivers which become sullied and tainted on their course to the sea. But just as the water is purified by its re-ascent into the heavens, so our blood is purified in the lungs and can flow forth again bright and fresh as the bearer of life.

Lastly the conversation could be led to the theme of the skeleton and how it is similar in substance to the limestone rocks. Just as the earth needs the foundation of solid rock, so that life can be sustained, we need the firm support of our bony system. The teacher could describe the beautiful cascades of limestone stalactites formed under the influence of water, and he could show how the molding of the bones in our legs and arms also gives the impression that they have been shaped by a moving stream. As we grow, the perpetual flow of life, passing around the sediment of the bones, gives them their beautiful design.

While the various processes are being described, the teacher could also draw a comparison between the form of the human being, as it has been described, and the dignity of his position in life. The human being can show warmth and enthusiasm for his ideals; he can be enlightened in his understanding; the alternation between his in-breathing and out-breathing can be reflected in his receiving and giving away the gifts of the earth; and just as the stream of his blood becomes tainted with death and decay, so his character during the course of his life becomes stained with faults and imperfections; and he too can become purified when he learns to overcome his weaknesses and to reunite himself with the good and the beautiful.

These thoughts should be given only as thoughts or comparisons; for moralizing can arouse opposition. Also there needs to be a skilful interweaving of the students' response and the teacher's own artistic description. The asking of questions is a great art, and students can easily be driven into silence. Finally the content of these opening discussions could be summed up in the verse, *The Being of Man*:

O man, thou bearest within thee the hidden fire;
Bear it also in feeling and thought and will;
Thou livest within the life-endowing air;
There flow through thy veins the surging streams of the blood;
Thou bearest also within thee the cold, hard rock.
Thou movest through life a pillar of fire and air,
A living stream and a steadfast column of stone.

After the opening conversation, the first lesson should become practical. The students could be led to observe a process of burning, perhaps for instance, a branch of yew could be set afire and they could write their impressions of what they see, hear, smell and feel. They will notice the color of the flame and the flickering movement as it leaps from twig to twig. They will see the red afterglow of the charred evergreen and follow the movement of the heavy smoke. They will hear the pleasant crackling sound and smell the resinous scent. Finally, they will see the delicate grey ash drift to the ground. As a conclusion to the opening conversation the students will feel that the light and warmth have disappeared into the far spaces where they belong; and the frail mineral shell has fallen back to earth.

Observing should not merely be making a list of different events. The students' enthusiasm needs to be stirred so that they live with the whole process. Therefore this first experiment should take place with something which is a little unusual or unexpected. In the case of the yew bough, they are led to think of the Advent wreaths and Christmas decorations, and a train of thought is set in motion. One might, however, equally well, burn a piece of dried seaweed or a spray of mountain ash with berries.

Afterwards a comparison could be made between what happens in the heat of the flame and what happens in the warmth of the summer. On a warm August day when the air is heavy with the resin from the pines, when the grass is brittle and dry and the bees are busy collecting pollen and nectar from the hot-scented flowers, we can hear the popping of the dried broom pods. And here again is a twofold process. There is a raying forth of color, pollen and scent that disappear into the atmosphere, and there is a concentrating of the life of the plant in the minute dried seed. The blossoms with their bright hues are like the flames, and the seed like the ash that falls back to the earth. Frances Thompson described a poppy:

Like a yawn of fire from the grass it came,
And the fanning wind puffed it to flapping flame.

The students could then be asked to bring all the substances they can find that will burn. The classroom will soon be filled with a collection of straw and feathers, of oil and fat, and many other pleasant and unpleasant combustibles. These manifold substances will tend to fall into groups. The animal products generally give off a heavy oily smoke and have an unpleasant smell; but plants are almost always aromatic and burn with a beautiful flame. Very few minerals will burn—though of course there is sulphur with its special connection with the volcano. Plant and animal substances which lived in the warmth of the sun and have been transformed through its power are able, when ignited, to give back what they have received; but the stones, which have done nothing but gradually crumble away under the pressure of the heat, have nothing to return. Coal, though it has been so long underground, still hoards what it acquired while it lived in the great primeval forests. It is thought today that the mineral oils, which are so much used for lighting and heating, are the fat residue of great prehistoric creatures. Their potential warmth has been stored in the earth for countless ages and survived.

At this stage it is better not to deal with the subject of the oxidizing of metals. Students find it difficult at first to recognize this as a combustion process, and there is ample time later for them to learn of the character and behavior of oxygen. In the act of burning, however we view it, there is a release from the bonds of solid matter. In crystallizing we see an opposite process. The invisible becomes visible. If possible the students should be given the solution without knowing what is to emerge. Then they can watch how perhaps the liquid trembles and then suddenly needle-like forms shoot across the evaporating dish: or, as with carbon disulphide in which sulphur crystals have been dissolved, the liquid evaporated, and beautifully formed octahedral crystals appear.

One of the difficulties of teaching today is that students are already blasé. They have seen experiments on the television, or they have heard science talks on the radio and imagine that they know everything. The teacher needs to have a few surprises. For instance, after the first experiments the students could be allowed to prepare their own solution, and before crystallization each could add a few drops of some different plant juice, rose or lime, sage or rosemary, lemon or apple. Some interesting results are thus obtained with copper chloride crystallized on watch glasses. The crystals tended to appear in moss-like or star formations. The students could then be stimulated to notice how frost patterns upon windows and cold frames form differently over plants and flowers than over the bare sill or the naked earth.

Another theme that can be taken up by the students entering the Upper School is the contrast of acid and alkali. This could be linked with their lessons on combustion, for the ash of the substances they have burned when moistened, will give an alkaline reaction. Hence the Arabs gave the name 'alkali' meaning 'ash.' Examples should be taken first of all from daily life. The students will already know the acids of vinegar, of unripe fruit and of sour milk, and the alkalis of washing soda, sodium bicarbonate and ammonia. They will recognize the stinging fiery taste of acid which colors litmus red, and the dull soapy quality, both on the tongue and to the hands, of the alkali. An amusing experiment is to boil fragments of colored cloth, silk, cotton and wool in water saturated with washing soda. The students will then realize how water impregnated with an alkali will rot the cloth and dull the color.

Once they are familiar with the more general qualities, there is no reason why students should not see a few more spectacular experiments to strengthen their impressions; for instance, sulphuric acid burning sugar to carbon, hydrochloric acid apparently cooking raw egg and meat and destroying marble, nitric acid dissolving copper. They can also be shown the highly destructive effects of caustic soda and caustic potash.

Then there can come as a last surprise the miraculous result when two powerful extremes meet: when the fiery hydrochloric acid and the caustic soda, that rots whatever it touches, come together. The new substance that is formed is common salt. Then it is possible to awaken a new understanding for the saying: "Ye are the salt of the earth." Human beings can also go to extremes. There are the mad, fiery cholerics who sweep all before them and do not care whom they destroy. There are the negative, fearful doubters before whom all hopes fade and enterprises pale. But the personality who can bring the two extremes into harmony can become a wise leader. Without salt all food is tasteless; without wisdom no true values can be established.

Naturally during their school course, students will need to learn much of the acquired information of modern scientists and perform many well-known experiments. As they grow older it becomes increasingly possible for them to analyze and separate phenomena without losing the experience that the world around and the life of the human being have sense and meaning. We can, however, still present many themes from a wider aspect. In the Upper School, students will be impressed by the wonderful achievements of modern laboratories in the making of such substances as nylon, plastic and fiberglass, to give only a very few examples. But at this stage they can be shown how the human being first learned to create these substances by watching nature at work. In the plant world many of these transformations take place which the human being has copied and turned to his own use. Marcus Aurelius wrote:

O Nature, from thee are all things,
In thee are all things,
To thee all things return.

Students can be shown how the growing plant is perpetually creating substance out of the atmosphere. Only a very minute part of its structure is taken from the earth. In the light of the sun the green chlorophyll, which is like a reverse picture of our own blood, is formed in the leaves; and through its aid, the plant is able to build up starch from the carbon dioxide of the air. We can show how this substance tends to accumulate in the leaves, stem and root; but how, when the light is withdrawn, a change takes place. The starch then is transformed into a soluble sugar and is borne up through the plant to give nectar to the blossom and sweetness to the fruit. Although chemically starch is the same whether it is found in the root of the potato, the trunk of the sago palm or the ear of corn, students naturally feel that there is a difference between the starch which has been hoarded underground and that which has been ripened by the summer sun.

If we compare the grain-bearing grasses with those plants which complete their cycle of root, leaf, blossom and fruit like most of the dicotyledons, we see that the grains have withdrawn from their full development. They have renounced the true attributes of blossom and fruit, color, scent and sweetness, and the attraction of the insect world. Their flowers are minute and green, pollinated by the wind, and they have carried their root substance in to the ear so that instead of the sweet fruit we have the sun-ripened grain. Thus our daily bread is made from the most light-filled starch.

Now we can contrast with the wheat, the fruit which has attained the purest sugar. The grape has outgrown the coarser substances of the rind and stone, of the shell and the heavier texture of the pulp, so that it is almost entirely juice. Most fruits contain fruit sugar which requires a certain degree of digestion, but the grape has the highest content of glucose, the sugar which can be absorbed straight into the blood without further transformation. The grape with its long ripening in the southern sun has acquired qualities of fire and light.

So that our bread may rise, we add the minute cells of yeast which, acting upon the heated starch, form alcohol and carbon dioxide. But no special preparation is needed for grape juice to become wine. The yeast cells are already present in the surroundings and fulfill their task without the aid of the human being.

The nature of alcohol is unique. It can be considered as a further transformation of sugar. A very much-appreciated experiment is to leave a little yeast in a bottle of sugar water and collect the gas that is given off. The gas is found to be carbon dioxide; and after a few days the sugar water tastes of alcohol. Pure alcohol burns with a wonderfully delicate flame and leaves no residue. If left to stand it readily evaporates. Those who drink it can experience a pleasurable sensation of warmth, and life takes on a brighter hue.

Now, perhaps, when we think of the grape and the wheat, of the wine that bears warmth and light and the starch ripened by the summer sun, we can sense a deeper meaning in the symbols of the wine and the bread in the sacrament of the Last Supper.

It is arbitrary for a division to be made between organic and inorganic chemistry. Before students learn how to prepare oxygen and hydrogen in the laboratory, they should realize something of their character in the life of the plant. Sugar, starch and cellulose consist only of hydrogen, oxygen and carbon. The plant oils and wood alcohol are almost entirely hydrogen and carbon. Nitrogen and sulphur are rarely found except in the seed or pod. If a plant is dried to a shriveled, black remnant, then carbon and a very minute quantity of mineral salts are left: for carbon is the foundation of the form and structure of the plant. The oils of eucalyptus, pine and juniper known as camphene and pinene contain only hydrogen and carbon. The qualities of warmth and light are given by the hydrogen. This can be confirmed later when hydrogen is prepared as a gas and is found to be one of the lightest of gases and to burn with one of the hottest flames. We can follow the part played by oxygen, not only in the breathing process but also in its connection with water. Long ago chemists claimed that no chemical change could take place without water, but later experiments proved that oxygen could play the same part. It is not possible to illustrate fully here but only to give indications of how the qualities of substances can be understood from their interactions in plant life.

In the growing plant, in the living animal and in the human being, the variations of compounds are incredibly complicated. Nevertheless it is good that first of all we should become aware of substance in its living context. Matter can very rarely be found in the form of elements except when it has fallen out of the cycle of life. Iron, carbon, nitrogen, sulphur, and so forth, can exist in isolation, but they are liable to be taken up again in the breath and the blood, to be absorbed or digested and woven once more into the complexity of a living organism. It is this interweaving of life and matter of which we need to be aware. The cataloguing of the properties of elements can be acquired later by the specialists.

Events in the world of nature can appear to the human being not only as the illustration of natural laws but also as pictures full of meaning for his own soul life. Before our eyes there are continually examples of higher forms that emerge from lower states of being. The grub is transformed into a butterfly; from the mud of the pond there rises the water lily; the harsh poisonous bark of the blackthorn bears a white blossom, For the artist and the poet it is impossible to regard these as blind chances. The rainbow is not only an illustration of Newton's theories of light, it still speaks to the heart as an emblem of hope. Those who have learned to see the world in this light will never entirely lose the experience and will find the way to meet the problems of their time.

Michael's Sword of Iron

An Examination of the True Nature of Iron

by DAVID LANNING

[The study of metals is included in the Class 8 Chemistry curriculum. Though not written as such, this article contains much that can provide a background to the study of iron at this stage. –Ed.]

Is it entirely poetic fancy that a spiritual being like an archangel should overcome the dragon, with a sword made of iron? Surely, one is a being of the heavens, and the other very much a substance of earth, and the two do not really go together to our way of thinking, if we really think about the picture. One does not discuss the properties and nature of iron in the same sort of breath, or even with the same sort of people with whom one might discuss the attributes of the Archangel Michael. The nature of the substance of Michael's tools or weapons must be irrelevant, if not immaterial, in the realms in which he operates.

But the very word 'substance' has a Latin origin whose literal meaning is 'standing under,' or rather, perhaps, 'behind.' What is it that stands behind iron? Well, of all the metals, iron is the one most used by the human being to transform the earth; whether in the right way or not is not so much the point as that, through iron, he has wrought his will upon the earth. The next most used metal is aluminum, but the total world production of aluminum is about equal to four blast furnaces producing iron; and in a liner like the Queen Elizabeth, some 60,000 tons, all but a few hundred are iron. It is all-indicative of our widespread use of iron. Even when some of the substances used in technology are not iron, we are likely to find that the tools which fashioned them, the furnaces which prepared them, and the mixers which churned them up, were made of iron, and that it is through iron that our will has been done. Iron too is associated with the planet Mars, and Mars was the god of War, and so iron also becomes the substance of warfare, which is basically an activity whereby one people imposes its will upon another. We associate it with forceful strength, with cruelty and destruction. But is this the true nature of iron?

Iron, in its own nature, shows a state of balance, an avoidance of extremes; it is not extremely heavy nor light, neither is it very reactive nor very passive. The chemist finds it halfway down the Periodic Table, that is midway between the lightest elements like hydrogen and helium and those which appear to disintegrate under their own mass into sub-earthly states of nature, like the radioactive elements. If the chemist is also a follower of Goethe, he will note that iron and its allies form colored compounds, as for him color will arise as an interplay between the dark substances and the light. It is iron which makes the ruby red, the sapphire blue, and the emerald green, and which turns quartz into amethyst. It is iron which gives us the green sands of the southeast of England and the red sandstone of the West Country.

But if mankind has imposed its will upon the earth through iron, it is also through iron that the individual human being carries out his own acts of will. For iron we know forms an important part of the blood, and whenever we perform an action, the blood streams to that part of the body concerned in making it, whether it be digestion, cerebration or moving the limbs. We all know that this is why it is not good to eat too much before swimming or taking an examination. Even when, in the dark, we make to take a step which is not there, the blood goes to the limbs, and we stumble. Iron is also in muscle in its own right, except when, as in the breast of a chicken, it is the muscle of a flightless wing, and so the meat is white. The meat of a chicken's leg or the breast of a pigeon which can fly is red or brown when cooked, as it contains iron. It is through iron that the will is incarnated.

But will incarnates in stages. At first it is instinct, as we see it in lower animals like insects; then impulse, as in the snapping of a fish at the baited hook; then urge, as in the higher vertebrate. Finally in the human being it becomes resolution, but now it undergoes a 'sea change' as it were, a sort of inversion, for the cause of the willed action no longer precedes it. It follows it. Human will points to the future.

If the will is incarnated into the blood through iron, so does the iron, through its affinity to oxygen, purify and recharge the blood. An affinity with oxygen is manifest in burning, and iron burns in a special way, as we see in sparklers at fireworks time. We see it also in the shooting stars or meteorites as they flash through the atmosphere in the autumn, and burn up the sulphurous summer haze which spreads right over the sky, separating it off into the mists and clear air of autumn. There is a big difference between the mists of autumn and the haze of summer, and beyond the mists the air is clear and the outlines sharp.

Iron also has a very strong affinity with warmth. It appears first (apart from a brief flirtation with it in the earthworm family) in the blood of cold-blooded vertebrates, but this is really only a preparation for the chief function which is to come. The affinity can be seen in the high degree of warmth which iron will absorb before melting and in its ready conduction of heat. Anyone who has seen a blacksmith's forge will have no difficulty in associating iron with fire and heat. The connection with warmth is not altogether separate from that with will, and we often speak of 'warming' to a task when we gain enthusiasm for it. Enthusiasm, warmth and will rather go together for they are carried by the same vehicle of iron. But if we can feel warm to a task, we can also feel warm to a person when we get to rather like him or her. Perhaps here there is another qualitative change like the one between urge and resolution, when the faculty becomes no longer shared with animals, but is specifically human; that is, the warmth becomes love. Then iron, which was the substance of forceful and cruel will in warfare, becomes the vehicle of love. It is interesting that the animals which can best be tamed and made into gentle pets are the carnivores, the cats and dogs, which in nature have the claws and fangs to rend their prey. A turtledove kept in a cage with another may tear it to bits. And dare one suggest that there is probably more brotherhood in the fighting services, where danger is shared, than among those who campaign strictly for peace?

The Archangel Michael used his sword of iron to drive the dragon from the heavens. He is shown as the strong angel, the fighter and the conqueror. But he does not seem to have done us a service, for he has driven the dragon down to earth, understandably in great wrath, knowing he has "but a short time." However, Michael gives us his sword of iron in our blood, knowing that, if through it we can transform the warmth which nature has given us into love and compassion, we too can overcome the dragon on earth. We can beat our swords into ploughshares only because they are both made of iron.

UPPER SCHOOL SCIENCES

Science in the Upper School
by HANS GEBERT

[Following an introduction that has little relevance in the present context, the article continues as follows.]

It seems that schools will do best for all their students, including the future scientists, if they insist on a wide scientific education without undue specialization. Moreover the science teaching will not have fulfilled its task if it does not acquaint the children, at least in rough outline, with the present position in science and with the historical process which led to it. It is just such historical studies which will bring home to the children that our present science is a stage on the path of human development. They will learn about the modern atomic theories in physics and chemistry and about the genetics theory in biology, but they will appreciate how they developed out of quite different conceptions of the world held by peoples who apprehended nature with different faculties of the mind, and they will therefore learn to expect that the modern theories, too, will give way to new ones as our consciousness expands. Such a course requires a certain maturity in the students and cannot be given to boys and girls below the ages of seventeen and eighteen.

A course of general science up to age fifteen or sixteen followed by specialization in two or three directions, as practiced in some schools, can therefore not be adequate. Physics, Chemistry, Biology and Geography are therefore taught in every one of the Upper Classes of a Waldorf school. The biology syllabus starts with human anatomy in Class 9, goes on to physiology and some anthropology in Class 10, and continues with botany and zoology in Classes 11 and 12. Geography includes a good deal of geology and mineralogy.

One of the aims of the Upper School is to lead the students to the point where they can take a positive part in present-day social life. They must therefore not only have some idea of current scientific thought and possible future developments, but they must also be led to an understanding of the vast technological and industrial applications of scientific knowledge. This need is always borne in mind in the physics and chemistry lessons. The Class 9 physics syllabus centers, for instance, around the various heat engines and around the telegraph and telephone, while a large part of the physics curriculum of Class 11 is concerned with such modern achievements as radio and x-rays.

Waldorf schools are, however, by no means unique in aiming at such a wide syllabus; much that has been said above would probably be read with approval by many a modern educationalist. Some of the things which will have to be said about the method and content of the science teaching may not receive the same approbation and therefore may need some more justification.

I shall now try to describe a piece of work which could form part of the physics main lesson in Class 11. It will be easier to give the reasons afterwards for some of the peculiarities of the treatment of the subject. It will then also become apparent that another teacher might approach the same subject from a different point of view and yet do it in the same spirit.

Among other things, one wants to convey a certain understanding of electricity to the children at that age, which goes further than the elementary facts which they must have learned in Class 9 to understand the telegraph, and so forth. One might start by taking a number of test tubes and filling three of them with a solution of a silver salt, three with a solution of a copper salt, and another three with a solution of a zinc salt. One now takes four strips each of copper, zinc and tin and puts one each in the silver salt solution, one each in the copper salt solution, and so on. If the school is wealthy enough to have some pure silver available, obviously the experiment should logically be extended to include one solution each with a piece of silver in it. Leaving these test tubes overnight, a deposit of silver will be found in all the test tubes which contained silver solution and the other metals will have to some extent dissolved away. The silver solution in which the copper strip has been will have turned blue, showing that it has become a solution of a copper salt. Similarly the zinc will have driven out the tin and copper from their solutions and replaced them. The tin will have driven out the copper, and copper will have reacted only in the silver solution. We shall then tell the students that all the metals can be arranged in a series so that each one tends to drive out all the metals following it in a series from the solutions of their salts.

Next we can remind the class that they learned in Class 9 how the simplest electric cell works. They will remember that they put a zinc plate and a copper plate into a solution of sulphuric acid. The zinc dissolved and the copper did not, and when the two plates where connected by a metal wire outside the solution, an electric current flowed in the wire. The zinc plate became charged with negative electricity and the copper with positive electricity through the chemical action of the sulphuric acid. In the next experiment we could show the class that a similar effect, only weaker, can be obtained by putting zinc and copper plates into a solution of copper salt in which the zinc dissolves driving out the copper. Again the zinc becomes negatively charged and the copper positively charged. Finally we could tell the students that a cell might be made up of two copper plates, one surrounded by a weaker solution of a copper salt than the other. There would now be a slight tendency of the copper to dissolve into the weaker solution and to come out of the stronger solution, and the plate in the weaker solution would again become negatively charged, and vice versa. Thus it becomes apparent that the production of electricity in cells depends on the dissolving or the depositing tendencies of metals in solution. The negative electricity always appears where there is the stronger dissolving action.

Now we might ask what happens if we put charged metal plates into a solution of a metal salt. So as not to mask the effect, the plates should be made of a metal which does not react with the solution of its own accord; platinum is best for this purpose. If one platinum plate each is connected to the positive and negative poles of a battery and the plates are then immersed in a solution of, let us say, a copper salt, copper will be deposited on the negative plate. If this experiment is allowed to run for a while and the plates are then reversed so that the copper coated plate is made positive and the uncoated plate is made negative, the copper on the coated plate will dissolve and the previously uncoated plate will be coated.

The negative electricity which in the cell is produced by a dissolving action, therefore causes deposition, and vice versa for the positive electricity. Once that has been realized, one can certainly not yet say what electricity is, but one can get an idea how it behaves and acts in one realm of nature. It can establish balance because it opposes the activity which calls it into play. If we have a simple zinc-copper-sulphuric acid cell in which the ingredients are absolutely pure, the zinc will not start dissolving to any extent until the cell gives an electric current, until the two plates are connected by an electric conductor. This can now easily be explained from the phenomena without recourse to any theory. One can picture the chemical activity producing electricity, which opposes the chemical action, and therefore the two keep each other in balance. An electrical conductor tends to remove the electric charges from the plates and therefore upsets the balance so that the chemical forces now have a chance to act.

From this starting point one can make connections with other realms of nature and one can for instance draw attention to the difference between the chemical action taking place between metals, acids, bases and salts in the mineral world and the chemical activity in digestion. If electricity were allowed to play the same part in the latter as it does in the former, digestion would stop, with fatal results to the organism.

I am well aware that the above phenomena can also be explained by the ionic theories of modern science. There are further developments of the atomic theory assuming that atoms consist of electrically charged particles. In effect these theories try to explain all chemical action in terms of electricity. Indeed, in the historical treatment of the subject, which will go side by side with the lessons described above, the children will be introduced to these ideas too.

Why then bother to give the above rather complicated treatment? Why not teach straight away the explanations current at present? What indeed is the justification for suggesting other possibilities than those accepted nowadays by the overwhelming majority of scientists? Those are questions which scientific readers are almost bound to ask.

One justification I think is this: As long as one keeps to the phenomena, one remains free to form one's own opinions, to make one's own deductions. Anyone who has had the above presented to him might, for instance, ask the question whether it is possible to explain electricity in terms of chemistry, just as it is possible to explain chemistry in terms of electricity. This naturally leads to further quite fundamental questions of a philosophical nature. If one confines oneself to teaching accepted theories more or less dogmatically, the student is robbed of this freedom and will find it very difficult to break new ground later on. It is good that the boys and girls should enter life with questions rather than with readymade answers. Such answers tend to dull the interest and wonder, which should be aroused by the manifold and often very complicated connections in nature and our relationship to her. Interest and wonder are the most potent driving forces in the search for knowledge. I am convinced that the methods illustrated by this single example will not only produce better educated people but also better scientists, much more open to new possibilities and developments, than the strictly academic courses followed in many schools.

Such academic courses leading to ordinary or advanced level examinations in the G.C.E. [state examinations] are essentially the first steps in the training of a professional scientist. At Waldorf schools we are concerned with developing faculties in the students and giving them the background knowledge on which future professional training can be based and not that training itself. What are these faculties? I think those are right who indicate that it might be necessary to bring into conscious use some of the capacities of the human soul which are so far subconscious or semiconscious. So far the feelings of the human being, the verdicts of the heart, have been excluded from consideration as scientific evidence, as being unreliable and subjective.

On first sight this is certainly true, but the question is really whether they can be trained to become reliable just as the human being had to train himself in the process of evolution to detach his own wishes and predilections sufficiently from his sense impressions to make them reliable evidence.* The more contemplative approach to nature, for which examples have been given in this article, is designed to be a first step in this direction. It may be expected that a further evolution in this direction will also make our scientific knowledge again into a guide for moral action. This is essential if science is to be a positive factor in social life, and it must certainly be the main task of any school to help young people to establish in their further development a responsible, moral attitude to their fellow men and to their natural surroundings.

*See: Abraham H. Maslow, *The Psychology of Science*, New York: Harper and Row, 1966; and Owen Barfield, *Saving the Appearances*, London: Faber and Faber, 1957. Both these books bring discussions of the questions raised here.

Science at the Age of Fourteen
by K.M. JONES

The class speaks with one voice. This the Upper School teacher invariably experiences when listening to the morning verse spoken by a new Class 9 at the beginning of the school year. Yet even before Christmas this chorus has become a concord of many notes and inflections of tone, as individual qualities of soul rise to expression in speech. And here we have an indication for teaching.

In the course of the next years the teachers of this class will be dealing with problems of long duration which arise out of the inner being of their students. Hitherto it can be said that the children's difficulties have arisen from outer circumstances and surroundings. Henceforth many of these children will have a long inner struggle, each of a unique and personal nature; this is the inner aspect of that which prints itself outwardly as the changes of puberty.

The life of the soul is greatly stirred at this time and receives into itself forces which will grow later into the personality of the adult. Previously there was an inner stillness and receptiveness but this is left behind and a deep feeling of insecurity has taken its place. It is this which brings about the awakening of thought. The old supports have gone. The collective response of the class was based on a willingness to receive and confidence in what the world and the teacher had to bring. Clouded though it was after the ninth/tenth year by a dawning sense of self-identity, it was still the underlying mood.

The soul forces which enter with such a storm during the next one-and-a-half years cause an inner darkness; they threaten to take control and the child is fundamentally unsure. Thinking is the response to this. In thinking one can be shielded from the too immediate impact of the outer and inner worlds; thought is a mirror in which events can be viewed and robbed of their suggestive power, where they can be brought to rest and can be evaluated and assessed. They offer points of reference and support. With what firmness will the students of Class 9 maintain their judgments and arguments! The teacher does not question them. They will, in all events, be surrendered after a few weeks for another standpoint as ardently held. The teacher goes into all questions characterizing but never asserting, rather making the contact with the students indirectly through the subject matter *which both are considering.* In this way only, with one student after another, can that relationship gradually be established which gives support over these years.

The Class 9 in the Edinburgh Waldorf School has two main lesson periods of two hours a day for four weeks, which incorporate the physical sciences. One is based on the substances derived from plants, the other focuses on steam power and the electric telegraph and telephone [1953]. Two realms are involved: that of nature in which, through the influence of the seasons of soil and weather, nature works and the human being tends its working; and the other in which the plant substances as food stuffs, fuel and chemicals of all kinds acquire a form and circulation impressed upon them by purely human endeavors. They thereby become commodities and the shadow of social and money values accompanies their circulation. The plant has its place in both. Even before the natural product has severed its connection with nature, human foresight and intention are directed towards it, leading it into the new social connections. The plant is removed from its nature connections and is given its place in this other domain. Abstractions arise when we ignore this and only deal with substances and their properties.

The plant substances arise also in connection with key phenomena in the realm of life: Thus the magic girdle of cambium around the trunk which builds its substance and mediates between the mineral waters rising within and the products of photosynthesis in the leaf moving outside it; the remarkable chemistry of the leaf surface in sunlight; and the phenomena occurring around the growing point are all of the greatest significance for carbohydrate chemistry. These regions of life are natural sources for the beginning of chemical studies.

The use made of plant substances by the human being is also a mirror of his own development. Is not the change in his sugar diet from honey to cane sugar with the Arabs, and to root sugar in the modern age, a dietary development which parallels changes in consciousness? Did not the drinking of wine play a special role in the first millennium BC in overcoming the bond of blood which was the conserving force among the ancient peoples? And with the coming of synthetic fibers we make the third step—from clothing ourselves in products of animal and plant to mineral garments! While familiarizing themselves with the oils, fats, ethers, soaps, explosives, dye-stuffs, and so forth in the laboratory, the children are also introduced to some of these perspectives.

Independence of judgment is not yet asked for, but the students strengthen their thoughts in writing essays which include these backgrounds and yet are saturated with substantial content which has been observed or has been related to them. The essence of this approach can be expressed by modifying a phrase used by David Lillienthal, sometime chairman of the Tennessee Valley Authority undertaking. In his book he speaks of "the seamless web of nature" which all the specialists must respect when planning "unified resource development" in this great valley. We are concerned with "the seamless web of knowledge," which is essential for the child's absorbing interest in everything around him. If we can preserve this intense and broad interest through the time of the advent of thought, we shall later perhaps have a man who has the degree of love for the world and for the human being which is needed for the great self-discovered responsibilities. Thinking too must spring "from the grass roots"—another well-chosen phrase of Lillienthal's, for is it not the first few feet of humus which is the foundation of our life on earth?

By the end of the period the children will have acquired a good deal of knowledge about many of the industrial processes and products used today which spring from the plant; from paper and margarine, to cordite and rayon, and so forth.

The treatment is the reverse of that usually followed in teaching chemistry traditionally, wherein the substances come first. That would be to take the condition of rest as a satisfactory starting point. This ignores the process of coming to rest. In those realms where we can see mineral substances coming into existence, for example in the human bones, they are an end product formed out of mobile living conditions. Only later, when they have become mineral, are they of service to the human being and obey his dictates. Mineral Chemistry is reserved for Class 10.

The second science period has a different emphasis; it deals with the human being around machines. It is not for nothing that the machine—car, locomotive, or whatever it is—makes such a deep impression on young children. It is an object in nature entirely created by the human being. It probably stands out for the young child quite starkly as the one element in his surroundings with which he is continually not relating himself. Though he takes it to bits with great absorption, it still does not reveal its nature to him. Any machine points to the social discovery which gave rise to it—*the division of labor.* This is an outstanding theme in the history lessons of this year. Of more concern to the science teacher, it points to a thought, for without the thought of that machine, it would never have come into existence, and the thought lies in the context of what might be called "the spiritual history" of mankind. In that spiritual history the whole of modern science has its significant place. This is a new world which none of the children could previously glimpse or enter. They have certainly been stirred with admiration by stories of fortitude and discovery, they may have been profoundly moved when listening to Plato's account of the death of Socrates, but they have never hitherto experienced enthusiasm for a thought. It will come back gradually. Its small beginnings are to be sought for in this lesson.

One would not proceed far with the study of the flow of energy, the simple mechanics and heat in connection with the steam engine, without meeting the principle of the conservation of energy. In Classes 10 and 11 one will describe the background out of which this thought emerged, and the lives and the relationships between Julius Robert Meyer, James Joule, Carl Helmholz, Eugen During, John Tyndall and others connected with this discovery. One would be able to characterize the philosophic setting in which this idea emerged and then perhaps something would be felt of the 'necessity' of the arising of this principle at this time. Certainly, if this could be achieved, a certain freedom would come into the students' relationship to such a 'law.' How often in the history of science do we see laws becoming scientific blinkers for generations of scientists. Though such range of thought is not yet possible in Class 9, it calls for reticence in handling these fundamental laws so that they do not weigh too heavily on the students. The teacher should have an understanding for these earlier stages so that if he speaks of the fire in the locomotive it can still be felt as part of that first Promethean fire which the human being has taken into his charge throughout the ages.

The locomotive is studied first. The processes are described: the conditions of warmth throughout the engine, the transformations of water (in the boiler, superheater, cylinder and so on), the transmission of force through the mechanical system. All these are thoughts which are close to the phenomena and rise simply from them. How far they can be built up has to be decided in the course of the lessons; compensation, balance and moments in the mechanical system will probably be treated; latent heat, calorific value of fuel, specific heat on the heat side, all of them very closely related to the locomotive.

From this we pass to the electric telegraph. The children will make one and later see its development into an automatic telephone exchange. Here they will easily be fascinated by the completely cold automatic responses of the electric instruments; it is like the clicking of dry bones; the only relationship one can make with them is through logical and abstract thinking.

The simpler electric circuits are studied in terms of current, potential and resistance; each child should feel that there is some portion of this field which he understands. Through the telegraph (after the accounts of the laying of the Atlantic cables) the children hear of the many clever uses to which the instrument has been put. The intellectual pole in the child is called forth by this study; the will pole was approached through the prime movers.

The subject matter taken in these main lessons has been built up out of the needs of the child at this age and background. The science teacher may meet the children for a few months only at this important age between fourteen and fifteen. In it he must support the first stirrings of independent thought life, must let it breathe freely and easily in the airs and currents of outer experience, must give it a connection with the depth of the soul from which it rises in warmth and strength, and must finally direct it upwards to the pure weaving of the light of thought confident in its own element But this latter must grow in Classes 10 and 11, when a different approach to science will be required by the different conditions then prevailing.

Transportation Technology and Human Evolution

Grade 9 Physics

by ROBERT OELHOF

Modern transportation technology arose from three fundamental inventions: the steam engine, the internal combustion engine, and the rocket. Each appeared at its own particular time, reflecting the state of human consciousness and challenging mankind to use the new engine for good or evil.

The steam engine is at least two thousand years old, having been used as a toy and in the temple service before the time of Christ. Although first harnessed for practical (social) use in the 1600s, it was George Stevenson and his son Robert who built the first railroad locomotive and line in the 1820s, running a passenger train from Manchester to Liverpool, England, at the unheard-of speed of thirty miles per hour. Powered by steam (external combustion), the railroad carried its own society along, arranged as if by fate, in such fabled mysterious sources of intrigue as the Orient Express. Even today one may meet new friends (or enemies) in the compartments of European trains linking the continent. These naturally arising social settings correspond to an energy source which moves society from the *outside,* namely, from the great locomotive in front of the train.

Murder on the Orient Express was a famous thriller. Who would propose a title like *Murder at the New York State Tollbooth*? The foolishness points to the individualization which comes with the internal combustion engine. The idea for such an engine was not even conceived until 1804, when Sadi Carnot proposed it on theoretical grounds. In contrast to the steam engine—developed in social settings by practical men such as blacksmiths, coalminers and repairmen—the gasoline engine was only possible after a thorough analysis of thermodynamics by Carnot and fellow Frenchman Alphonse Beau de Rochas in 1862. The idealism lying behind the internal combustion engine is best embodied in Rudolf Diesel, who held to the goals of an individual power source for all men, which he felt would bring world peace! The Diesel engine, designed to run on any readily available fuel, appeared in 1895 (at the dawn of the Michaelic Age). With the source of energy now within, reflecting the ego awakening in each individual, the challenge was, as Diesel saw, to use this new individual power to establish peace. Crisscrossing Europe in his crusade for peace, Diesel met his end in 1913 on a ferryboat on the English Channel, on his way to a peace lecture in England. It was rumored that he was the victim of foreign agents

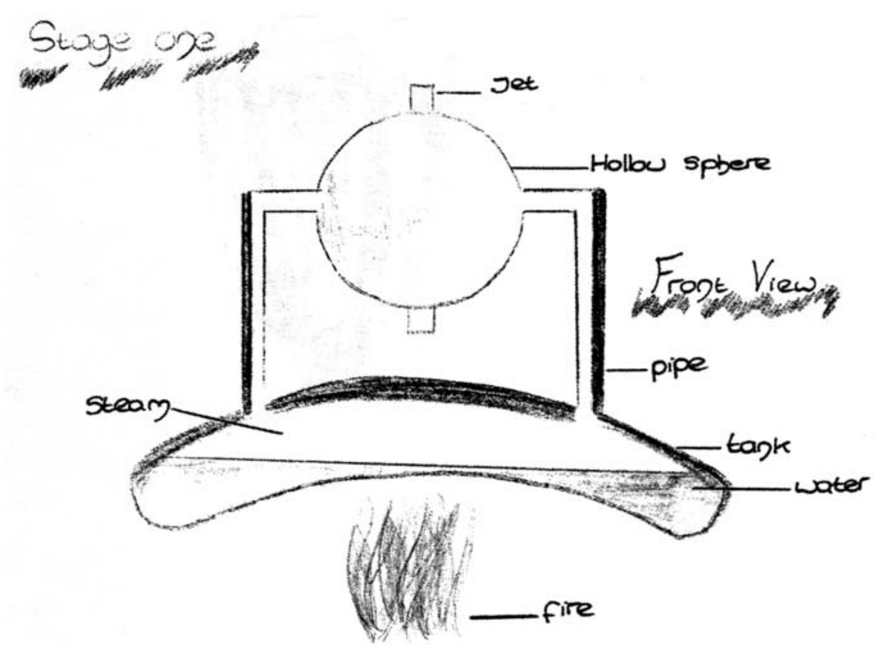


Fig. 14 *Stage one in the development of the steam engine (Ancient Greek)*

seeking to deny his genius to the coming German war effort. Diesel's engine was used first for tanks and warships. We still await the transformation of universal individualism into universal world peace (see fig. 14.)

With the 1930s came the opportunity to recognize this world order of love through the approach of the Christ into the energy field of the earth itself, the etheric aura. And now appeared the latest transport technology, the rocket, and fast on its heels, nuclear weapons. The rocket totally loses the element of internal control as in the diesel engine, rather propelling itself by giving away, totally out of balance, by action and reaction. It is impossible to grasp the rocket, or jet engine, from within. By its speed, by its activity, the rocket links the whole world. It carries people, parcels, and messages, and launches communications satellites. It demands a global consciousness. Instead, the rocket is now tied to the nuclear bomb, with a split between propulsive power at the tail for the flight, and explosive, uncontrolled power at the head and end of flight. This degradation of the third element in the transportation revolution is forcing us to see the world as a whole, not out of love, but out of fear.

Individuation brings the need for communication. The worst party I ever attended went something like this. My friend Donn, a shy person by nature, finally worked up enough courage to throw a party. The format was modest. He had a small apartment in the city. When I arrived, there were already several people sitting on the chairs which had been set around the walls of the small room. I took a seat and waited for the conversation to continue. It didn't. Questions were met by monosyllabic responses. People continued to arrive until the chairs were filled. Then people gradually left. No conversation took place; there was only the embarrassed silence. All agreed afterwards that it was the worst party anyone could imagine. I related this story to an Indian friend, who had been raised a Christian in a family with Brahmin roots. "We have many parties like that in India," he told me. "You Americans think you have to talk, but we sit for hours with our friends without saying anything." When connections are given from outside, there is little need for communication. Today the individual lives must reach out to each other, for we lack the context of natural connections.

Arriving as they do, ready to enter fully into the modern age, the ninth graders are met with a physics block which deals with just these crucial technologies: transportation and communication. In this context, the physics of heat, pressure, and radio arise naturally out of this study.

Organic Chemistry and the Ninth Grade

by DAVID MITCHELL

The fifteen-year-old ninth graders stand before us. When we observe them, what is it that we notice? Right away we may see that they are filled with emotional energy. They don't seem to think, but rather they 'do' things and then watch the results. They are passionate, irascible, and apt to be carried away by their own impulses; and yet they have high aspirations. At this point in their lives they have met few humiliations and can be brazen and all-knowing. They can carry everything too far, whether it be their love or hatred or anything else. They are compassionate and suppose all people to be virtuous, or at least better than they really are.

Riding the waves of advanced adolescence they can at any given moment be lonely, moody, argumentative, depressed, ecstatic and challenging to all authority. Adolescence is a time of tremendous physical and chemical changes. The body is in revolution and the soul is in conflict. Rudolf Steiner refers to the onset of adolescence as "a gentle sprinkling of pain that never goes away!"

What is it that is going on inside our ninth graders? Physically their heart is doubling in weight. Their blood pressure is increasing. Their lymphoid system is shrinking, which may open up infections to the throat area. Boys' voices are changing (they drop a full octave while the girls drop only one tone). The limbs, starting with the feet and legs, are beginning to elongate (this can cause pain and restlessness). The lungs are increasing in size and the breathing is changing—costal in the girls and a deeper diaphragm breathing for the boys. Two dozen different hormones are being released leading to the emergence of individual sexuality. Fat becomes distributed over the body, lips thicken, thighs firm up, and the hips take on adult curves. There is a rapid acceleration and deceleration of the skeletal growth, and a consequential need for lots and lots of sleep—usually saved up for Saturday and Sunday mornings!

The alpha waves of the adult become added to the low frequency waves of the young child as the brain experiences change. The adolescent feels alone, restless, sometimes angry and begins to formulate questions for his/her teachers such as: "What really matters? What is the point of it all? Who am I?" It is a difficult passageway in life and calls for a lot of compassion from adults.

The end of the fourteenth year is that point in time when the intellect is being born and the individual begins to find enjoyment in logic. Teachers and other adults become the whetstones upon which the teenagers can sharpen this newfound ability to reason. They must be met in their school experience with subjects and teachers who challenge them.

The curriculum of the Waldorf school attempts to meet and exercise these forces. For the ninth grader 'what' has become the significant question, and proper directed activities such as a phenomenological approach to science is one of the answers. Rudolf Steiner organized the Waldorf curriculum so that the chemistry studies in the ninth grade should be carried forward from what was done by the class teacher in the eighth grade. This recapitulation involves experience and prepares for an intellectual grasping of the subject which is not abstract. It becomes then a living knowledge.

This age group benefits from a comparison of contrasts: black with white, inhaling with exhaling, heat with cold, anabolic with catabolic, and acidic with basic. A key to working with this age is to have them summarize as much as possible. This helps to center and pull the student in.

Organic chemistry is one of the ninth grade main lesson blocks. Chemistry is the study of the inner nature of substances; the organic is the world of the living. Everything we refer to as organic has carbon in it and has had to be living substance at some time. As said before, the ninth graders are confronted by the task of maturing not only with regard to sex but also to earth-life. Organic chemistry is placed at this point in their blossoming self-knowledge for very specific reasons. The teacher must invigorate their awakening in their surroundings in order to help them retain their health. This will help to regulate their impulsive jumping into activity.

Their thinking is, however, a 'willed thinking.' They learn by doing. Science is filled with activities which, when structured properly, lead the students into discrimination in their thinking. The material covered should include the symbolic relationship of the human being and the plant world, a deep understanding of photosynthesis, the assimilation of carbon dioxide, and the carbohydrates and their two-pole direction, toward solidification on the one hand (cellulose) and toward rarefaction (alcohol) on the other.

The contents of this block should be discussed in relation to the physiological process going on in the students' bodies. They should experience the respiration of the plant in photosynthesis and contemplate nature's manufacturing 'factory' for making carbohydrates. The technological process of making paper as well as artificial silk (rayon) can be demonstrated. Finally, vegetable and animal fats can be examined as well as mineral oils, rubber and petroleum. Joseph Priestley's achievements and studies of phlogiston are studied as well as the nature of oxygen and carbon dioxide. Jan van Helmont's observation of the plant and Jan Ingenhousz's discovery of the oxygen–carbon dioxide respiration cycle in plants can be read to the class.

In the teaching of chemistry there are four general rules which Frits Julius suggests we follow:

1. Everything we present must be in correspondence with what is happening within the child.
2. We must develop an all-embracing world outlook.
3. The students must understand and remember the material we present.
4. We must allow breathing space.

Present a phenomenon, give it a chance to breathe, then bring it back, This is the fundamental rule within our block schedule. We present a block of chemistry, or physics or astronomy, and so forth, we let it rest, and then we bring it back later.

Waldorf chemistry teachers have wonderful resources in the work and indiations of Rudolf Steiner, Stockmeyer, Eugen Kolisto, Fritz Julius, Gerhard Ott and Manfred von Mackensen. Their writings can be referred to for specific experiments and directions in Waldorf science teaching.

In my class I like to keep the students actively involved in the experimental process. Besides demonstrations, I involve them in nineteen different experiments over a three-week main lesson block. These experiments involve chromatography, the making of synthetic rubber, the fermentation and distillation of alcohol, the making of rayon, the creation of esters, saponfication, the chemical identification of sugars (both monosaccarides and disaccarides), starches, cellulose and photosynthesis, to name but a few. The starches (corn, wheat and rice) as representatives of the West, Europe and the East, are discussed. We do solubility tests, density tests, flame tests, fractional distillations, and so forth. We do microscopic tests, distinguishing between vegetable, animal, mineral and synthetic fibers. Every student concocts a synthetic rubber ball on his/her own after our study of rubber. The students are asked to write reports in their main-lesson books on these experiments to include (see fig. 15):

– a list of apparatus,
– a sketch of the set-up,
– the procedure,
– their observations, and
– whatever questions (at least two) that this particular experiment woke in them in the evening as they reviewed their main-lesson work.

The next day in class we review the experiment and try to evolve any conclusions, which are then written down in their block books. The conclusions, concepts and questions are drawn from the experiments. The airy side of the carbohydrates (alcohol and exters) can now, after a night of contemplation, be contrasted with the earthy side (cellulose and starch).

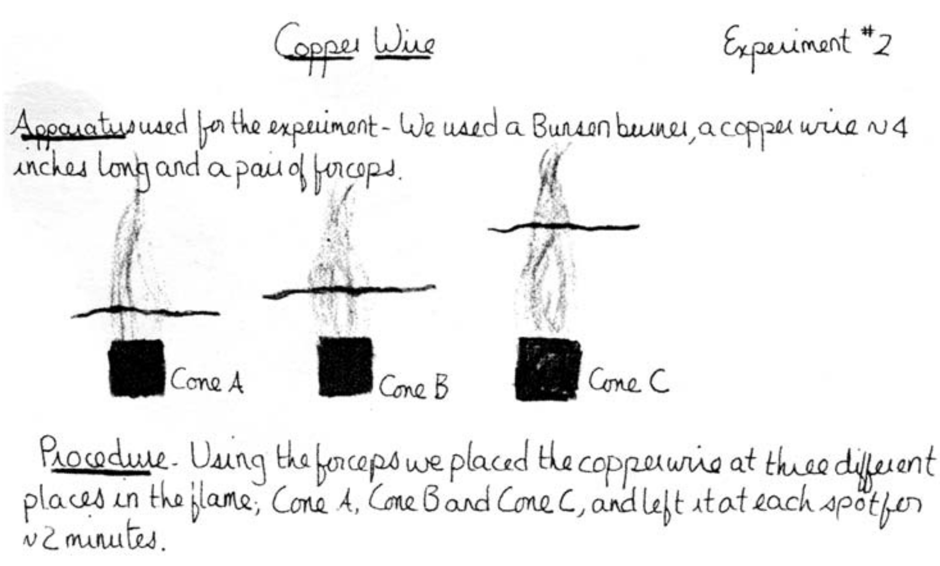


Fig. 15 *A sample from the file of a Grade Niner. Further observations, conclusions and questions follow.*

One assignment I like to do with my students is to have them research a biography of a modern scientist for both an oral and a written report. In the oral report I ask them to include: where the scientist lived, what his or her upbringing was like, how he/she became interested in science, an explanation of his/her most significant discovery and what it meant to the development of science, and a description of the difficulties encountered in life and how this individual overcame them. I ask them to also include one humorous anecdote from the life of the individual they research. Scientists included have been Nobel, Boyle, Newton, Cavendish, Priestley, Dalton, Pasteur, Curie, Einstein and others. I first contemplate each child and then assign a specific biography and a give them a picture from Isaac Asimov's book *Asimov on Chemistry* to get them started. They are required to write notes from each other's reports.

It is beneficial for the teacher to plan one or two field trips during the block so that the stuents can have a first-hand experience of an industrial process created from human thinking and borrowed from the human being's observations of the activities of the plant world. I like to visit a distillery and schedule a brewmaster to give a talk on fermentation some days after we have studied the subject in class.

The ninth grader needs to experience the world as his own, and should feel that the world is an important and fine place to be. The task of the teacher is to bring the students of this age down into their physical bodies—to plant them firmly on the earth. We must invigorate their awakening in their surrounding in order to help them find their own personal health and balance which they will need in their adult life.

As described above, the building up and the breaking down of the natural world is experienced through ninth grade organic chemistry. By describing the physiological processes one can come to questions like alcoholism from an objective point of view at a time when the students are still open to such observations. They can see how sugar develops warmth in us while alcohol overheats us. Instead of stimulating our forces, the alcohol creates a bluff and develops exaggeration and illusion.When the students meet these realities through their own observations and experiments within the chemistry lab, then they learn objective lessons for life.

The fifteen-year-olds entering the ninth grade should be taught in such a way that they are led to the feeling that everything in the world is important. They must learn to trust human thinking, and they should experience that thinking is capable of dealing with inner as well as outer problems. In their science courses, in particular, they should realize that it is human consciousness which awakens technology, and that a proper, moral technology can provide us with a better world to live in.

Further reading:

Eugen Kolisko, *Elementary Chemistry.*
Frits Julius, *The World of Matter.*
Gerhard Ott, *Gundriss enier Chemie*, Vols. I & II.
Manfred van Mackensen, *Vom Kohlenstoff zum Äther und Salze – Säuren – Langen Laborunterricht in Chemie.*

Computers and General Education

Computer Literacy and Computer Business

by HORST ADLER

You may have noticed that home computers are nowadays sold with precisely the same aggressive tactics as were customary in the selling of encyclopedias, the 'education' of our children providing the lever. "If you care about the future of your children, you had better acquaint them now ..."

Here is an example of how the media try and push the idea down our throats—an American television commercial trying to sell household computers. Mum, Dad and Son are at the quaint old railway depot. Mum and Dad wave Son goodbye as the train pulls out. Son is off to College to realize the American dream: a future with an expense account and so many tax lawyers that the IRS will never lay a paw on his annual income. In the next shot the train is pulling into the same depot. Mum and Dad are standing there looking lugubrious, and no wonder. There is Son about to disembark with his luggage. He looks wretched. He has been kicked out of college. The invisible narrator says the lad lacked the computer savvy needed to pass. Mum and Dad didn't buy him a computer when he was a little boy. Do you want this to happen to your child? If not, better buy him a computer at once. The narrator recommends the computer made by the sponsor.

If the phenomenon of overselling the computer as an indispensable teaching aid were restricted to television commercials, it would not be too bad, for television commercials are not renowned for their impartial presentation. But it is much worse, since the phenomenon has also intruded into the scientific world. I recently came across a new scientific journal called *Machine Mediated Learning.* To begin with note that, if you have followed the development of this area, and if you are linguistically sensitive, then this title should make you rather suspicious. What started as *Computer Instruction*, via *Computer-Aided Instruction*, became *Computer-Assisted Learning.* And now it is *Machine-Mediated* …

I can think of only one explanation for such frequent renaming: a new name was needed each time the previous one had lost its luster. A convincing demonstration that the whole idea of *Machine Mediated Learning* is a dreadful mistake would certainly be pertinent to this journal's area of interest, but it is very unlikely that such a result would reach the pages of this very journal, since its editorial mentions only one criterion in the evaluation of articles considered for publication, viz. "the extent to which they facilitate the development and utilization of effective machine-mediated learning systems." The conclusion is clear: Rather than classifying this journal as scientific literature, we should classify it as propaganda.

There is a widespread, but generally unchallenged, belief that making something 'computer-aided' amounts to making it much better. Computer-aided design, computer-aided management, computer-aided composition, you name it.

(The misery of computer-assisted examinations, better known as 'multiple choice,' should have cured us.)

Take for example, the word processor. It is sold as a timesaving device. Recently experiments have been made with people who were both experienced writers in longhand and experienced users of word processors. The outcome was, firstly, that the linguistic quality of the letters produced with the aid of a word processor was not noticeably higher than that of the handwritten ones, and, secondly, that they required fifty percent more time to be written. The use of the word processor turned out to be so time consuming because it is so easy to make changes in text. It is an open invitation to write first, and to correct and improve (often to think) later, thus *eroding the intellectual discipline.* I think word processors should carry a notice saying: "Warning! The Educator General has determined that computerized word processing is detrimental to the development of your writing proficiency."

To the best of my knowledge it was not industry that invented the term 'computer literacy,' but society. Quite early in the game it was firmly implanted in people's minds that computers were there to save our economies (and later also the economies of the countries of the Third World). For a while no one knew how, but unfortunately someone hit upon the bright idea that information was a 'resource,' so that solved the problem, the more so since, for the first time in history, we now had a valuable resource of infinite supply. Then people remembered how oil had created immense riches for a happy few. This time that should not happen again, so 'computer literacy' for the millions was invented to solve that problem. What this term should mean is still an open question. In fact, the U.S. Department of Education provided funds to develop a 'working definition.' But that did not prevent our visionaries from happily proceeding to invent the post-industrial society, a kind of renaissance world of high technology in which people, if not happily teleconferencing, would devote their ample leisure time to creative video games.

There is nothing novel in people's expecting that 'Heaven on Earth' will be established in the near future (though to me, this vision is more like Hell on Earth). Novel, however, is that computers will do the job. I am not exaggerating, expectations are so unrealistic that what should be reasoned discourse sounds more often than not like people participating in a strange ritual, faithfully reciting prayers in a language they do not understand.

What could be the role of general education in all this? We should keep in mind that it is not the computer *hardware* but the software, i.e., the programs controlling the computer's operations, that constitute the heart of the matter. The computer hardware is no more and no less than an extremely handy device for realizing any conceivable abstract mechanism without changing a single wire. Studying computers as electronic technology contributes little to the understanding of their potential. However, *programming,* i.e., the design of such abstract mechanisms, is much too difficult to teach to the public at large.

But the business world is urging schools to 'familiarize' students with computers, and there is often the feeling that "well, with a little personal computer and simple programming language, you should be able to show the kids something, shouldn't you?" Regrettably, showing the kids 'something' is precisely what is happening in many Upper School courses in computer studies. I say 'regrettably' because when the students get such a misleading experience that it will never clear up the confusion, they are likely to acquire patterns of thought that are deeply inadequate when they wish to become professional computer scientists.

Students who have learned a (conceptually often entirely inadequate) programming language rather than the (art and) science of programming, tend to confuse—if I may use the analogy—the composition of a symphony with the writing of its score. Furthermore, programming some toy problem (writing a simple tune) on a little personal computer will not help to develop any feeling for the conceptual challenge implied by any nontrivial software development task (composing a symphony) and as a result people's expectations remain unchecked by an understanding of the limitations both of the equipment and of their ability to master it. They are, to use another analogy, led to confuse the skills required of a barber with those of a highly qualified team of specialized surgeons.

These conceptual problems are compounded by quantitative characteristics of modern computing equipment: storage capacity and processing speed are so huge that what takes place inside a computer at work completely baffles the human powers of imagination. And, when I say 'completely' I mean 'completely.' A simple factor of ten makes all the difference. I remember asking a housewife who did not believe this how many children she had, knowing that she had six of them. Then she saw the point.

Add to this the fact that for several decades, computers have gained a factor of two in processing speed and memory size each year—this is a factor of one thousand within twenty years. When what was a gradual difference becomes big enough, it becomes an essential difference because the analogies break down.

It should become clear from the preceding that a computer course at school level can hardly be expected to give an interested student—the future businessman, engineer, natural scientist, and so forth—a balanced and useful picture about the potentials and the pitfalls of professional computer usage. And for students wishing to become professional computing scientists, the situation is far worse. They are likely to acquire patterns of thought that are deeply inadequate and have to be undone at the university level,. For instance the widespread teaching of the programming language BASIC should be rated as a criminal offense: it can mutilate the mind beyond recovery.

We should try to make our children more immune to all the humbug and dishonesty in which the world of computing abounds. I believe that it can be done. We should begin by teaching them the critical, skeptical reading of advertisements. Advertisements are a significant source of information in, at least one respect: they reveal the manufacturer's perception of his customer's appreciation of his products. It must be possible to make evident that so-called Artificial Intelligence or Expert Systems are more a product of a public relations effort than of a scientific one. This will hopefully make people immune to advertisements such as the recent one, that, under the slogan: "You can't reach the top by being a pencil pusher," suggests that, in order to become vice president, it suffices to buy one of the company's 'thought processors.'

Students should learn to identify as misleading the messages coming from the professional public relations men, viz. the advertisers. This might also give them some immunity against more subtle misrepresentations such as the one given by the enthusiastic computer user (fascination with the equipment being the hallmark of the amateur). The trouble with the latter is that he need not be dishonest: he may simply be a propaganda victim himself.

In the early days of business computers, one of the most sober articles on office automation appeared on the solemn pages of the *Financial Times.* It discussed the possibility of replacing a secretary with an office computer. Having estimated the huge amount of shelves and wall space that, at the very least, would have to be filled with computer cabinets, the article ends with the conclusion that the traditional secretary is cheaper and more pleasant both to work with and to produce.

Regrettably, this enlightened warning was not heard. By the time the mass-produced personal computer (PC for the *cognoscenti*) arrived, the space requirement was reduced to a square foot of desk space (however, now walls and shelves are lined with impenetrable computer manuals). And the public perception created was that of 'antitechnological technology,' IBM using an icon of antitechnological innocence as a trademark of its PC: the Charlie Chaplin tramp, Charlot with the rose.

Huge quantities of personal computers swamped the corporate world, sold as universal automation tools. Vendors were preferably dealing with such a high level of the management hierarchy that incompetence in computing was assured and objections from the technically competent staff could be overruled. In retrospect this development has been a disaster, since almost all the 'opinions' pushed by the commercial propaganda were false. And, in addition, the brain washing campaigns have been so effective that for many, those opinions have become dogma that can no longer be challenged without committing heresy. As an example of the ridiculous style of advertising, I remember the recommendation that such-and-such a personal business computer could make "200,000 business decisions per second" for you!

Two years ago, still, it required the courage of an outsider, a columnist of the *New York Time*s, to describe the emperor's new clothes: "Personal computing seems to promise simplicity and deliver complexity. Hardware is not compatible with other hardware or, when it is, requires a mechanical genius to connect the pieces. Manuals are incomprehensible. Software is an almost endless source of frustration. Confronted with such intricacies, the computer neophyte may feel that either someone has pulled the wool over his eyes or the rest of the world is a lot smarter than it appears."[1]

But meanwhile the corporate world itself seems to have come to its senses. Let me quote from the editorial of a recent issue of a leading business data processing journal: "PCs have touched a large population. Productivity lagged mightily while we learned to use them. Intellectual discipline was eroded and now stands at an all time low. It will be years before our business institutions catch up and recover organizationally from all the amateur computer users ... What the field needs is not rank amateurs who can use a PC, but seasoned leaders to help us assimilate what we have and lay the foundation for the next surge. These people are in short supply and are hard to grow."[2]

Remember that the corporate world lamenting here about the PC-induced erosion of intellectual discipline in their own quarters is the very same group that tried hard to export intellectual erosion by urging schools and colleges to make their students 'computer literate' and to provide crash courses in the use of personal computers. And vendors have been providing 'generous' grantsmanship assistance as well as 'free' computers to schools to secure shares of the education marketplace they consider to be crucial for their future business success.

But the tide might be turning. There are encouraging signs that the period in which each newly coined slogan could be turned overnight into a respectable educational topic is drawing to a close, and those signs go beyond the badge I received last year: "Stop BASIC before it stops you." The fact that the Siberian branch of the USSR Academy of Science has launched a serious effort to prevent BASIC from being introduced in Soviet high schools is a more telling sign.

And also for the computer industry the tide seems to be turning. Not only are computing companies in Silicon Valley offering 'artificial intelligence' systems and other pipe dream gadgets are folding up at a much higher rate than they are erected, but even market leaders such as IBM have been facing an increasingly stagnating market in the last few years as corporate customers are now beginning to realize that the 'next generation' products offered by the computer industry as solutions to their problems are rather often a source of terrifying new ones.

I consider that to be good news because it could drive home the message that neither slogans like 'knowledge-based decision aids' nor a combination of ad hoc and brute force will do the job. It is regrettable that large groups come to their senses only after their daydreams have turned into nightmares, but, this being so, we should occasionally welcome the nightmares.

The computer literacy movement is aimed at introducing the masses to computers by providing some minimal level of instruction in order to allow them to be 'comfortable' with the new technology. There is no good reason for Waldorf schools to jump onto the computer literacy bandwagon so typical for the era of 'minimal competence education' (more so, since this bandwagon appears to have already gone into a skid).

What is required is a careful analysis of the relevance of the young field of computing to the time-honored goal of general education as a basis of a thoughtful adjustment of the Waldorf curriculum. Careful research is needed to determine how the essential nature of the computer can be understood properly, and how the Upper School curriculum should take developments in the discipline of computer science into account.

Acknowledgement

I am greatly indebted to Professor E.W. Dijkstra, the 'Newton' of computer science (and by some regarded as a 'Don Quixote' of computer practice), whose imprint is present in almost every section of this article.[3]

Endnotes

1. Erik Sandberg-Diment, *New York Times*, quoted in the "Words of Wisdom Award" section of the computing journal *Abacus*, Winter issue, 1987.
2. Rebecca Barna, Editorial in *Datamation*, January 1987.
3. E.W. Dijkstra, *Computers and General Education: a position* paper, unpublished technical note EWD868, December 1, 1983.

Computers in Education: Surveying the Field

From an Editorial Introduction

by BRIEN MASTERS

Information technology, a product of our advancing age, is a phenomenon which has a significant influence on us all. Rudolf Steiner emphasized the importance of giving students the basis for understanding such phenomena. This does not remain as mere knowledge or simply become transformed into skill; it strongly affects and supports the human being's personal relationship to the world. It also educates that attitude towards life which can become "an insatiable thirst" for knowing and understanding the world, as personal horizons widen and as discovery of the world increases continually.

Such considerations are important points of reference and help us to keep scientific developments within the context of the whole education. Hi-tech is not something which will come and go in schools like cap badges or government subsidized milk for morning recess. On the other hand, in our well-nigh craze for resources, it should not be allowed to become the cuckoo in the nest of our teaching methods. There have been many years in which physicists, mathematicians and historians in Waldorf schools have introduced different aspects of computers to their students through their respective disciplines. This work has continued in a more or less isolated fashion, though this is not to imply that experiences have remained unshared. Recently, however, there have been several moves to confer, to compare on a larger scale, to ascertain whether a more 'official' statement or recommendation can be made concerning the Waldorf approach to computers in education at various stages. Foremost is the conference (March 1985) which was held at High Mowing School (Wilton, NH) with Joseph Weizenbaum of the Massachusetts Institute of Technology (MIT) present, organized by David Mitchell and others and reported in this volume by Hans Gebert. This, together with the other articles which address themselves directly to the subject, may perhaps be seen as making a contribution towards what would constitute such a statement or recommendation.

The point at which we are arriving is somewhat unique in Waldorf history. Initially there were the indications, suggestions, guidelines and clear-cut statements of Steiner, given as a result of his depth of insight and his considerable teaching experience. Then came the indomitable *voortrekkers*—to whom we also owe a great deal—who put Waldorf onto the world map. Their voortrekking involved much hard work and sacrifice in human terms; in professional terms it involved study, consultation, translating ideas into educational ideals, elaborating and extending Steiner's suggestions, taking indications from lectures and discussions into the classroom, into meetings and personal preparation. From this we have the art of education which Waldorf has become today and is still in process of becoming. Meanwhile a multitude of scientific discoveries has found its way into the classroom, into the Waldorf classroom in accordance with the basic principles of child development and the resultant curriculum for which Waldorf is well known. The topics of discovery have ranged widely from the latest virus to aeronautical studies in air pressures during trans-sonic flight, and from nuclear research to the ecological consequences of building a dam at Nagymaros. Some may be seen as vociferously epoch-shaking, others as whisperingly modest. Nevertheless, educationally they have all been taken in the exciting stride of being a Waldorf teacher. When, however, something emerges which infiltrates as many aspects of life as the microchip has, it creates something of a revolution in culture and as such cannot help but threaten to invade the classroom.

This invasion brings with it a swarm of questions, disturbing observations, gut reactions, sharp insinuations, pressure from all sides. There is the strong line taken recently, for instance, by the Scottish consultant psychiatrist, Dr. Prem Misra, who was confronted with young patients suffering from computer addiction with attendant psychosomatic symptoms of extreme mental fatigue and lack of concentration as well as "backache, body pains, dizziness and headache." He warns: "There can be no more dehumanizing retreat than a computer ... [S]uch obsessions harm young, immature minds ..." Or again, Michael Shallis, a staff tutor at Oxford, author of *The Silicon Idol,* attacks the machine from other angles: "In allowing a teaching machine to take over a large part of the teacher's functions, the student loses out on a real relationship with another human being, however fraught with problems that may be. And those problems, after all, are part of education." He points out how learning must include "understanding attitudes, expression, emphasis," and that no machine can provide "emotional contacts, negative and positive, that take place between people." Further, the dangers of atrophying other human senses, or of replacing an accountable teacher with an anonymous programmer; also, the ugliness and crudity of the forms it 'draws.' His main condemnation of the machine is that it is "denying children their childhood." Weizenbaum expressed similar views.

These voices are by no means alone, nor do they illustrate the only approaches. We should not lull ourselves to sleep, however, deaf to their message, with the platitude that computer 'literacy' is essential for the future. Andrew Cowie, a systems analyst within the electrical industry itself, stressed this recently, urging educationalists to bear hardware obsolescence in mind and also the "fourth generation" systems which "do away with the need to write a program at all." To the thousands of dollars and yen being spent on research, he maintains that "it makes as little sense to train a generation of computer programmers now as it would have done to train a generation of motor mechanics when the Ford Model T went into production." (Accordingly, therefore, the earlier that education launches the child into computer literacy, the greater the damage.) Moreover, he cautions that it puts the future of children in jeopardy and urges that what we need, in common with every other industry and profession, are "people with a decent, all-round education."

This certainly clears much of the ground. But we are still left with the fact of the importance and the influence of 'artificial intelligence' in our age and the need to incorporate this appropriately into education—the technical background of its developing hardware, the foundation of those mental skills required to master its equally developed software, and its social and ethical consequences and implications. The pedagogical questions therefore revolve around two main points:

1) How can we do justice to this truly remarkable invention and its ramifications, which are able to lend us so much aid in our existence, while at the same time we preserve and develop a sense of perspective, proportion and appropriate application?

2) While facing these issues, how can we become clearer what other faculties can be developed in education to counterbalance adequately and therefore to complement the mechanical form of thinking which the pursuit of this technology can easily over-enhance?

Looking the first fully in the face will help guarantee that our defense against this classroom invasion will not deteriorate into a mild form of computers-in-education witch-hunt. Striving for the second will enable us to provide the students with an efficacious antidote to being overruled by this type of thinking in their lives.

A Computer Conference in America

Reported by HANS GEBERT

Monthly Detroit is a glossy periodical bought mainly for its excellent coverage of all that goes on in Detroit and its suburbs. The September 1985 issue has also an article about the damage to children through indiscriminate television watching. The article is coupled with a "Un-TV Guide" suggesting substitutes for the tube. The guide has four sections. The third section, headed "Using Home Computers," is the important one for our purpose. It is the only section with a picture. This shows two three- or four-year-olds obviously fascinated by a computer and the caption is: "Computers and kids are a natural combination." Magazines of the kind of *Monthly Detroit* are very carefully targeted at their readership and the caption of the picture is probably widely accepted by the educated and reasonably affluent members of Detroit's middle class, who are just the people who might send their children to the Detroit Waldorf School. The caption would probably be accepted as a truism in most cities in the United States.

A similar attitude was apparent among educators at a conference on computers for local teachers, which I attended recently. It was assumed without discussion that computers belong to the classroom from kindergarten onwards. The conference had only to decide how to train teachers to use them effectively and to stimulate providers of software to improve their offerings. Douglas Sloan wrote an excellent article in a prestigious educational journal describing and criticizing the indiscrimilate acceptance of computers by the teaching profession.[1]

Needless to say, in this euphoric atmosphere regarding computers in education, Waldorf schools up and down the country have been pressured to introduce computers too. Parents are frightened that their children will be condemned to a miserable existence in abject poverty if they grow up 'computer illiterate' and they assume that 'computer literacy' can be achieved only if children deal with computers as soon as they learn to read and write. Many schools have found it difficult to meet this pressure. High Mowing School therefore recognized a very real need when it arranged a conference entitled *Computers in the Waldorf High School* (March 22–25, 1985).

As it happened, the conference did digress at times to discuss computers in the Lower School. In fact the official report includes the sentence, "There was a shared conviction that early computer education constitutes an assault on childhood, and that it robs the children of their rightful kingdom." However, the title of the conference indicates general agreement among Waldorf teachers that computer education is a task for the Upper School and not for the Lower School. In this article it may be useful to outline some reasons for this opinion.

A short digression discussing the place of technology in Waldorf schools is necessary to do this. Waldorf schools were among the first to insist that students should leave school with a general understanding of the major technologies. But what constitutes 'understanding' of technology? An example will make this clear.

Consider the automobile, for instance. A non-driver can understand the working of a car and can appreciate the effects of cars on the environment, on the planning of cities, on their lifestyles of the populations, and so forth. Conversely, it is possible to be a competent driver without understanding the working of the car and without ever giving a thought to the effects mentioned above. I would like to suggest that the thinking non-driver has a socially more useful understanding of the car than the non-thinking competent driver. Of course, the car is only fully understood by someone who can drive, who knows how a car is made, who understands the working of the engine and all the other systems, and who has studied the effects of the car on society and the environment. Such a full understanding cannot be conveyed at school for more than a very limited number of technologies. Schools must, therefore, choose which aspects of understanding are the more important. It seems clear that this importance is in the reverse order in which the aspects of understanding have been mentioned above. The most important aspect, the appreciation of the social and environmental aspects of the motoring age, presupposes some understanding of humanity and its relation to the surroundings generally.

To return to the main subject, we can now see the reason for the well-established and well-tried educational sequence in Waldorf schools. The Lower School lays the experimental foundation for understanding humanity and nature. Here students progress from doing to feeling appreciation and then to knowledge. Technology is introduced in the Upper School after the Lower School has provided the firm starting position, without which understanding technology would be impossible.

Computers are in general a technology among many, but introducing them does also present new problems. High school faculties and particularly mathematics and physics teachers have tried to grapple with these problems since the mid-1960s, when it became obvious that information technology had to find a place in the already overcrowded curriculum. The conference was, therefore, a very welcome opportunity for exchanging ideas and trying to hammer out common policies. The Waldorf school movement has to be very grateful to High Mowing for arranging a conference on a very important subject, in a very excellent way. The beautiful setting in the New Hampshire hills (even the weather cooperated), the pleasant accommodation and the fine food helped us all to concentrate our energies on the task in hand. David Mitchell, a longtime faculty member of High Mowing, and Arthur Fink, a consultant on computer application who runs the computer program at the school and also a center for Appropriate Computing, planned the conference. They had collected a small but very impressive group of resource persons.

The central figure was Joseph Weizenbaum, professor of computer science at Massachusetts Institute of Technology and pioneer in artificial intelligence research.

Many readers will know his book, *Computer Power and Human Reason*,[2] in which he questions many aspects of computer use and points out many dangers of the uncritical application of computers. The others were David Black, Andrew Linnell and Swaine Pratt. Each one works with computers in his main profession and all of them are familiar with Waldorf schools and are concerned that computers should be used appropriately.

The general arrangements of the conference also contributed very much to its success. There was one full-scale lecture given by Professor Weizenbaum. Otherwise, there were short contributions from the resource persons, and there was very much time for discussion in small groups and by all the participants together. The thirty participants all had personal experience of some aspect of the problem. All the Waldorf high schools and teacher training institutes in North America [at that time] were represented, and many participants knew each other from previous work together. The organizers have produced a seventeen-page report.

The conference started by surveying what was actually being done in schools at present. No school reported that computer studies were introduced in the Lower School, but all Upper Schools, except one, had introduced computer studies of one sort or another. Many schools have a good deal of capital invested in a number of microcomputers or in some mainframe computers. Both main lesson blocks and weekly lessons are used for the computer courses. Usually the time for computer courses comes out of mathematics and physics allocations, but time has also been taken from history, languages and art. In two of the schools formal instruction is supplemented by computer clubs.

It will be interesting to compare what is happening at present with the recommendations. The success of the conference can be gauged by the extent to which current thinking was changed and by the way in which even participants with large investment both in money and in time agreed to quite new recommendations.

I can mention only the most important ideas and arguments which led to the recommendations. Many, but by no means all of them, came from Weizenbaum's lecture. It would be too cumbersome to mention the author of each idea, which is more apparent in the full-scale report, and I hope I shall be forgiven for not giving due credit in every case.

Let us deal first with the considerations meeting the fears of parents who are afraid their children will suffer greatly in the job market if they are not 'computer literate.' First of all, it was pointed out that many people are successful computer users without training. They use computers in the automatic cash dispensers in banks, when they order items in mail order stores, or when buying tickets at many of the larger European railway stations. In the future we may use computers in a similar way for shopping and/or paying for our orders. In no case will it be necessary for the user to know how to program the computers. It will be enough to know how to use apparatus similar to a telephone. Telephone and television are ubiquitous in our lives, but we do not feel that anyone, let alone children, must be trained to use them.

As and when the writers of so-called 'fourth generation computer languages' are successful, many jobs in programming will disappear. Computer designers are on the verge of making computers which will take over many programming functions. Thus many of the lucrative jobs now available after a comparatively short training are likely to disappear. Those who will have to use computers in offices, travel agencies, stores and the like will have at their disposal the 'user friendly' computers which are now coming on the market. Learning to use such computers will be less difficult and less time consuming than learning shorthand and typing.

Regarding preparation for college, Weizenbaum told the conference of his experience with freshmen at MIT. The introductory computer course, which everyone in his department has to take, is flunked more often by those who have had computer courses at school than by those who have not had any direct computer preparation. He puts it down to the fact that MIT selects students very rigorously for intelligence, so that all of them should be able to cope with introductory courses. Those who have had computer courses often have had to overcome bad habits and to unlearn primitive techniques which they brought from their previous training. Many have, for instance, learned to program only in BASIC, which Weizenbaum called on another occasion, "a barbaric language."

This learning to use computers at school is unnecessary and can even be harmful for those who really want to make a career in computers. I expect that these facts will soon be generally realized and parental pressure for computer literacy courses will abate over the next four years.

What will not abate so quickly are the attempts to computerize education. Here we are in a much more controversial area. Questions such as the following are being fired: "Couldn't the word processor liberate school children from the drudgery of worrying about spelling so that they could more quickly develop their creativity? Doesn't the pocket calculator eliminate at last the need for learning multiplication tables? Couldn't many mathematical ideas be taught much better by computers, as Seymour Papert advocates?"[3]

To answer such questions we need first to consider the deeper objectives of education and the nature of the human being. If we educate mainly to give students survival skills in the commercial and political world, many subjects we cover in schools are as redundant as the learning of multiplication tables and spelling seem to be. But are the aims of education really as restricted? Does the effort in learning the tables, for instance, not foster capacities of mind and will which are essential for future efforts of self education and which may, in the last resort, even be useful in the market place in a less direct way? Weizenbaum pointed out that in learning to write 'abduct' rather than 'apduct' we get a glimpse into what links all the words with the prefix *ab.* It was also pointed out that word processors are no help in reviewing the overall structure in a piece of writing and that learning mathematics on a small screen "contracts space, sucking students' attention and consciousness into the small terminal screen." These questions have all to do with the nature of the human mind which can link the finite individual to the infinite and which can penetrate the deeper secrets of language. These capacities are fostered by (apparently useless) mathematics and by attention to spelling and grammar. The conference seems to agree that computer instruction tends to limit and confine the mind to the merely useful and the finite.

These considerations led into the most challenging questions raised by the computer. While pre-computer technology replaced only the labor of limbs and senses, computer technology seems to replace our minds. Used in conjunction with the older technologies, computers make it possible to construct systems which go a long way towards mimicking the whole human being. Do such systems really replace the whole personality? Or, putting the question the other way round, is the human being nothing but a computer controlled heat engine with some chemical messenger systems? When the conference visited the MIT Artificial Intelligence Laboratory we learned the expression *carbon-chauvinism* for those who still think that there is something special, distinguishing the human being from its silicon counterpart.

While Waldorf teachers have little doubt that computer systems are a poor caricature of human beings, they also realize that these questions divide the minds of our generation. Schools must, therefore, equip their students for retaining balance and sanity in a world torn by such controversies. They must also be equipped to deal with the kind of questions Weizenbaum asks in his above mentioned book: "Where can computers be used appropriately and in which spheres of life have they no place?" Those who work with computers told the conference that computers do tend to change their users, by making them computer dependent, by forming addictions and by producing computer deification. There is also a real danger that social organization, environment, and lifestyle will change to accommodate the car and electricity distribution systems. All technologies have a tendency to become masters if they are not consciously relegated to be servants of truly human needs. The real challenge of the computer to education is not to make students 'computer literate' but to prepare them for life in a world in which all these unresolved questions will have to engage their interest and their best efforts to find solutions.

These questions show that Waldorf education is ideal for preparing students for the computer age. All the questions raised have different answers for people with differing ideas of the nature of the human personality and of its task in the world. And is it not one of the main aims of Waldorf education to give every student the wherewithal for gradually forming his or her own peculiar view of humanity?

Once the position outlined in the last section had been reached, it was not difficult to come up with general recommendations. Perhaps it is best, therefore, to finish this report with the last few paragraphs of the official report which contain them: "If we teach about the computer, the student must also learn something about himself. All of mankind's accomplishments need to be brought to our students in the right way in order to activate a healthy process in the child.

"We don't want our children to idolize the computer nor do we want them to flee from it in terror. We want them to understand it. Taught in the right way, the students will be imbued with confidence. Such teaching fulfills one of Waldorf education's fundamental precepts—to prepare our students for life."

The conference reached several other practical conclusions about the place of computer work in the High School curriculum:

1. Waldorf teachers in America have a special task to develop the ideas of Rudolf Steiner with regard to what he referred to as *Lebenskunde* [4] in the curriculum. It is within the study of *technology* that the computer will find its rightful place in our Waldorf schools. We must be careful not to separate the 'computer' into a deified study of its own.

2. American Waldorf high school teachers should plan an entire conference on "Technology in the Waldorf High School Curriculum" in the near future.

3. Certain aspects of computer work might be offered as elective courses in eleventh or twelfth grade, but not before. It is an interesting statement about the conference that we did not map out such courses at any level or detail. Almost no time was spent on such questions as the 'best' computer language for school instruction.

4. Hands-on work with the computer needs to be balanced with examination of the computer in a social and spiritual context.

5. Most of the work with computers in high school should be integrated into other subjects—rather than being offered in separate computer classes. The history and development of the computer fits naturally into the history of technology; computer languages relate to other languages; principles of computer operation might be taught as part of physics or maths; similarities and differences between the information processing in the human being and by the machine can be taught in physiology; moral and ethical issues involving computer usage can be considered along with other contemporary problems. Computers must be acknowledged by all teachers throughout the school, regardless of their subject.

Ultimately, perhaps, we learned from this conference that we must not apologize about what we stand for. We must not succumb to the temptation of finding relief from today's pressures.

Many teachers had arrived at the conference asking whether Waldorf high schools at this time should avoid student involvement with computers. As the conference concluded, many of us were repeating Weizenbaum's suggestion that computers should only be taught as part of such a broadly based program as is offered in the Waldorf curriculum. And Waldorf schools may be, in fact, the best places to teach computers, because "nowhere else does a true image of the human being exist to counteract the computer's 'bedeviling influence.' "

This account of the conference is probably colored by my own ideas and prejudices. I hope these will not blur the fact that the American Waldorf school movement is tackling an important study resolutely.[5]

References:
1. Douglas Sloan, *On Raising Critical Questions about Computers in Education.* The Teacher's College Record, Vol. 85, No. 4 (Summer 1984). Also in *Computers in Education: Critical Perspectives*, Teachers College Press, 1985.
2. Joseph Weizenbaum, *Computer Power and Human Reason,* San Francisco: W.H. Freeman & Co., 1976.
3. Seymour Papert, *Mindstorms.* New York: Basic Books, 1980.
4. The word *Lebenskunde* is difficult to translate. Steiner visualized a subject going right through the school, or at least from sixth grade onwards, in which the students would be introduced to what happens on the farm, in factories, in offices, in parliaments and law courts, and so forth. This subject still needs further development.
5. Parallel major work is also being done in the United Kingdom and Europe.

Where Do You Have Breakfast?
Putting Computers into Electronic Perspective
by ALAN HALL

"Daddy, how do all those people get inside the radio, and do they all have breakfast in there too?" To such an innocent, young child's question I suspect that most adults would find difficulty in giving an answer that both satisfies the child and speaks about the reality of radio transmission. Exactly the same type of questions can arise for television, tape recorders, computers, and all the burgeoning electronic devices which change the local spatial and temporal relationships of natural events. At home as parents and, more formally, as teachers in the classroom we have a difficult task to bridge the gulf of understanding between the open childlike perception of "Daddy, how ...?" to a real understanding of the processes and realities involved in electronic media.

Books abound which explain the details, the nuts and bolts of how electronic apparatus works, but the majority are written for the specialist, and most children and many adults are soon lost in the labyrinth of detailed concepts and technical language. In the classroom a group of adolescents can very quickly polarize into a small minority, which has a keen interest and tries to understand, and a large group which simply 'switches off.' Teaching electronics to mixed-ability, mixed-interest groups begins to raise very fundamental questions about how we all relate to our new electrical media culture, and the following thoughts and observations are distilled from classroom and school experiences in recent years in teaching students aged fourteen to eighteen.

One of the most common early questions, when teaching electricity, is: "What is electricity?" The very question demonstrates clearly that we have a problem in relation to such an entity. The reply to such a question could be: "What is an apple?" Answering *this* question is fairly easy, as we have all seen, smelled, touched and tasted apples. We have seen them growing and understand to some degree at least how they came into being, as we are able to follow the processes of growth. To the questioning adolescent one can then say, "Then why can we not answer the question about electricity in the same way?"

"Because it is different."

"In what way is it different?"

"I don't know, it's just different You can't eat it for a start."

"Let us try another question then: What is fear?" Quite often a lively discussion follows such a question, about situations in which fear has been experienced, but usually not about what fear is. If one presses the question there develops a problem in reaching clarity, although without exception every student knows what fear is from direct experience but cannot easily grasp it in thought as an entity. It is more a quality of experience.

Using such a ding-dong question and answer Socratic method can be very valuable in tackling such difficult questions as: "What is electricity?" For one can establish clarity through the students' experiences of the differences between, in this case, an apple and fear, and electricity is clearly not apple-natured, as we do not have access to it through our senses in the same way as we do an apple. In such a way one establishes through comparison that electricity is not material in the way that we normally experience material things, hence the original question. This is a very important step in understanding, for if it is impossible to get a bucketful of electricity a new question arises: "If the nature of electricity is not material, then what is it?"

Fear is nonmaterial but it is real enough, for we experience it deeply. So, is electricity in some ways like fear? We cannot experience it as we experience fear; we cannot sense it in its reality, for it lies outside our senses. What we can sense are many of the effects it produces in our environment. To establish clarity between what we sense as things—apples and so on—and what we cannot sense—electricity, magnetism, radioactivity, for example—is vital, for our investigations of the two realms need to proceed differently. If one establishes that electricity is not accessible to the senses, then by what faculty can we so determine what it is?

So one can lead the original question, "What is electricity?" to a new, very serious question in science: "How can we come to understand an entity which is beyond our senses of perception?" For an adolescent struggling to master his thinking, this is a challenging thought.

All this may sound rather philosophical and rather tedious, but it seems to me vital groundwork, for almost every textbook on this subject totally ignores this fundamental question in science, telescoping and confusing the material-sensible with the non-material. We have a direct experience of color but x-rays are totally outside our senses, and yet these are treated as similar entities on the electromagnetic spectrum. All of the entities of which we see only effects—such as radioactivity, x-rays, forces and so on—must be realities, but we experience only a shadow and their real nature remains hidden. So at the beginning of a study of electronics one can establish with a class that the answer to the question "What is electricity?" is clearly: "We do not know what it is, because we do not appear to have the means of knowing." We may be able to develop a means of knowing, but to begin with we are dealing with something of an unknown nature, and as we now base our material culture on its use, serious questions arise about the effects it produces.

Clearly the method of scientific investigation in such a case must be to find the phenomena and effects that electricity produces and to characterize from these rather than define. So one can begin a systematic, practical investigation and study in detail the whole range of phenomena, but from the point of view of getting to know about something that at the outset seems to be unknowable. A good example is the connection that exists between electricity and magnetism.

Everyone has handled magnets and the idea of a magnetic field is familiar enough as one can feel the effect of the field on a piece of iron. But what is a field? The iron of the magnet clearly has an influence beyond the limits of the iron just as the solid earth has an effect beyond its surface. Let us call this sphere of extended influence a magnetic or gravitational field. In this moment we cross a vital divide between observation of that which is accessible to our senses and the ideas we create of that which remains hidden from our senses. The concept of a field is a very useful one having a very wide range of application and is a vital crutch to our understanding, but it is an idea that describes a quality or property of space and does not necessarily describe the reality that produces the quality. So one can show that to reach into those areas that are not accessible to our senses we need to create ideas or models in our thinking, such as a field of influence. However, these are only models and not realities.

Such ideas as these need to grow out of direct experimental work and take quite a time to build up with a class. Having firmly established, after many a struggle, the idea of a magnetic field being an extension of the magnet, many students are completely bewildered by an experiment that shows the presence of a magnetic field without any magnet, and without north or south poles. The picture that we carefully build up of the field as an extension of the iron of the magnet is clearly inadequate, and our model needs to change to fit the new phenomenon of a magnetic field around a copper wire connected to a battery. This is often quite difficult for many students, as they now have to picture the field without a focus, and it is a good example of a common process in scientific investigation, demanding inner flexibility.

Further experiments can show that magnetic fields can be transformed into electric fields and that electric fields can be changed into magnetic fields, which again demands a revision of our idea of the field, for we see that it can metamorphose and take on different properties. These two phenomena we called magnetic and electric fields, and they have an intimate reciprocal relationship like a glove turned inside out; each field can suddenly become the other but it cannot be both at once. Every telephone call, every radio broadcast, every television image, every electric drill, every washing machine depends upon the application of this fundamental discovery, namely the reciprocal transformation between the electric and magnetic fields.

This is a real touchstone for our understanding that requires no detailed, specialized knowledge in order to be understood, and yet is fundamental to so much electrical equipment that we handle. Such knowledge can help to create a sense of orientation and fundamental understanding in a world of bewildering complexity.

Let us use this in the example of the radio. If we look inside a radio it is a mass of wires, little cans, blobs, bits and pieces, and we instinctively say, “How on earth does it work?” Well, all you really need to make a working radio is: a milk bottle, a length of wire, two pieces of kitchen foil, an old polyethylene bag, a rusty razor blade, a piece of coke, a telephone ear piece and a water tap. It is possible to make this odd collection of bits and pieces appear to play music or to speak. I should mention that if you try this, the razor blade and the coke are very temperamental and are better replaced with a diode. However, it is possible to get such a radio receiver to work and all the components are familiar, everyday things, and so the mystique about electronics begins to dissolve. Eighty turns of wire wound on a milk bottle is just a coil of wire, and a sheet of polyethylene sandwiched between two sheets of kitchen foil is all there is to a capacitor, and these two components are at the heart of every radio transmitter and receiver. If the two ends of the coil are connected to the two sheets of kitchen foil, a loop is created which has unusual electrical and magnetic properties. The coil of wire can briefly store a magnetic field and the polyethylene sandwich can store an electric field, and since each of these fields can transform into the other, an oscillation between the two can be set up. This is a simple oscillator, like a pendulum that changes from blue to red as it swings from left to right, but in this no *thing* moves; all that changes are the two fields, and this is at a very high rate of maybe millions of cycles a second, the rate depending on the physical size of the coil and the polythene sandwich. This oscillation is the ‘heart beat’ of every radio and its rate determines which program you hear, either by changing the coil size with the waveband switch or moving the foil of the sandwich apart, which you usually do with the tuning knob. Both of these adjustments work well on the simple model, and the ‘knob mentality,’ with no idea of what one is really doing, changes to one of understanding simple processes of physical and nonphysical change.

Of course, other experiments are needed to fully understand the process, but by using such fairly simple means it is possible to go to the heart of a complex technical apparatus and understand the basic processes without getting lost or bogged down in highly technical language and detail, which are for the specialists. Such a level of understanding the world around us is, I think, essential on the journey through childhood into adult life.

Although everyone today listens to the radio and it is a familiar experience, every time a student makes such a rudimentary radio, the moment it works is one of great excitement and disbelief that an array of such simple apparatus can really work.

The sense of achievement helps to dispel the sense of fear of the electrical unknown, which I find is one of the biggest barriers for students to overcome.

One of many pieces of equipment tucked away in the back of my laboratory is a transparent box full of invisible magic glasses. On occasion I issue these with great ceremony to the class, telling them to put them on with great care. These glasses are capable of making the invisible visible under my direction. So if I give you a pair of these now and ask you to put them on, decreeing that all you will see will be magnetic fields, what do you see? Firstly you will see a faint haze all around you caused by the earth's magnetic field. Then, if you are in the kitchen, you will probably see some quite bright blue (all magnetic fields are in shades of blue with these glasses) small areas on the kitchen cupboard catches, and the fridge will have a halo round the outside of the door where the magnetic sealing strip is fitted. Suddenly there is a brilliant flash of pulsating color from the washing machine—and so we could go on. The whole world is engulfed by active magnetic fields, part natural and part manmade, and the same is true if I change the glasses now to see only electrical fields. Every washing-up bowl, every telegraph wire, every cloud in the sky is scintillating with dynamic electrical fields, again part natural and part manmade.

One radical and far-reaching change in the appearance of the electrical fields that you would have seen with your magic glasses would have been the arrival of many compact, rapidly scintillating patterns located in homes, offices, banks, factories and schools all over the industrialized world. These would be surrounding the ubiquitous computers of our time. There would also be slightly less compact but highly complicated magnetic patterns, but these would not be in such a frenetic state of activity. For most people this latest brainchild of mankind appears brilliantly clever but remains a closed book in the way that it works. The detailed understanding is for the highly trained specialist, but the overall grasp of basic functions is for everyone.

For the first time in our electrical history we have produced a machine which has gone a long way in separating the electrical and magnetic field effects, and we only now begin to use electricity as such, rather than using it permanently wedded to magnetism, as in the electric motor for example, and hence its real nature becomes more apparent.

Using your special glasses, look first at the reels and discs that are used for storage of computer information, for these are static patterns and easier to understand than the whirlwind of electrical change. What you see are millions of tiny patches of magnetism and between them small spaces. That is what the storage of computer data really is, and has nothing whatever in common with the names and addresses, for example, that we store in a computer, except that the two are connected by a code. The code is very similar in principle to that invented for the telegraph by Morse in 1832 at the very beginning of the electrical era. All the letters of the alphabet, punctuation and numerals 0 to 9 are represented by a series of three types of symbol: a dot, a dash and a space. Using this any written words can be encoded and decoded, but the process is slow and laborious.

The code used in most computers consists of only two symbols or a binary code as it is called. The symbols could be anything you like, a flash of light and darkness, a bang and silence, A and B, A and 'No A,' 6 and 9 or even 0 and 1. The latter is the usual shorthand symbol. In the computer 'memory' this code can be represented by a patch of magnetism followed by nonmagnetic space, or, in the active part of the machine, by an electric field and no electric field. These two representations of the binary code as electric and magnetic fields are at the very heart of almost every computer. The magnetic patterns on tape or disc form a permanent record, while the electric fields are a transient dynamic process of change. These changes happen at very high speed and are preordained by the design of the machine, the codes in the magnetic memory, and the actions of the machine operator.

It is rather like playing a piano. The music is a very complex permanently coded record like the magnetic memory, the player is the machine operator, and the string vibrations created in rapidly varying patterns are the electric fields in the machine.

The huge leap forward that computers have taken is that they can to some degree play their own tunes automatically, and this they can do at unbelievable speeds. This process mimics the processes we ourselves go through as we juggle our own thoughts, which shows new characteristics of the nature of electricity.

Over the past one hundred fifty years or so we have spun round the earth a vast complex web composed of billions of miles of wire, under the oceans, through our cities, into our homes. Just keep your glasses on and go for a walk in your nearest town or city, but this time the glasses will show you only wires. Every lamppost, office, shop and factory is a labyrinth of coils of wire, each positioned carefully by hand in the correct place to perform a specific function. Quite a sight, isn't it? What is it all for? It controls power from power stations to our machines and it communicates information from place to place with telephone, radio and television. At least, the wires don't but the electric and magnetic fields do, but these are only our ideas, our models of what is really active. What has happened for us is that the world has shrunk and become one place.

An electrical system that allows almost instant communication between far-flung places has a similar function to that of the nervous system in an organism. Awareness of what is going on in the world and the ability to communicate instantly are what we are all experiencing as the network rapidly develops. No piece of electrical equipment really exists in total isolation but is all part of this gigantic world web, and if we consider a radio and examine only one instrument alone, it is rather like examining one leaf on a tree. A radio is really only one focus of the whole system and has meaning only when it is related to the whole communications network.

The answer to the six-year-old's question: "How do all these people get inside the radio?" is not perhaps to imagine that we have to compress everyone into one specific box, but rather to expand our ideas of the global nature of the electrical culture, and then, why, yes, we even all have breakfast inside, too!

Introducing Chemistry to Children in Their Fifteenth Year
by H. FRIEDBERG

The awakening of an understanding in children of the colorful and manifold world of chemical processes can well be compared with the activity of weaving. Threads from various directions, partly from everyday life, partly from what the children have learned in other lessons such as physiology, nature study and physics, have to be woven into a tissue which, in spite of the variety of its pattern must become a unity of its own.

The four elements have already been introduced to the children in earlier classes as well as the great opposing forces of gravity and levity; they have acquired an understanding of the threefold human being and of the plant. On this basis we can hope to be able to build up the concepts of acid and alkali, oxidation and reduction, and of earth, salt, metal and nonmetal in a living and meaningful way. All processes are introduced in their full significance for the inorganic and organic kingdoms of nature and for the world of human activities.

We can begin with a simple experiment burning a handful of straw under a funnel. The result is fumes and ash, both of which are tested with litmus paper. We find that the fumes turn it red like lemon juice or vinegar and the ash turns it blue like soap or soda. In passing we may draw attention to the charcoal appearing as an intermediate product and still bearing the exact shape and structure of the original straw. Carbon appears to be the structural element, the bearer of shape in plants. The elusive, volatile fumes appear as acid, the earthlike, dead ash as alkali. Fire seems to separate the opposites. While the plant grows it draws from both the atmosphere and the soil, water being the element uniting the two. Fire splits what the water has united in the living plant.

Something similar to this fire process takes place in the human being and the animals: breathing. Here also an acid air is exhaled and an alkali solid deposited. But in this case the latter has an organized structure appearing in the form of bones or shells whereas ash seems to be shapeless. We need, however, only dissolve it in a little water, filter and leave it for a few days and its shape will appear as crystals. They are the bones and shells of the earth organism. We are thus led to see an external combustion process as an organic function of the earth as a whole, belonging to the macrocosm as breathing belongs to the microcosm.

We can then draw attention to the part played by light and warmth. The black, charred residues of a plant showing all details of shape bear witness that light has died into the plant in order to create shape. In burning, light once more appears while form is destroyed.

By burning other substances, such as sulphur, phosphorus, and magnesium, and testing the combustion products with litmus, we can show that they are not so balanced as plant substance, yielding either an acid or alkaline product, never both. Thus onesideness is a feature of all pure chemicals.

By letting a candle burn in an inverted flask whose neck is immersed in water, we find that combustion soon comes to an end. The air has obviously undergone a change, for another flame introduced into it now goes out immediately. The duality of air can be dwelt upon here. Oxygen and nitrogen, active and inactive air as they were suitably called in the past, a life-intensifying and a suffocating substance, are contained in it.

By preparing some oxygen we show how much more intensively substances burn in it, even iron. But what would happen if this substance were alone in the atmosphere? Life would proceed at an enormous rate and come to a speedy end, intensive life soon followed by universal death. Nitrogen, the bearer of the death forces, wisely mixed with oxygen and mitigating its violence, brings balance into the atmosphere. In the protein substances where it also occurs in proper proportion with oxygen, it builds up the body of those beings in which consciousness is awakened. Thus we see the same substance occur as an expression of wisdom of the macrocosm and as the physical bearer of consciousness in the microcosm.

Active air or oxygen is the driving force in all processes of combustion. By burning the substances it takes them out of their state of isolation and brings them into the interplay of chemical reactions. The metals too, which in their pure state are much more cosmic than earthly in their nature, are forced by oxygen to assume an earthlike appearance, except the most noble ones. Here it is not actual burning but a process of slow oxidation which turns a metal into a calx, a kind of earth, destroying its shine and coherence.

Most metals occur in the calx state as ores and have to be extracted. This is done with charcoal or coke which turns into carbon dioxide during the process, giving up its structure which it acquired through plant growth. In return the metal is obtained whose coherence and elasticity enables us to build rigid structures, towers reaching high up into the air and bridges spanning wide rivers. This metallic force capable of overcoming gravity has been gained by imparting the levity of the plant in the form of carbon to earthlike ore. Thus the force enabling a construction like the Eiffel Tower to stand upright against its weight is nothing but a metamorphosis of that which upholds a tall tree. The bright shine of the metals reminds us of the light which once made the tree grow. Here we can demonstrate metal extraction by reducing some lead or copper oxide on a piece of charcoal in a blowpipe flame. After having stimulated an initial understanding of the metallic state in this way, we can suitably proceed to a study of oxidation and reduction. With a piece of copper sheet we can easily show how on heating it in air the shining, elastic metal forms a skin of black, brittle oxide. The intermediate state where metal and calx seem to fight with each other manifests itself through the appearance of bright spectral colors on the surface. Color comes about always as the result of a struggle between light and darkness, represented in this case by the metal and its calx.

We now detach some of the black skin from the copper and, after having shown that it is insoluble in water, heat it with strong sulphuric acid. Dilution with water produces a blue color. The levity of the acid has lifted the calx into the water element by turning it into soluble salt. We can carry out the same experiment using as ash, say, that obtained by burning magnesium.

Thus there are three successive stages: metal, calx, and ash salt. On this basis we can now investigate what happens if we try to skip the calx stage by treating the metal with acid directly. Iron or zinc is more suitable for this experiment than copper. We find that a gas is liberated while the metal dissolves forming salt. With this gas, hydrogen, or inflammable air by its old name, we carry out a number of experiments which show that it is very light, that it burns with a very hot flame, forming water as its product of combustion, and that it can recover metals from their calxes. It is the polar opposite of oxygen, and other experiments, which cannot so easily be carried out in a school laboratory can show that it has a strong relationship to metals.

In our reaction of metal with acid the metallic qualities which in calx formation are overpowered by oxygen thus seem to escape in the form of hydrogen which therefore might suitably be called 'spirits of metal.' The four gasses with which we have so far been dealing bear a definite relationship to the four elements:

Hydrogen, inflammable air, spirits of metal	*Fire*
Nitrogen, inactive air	*Air*
Oxygen, active air	*Water*
Carbon dioxide, fixed air	*Earth*

We can now proceed to deal with those substances which play their main part in the watery element, the salts. We had obtained salts by treating copper calx or magnesium ash with sulphuric acid or dissolving zinc in it. If we now take some copper sulphate, put it in water and heat it, the crystals disappear, imparting their blue color to the solution. An expansion, a levity process takes place; shape is lost but the qualities of the copper sulphate—its color, taste and chemical properties—have spread throughout the liquid. If we make our solution rather strong and then let it cool slowly, the opposite process takes place, crystallization; shape is recovered. The salts stand between earth and water, some of them so strongly related to water that they become liquid even on standing in a damp atmosphere, others so earthlike that they are practically insoluble in water. If alkali is added to a salt solution, in very many cases a precipitate is formed which dissolves again on adding acid. We have in this another aspect of the relationship of acid to levity and of alkali to gravity.

When we were burning plant material, we obtained acid fumes and an alkaline ash. By heating a salt, say the one obtained by dissolving iron in sulphuric acid, we can bring about a similar separation: acid fumes escape and a brown earthlike iron calx is left behind. This process as the formation of salt from calx or ash and acid shows that salts are built up of acid and alkali. The fumes escaping from the iron sulphate are an oxide of sulphur, similar though not the same as that obtained by burning sulphur. Both acids and alkalis thus originate from burnt substances and the process of salt formation can be represented in the following way:

Metallic substance	Nonmetallic substance
burnt or oxidized	*burnt or oxidized*
forms an Alkali ash or calx	*forms an Acid fume*

They neutralize each other
forming a Salt

We can demonstrate very impressively what neutralization means by first showing the corrosive nature of hydrochloric acid and caustic soda, then neutralizing one with the other to produce a 'harmless' salt solution.

Some salts do not have a neutral reaction to litmus, but either a weakly acid or a weakly alkaline reaction. In the first case we have a salt of a weak alkali with a strong acid (copper sulphate, iron chloride); in the second case one of a weak acid with a strong alkali (sodium acetate, potassium carbonate). By heating common salt with sulphuric acid, we can then show how a strong acid can drive a weaker one out of its salt. The result in this case is hydrochloric gas or spirits of salt as it used to be called, a very acid gas, and sulphate of soda.

In the salts we thus have substances bearing a strong polarity within themselves. They are mostly soluble in water and when dissolved show a tendency towards separation of the acid and the alkaline constituents so that each of the two can easily react on its own. Because of this, in a solution containing several salts, reactions of exchange take place easily, the mixture is in a state of equilibrium and lability, and only when crystallization begins will it become apparent which individual salts will actually be formed. This depends very much on the conditions, temperature and concentration under which crystallization takes place. These are the factors determining the structure of the salt deposits found in many parts of the earth with their manifold layers each containing different salts. Although they form part of the solid earth they still remind us of the instability and variability characteristic of the watery element. We can show this by mixing, for example, dilute solutions of chloride of lime and sulphate of soda. A crystalline precipitate appears which consists of neither of the two salts originally mixed but is sulphate of lime, gypsum, a salt often found in thick layers at the bottom of salt deposits.

We can now go on to dealing with the substances forming the bulk of the solid crust of the earth. The children have already learned something of the principal kinds of rocks which we meet in various parts of the earth. There is limestone which forms such mountain ranges as the Cotswolds and the Jura, never very high and mostly round shaped and overgrown with vegetation. Fossils are found in limestone, showing that it was formed by precipitation from the sea.

The earth's highest mountains ranges are built up of a different kind of rock. Their shape is pointed and they are very steep. No fossils are found in this kind of rock; the whole appearance and also the finer structure suggest volcanic origin. These rocks consist of silicates, and silica is found in them as rock crystal and quartz.

Thirdly there are clays and slates. The former are too soft to form mountains; the latter occur in low mountains and also bear fossils, especially plant fossils which are found less frequently in limestone. Alumina is the most important constituent of this kind of rock. In its chemical nature it stands in the middle between lime and silica.

We treat a piece of limestone with hydrochloric acid and see that a gas is liberated while the limestone gradually dissolves. This gas is carbon dioxide which was fixed in the limestone, fixed air, which in this state is taken out of the carbon life cycle between the human being/animal and the plant. The solution we obtain as the result of our experiment contains chloride of lime (calcium chloride), a salt with an enormous affinity to water. A crystal of it will become liquid if exposed to the atmosphere.

Fire also drives fixed air out of limestone. If we heat a piece of it strongly for a while we obtain a substance which reacts violently with water. If we pour some water on a piece of this quicklime it will sizzle, form steam and in the end turn into a powder which is quite dry. This is slaked lime, an alkaline substance used for building. Its hardening is a reversal of the process shown in our last experiment.

We can also dissolve finely divided limestone, calcium carbonate, in water containing carbon dioxide, which all natural water does. Caves in limestone mountains are formed in this way. On boiling or even standing in the open this solution will precipitate the lime again. When this happens in nature various lime structures are formed—imprints of leaves found as fossils, stalactites, and so forth.

We have thus discovered that limestone is soluble in acids and has a strong relationship to water which carries it with it in its course precipitating here and there and dissolving again. This behavior reminds us of the part played by sugar and starch in plants and animals.

If we pour some hydrochloric or sulphuric acid on silica in the form of a piece of quartz or some quartz sand, nothing happens at all, not even if we use highly concentrated acid and also heat the mixture. But if we heat quartz sand, preferably finely-powdered, with a strong alkali, say caustic soda, it will dissolve. We can then treat the mixture with water, pour off the clear solution from the undissolved sand and add acid to it. A white precipitate of gelatinous silica is formed. We see that whereas limestone is soluble in acids, silica is soluble in alkali, the substance formed being water glass. If both lime and soda are melted together with silica, real glass is formed. Most precious stones consist of silica which has a strong relationship to light. The more silica glass contains, the more light can pass through it.

In contrast to lime, silica has no great affinity to water—only water glass is soluble in it—and this is reflected also in the fact that limestone mountains are dry as they swallow the rainwater, whereas in mountains consisting of silica rock, every slope abounds with streams.

Clay and slate form the third group of rocks we have mentioned. Clay is partly soluble in both acid and alkali. By heating it with strong sulphuric acid and diluting it with water, we can, on adding some potash, obtain beautiful octahedral crystals of alum. Heating with strong alkali and diluting produces a solution from which alumina can be precipitated in a gelatinous state by neutralization with acid.

Clay thus gives both the reactions which occur with lime and silica: it can be dissolved in acid which leads to the formation of a well-crystallized salt as well as in alkali. Through its plastic qualities, its impermeability to water and its dual chemical nature, clay reminds us of the fats in a living organism.

Lime has an alkaline nature, silica an acid nature, and alumina can react as both an acid and an alkali. In living organisms lime occurs in the bones and shells, silica occurs in the skin and hair and the feathers of birds. The formative element of silica tends to produce subtle shapes, that of lime mostly round ones.

In a well-balanced soil all three kinds of rock occur in a disintegrated state mixed with organic material. We can demonstrate this by heating some soil so that the organic material is burnt, then treating it with acid which dissolves the lime, and finally extracting some of the alumina and silica by heating it with alkali. This experiment is quite impressive because of the surprising changes which take place in the appearance of the soil during such treatment.

Manufacture of quicklime, glass-making and pottery are the three main industries based on lime, silica and alumina respectively. Being the oldest chemical industries besides metallurgical processes, they can be brought in at this stage of the lesson.

In the way described above we have been dealing with chemistry in an elementary way on the basis of the four elements. Beginning with combustion we went over to a study of the most important gasses and their chemical actions. Then we proceeded to the substances occurring in the watery part of the earth, the salts, and finally to those building up rocks and soils. On the basis of such a study we can easily go on to a more detailed treatment of the subject in the following chemistry periods by widening and deepening the various aspects touched upon here.

The Place of Physics in the Waldorf Curriculum
by ALAN HALL

Our everyday life is becoming ever more enmeshed in a highly technical culture, from satellite communications to computers, plastics to credit card money. We all need a basic map of modern technology, and how it has come into being, to keep a human orientation in a very complex world. Our children will grow up with such a world and must learn to live and work with it, to be able to use these developments wisely and not be used by them.

This high-tech world has developed in recent centuries through a particular mode of thinking and working with the natural world around us—the application of experimental science. At school these two important areas of human activity, science and technology, need to be introduced in such a way that students of differing abilities and interests are able to learn the technical, scientific, human and historical aspects of such fundamental changes in human affairs.

In physics, the range of subject matter is at first sight bewilderingly large, but there are certain areas of study that show principles and processes very clearly. The key initial process for all children to experience in the experimental and scientific method is observation—of simple everyday phenomena—followed by thought. A dripping tap, a puff of wind, the chime of a bell, a snowflake. Through imaginative presentation, natural curiosity can be aroused in all students. For the potential specialist in science, there is much that can be done to sharpen the senses and clarify the thought processes that are essential for later specialization in all subjects.

Already at the stage of early adolescence, the class teacher tries to guide the students in their first efforts at observing the world objectively—'scientifically'— in order for them to discover and comprehend some of the natural phenomena by means of their evolving powers of thinking. Whereas up to now animals, plants, geography and history were the immediate objects of study, now more indirect questions arise, such as: How do things work? or better, What is it that makes them work? To creep behind the outer show of things in order to discover hidden forces of nature working there becomes the order of the day.

Light is invisible—as a duster shaken into an invisible beam of light in a darkened room will reveal. Sound is a purely immaterial force. How else could one understand that it will travel faster and more freely through the hardest rock than through air? How is the teacher to tackle such subtle questions in a Class 6? An adult may well begin by pondering about them, but twelve-year-olds are only just beginning to develop the activity of thinking, and this, to many of them, is by no means an easy task. To expect them to adopt adult ways would be like asking them to ride nonexistent horses.

The answer lies in making many simple experiments. Not the sophisticated kind, artificially contrived in the laboratory, but experiments which bring into focus common and already familiar occurrences in ordinary life. For example: What is it that makes a setting sun appear red in the sky? After a burning candle has been fixed to a desktop, each student was given a piece of clear glass. Carefully and skillfully it had to be moved to and fro above the candle flame until a graded layer of soot covered the underside. A welcome silence during this operation was suddenly interrupted by a call of surprise: "The candle flame now looks red!" And when we went outside to look through our darkened glasses at the pale winter sun, it appeared deep red although it was only morning. We had made an artificial sunset!

Having lived in the world of light and darkness, in ethereal rainbow colors and grey shadows, we now entered a more mysterious realm, the realm of sound. Objects were knocked, tapped or otherwise coaxed into emitting a sound. Blindfolded we could distinguish a cracked plate from a whole one, the sound of a noble metal from the thud of a plastic spoon. We realized why doctors knock at our chests and dentists at our teeth: Sound reveals hidden qualities.

How does it travel? How fast does it travel? A resident in the adjoining neighborhood may well have wondered what the class was up to, as one student was clashing a pair of cymbals at the bottom of the hill while we others stood at the top end, counting the seconds between what our eyes could see and our ears told us.

Back in the classroom we found that it is possible to make music with practically any object. Glasses were ringing, wine bottles were singing, ordinary pieces of string provided pizzicato tunes whose pitches were determined by length, thickness and tension of the strings. What is the 'vibrating column of air' and where is it used? A trombone, clarinet, oboe, flute and trumpet appeared in the classroom. One day, so did a whole collection of twisted and defunct gas pipes which a boy had carried to school, trudging four miles through ice and snow. (It was interesting to find that only a few students had a natural skill for making these pipes sound like a herd of cows, while others, cheeks abulging, could not produce a single sound.)

Why do larger objects produce a lower sound than small ones? What is the difference between pitch and volume? One rainy morning Mrs. Syed's well-worn bicycle provided the answer, just in the nick of time. While eager volunteers turned the pedals of her bicycle, now upside down on the teacher's desk, the rear wheel was spinning in midair. When, with increasing speed, a strip of cardboard was held into the spokes, there was convincing evidence indeed: the faster the vibration, the higher the pitch. (As the rear wheel was spinning madly, a generous splattering of rainwater, dirtied from the road, reinforced the message.)

The daily experiment was like the daily bread whose nutritional value was enhanced when each student could share in actually making the experiments. There were those gratifying moments when students invented their own experiments in order to illustrate underlying principles. It was no longer a case of 'teacher telling them all about it,' but there was a common striving towards finding answers. The child had become a fellow seeker.

Throughout the hurly-burly of these first science lessons, over which there hovered a spirit of adventure, there gradually arose a growing awareness of the grandeur and sublimity of the divine forces which once created this world with all its hidden laws. A feeling of wonder emerged, expressed so beautifully in a poem by John Dryden, a poem which became the theme of this main lesson period:

From Harmony, from heavenly harmony
This universal frame began.
When nature underneath a heap of jarring atoms lay
And could not heave her head,
The tuneful voice was heard from high:
"Arise, ye more than dead!"
Then cold and hot, and moist and dry
In order to their stations leap
And music's power obey.

After receiving a rich and wide-ranging introduction to science from the class teacher, the Upper School student's faculties change and grow a great deal, so that each year different subjects and approaches are used to suit the stage of the class. For instance, in Class 9 the fourteen-year-old adolescent meets the principle of polarity in art and through working with black and white, or in English with the contrast of tragedy and comedy. He needs to come to terms with the physical environment, so in physics the principles and historical development of engines from early steam to satellite rockets are discovered, together with the beginnings of modern communications through the telephone. These two developments have changed the face of the earth in the last hundred years. Children should be aware of how this has happened and of the scientific discoveries that have made it possible. At this stage the work is treated in a very practical way. These two subjects show very clearly how the activity of polarities of heat and cold in engines, positive and negative in electricity, and north and south in magnetism—have been harnessed by the human being.

In Class 10, with the growth in self-awareness, physics subjects move away from the purely practical to areas of more inward experience such as sound, rhythm and vibration, and to the principles of mechanics. In Class 11, the analytical faculties are really developing strongly, and the communications theme from Class 9 is continued with the study of electronics, radio and television in their scientific, technical and social aspects.

In the last year at school, science main lessons can meet the more intellectual teenager by looking in detail at some of the modern questions in science, such as the wave-particle duality of light and particle physics, and by looking back over the preceding years to see how such questions have arisen. The study of astronomy, for example, clearly shows the human being's changing understanding of and relationship to the world around him from early mythologies, through the Renaissance up to the quasars and black holes of modern cosmology.

Many deep questions arise from such a course of study, which is completed by all students in a Waldorf school, and it is the asking of right questions that ultimately leads us forward. Part of the task in the science curriculum in a Waldorf school is to encourage the student to formulate the right questions.

Discovering the Seashore
by DAVID SHARMAN

What a delight it is to walk on the seashore with the feel of the sand, the smell of the sea, the cry of its birds and the restlessness of the waves. This natural space usually allows us to relax and dream, dig sand castles or play in the water. But how many of us are aware of the rich world of plants and animals that inhabit this place?

The curriculum of a Waldorf school suggests courses in botany and zoology in Classes 11 and 12 (ages 17 and 18). Here the teacher can introduce the great diversity of the plants and animals and their dependence on one another. However, it is also important to introduce a more detailed study of a particular environment, in order that the students can become involved and observe nature themselves. This is not an easy process and calls for patience and perseverance in the young observers.

The teacher has the task of encouragement and sharing his own observations with them. In this way a world of beauty in form, color, biological association, feeding habits and reproduction is revealed. This is one of the joys of a teacher and has been mine particularly. In Classes 11 and 12, I have arranged short marine biology courses, either as visits to the same shore through different seasons or, sometimes, as visits to different shores over several days. Most of the time the rocky shore is our chosen site, as here is found a richer variety of organisms, and the plants of the seashore—the seaweeds—are confined to the rocks for secure attachment. Our visits are chosen to coincide with the lowest tides, thus most of the shore is exposed for our observation. We always set off carrying collecting equipment—buckets, jars, nets—and notebooks and pencils for records.

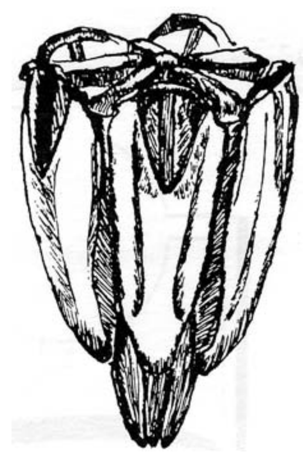


Fig. 16 *Aristotle's Lantern*

Time and tide wait for no one! So sometimes this demands a very early start or a later evening visit. Weather never deters us—even in a snowstorm or bitter cold we have been on the shore, and so each visit has its own particular quality as a total experience. Soon we are scrambling over rocks covered with wet, slippery seaweed. Now is the time for a pause and a chance to notice as we go down to the sea that different types of seaweed live on the shore. By type of seaweed, the shore can be divided into upper, middle and lower zones.

The continuous ebb and flow of the tides means that organisms in the upper zone are exposed to the air, wind and sun for much longer periods than those of the lower zones. Hence, all forms of life in the upper zone are seen to be well-equipped to resist desiccation; their lifestyles are drastically interrupted during the exposure, and life processes only return to normal when covered once more with water. The shape of the seaweeds is important to survive the constant movement of wave action. The simple dichotomous branching gives it a two-dimensional form, and buoyancy is maintained by some with air bladders and others with their inherent lightness compared with sea water. These plants all belong to the group the algae—green and photosynthetic by nature, in many of them the greenness masked by other pigments, giving a colorful pattern of reds, purples and browns.

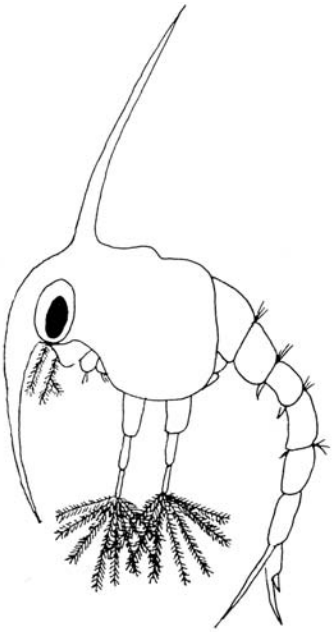


Fig. 17 *Shore crab*

It is, however, the animal world which abounds here: animals without backbones (invertebrates) are especially well-represented, and examples of most major groups are found. Fish, of course, are the important vertebrate, though many seabirds are often seen. Where are all these animals? As we look towards our feet, trying to maintain the balance of a tightrope walker, we see little.

We are perhaps nearing the lower middle shore and now is the time for diligent searching, bending down, lifting seaweed, turning and returning stones, peering into every nook and cranny. Now one enters the cool damp animal world. Catching our eye at first are perhaps the encrusting sponges and brightly colored sea anemones, both plantlike and sessile. Many common starfish and sea urchins are found, and under stones the brittle star hides. These radically symmetrical animals are most beautiful in color and form. The starfish with great strength can pull open the valves of a mollusk such as the mussel and rapidly digest its softer parts. The sea urchin is a vegetarian and lives by scraping algae from the rock surfaces using its complex toothlike structure which, when dissected, shows an amazing pentamerous form known as Aristotle's Lantern. Crabs and small fish can be disturbed in the rock pools. A rare and exciting find, I well remember one year, was an octopus stranded in a small pool. We were able to catch it in a bucket and all stood round fascinated as we watched its quick breathing and turning to a dark brown color as it adjusted to its surroundings; even as we

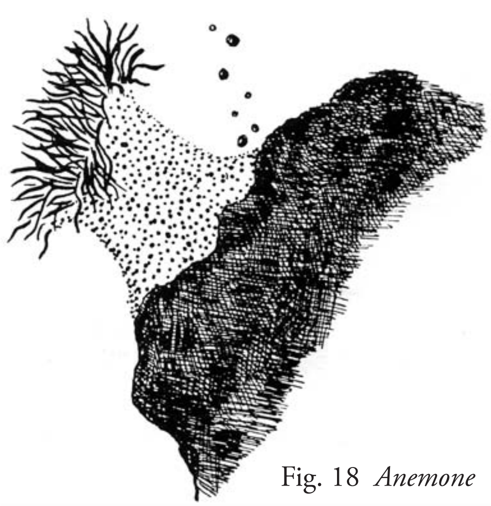


Fig. 18 *Anemone*

watched, waves of color seemed to pass through it. A little later we released this incredible animal into a large pool and watched spellbound as it swam away using its jet-propulsion pulsations to move body first and tentacles trailing behind.

How many of us have cut a foot on a sharp barnacle or tried to move a limpet from its seat? Very seldom can we observe the barnacle on the shore in action as a living organism, as it needs to be covered with water to unfold. So this is one of the treasures we take back to our marine aquarium for observation in the laboratory. Limpets, too, show activity only when the tide covers them; then they move off to graze on the algae, but always return to their 'home' seat before the tide ebbs.

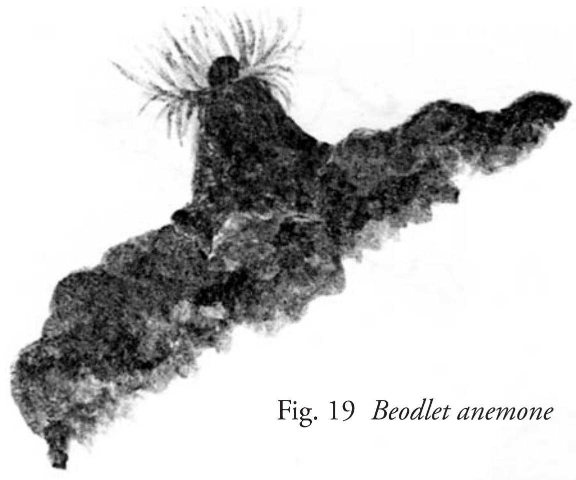


Fig. 19 *Beodlet anemone*

Now time must be given to looking at our collection, notes taken, photographs made. Some specimens are selected to take back to school for our marine tank, the rest are returned to the pools. Containers of seawater must be collected for the aquarium. On our return to school our collection is further investigated and identified with the help of a low-powered microscope and magnifying glass. This part of our study reveals so much more than is possible on the seashore itself.

One summer we brought back a female shore crab 'in berry' and she was put into our aquarium. Next day a puzzling mass of moving specks was seen. On looking at these under the microscope there danced before our eyes some queer little creatures—a large head, prominent eyes, two spines and a thin body and tail—these were the *zoae* larvae of the crab, so unlike the adult, and a wonderful example of a metamorphosis one can find in marine life.

Fig. 20 *Acorn barnacles and bladder wrack seaweed*

Barnacles too, are a good example of metamorphosis, the sessile adult having transformed from a free-swimming larva. These adults we enjoy observing in the aquarium when their feathery limbs unfold and beat in delicate rhythm, causing water currents to flow and provide them with food and oxygen.

When housed in our aquarium, tiny white calcareous tubes encrusting rocks, stones and seaweed, have revealed the beautiful delicate fans of the worms that inhabit them. These worms have also given us the interesting opportunity to observe under the microscope the process of fertilization.

Our thoughts can turn to the human being and see how he, in his uniqueness, can do many things which an animal, locked in its hardened nature, can do in only a single, limited way. We can use our soft, mobile, creative hand, its forefinger and thumb for one brief moment to pick up a crab, and for an instant we see it in comparison with the crab's set, harsh pincers, restricted entirely to a grasping nature.

For these young people, this experience of the wisdom and beauty of nature enhances for them their own being as a human, with his upright stance, his speech and his thoughts. It teaches them compassion for their fellow creatures and thankfulness in particular to the earth with its mantle of green plants and the gifts therefrom. The outer world can stir the inner world to thoughts of a divine nature even though no words of this are spoken (see figures 16–24).

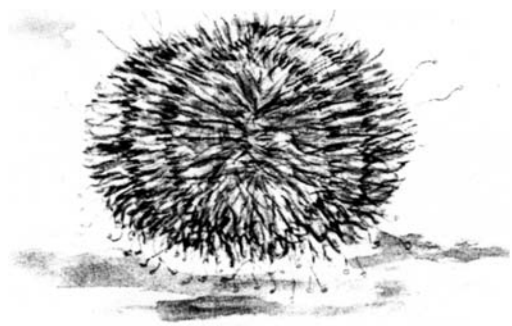


Fig. 21 *Common sea urchin*

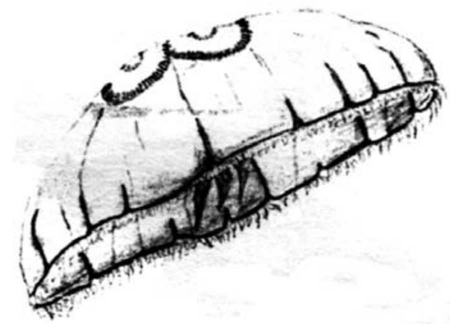


Fig. 22 *Medusa*

Fig. 23 *Octopus*

Fig. 24 *Common starfish feeding on bivalve*

Teaching Biology in a Human Context
by GRAHAM KENNISH

"Your body is a space capsule, your head the command module." So begins the introduction to a three-dimensional moving pop-up picture book on the human body now available in the UK. "When you reach puberty your hormones switch you on," announces a heading in the London Science Museum permanent exhibition called "A Study of Ourselves." An advertisement for beer, displayed on vast billboards in the UK recently, shows a series of apelike figures progressively reaching a vertical posture, the penultimate figure with a bowler hat (as symbol of the English business gentleman) and the final form carrying a can of the respective beer. A question mark points to the potential evolutionary leap which awaits discerning drinkers.

These three examples are particularly gross reflections of beliefs deeply held in the West, beliefs firmly underpinned by faith in scientific objectivity. One of these is that the human body is nothing more than a highly complex machine which human beings will eventually be able to take apart and reconstruct. A second, that our bodies and our minds are subject to the outcome of a complex chemistry. The third, that human beings have evolved from a primitive animal/condition and that any further evolution is in the random and arbitrary hands of environmental influences. In teaching any science to adolescents, one is aware of the forceful nature of these beliefs which are carried subliminally and openly throughout our culture.

One of the hallmarks of a good scientific theory is that it should be capable of being disproved. This would seem to guarantee the absence of dogma in science, as any theory, by definition, worth its salt will eventually be superseded. Human nature, however, is stronger than scientific principle, so from black holes in space to human evolution, theories rapidly harden into tablets of stone brought down from a mountain of research. If we experience surprise, displeasure or vague discomfort in reading such statements as those below, then we can be sure that we are taking current theories for granted or carry memories of school science unchallenged within us:

- Atoms do not exist.
- Human beings did not evolve from apelike ancestors.
- Life did not evolve from a primeval organic 'soup,' nor the universe in a gigantic explosion.
- The sun is not a ball of atomic fire.
- The heart is not a kind of pump.
- The brain is not a kind of computer.

Any twinges? How free are we in our thinking to consider alternative views or even challenge current ones? Cemented and consolidated as current theories are, through years of experimental measurement and poured out in textbooks, magazines, films, games and models, opposition can invite ridicule, disbelief or an accusation of a lack of objectivity or ignorance of highly specialist research techniques. Yet the history of science is filled with the birth of ideas that run directly counter to customary modes of thinking, and the very birth of scientific inquiry was the birth of an independent and free spirit of inquiry, unconstrained by tradition and religious or social pressures and prejudices. Galileo and Darwin illustrate the struggles; but it can take the kind of extremism in evolutionary fundamentalism or creationist ideas again to dent contemporary evolutionary science.

What is objectivity? Is it confined to what can be measured in mass, distance and time, or can it include the faculty of observation, thinking and an open mind? There may be few technological or military applications in an open-minded contemplation of the universe, but this must surely always remain the bedrock of free-thinking inquiry and scientific progress. We stifle or undermine it at our peril.

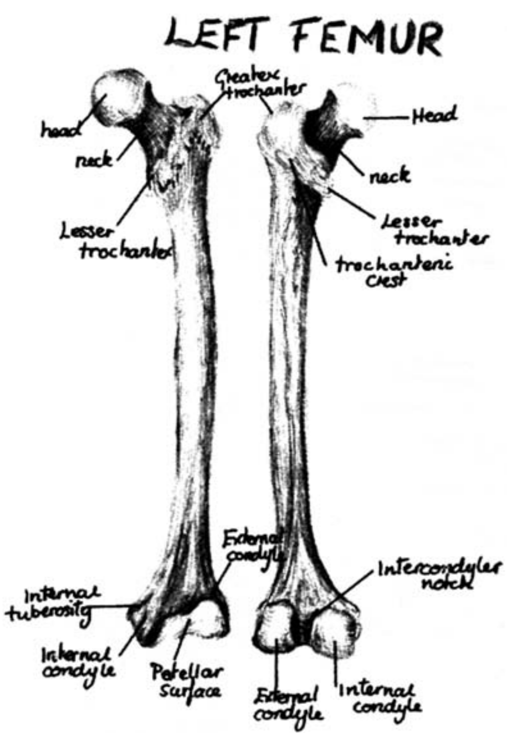
These considerations are crucial to the teaching of science to adolescents in a Waldorf school, and the main lesson in Human Science for Classes 9 and 10 (fourteen- to sixteen-year-olds) illustrates this. The periods are widely known as Human Science to allow the widest possible context to the biology arising from this. How can the wealth of knowledge currently available about the human body, for example, be presented without a fragmentary succession of organs and systems, implying that all these and more constitute the whole? What meaning does the liver have, torn from its context of blood and digestion? What meaning does the digestive system have, torn from the context of daily life? What meaning do any of these organs have in relation to one's inner experience as a human being? A teacher could be tempted to overcome these problems and make the subject relevant to life merely by linking the study of items of popular interest: alcoholism, liver disease, digestion and a healthy diet. Such connections stimulate interest, but alone they fail to meet the adolescent's deeply held conviction that there is meaning and mystery in the world. Unless there is a context for biology which carries 'food' for these, an adolescent's thinking will be confined by the practical or the popular, and so deeper, less conscious, questions will remain unaddressed.

One aspect of biology that has, until recently, received little consideration is that of *form*—why living things have the shapes they do. In human science a considerable part of the work should be an experience of form by drawing and modeling, so that observation and thinking retain all the mobility which other lessons like those in music, art and movement have developed.

To illustrate how observation and thinking can create a meaningful context within which fine details and invisible processes can be studied, let us consider the form of the human skeleton. The form of the human head is spherical. At the extremities of the body are opposite forms, linear, angular, jointed (see fig. 25). Between head and legs, the ribs (which are both linear and curved) create a materially incomplete enclosed surface (the ribcage), protecting the soft tissues of the heart and lungs, as the skull does the brain, and bone marrow. The head is still, the skull plates fused, with only the jawbone moving, like a limb. The upper ribs move in breathing but are fused together by the sternum. The lower ribs are freer hanging, limblike, opening up the chest cavity into the abdomen. Following these forms and their movement, the opposite qualities of skull and limb with the balancing features of the ribs are clear to see. Care in observation and a thinking faculty which can rove over the contrasts as well as remember details and named parts build a meaningful whole, not quantifiable, yet not arbitrary or fanciful.

Such a picture can be followed into the forms of individual bones (the 'head' of the femur, for example) before it fades into the detail of bony tissue and the process of ossification. This type of approach can be extended to other parts of the body as well as the systems of organs traditionally considered in quite a different context in any standard textbook or encyclopedia. The fundamental difference is that relationships between organs and systems of organs can be considered and grasped without recourse to theories about neural/electrical transmission, nerve/muscle reflexes or sensory/motor nerves. Such considerations should follow as elaborations of thought, but not be considered the foundation for understanding the whole organism.

The nervous system is centered in the head, with nerves leading to and from all parts of the body. The brain rests, partly floating free of gravitational pressure in the cerebrospinal fluid. There is no movement, impulses are silent, invisible—we feel most awake here and alert; our senses concentrate here. Below a sheet of muscle which divides the trunk, the digestive system begins metabolic processes whose outcome supplies the energy needs of muscles which meet the demands of gravity in the limbs. Movement, warmth and activity prevail here and, as a complement to the senses which receive impressions from the environment, limbs reach out and



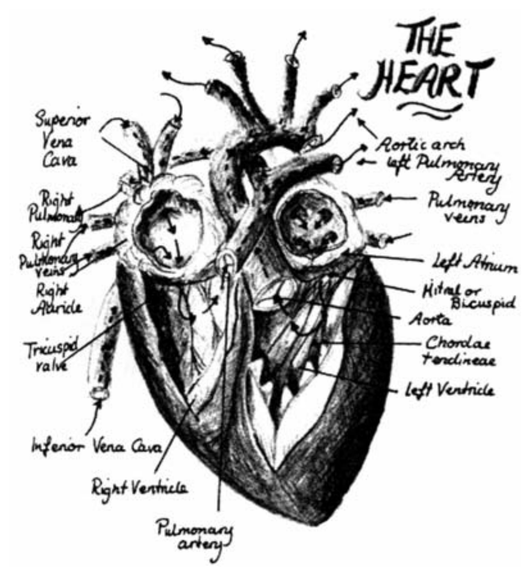


Fig. 25 (left) and Fig. 26 (top)
These drawings are taken from the classwork of a 16-year-old.

impress themselves upon it. Between the two extremes of shape and activity of head and limbs (nervous system and metabolic system) are the rhythmic movements of heart and lung. Rhythm is movement and stillness in harmony. Breathing leads substance outwards into the world and receives from it. The circulation of blood gives and receives inwardly. Our experience of feeling is centered here, brought to consciousness by the head or expressed in movement through the limbs. Our inner experiences as human beings have their reflections in the form and activity of the bodily organs (see fig. 26).

This brief and sketchy attempt to show the context within which the details of the human body may be taught to adolescents seeks to illustrate how a sense of wholeness and meaning can be the foundation of such a study. These pictures are neither fanciful nor arbitrary and are available to any keen observer with the controlled imagination which lies at the heart of objective knowledge about the world. They lead the adolescent to respect and have confidence in his own unaided faculties, so that further study of details and reading about experiments which explore the most minute aspects of physiology can be related to a meaningful whole. Another message received is that knowledge about the human body does not rest solely on the biochemical or genetic analyses of experts, but is a mystery open to any keen observer with clear and mobile thinking. Adolescents also have a context within which to appreciate and admire the results of medical technology alongside the deeper issues raised that challenge human attitudes to birth and death. The adolescent's burgeoning inner life is also confirmed as a reality which the body supports and responds: I have a brain, but I am not my brain. I have feelings, but I am not my feelings. I have a body, but I am not my body. I am, therefore I think. [sic]

Another outcome which follows a consideration of form in the human body is a consideration of the balance and harmony in its architecture. Observation of the animal world can show very clearly that by a one-sided emphasis of the peripheral parts of the human skeleton, for example, specialized animal limbs arise—an extreme development of the digits of the hand gives rise to a bat's wing, bone for bone. One-sided development of the forefinger alone creates the horse's hoof, while any distortions of the balanced forms of human teeth quickly create herbivore (cow), carnivore (cat) and rodent (rat). Distortions of the human form always give rise to animal-like caricatures, as the political cartoonist knows well. Such considerations leave open the question of how the human form evolved. Studies of the animal world return again and again to the human being without whom, after all, observations and questions would not exist

In contrast to this emphasis on form comes what is usually considered the 'real' content of biology—details of gaseous exchange in the lungs, respiration in the tissues, hemoglobin in the blood, excretion in the kidneys, enzyme activity in the alimentary tract. These substances and processes are not directly visible, and most of what is known about them is the outcome of detailed experimental investigations. They demand clear thinking and a vital exercise for the growing teenage intellect quite apart from the factual knowledge of their content. In different degrees, with examples to stretch the ablest students, a whole class should experience the real satisfaction in understanding such biological processes and how each is coordinated by another, to create a harmonious balance against a changing environment. The context outlined previously makes it harder to fall into the satisfaction of the clever intellect which would anticipate that if only enough details were known and added together, like a gigantic biochemical construction kit, the whole organism would be explained.

As with all Waldorf teaching, the choice of what to study is so vast that the question immediately facing a teacher is where to start. And so—also a Waldorf principle—the choice is best determined through consideration of the developmental age of the class. In Class 9, thinking powers are usually not so fully developed as they will be in Class 10 and adolescents live very sharply in their senses, so a beginning can be made successfully with a study of the skin and the very visible and obvious sense organs, for example, the eye. Its intricacy and sensitivity awaken and challenge any tendency to superficial comparisons with a camera. Analogies usually have very limited value and, when held to as teaching aids, seriously distort accurate observation, memory and thinking, leading quickly to the false sense that the eye has been explained. Details challenge such easy paths to understanding, as the following considerations may illustrate.

The light-sensitive cells in the retina actually point away from the light. The act of seeing involves the whole organism, not just the eye, and the image which reaches the retina bears little resemblance to our perceptions of the world around us. We cannot see light but only the outcome of its penetration of matter. At night, outer space is filled with light from the sun but appears black until reflected by the moon. So what is it that we 'see'? Is it a coincidence that we say: "I see" when we understand something? Dim stars cannot be seen when looked at directly but appear when the focus of our gaze is turned slightly to one side. Is this not often true when we search our memories and thoughts? Suddenly a thought 'dawns' on us and we see it 'in a flash.' The genius of language leads us to the wider considerations. So the opportunity arises to consider such fundamental questions as the nature of light, or the biographies of individuals who have been deprived of sight or hearing. The widest possible considerations should be able to arise within a human science period.

In Class 10, the main lesson includes embryology and, as far as time allows, such themes as child development, racial and cultural differences, temperaments and personality. At this age a student's thinking ability and maturity is usually much more capable of doing justice to such topics, particularly to the development of the organs and the human questions that arise over abortion and embryo technology. The major organs of the body having already been considered, their development from layers of folding and enfolding tissue within a matrix of sustaining membranes is a rich and rewarding study. I have felt very privileged to experience how boys and girls of this age can be together and feel free to share some of their deepest concerns and feelings on life, death and relationships arising from an objective study of this miraculous process of development.

At an age when sexual physiology and 'the facts of life,' as they are so inappropriately called, are outwardly known and serious relationships have often already begun, this study of embryology can come as a healing force to adolescents in their struggles to cope with the freedoms and the responsibilities our society has placed on them.

It can be a fitting end to such a period to include also the question of aging. While we talk easily of growing up, it can be quite a revelation to adolescents that to become an adult is to embark on a lifelong experience of learning and development. The "seven ages of man" need not be limited to decline from youthful vigor to dull senility but may include the pathway to self knowledge and wisdom. There rests an opportunity here for adolescents to perceive that the excitement and the challenge, as well as the doubts and anxieties they are struggling with within, are shared at other stages by parents and grandparents too.

Nerves and Senses: The Human Prototype for 'Artificial Intelligence'

by DAVID SHARMAN

Growing up with one's nervous system is a slow progress of awakening. This may be a somewhat surprising remark, as most, if not all, of the nervous system is present at birth, the head being a very large part of a baby. How does the growing child slowly engage in surroundings so that by adulthood the nervous system has reached its full potential? What are the educational implications of this for the Waldorf teacher?

The Waldorf curriculum is built on the child's development so that right educational opportunities are given by both parents and teachers at appropriate times. When to teach 'artificial intelligence' must take the process of maturation of nerves and senses into account. This process can be seen to evolve within the well-known seven-year periods. In preschool times the child is deeply imitative and active and needs surroundings of quality. Here the nervous system is actively engaged, albeit in an unconscious way, in the physical life, so that the baby lifts its head, smiles, responds to the family, crawls, stands upright and walks. Baby talk is followed by astonishingly complex speech. "What joys to behold!"

In the Lower School (ages 7–14 years), life is based on rhythm and authority, education proceeding through the stimulation of feelings for beauty of every sort. One can think of the nervous system now as awakening to a dreamlike existence compared to its sleepy state in the first seven years. The teacher of human biology in the Lower School—usually the class teacher—presents a picture of the human being as a threefold organism: head, chest and abdomen/limb systems. A more detailed study of the digestive and rhythmic systems usually follows part of this presentation, particularly from the point of view of health, hygiene and nutrition.

Next in the Upper School the nervous system comes into its own and should be allowed to awaken fully. The young people are surrounded by specialists to stimulate the thinking, reasoning and critical capacities in the search for truth and the development of integrity and self-discipline.

The nervous system is studied in the human biology main lessons, with fifteen- to sixteen-year-olds, in all its complexities and the problems it poses to our thinking. This having been done, the student is then 'ripe' in Waldorf terms for studying the extension of intelligence as developed in the mechanical world in an 'artificial' form such as we have harnessed in the calculator and computer.

The physical structure of the human brain far surpasses anything found in the animal kingdom. Arising from folds of the outer ectoderm cells of the embryo, it later becomes embedded within the body tissues as a tube. Thus it has the same origin as the skin and sense organs. During further development the forebrain rises and overarches in a backward direction to cover the rest of the brain. Thus are formed the large cerebral hemispheres unique to the upright human being. The cellular construction is so specialized that if it is damaged, regeneration is virtually impossible. This nearly inert system is carried within the body, bathed and floating in the cerebrospinal fluid which protects and lightens it.

Neurologists have located and mapped the cerebral hemispheres and shown them to mirror the whole human being. They allow us to possess the faculties of intelligent behavior, memory and conscious awareness of ourselves. Right and left cerebral hemispheres appear to relate to different capacities associated with the crossing over of nerve fibers in the base of the brain. Usually right-handedness leads to the use and sophistication of the left hemisphere, and vice versa. With further research still to be done, it is thought that a logical deductive type of thinking is connected with the left hemisphere, whereas the right hemisphere is connected with artistic and spatial intelligence. What is intelligence? Here is a baffling question, for each person has "a mind of his own." At one time, IQ tests were considered viable; now their limitations are recognized. Other types of 'intelligence' are seen to be equally valid, e.g. spatial, interpersonal (social), sense of self-centrality, and so forth. *Frames of Mind* by Howard Gardner, an American writer, suggests seven types of human intelligence, all equally important but not all equally developed in one human being. As a human individual gains in achievements, the central nervous system can become more refined and developed so that it is also within a person's will to become a 'self-made man.'

We cannot get a full understanding of the human process of thinking and intelligence without realizing the tremendous importance of the whole system of sense organs—it is in the backward arching hemispheres of the brain that the highly developed areas of perception for external stimuli, through the sense organs, are situated. Each sense perception is met by an inner activity of the human soul and, as Dr. Kolisko says, "Reality lies in the dialogue between the two." Normally, we recognize the five main senses of sight, hearing, taste, smell and touch with complex physical organs present to receive them. Rudolf Steiner also helps us to be aware of several other senses: balance, motion, warmth, and a general sense of life or well-being, all connected with the physical body; and three more spiritual senses—the perceptions of speech, thought and personality. In all, twelve senses sustain the human being's awareness of the world.

In the animal kingdom we find peculiar adaptations where a species has lost its sense of sight due to a lack of stimulation by light, since it has become a cave dweller. Can we see parallels elsewhere? Must the total capacity of twelve senses be continually stimulated in order that a young person grows and matures to have balanced objective judgments? What do machines do to the sense perceptions, particularly at the spiritual level of speech, thought and personality? The extent to which we deprive and dull the senses of our young people by too early and too much exposure to calculators, computers and other machines is becoming a matter of increasing concern.

The twelve senses might be compared perhaps with twelve points of view and only a true picture of a totality is possible by a summation of the parts. This is the task of the human ego, and to be able to do this it must be versatile. Without the ego's activity and versatility, objective judgments and the perception of truth would be impossible. Such judgments and perceptions will become increasingly important if the human being is to remain master of the rapidly advancing artificial intelligence technology which is now flooding the world's industrial, domestic, commercial and educational markets. Moreover, much educational research needs to be done if the foundations for this mastery are to be laid *in the right way* at school (see figs. 28 and 29).

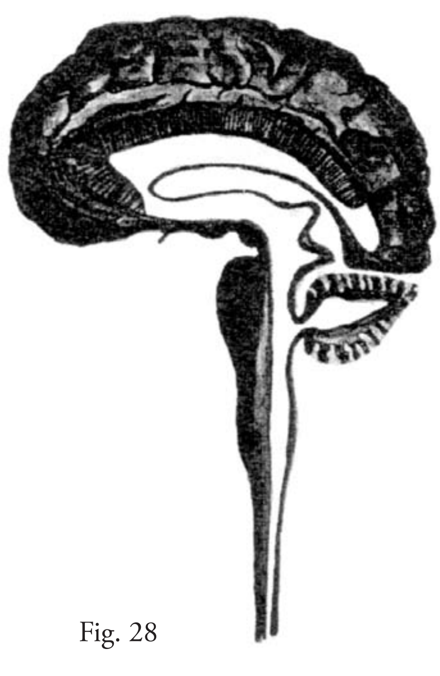


Fig. 28

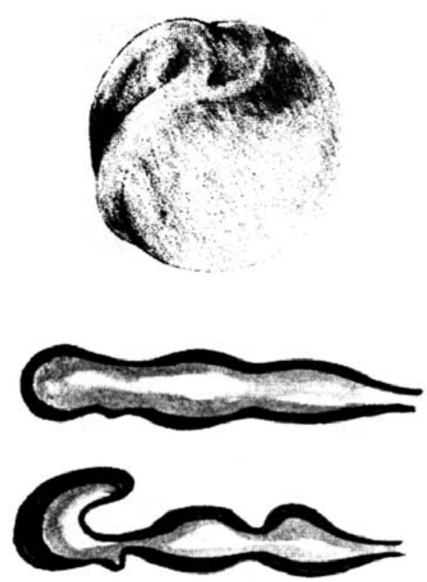


Fig. 29

"The Tooth, the Whole Tooth and Nothing but—"
by NORMAN NIVEN

Our language has many metaphorical references to teeth, e.g. to fight tooth and nail, to escape by the skin of our teeth; and although our memories of cutting our own baby teeth may no longer be vivid, we can observe this phenomenon in children. Also, who has not (or is not likely to do so in the future), experienced a twinge of what that great humane poet Robert Burns described as "the hell o' a' diseases"—toothache? But the physical nature of the tooth itself and its surrounding structures together with their development may not be as familiar to one as they deserve to be.

Shape and Structure of a Tooth

Every tooth consists of a crown and one or more roots. The crown is the part visible in the mouth, and the root is the part hidden in the jaw. Every tooth is composed of enamel, dentine, cementum and pulp (see fig. 30).

Enamel. This is the outer, protective covering of the crown. It is the hardest of all living substances, but unlike most other bodily tissues it cannot undergo repair. Therefore any damage caused by disease or injury is permanent. The main constituent is apatite (double salts of calcium phosphate and another calcium salt), and since it contains no nerves, it is insensitive to pain.

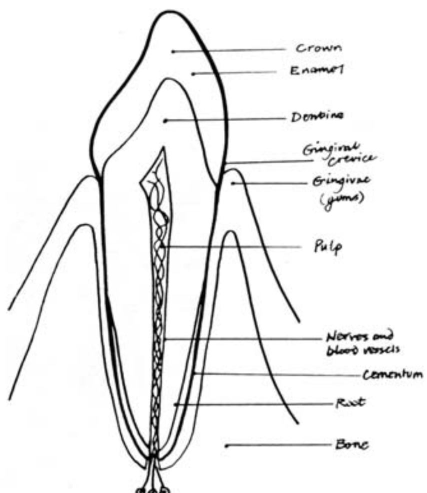


Fig. 30

Cementum. This substance is the root's outer, protective covering, similar in structure to bone; it meets the enamel at the neck of the tooth.

Dentine. This is the softer, pain-sensitive material forming the main part of both crown and root. Ivory is the dentine of an elephant's tusk—exactly the same dentine as our own.

Pulp. Rich in nerves and blood vessels, the pulp fills the center of the dentine.

Teeth and Dentitions

Incisors are the front cutting teeth and are made up of the central incisors and the lateral incisors. They are positioned next to each other and are identified by dentists in this country as numbers 1 and 2.

Canines or cuspids are the 'dog teeth.' They lie next behind the lateral teeth. Their number in the arch is 3.

Premolars or *Bicuspids* are the narrow chewing teeth with two cusps which lie behind the canines. There are first and second premolars, again on both sides, top and bottom. They are numbered 4 and 5.

Molars are the larger chewing teeth which have more than two cusps and they come successively behind the premolars. They are given the numbers 6, 7 and 8, the last representing the wisdom teeth.

The primary (deciduous) dentition consists of twenty teeth: eight incisors, four canines and eight molars. Their notation is as follows: Incisors A and B, Canines C, and Molars D and E. These teeth begin to erupt at about the sixth month of a baby's life, and the dentition is rarely complete before the age of three years. There are often small spaces present behind the lower canines and in front of the upper ones. Known as 'primate spaces' they are named after similar gaps in the dentition of the primates.

The mixed dentition phase begins with the eruption of the first permanent molars (No. 6) at approximately six years old, i.e., be it noted, before any baby teeth are shed, a fact which is often a surprise even to otherwise knowledgeable parents.

The permanent dentition is made up of thirty-two teeth: eight incisors, four canines, eight premolars and twelve molars. The eruption time span is from roughly six years of age to twelve years, except of course, for the third molars or wisdom teeth which usually make their appearance between the ages of seventeen and twenty-five. A point of interest is that the first permanent molar may have begun its calcification stage *in utero*.

When the upper central incisors first erupt, a space (*disastema*) in the midline of the arch is normally present. This phase of development, described once as the 'ugly duckling stage,' can be a cause of concern to parents and they may seek dental advice. This appearance should not be mistaken for a malocclusion, and treatment is not indicated to close the space—which ought to happen spontaneously on the eruption into the arch of the upper permanent canines.

The upper canine is the wanderer of the upper dentition. It begins its development under the floor of the orbit (hence 'eyetooth'), and so has a long path of eruption from which it can be displaced. Ultimately it may lie horizontally, be moved towards the midline or may be high on the cheek side of the upper jawbone. More commonly it just misses the correct eruptive path and is deflected slightly towards the palate or to the cheek and the deciduous canine is retained.

Teeth in the lower labial segment usually erupt before their upper counterparts. They may appear lingually and then move forward under the influence of the tongue into their correct positions as their predecessors are shed.

Supporting Structures

The jaws. The upper jaw is called the *maxilla*, is fixed to the skull and is immovable. It contains all the upper teeth in a ridge of bone—the alveolar process. The maxilla consists of halves, the right and left maxillae. These are joined together below the nose by the hard palate and alveolar process, but they are separated above by the nasal cavity. So you can see that the lower surface of the hard palate forms the roof of the mouth while its upper surface forms the floor of the nose.

On either side of the nasal cavity there is a space in the maxillary sinus or *antrum*. The nasal cavity is continuous with the antrum through a small hole in the latter's top. This connection between the air spaces of the antrum and the nose gives resonance to the voice.

The lower jaw is called the *mandible* and is the jaw which moves. It is horseshoe shaped with its ends bent up at right angles for some distance. These upright ends are called the ascending *rami*, while the horizontal part carrying the teeth is the *body*.

The *periodontal membrane* consists of collagenous connective tissue, cells, blood vessels and tissue fluids. It has visco-elastic properties. This membrane is connected with the root cementum and the compact bone lining the tooth socket, acting as a kind of shock absorber. In addition to 'fixing' the tooth in its socket, this important membrane attaches the gum margin to the tooth and the alveolar bone, and each tooth to its neighbor. What all this means is that the teeth are kept firmly in position, but are still sufficiently mobile to cope with the considerable forces exerted on them during biting and chewing. The nerves of the periodontal membrane are particularly sensitive to excess pressure, cause pain and thereby warn off abnormal forces acting on a tooth, e.g. newly-placed fillings which are too 'high,' trying to eat extra hard foods, and so forth.

Three Functions

Remembering that the moving jaw is the mandible, we see that by its movement backwards and forwards, a shearing action of the incisors is produced which, just like scissors, cuts food into pieces ready for chewing. Chewing and grinding are brought about by rotary movements of the mandible which swings from side to side, crushing food between the cusps of opposing premolars and molars. When you are next in a restaurant observe discretely the eating habits of your fellow diners. You will find many have the air of ruminants, but it is unlikely, I think, that a café calling itself "The Cud-chewer's Rest" would have universal appeal.

The ability to masticate our food thoroughly, bringing the saliva with its enzyme amylase into contact with our nutrients, is important, but it is more vital to ensure that the food particles are bound together and lubricated for their easy passage into the lower depths. Having said all that, it is interesting to note that before the introduction of the National Health Service into the UK, many people existed quite happily with no teeth at all—not every edentulous person could afford to provide themselves with dentures.

Teeth give and maintain in us a pleasing appearance. Facial appearance can be very important to a person's self image and well being, and even success in society. A social respectability of a dental relationship depends not only on the arrangement of the teeth but on other features of the face, e.g. the nose, lips, and so forth, and in addition on the attitudes of a particular society.

The third function in which teeth play a role of some importance is speech. Between six and seven months, babies of different language groups start to show distinguishable differences in sound usage. Syllables with plosive consonants preceding vowels are made, giving the typical "dada," and so forth. Although gratifying to fond parents, they have no meaning. Speech is an acquired skill. (James VI of Scotland, of a scientific and inquiring mind, conducted an experiment in which he placed a baby with a mute wetnurse on one of the uninhabited islands in the Firth of Forth for a year or two. When the child was brought back to the mainland, had possessed feathers, it would have passed as a seagull.) It is a very complicated process involving the production of basic notes in the larynx, known as phonation, and their modification by changing the shape of the cavities in the mouth, nose and throat, known as articulation. The teeth being part of the oral cavity have a significant role to play in this.

Finally, a brief description of the nerve supply to our teeth is necessary to complete the oral tour. The face, maxilla and mandible, and the teeth and supporting structures are enervated by the fifth cranial nerves, i.e., one for the right side and one for the left. Another more recognizable and descriptive name for this nerve is the *trigeminal*. As its name implies it splits into three branches, viz. the ophthalmic, maxillary and mandibular nerves. The ophthalmic is purely sensory and serves the eye and upper face. The maxillary is also purely sensory and supplies the upper part of the face, the upper jaw and its teeth. The mandibular, in addition to the sensory supply to the lower part of the face, the mandible and its teeth, has a so-called motor component which supplies the muscles of mastication.

Having given you the bare bones of this subject you may be encouraged to get to the root (sorry!) of the matter, but do remember the following thoughts. Primitive man had excellent teeth; how else could he have coped with raw flesh and bison bones? Then cooking and agriculture came along and that was that. We have evidence of tooth decay from Bronze Age skulls.

Toothache is as old as history.

Evolution as a Descent from the Spirit

by J.D. LANNING

Our birth is but a sleep and a forgetting:
The Soul that rises with us, our Life's Star,
Hath had elsewhere its setting,
And cometh from afar:
Not in entire forgetfulness,
And not in utter nakedness,
But trailing clouds of glory do we come
From God, who is our home.
– Wordsworth

According to the current evolutionary theory, mankind evolved from animals, more specifically from an ancestor common with the higher apes. This common ancestor is the famous 'missing link' of the Victorian biologists, and in spite of considerable advances in knowledge up to the present day, he has remained undiscovered. Indeed, with further study, other links at lower points in the evolutionary chain, such as between the reptiles and amphibians or the reptiles and birds, have become less firmly established. This is not to say that intermediate types are not known which would suggest an evolutionary sequence, but that on closer study these intermediates reveal themselves as being too specialized to have been able to give rise to the forms which succeeded them. Such early human types as Australopithecus, Pithecanthropus (whose name means ape-man) and Neanderthal man are undoubtedly more like apes than is the modern human being, but although they are not regarded as being on the direct line of man's descent by competent biologists and anthropologists, they are often so regarded by the layman who reads about them in popular magazines, or by the child who has the picture very much oversimplified in children's encyclopedias. It is worthy of notice that no obvious missing link has yet been definitely established. This is explained on the grounds that such forms would quickly adapt themselves to their environment, and so be transitory, and that no large populations of them would arise, so that, in view of the fragmentary nature of the fossil record, it is not surprising that they have escaped discovery. However, it would undoubtedly afford enormous support to Darwin's theory if only one such missing link could be firmly established.

The process by which evolution is said to have taken place is as follows: the young of animals are produced in too great a number for them all to be supported in nature, and in the struggle for existence which inevitably ensues, the fittest (i.e., those which are best adapted to their environment) survive and reproduce their kind. This assumes that there are differences between individual animals in the same litter, a fact which is borne out by experience. Furthermore, mortality among animals would be heaviest in the young and relatively defenseless stages, and it is unlikely that the unfit would ever reach the age of reproduction. A second assumption is that the characteristics of an animal are transmitted to its offspring in inheritance, and there is plenty of evidence that this is so. For species to arise it is necessary that a population of animals should evolve into a number of distinct groups, and for this to happen it is essential that groups of the population are separated into different environments, so that their evolution can proceed along different lines. If this is to happen, one must postulate that, in the course of time, natural barriers such as mountain ranges split up the animal population and so enable the separate groups to continue their evolution in different directions. Darwin observed many differences of detail in closely related animals on different islands of the Galapagos group. After many years the groups would become unable to interbreed, and so would retain their distinctness, even if subsequently they should happen to mingle together again.

Such a theory offers a casual observation of a variety of animal and plant forms, and of the origin of the human being upon earth. According to it, there is a steady series of gradually more complex forms, from simple unicellular protozoa, invisible to the naked eye, to the human being who is at the top of the evolutionary tree. It has its limitations, and these are well known to the biologists, and they can be generally explained by making further assumptions similar to that made to explain the absence of missing links. Failing any other equally convincing or readily acceptable theory, it holds general sway today, particularly in Western Europe and America.

The origins of life itself are not so simple, but the easiest assumption is that a fortuitous arrangements of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus atoms resulted in a chemical system that was capable of self-reproduction, and that natural selection acted on the result. That this could be feasible is shown by the behavior of the tobacco mosaic virus which can be kept like any chemical in a bottle in a laboratory, but if injected into the tobacco plant, grows and reproduces like a living organism. In fact, many scientists today regard the word 'life' as being without meaning, 'living' systems differing from 'dead' ones only in degrees of complexity.

Against such a background of belief it is difficult to find room in education for the divine nature of the human being. Generally such thoughts are dismissed as being outside the provinces of the sciences: the biology teacher presents the facts as he knows them, and makes no judgments in other fields. But he cuts away the ground from under the feet of the religion teacher, and if the latter has only traditional belief to draw upon, then the chances are that his students will either reject what he says and follow the sciences, or they will set up two separate compartments in their minds, one for science and one for religion, or they will feign an inability to understand science in order to avoid the inescapable conclusions in which they have no wish to believe.

A compromise can be effected by imagining that at a certain stage of evolution an immortal soul descended into early man, or the animal which was to become the human being. But although such an idea is useful for overcoming the charge of materialism, it is not necessary for the evolutionary process as otherwise conceived, and the arch-materialists do not believe in it. Such a soul is generally held to have its seat in the brain, from whence it controls the rest of the body through the nervous system, dangling the limbs behind it like those of a puppet on the strings of the motor nerves. At best it is a rather wishy-washy afterthought of the Divine, at worst a frail and tenuous ghost in the machine. There is really no escaping the conclusion that one cannot trail clouds of glory from an association of carbon, hydrogen and oxygen atoms in the primeval slime.

Perhaps one of the chief dangers in the teaching of science comes when it is presented to minds not yet mature enough to form their own judgments, so that the distinction between fact and theory or cause and effect cannot be properly made, and when at the same time it is presented in an over simplified form. The scientist, with a wealth of data at his command by which he can modify his opinions, may well be in a better position than the elementary science student in whom the latent materialism of scientific belief is present in its starkest form. For the effects of the thinking engendered by a materialistic biology can be disastrous. It requires an iron constitution of soul to withstand them; certainly the type of soul characterized above would be inadequate to the task. If the human being thinks he is an animal, he will tend to behave as one. If the animal passions for which a physical cause in nervous activity or endocrine secretions can be established are believed to represent the human being's true individuality, is it surprising that sexual crimes are on the increase? If it is my genes alone that form me and make me what I am, and these I receive by a process of random segregation over which I have no control, then is it surprising that I have a "diminished sense of responsibility"? Leading biologists like Professor Cannon and Professor C.D. Darlington have pointed out that most of the work on genetics is concerned with minor characteristics such as eye color or the number of bristles on the abdomen of the fruit fly, Drosophila, and to apply the same to major evolutionary changes is making a major assumption, but this is in general what the neo-Darwinists have done. The mechanical picture is completed when the genes are found to be protein molecules which discharge their products into the cells of the body, and so help to bring about the characteristics which they control. "Not I, but the proteins in me" makes a ghastly travesty of the Pauline saying.

Rudolf Steiner gave a very different picture of the nature of the human being, and on it the whole of Waldorf education is based. It would be beyond the scope of this article to go into this in any detail, but fundamentally he described the human being as being of body, soul and spirit, as opposed to the Church dogma of body and soul only.[1] As the soul is so close to the body, and as its nature is so imperfectly understood, it is very easy to imagine its activities to be the effects of chemical processes within the body, cause and effect being so very difficult to disentangle in physiological psychology. Thus the early Church dogma prepared in no small way for the materialism of modern science. In the field of the sciences of the living world, Steiner pointed out that the causes can not be sought for in the same sphere as the effects. In the mineral kingdom this is legitimate; hence the progress of physics and chemistry in the causal explanation of natural phenomena is much greater than that of biology. But the concepts of physics and chemistry are not in themselves sufficient to explain the phenomena of biology, and the evolution of the great variety of living forms on earth cannot be explained in terms of forces working on the earth alone.

The human being, said Steiner, was there from the beginning. At first his evolution took place in the spiritual world, and for a long time his bodily nature was far too finely attuned to exist on earth. But from the stream of evolving mankind, other forms were cast off, as it were, and incarnated on earth before Man. These were the animals. In a way they mark the stages of the development of the human being in the spiritual world. In a way, too, they mark the stages of the descent of the human being, so that the fossil record becomes a record of the Fall of Man. In another way the premature incarnating of animal forms was a sacrifice on their part, in that they brought with them certain characteristics which would have hindered the proper development of the human being. Animals often show human characteristics developed to an extreme, or in a one-sided way, both in their bodily structure—as for instance the cuttlefish which developed the head especially, or the true fish which developed the trunk—and also in their natural dispositions. Examples of the latter would be the *cunning* of the fox, or the *ferocity* of the killer whale as opposed to the *playfulness* of the dolphins and porpoises, which are very closely-related forms. Another aspect of the same principle is that when the human being breeds domestic cattle and produces a placid cow, he produces at the same time a somewhat aggressive bull. Could the cow be so phlegmatic if the bull were not so choleric? Somewhere between the two must lie the more balanced temperament of the cattle. This is the theme of early lessons about animals to children in the lower classes of Waldorf schools, in which the human being is shown as uniting in himself the whole animal kingdom.

Eventually the human being incarnated fully on earth in a body that is held completely upright and which can be a vehicle for his ego. The human spirit which previously had guided its evolution from without can now undertake it from within, and mankind's evolution, as Dr. Julian Huxley and others have observed, has become the business of Man. Immediately preceding the human being, incarnating just too soon for the ego to obtain a proper foothold on earth, came the monkeys and apes.

Now, it will seem all very well to criticize modern theories of evolution, and to lay at their door many of the social evils of mankind. Neither will it be adequate to outline in their place, in a very fragmentary way, another theory which cannot be discovered except through spiritual perception, unless this theory can claim to explain the observed facts better than any other. It is, of course, impossible to cover here the whole field of evolution in any detail, but a small section of it can be considered, and obviously a very important point of time was that when the human ego started to incarnate fully on earth, and when we find the remains of forms known popularly as ape-men.

But we must first be clear about what human characteristics we are looking for among the fragments of bones which we shall find. The best criterion is the fully upright carriage of the human being. This is absent in the monkeys, becoming only superficially apparent in the great apes due to their habit of swinging from the branches of trees. The gibbon, which is perhaps the closest of them all to walking upright, cannot take more than about four steps without supporting itself on its forelimbs. An upright carriage is reflected in the skeleton by a completely rounded skull, which, since it is balanced on the backbone, needs no muscles for its support, and consequently no ridges for their attachment; and further reflected in the position of the *foramen magnum* where the spinal chord enters the skull. Other features are a straight *femur,* and a flared or widened *ilium* or hip bone, to which the muscles which keep the trunk upright are attached. Details of the teeth are of help to the expert, and also the human being has a chin, while all monkeys and apes have a receding lower jaw, and in the place of a chin, a small shelf of bone in the inner angle of the lower jaw—the so-called *simian shelf.*

Now, these characteristics which are associated with uprightness are more noticeable in the young of the great apes than in the adults. A remarkable feature of humans is that they preserve into maturity embryonic characteristics; thus the paddles of dolphins and the hooves of horses had, at one time in the embryo, the form of a human hand—only later do they become specialized for their specific tasks. It is fascinating, almost horrifying, to observe how the skull of a young chimpanzee, at first quite like a human skull, becomes drawn out in the facial region and thickened over the eyes, as the animal becomes more adult. The early form is human, and then it becomes more ape-like. This process is fully described by Dr. Hermann Poppelbaum in his book *Man and Animal.*[2]

Now, the very earliest apes are known from remains found in East Africa from a period known to Geologists as the Miocene. But although the majority of finds have been in Kenya and around the shores of Lake Victoria, other finds elsewhere have indicated a wide distribution, and they certainly existed in what is now Southern Europe. These apes are generally believed to be the forebears of modern apes: the chimpanzee, gorilla, gibbon and orangutan. As is the infant chimpanzee, they were much more lightly built and agile than modern apes, and the femur was straight and slender. The position of the *foramen magnum* and the width of the hip bone show that they walked upright, and there is no sign of *brachiation,* i.e., swinging from branches—in fact a forearm from one of them was proportionately much shorter than it is in modern apes. Furthermore the teeth were quite human, and there was no simian shelf. If these forms gave rise to modern apes, then the line of evolution they followed was in a direction *away* from the human being.

Africa was again the home of another group of near humans discovered by Dr. Robert Broom at Sterkfontein in the Transvaal. They are known as the Australopithecinae. Their size was comparable with modern pygmies, but like the East African Miocene apes, there was considerable variation in this, and some must have very closely approached the full stature of the modern human being. They lived in open country and were definitely not tree dwellers. The body was distinctly human in its form, having acquired the *lumbar curve*, a backward twist above the pelvis which helps to keep the upper half of the body erect. The hipbone was broad and the femur straight—there seems to be little doubt that they had an upright posture. However, the skull, on first examination, would appear to be that of an ape, although the brow ridges were not so prominent, nor was the face so much pulled out as it is in the modern apes; in this respect they were intermediate between the chimpanzee and the human being. But the teeth were very similar to the human, and in particular there was no very great development of the canine teeth, which are especially large in the gorilla. The *foramen magnum* indicated an upright posture, and the *sutures* between the skull bones had not closed over. This latter is an embryonic character which we have seen to be a feature of mankind; the sutures fuse early in apes. There is plenty of evidence that these creatures used weapons, tools and fire.

Coming next was Java man, named, alas, Pithecanthropus erectus by Ernst Haeckel. Recent discoveries have suggested that there may also have been similar forms to Java man coexistent with Australopithecus in Africa, but this is not yet established to the satisfaction of all authorities. Java man lived at the beginning of the Ice Age, and his progress in the direction of humanity is very dubious. He was of the same size as the modern human being, and the thighbone was distinctly human. But, although the brain was much larger than that of Australopithecus, proportionately as well as absolutely, the skull was so apelike that for a long time it was debated whether it could possibly belong to the same individual whose thighbone had been found close at hand. In particular it showed those characteristics of the skull which a chimpanzee develops as it grows older: massive ridges developed across the eyes, the forehead sloped backwards, the face was protruding and the lower jaw receding, there being no chin. Neither was there a simian shelf. There was, however, a gap in the teeth of the upper jaw to take the massive canines of the lower. Another form living at the same time in China may have been slightly more human, but was very similar.

Neanderthal man, who followed a little later in Europe, may at first have appeared to have offered something more in the way of progress. The face did not project in the mouth region to anything like the same extent as it did in Java man. But the forehead was sloping, and there was a prominent bony ridge across the eyes; the face must have presented a brutish appearance. The brain was large—quite as large as that of the modern human being, and was well-developed towards the back, i.e., in the occipital region. Whereas our brain is higher than it is wide, this brain was wider than it was high. Neanderthal man was well established in Europe in the Ice Age, and many remains have been found, but the interesting thing about him is this: The later forms seem to have progressed backwards rather than forwards. The head became long and low, and must have begun to hang forwards, for the neck vertebrae started to develop massive processes, presumably for the attachment of muscles to hold the head erect. The limb bones too, which even in Java man had retained their human character, became thickened and bent. Mankind's most fundamental characteristic, his uprightness, was slipping away from Neanderthal man.

The complete disappearance of Neanderthal man from the European scene at the end of the Ice Age remains a mystery. He was succeeded by the Aurignacian culture, represented largely by the Cro-Magnon types which were certainly not derived from the Neanderthals. Remains of the former are plentiful in France, and in England they have been found at Cheddar Gorge and in Kent. They differ hardly at all from the modern human being, and where they do, they seem to be our superiors, for they were of magnificent physical build, perhaps slightly longer in the leg than ourselves, with high foreheads and long heads.

The picture is still not quite complete, for at Swanscombe in Kent, and at Fontéchevade in France, remains have been found of human forms which must have been living at the time of the earliest Neanderthals—the Swanscombe man may have even preceded them. Remains are too fragmentary for anyone to say that they were definitely not Neanderthals, but they appear to differ from ourselves only in the fact that the bones of the skull were much thicker.

The interpretation of these remains has been a matter of great difficulty for biologists and anthropologists, and they are far from unanimous about them. However, one thing seems clear, and that is that the early forms are more human than the later, and when a line of descent is traced, it departs from rather than approaches the human condition. This becomes very difficult to explain on the basis of a theory of mankind developing from a sort of man-ape, with the modern apes evolving in a different direction at the same time. Furthermore, the sudden appearance of new types upon the scene, such as that of Cro-Magnon man, must be explained by migrations from places unknown—generally Asia is assumed. The postulations of migrations is incidentally becoming more and more necessary at other points in the field of evolution, as further study indicates that the forms found in a certain region could not possibly have been derived from those existing there just previously. Thus G.G. Simpson, a leading American worker in this field, speaking of the evolution of the early placental mammals, says that it is inconceivable that they could have developed from the preceding faunas in the places in which they were found.

But there is still another man whom we have not yet mentioned. Although he was a fake, he is not without significance. Whoever perpetrated the hoax of Piltdown man was trying to create what he was hoping to find—a stage from the ape to man. But Piltdown man just would not fit in with the evidence that was coming from other quarters, and it was a great relief to the scientific world when the fraud was finally exposed—in fact, ten years before this, Franz Weidenreich had already called him "a chimera which should be erased from the list of human fossils." Piltdown man had the skull of a human and the lower jaw of an ape, and was the only form among those we have discussed to have the simian shelf. He was a product of a thinking which must now be subjected to the same close scrutiny by which Professor Le Gross Clark exposed the faked physical remains.

For the conventional evolutionary of today cannot really explain the presence of those early human remains which were once thought to be our forebears. But if one has the courage to conceive the possibility that the causes of organic evolution can lie in fields other than the effects, and to accept at least as a possibility the process given by Steiner, then the whole picture becomes more intelligible. *For the missing link becomes the human being,* although he has not always existed in physical form upon earth. Then these forms which I have described were close to the human being when they first appeared, and depart from the human form as they pursue their evolution on earth. This is what we find, and it is beautifully shown in the sequence of earlier to later Neanderthal skeletons, and in the transition of the Miocene apes to modern forms. The sudden appearance of new types, in regions in which no possible previous ancestors have been found, and the complete absence of missing links become at once more explicable. Furthermore there is strong embryological evidence in support of this view.

Whence then do we come? We are already getting a little nearer to Wordsworth in answering this question. Not in a whirling complex of atoms in a primeval nebula, but "from God, who is our home." The religious element in the biological sciences will come when the biology teacher can teach that out of God we are born, with an at least equal conviction to that of the religion teacher who says that we go to Heaven when we die.

Endnotes

1. The dogma referred to is that of the Ecumenical Council of 869.
2. Hermann Poppelbaum, *Man and Animal: Their Essential Difference*, Anthroposophical Publishing, 1960.

Alternative Technology in Waldorf Schools?

Young People Want to Know about Energy without Pollution

by PETER CLEMM

There is much talk these days about 'alternative technology,' 'appropriate technology' and 'intermediate technology.' Is this something we should not only be aware of, but something we should actively cultivate in our Upper Schools?

It is the aim of the Waldorf curriculum not only to give a historical perspective of science and technology, but also to awaken an awareness of what is going on around us today and its implications for the future. In the form of centralized mass production, automation and vast computer networks, present technological developments and the way they are used threaten ever more to invade our privacy, curtail our freedom of action, and make us become slaves of 'the system' in order to survive.

The recent upsurge of interest in alternative lifestyles is in large part a response of the individuals to this threat. But it has also arisen out of a real concern for what the technological aspects of 'the system' are doing to our environment and to our prospects for the future. It is in this area that I would like to put forward some tentative thoughts for areas of study and practical work in the Upper School.

The problems of pollution and irreversible destruction of the environment are particularly connected with the following: the production of energy and raw materials and the methods of transportation and waste disposal. In each of these four areas one can explore the various ways in which the basic 'four elements' are being used or abused.

For example, in energy production, *solid* fuels, some renewable, some not, are extracted from the earth and made to produce energy in a variety of forms. Principally coal, but also wood, peat and dung are burned, and uranium is reacted, to produce heat. This 'fire' energy is then usually transformed to mechanical, then to electrical energy. The other two of the four elements are usually called in to assist in this double transformation: water and vapor in the steam turbine. Actually, in most modern steam turbines 'super-critical' pressures and temperatures are used, under the influence of which the distinction between liquid and vapor disappears and these two elemental states of matter are reduced to a kind of intermediate mush. Under these conditions, one might ask oneself (if not the students): What is happening to those other elementals, the sylphs and undines, when their physical sheaths are subjected to this kind of treatment? There are also solid fuels which are directly converted to electricity, such as the electrolyte in a flashlight battery.

There are *liquid* sources of energy: petroleum, and also water in a hydraulic turbine. Oil, when used, is irreversibly changed and depleted. Water only changes its position with respect to the earth's gravitational center—or is that the only change? It is totally restored when it is again raised by the sun into the clouds, to fall and be collected once more into the mountain stream, eventually to be engorged and spewed out once more by the hydraulic turbine.

What about *air*? Natural gas is another non-renewable energy source, similar in use to coal and oil. 'Bio gas,' on the other hand, is a renewable fuel. A relative newcomer on the energy scene, bio gas is made by allowing animal manure (from cattle, pigs, chickens) mixed with water to ferment in a closed vessel. The gas is produced by a bacterial digestion process and consists of two parts of methane to one of carbon dioxide. It therefore has about two-thirds the calorific value of natural gas and is an excellent fuel. In India there are currently about twenty-five thousand such methane digesters in operation. Their value to small Indian farmers lies as much in the excellent fertilizing properties of the 'spent' slurry as in the fuel gas which is extracted from it. With the present high cost of fuel, methane digesters are now also being manufactured for use by English farmers.

But to continue with the 'airy' realm, what about the wind? Because of anticipated fuel shortages in the next decades, there is currently a great resurgence of interest in wind power. Between 1880 and 1930 over six million windmills were in use in the United States for pumping water, sawing timber and grinding grain. Today only a scattered few remain. But a recent estimate by a reputable engineer indicates that one million modern high performance windmills strung out along the wind corridor of the Great Plains could supply twenty-five percent of the future energy needs of the US.

Again one is tempted to ask the question: What would be the overall effect of so many mighty fingers in the wind (propellers over a hundred feet in diameter rotating at high velocities), extracting such vast quantities of energy? Effects of some kind there might be, perhaps, but would they be irreversible? At all events they would probably be very subtle compared to the potential hazard to organic life of accumulating highly radioactive nuclear wastes where aura will remain lethal for many millennia to come.

Finally there is *fire* itself. The radiation of the sun can be captured as heat in solar panels or converted to electricity in photovoltaic cells. Geothermal steam wells provide power in Italy and California, hot geysers in Iceland.

So much for a few of the present day aspects of just one major area of technology: energy production. These can be seen and studied. But they can also be experienced directly in projects involving the actual designing, building and operating of smaller scale solar panels, windmills, waterwheels and methane digesters. The further problems of continuous or intermittent operation, and the associated problems of energy storage can also be tackled. Much help in actual projects is available in the rapidly growing alternative technology literature, as well as from such centers as the New Alchemists in the USA and the Centre for Alternative Technology in Machynlleth, Wales.

These thoughts are not primarily intended as actual suggestions for curriculum content, but rather to stimulate further thinking on ways to incorporate this important aspect of human life as both a study and a practical activity in our Upper Schools. Particularly if combined with vocational-type training in electrical and machine shop skills, projects in the building of usable alternative energy devices and systems might provide the kind of challenge and contemporary interest necessary to overcome the apathy and lack of involvement one so often meets in teenagers nowadays. It would also help prepare the ground for an increased awareness of our relationship with the being of the earth and its physical resources which is sorely needed today and will become ever more crucial to the future evolution of mankind.

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Astronomy New and Old
by NORMAN DAVIDSON

[T]he reason why there is such great variety in things, and treasuries so well concealed in the fabric of the heavens, is so that fresh nourishment should never be lacking for the human mind, and it should never disdain it as stale, nor be inactive, but should have in this universe an inexhaustible workshop.

– Johannes Kepler in *Mysterium Cosmographicum*

As far as teaching material is concerned, there is always something new to be presented in the subject of astronomy. An astronomy main lesson in the Upper School is likely to start, in its first few days, from the very latest modern developments in the subject so as to meet the students where they stand—as young people eager to step into modern life and who are already experiencing it socially or through the media, and so forth. Some already know a certain amount about cosmology and astrophysics, and starting with this leads straight into a natural interest at this age, and into the times in which we live when popularized science is on the screen and in the news columns each day. Pseudo-science or science fiction lends its weight in this direction, being inextricably bound up with science in general, in talk of black holes, life on other planets, and so forth. This natural interest and fascination of the young person gives the teacher of astronomy the opportunity to present the latest in technology and space discovery, and to lead his presentation over into a serious discussion on assessing the place of such developments in the overall picture of the human being and the universe.

Halley's Comet was a recent opportunity for a study of technology at its peak when the spacecraft Giotto intercepted it with astonishing precision and sent back computer data on the comet's physical composition which will take years to analyze and interpret in detail. A recent spacecraft encounter with the planet Uranus is another example. The teacher must be knowledgeable and up-to-date on such matters and enter fully into the enterprises of technology. The geometry of these flights alone is a cause for wonder.

But where would such a spacecraft end up if it flew on forever? Is the universe infinite? What is the philosophy behind the concept of life on other planets? Do UFOs exist? What is a black hole? Now the teacher can lead a discussion on such questions and try to discover the exact nature of these modern concepts. Interesting though they are, they are not pure astronomy. The spacecraft and its discoveries are physics. The black hole is abstract mathematics. The UFO is psychology. Yet all of these things are born from one mother—the appearances and movements of the stars on a clear night. That is what has given rise to a multitude of ideas and theories. These ideas fill the modern mind today, but the original phenomenon, the turning sky, is forgotten. The astronomy teacher can bring the young person to discriminate between these various topics and then enter a study of what lies at the root of the science—the phenomena themselves. If these phenomena are then studied without bias, and simply as they are seen with the naked eye by the observer standing in the open field, then it is surprising how rich and complicated the view becomes, and how the stars sing more than the popular, modern scientific song. They speak of the rhythms and nuances of nature and the human being, too.

An appropriate stepping-off point for this for the Upper School student is a comparison of the old earth-centered and the new sun-centered planetary systems models. It can be shown how each is one side of the same thing. The sun-centered view is justified and correct from the physical space standpoint. The earth-centered view is correct from the observer's position and a movement in time standpoint.

Fig. 31 shows the order of the planets in Ptolemy's system, where the earth is at the center. Here the order is according to the observer's experience of the planets' speeds of movement against the fixed-star background (outer circle). In the course of a day, the moon moves fastest against the stars in an easterly direction, Mercury is next in average swiftness, Venus follows a little slower, and so on. One feels what is fastest to be nearest to oneself. It is an ordering in one's personal experience, and justified on that account, as any qualitative effects must accord with what one directly experiences.

Copernicus transferred this into an external, physical space which can be reached only by abstract thinking. In terms of physical space his system is once again justified, but the ordering of the planets seen from Earth must now become different (as in fig. 32). Seen against the stars, Mercury moves faster than Venus and is therefore placed closest to the central sun (O). The Earth's moon makes a little circle round it. But seen from Earth, the ordering is now: Venus, Mercury, sun.

This is an inevitable switch, and it should be seen that the Copernican and Ptolemaic systems, though different, are entirely logical and consistent and do not exclude each other. One involves personal experience, the other mathematical calculation. The switch in position (not in name) of the two planets Mercury and

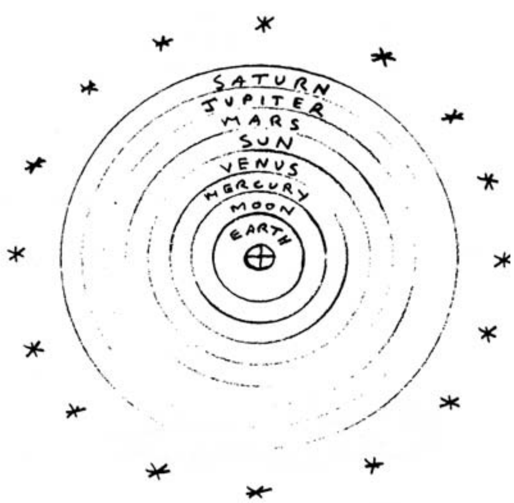

Fig. 31 *Diagrams drawn in a Class 7 astronomy main lesson* Fig. 32

Venus should be clearly understood, for it applies in studies of history, literature, and so forth.

The student should appreciate the genius of both Ptolemy and Copernicus without prejudice—and also perhaps dispel some popular misconceptions. For example, Copernicus' attempts to prove his system failed, and he did not simplify Ptolemy's system—in fact he had forty-eight circles to explain the movements of the planets.

This Ptolemaic/Copernican episode is vitally important in a presentation of astronomy, for only then can it be seen that one cannot properly start on the subject of the planets just from the sun-centered view. The latter is a derivation of the normally experienced phenomena of the earth-centered view and is, in fact, a very subtle and technical derivation which no ordinary observer can reach without technology. So the student returns to first beginnings and learns the movements and appearances of what is his greater environment—the sky as he sees it in terms of the celestial sphere with upon it sun, moon, planets, stars, eclipses, comets, meteors, and so on. The celestial sphere is found to be a reality—not a physical one but nevertheless entirely effective visually and in terms of mathematics. It is a concrete imagination.

The ordinary, visual impression of the sky is then allowed to speak its own language freely. What teacher and students make of it comes new each time. Unsuspected rhythms and laws are explored and discovered.

For the Lower School students the subject can be approached the other way round and linked with the historical development from the old world to the new. Again, one starts from where the students are inwardly. One begins with the external, visible phenomena of the celestial sphere, relating them to the development from mythology and earth-centered astronomy to the Copernican revolution. This relates to the Renaissance Age of Discovery, appropriate to the pre-teenager, and allows a culmination in the lives and works of personalities such as Copernicus, Kepler, Galileo, Tycho Brahe and Newton.

In the process of working through this program, the Lower and Upper School students can take on practical tasks such as making a nocturnal (star clock), a sundial, a moon phase calendar, a simple telescope, and so forth. With a modest telescope (even binoculars) they can view the moons of Jupiter and repeat Galileo's discovery. Geometrical exercises can include measuring the height of a pyramid using the shadow of the sun, thus connecting with historical topics. Astronomy in literature can also be investigated, as in these lines from Shakespeare—

> Banquo: *How goes the night, boy?*
> Fleance: *The moon is down; I have not heard the clock.*
> Banquo: *And she goes down at twelve.*

—the student would have learned enough about the moon to know at what phase it was when Duncan was murdered and how it would have looked in the sky when Duncan arrived outside Macbeth's castle, and thus enable a play producer to represent the moon correctly in the scene.

Astronomy has woven itself too deeply into human culture to be limited to only what is new. The new must be seen to have grown out of a legitimate and justified past, and one must also seek reality in a qualitative, human experience of the actual sky as it is seen on a starry night. This completes the subject and extends it into a whole, comprising what is both practical and imaginative. As for the teaching techniques—they are always new, arising directly out of the individuality of the teacher and the needs of the students.

A Visit to a Steel Plant
by ALAN HALL

"Why is this factory called a plant? I always thought plants grew in gardens and woods." For the Class 11 girl on an industrial tour the question is an obvious one, but the professional factory guide is caught off guard; the mechanical stream of statistics about steel output per manhour, coal consumption per day, and so on, stops dead, and for the first time in the tour the man comes to life.

"Do you know, I have worked here for twelve years, I know every square inch of this site, I show thousands of visitors round every year, and yet that question has never occurred to me before." She has set him thinking.

When Class 11 students are taken out on visits to industrial plants to see such vast machinery as can be seen in a steel works, it is usually the first time, and for many the last, that they will get close enough really to begin to experience such a basic process as the making of a sheet of iron. The word 'ladle' usually conjures up a picture of an ordinary kitchen soup ladle, but as we move into the furnace area, the word suddenly has a new meaning. Here everything is on a vast scale, a ladle no longer holding a mere plateful of soup, but handling a hundred tons of white-hot molten iron (that is about the weight of fifteen hundred hefty teenagers!), and the arm that carries it being part of a crane which travels the length of the building. An unseen hand tilts the ladle as if it were handling a mere milk jug, and the white-hot stream of metal pours down into the furnace amid a deafening roar and an explosion of sparks. Even behind the thick glass screen we feel the intense heat and involuntarily step back. To be so close to such a powerful machine in action cannot fail to impress anyone who has not seen it before: the size, power and control of such vast machinery dwarfs the individual human being, whose physical capacities appear insignificant in comparison.

The tour moves on to the rolling mill where four-ton ingots of red-hot steel from the furnaces are effortlessly cut in half by a gigantic pair of scissors. Everyone stops and stares in amazement as if in a dream world where one has no control of the happenings around one and yet one remains an integral part of the events. The mill reminds us of standing between two parallel mirrors when one sees an endless series of reflections of oneself stretched away into the far distance, but here it is a long series of large mangles, like Granny's old-fashioned scullery mangle, that we see stretched away almost out of sight. As we walk along, an ingot accompanies us, going first through one pair of rollers, then another, being squashed at each stage like pastry under Mother's rolling pin, but here the pastry weighs two tons and is red-hot. Nobody touches it; the machines do all the work. At each pair of rollers the ingot gets thinner and longer and soon is traveling too fast for us, and we watch it accelerate away into the distance amid a deafening roar. As we reach the last mangle the iron is now less than one millimeter thick, a hundred yards long and traveling at thirty miles per hour.

At the end of the mill we all watch in disbelief as powerful arms catch this two-ton, almost red-hot, 30mph snake, neatly coil it up, drop it down a delivery chute and prepare for the next one. No conversation is possible but none is necessary, for the experience speaks for itself and is unlikely to be forgotten.

In the open air again, one of the students asks the guide what all the sheet steel will be used for. "The majority is made into tin-plate and then converted into tin cans for the food industry, but about ten percent of our output ..."

The rest of the sentence was wasted on the boy who stands stunned. "You mean to say that all of this enormous factory is just to make tin cans that we throw away?" Suddenly our throwaway society is seen differently, and as we go home real questions begin to rise up as each of us feels in part responsible for the steel plant:

"What a terrible waste!"

"Why doesn't someone do something about it?"

"It shouldn't be allowed!"

"Why aren't cans recycled?"

"How did such a situation come about?"

We all enjoy a standard of living in our modern world that was reserved in the past for kings and princes, which brings with it new questions, problems and challenges for people of our time. To understand how this has become possible—to consider the changes wrought by such an overall improvement of our physical living conditions and how to meet them—is surely a vital part of any true education.

When students are coming towards the end of their home and school life and are taking their first steps towards leading an independent adult life in our modern complex technical world, such experiences of industry and the questions they raise meet an inner need to relate to the real practical adult world. When learning about such a subject as technology, many students are enthusiastic about the latest devices and inventions with which we manipulate our lives, but frequently the teacher meets a great fear concerning all that this technology is bringing into our world. The technology is all so vast and complicated, machines are powerful, relentless, unfeeling and amoral, with no ability to respect human values—it is little wonder that many teenagers 'don't want to know.' It is in their language. However, we all depend totally on our modern technology from the time we wake to the time we sleep; in kitchen, office, garden, school. So somehow we need to learn how to relate to it and manage the changes it is bringing. This is a real challenge for education which needs urgent attention, for the effects of not being able to manage them are becoming uncomfortably obvious.

What does 'change' mean for a young person today? For example, the idea that at our present rates of use, our global oil and gas reserves will be virtually exhausted within their lifetime, must bring about great changes in their way of life. The years 1990, 2010, 2020 sound so far off when you are in your last years at school and only thinking of tomorrow and the day after, that ideas of future shortages precipitated by yesterday's and today's excesses can seem quite unreal. And yet we all already experience some of these coming changes.

One of the most important examination passes for a teenager is the driving test, for it represents a real step towards the independence of the individual to be able to command a machine and move around at his own free will. The real price of this freedom of movement is now rising fast, as fuel and energy costs rise, and the expense of a journey is becoming a factor in deciding whether one travels or not. Some of the latest car models have an electric calculator built into the dashboard to give a constant indication of how many miles per liter one is getting, and, being constantly confronted by the cost of travel, one tends to drive more carefully. As we move from a world of plentiful supplies of materials and energy to one of comparative scarcity, costs inevitably rise steeply, and we have to pay more for the things we need and want.

The money we pay for goods and services connects us with the working life of many other human beings in various parts of the earth, the vast majority of whom we do not know and will never meet, but the money that moves through such a long complicated chain of transactions represents our mutual dependence. The rapid increase in technology, with its associated specialization and division of labor, has made us all interdependent, and today, more than ever before, as prices rise, we can say in our everyday life: "No man is an island."

When we are at home in the kitchen preparing a quick meal, one hand on the tin, the other on the tin opener, thoughts are usually on the meal and not concerned about how our actions affect anyone else. Our hunger is satisfied and we do not usually think any further about the tin can, for after all, it is only one small tin, and not worth worrying about really. A year or two ago a famous food manufacturer ran a poster advertising campaign which had a catch phrase: "A million housewives every day pick up a can of beans and say beans means ..." It also means a *million* tin cans are used every day in this country alone just for one product. That is roughly a hundred tons of steel, fifty of those ingots going down the rolling mill. So what really drives the rolling mill? Our hunger, and children eat an awful lot!

Take one tin of food from the larder and examine it carefully, listing down all the materials, processes and handling operations that are necessary for it to be in your hand. You begin: steelworks for iron sheet, lacquer for the lining, paper for the label, pigments for the printing, printing works, glue to stick it on with, and so on. And then, of course, there is also the food it contains! In many products the tin costs far more than the food it contains, and yet we carelessly throw it away so that the countryside is littered with millions of tins.

How different if, when opening the tin can in the kitchen, one remembers the steel plant, the noise, the machines, the people who worked there and the huge use of resources. One can feel part of a large, complex process, and that can lead to a real sense of responsibility for one's actions. Bottle banks have appeared in the past few years and other recycling systems will no doubt appear in the future. The actual use of these depends upon the individual's sense of social responsibility and this can be born out of experience of other people's places of work.

A plant is an organism in which each part relates to the whole. The steel factory is only a part of the organization of tin can manufacturers, food producers, wholesalers and retailers; but the needs of the individual consumer form an integral part of this whole and help to bring it into being. Without the large number of individuals, each having his needs met by the work of other individuals, no industrial plant would exist. The factory is part of a living, organic process in which all the parts relate to the whole and the whole depends on the parts. Perhaps the name 'steel plant' is a good one.

And how has all this come into being? Rudyard Kipling answers that poetically at the end of *The Secret of the Machines:*

But remember, please, the Law by which we live.
We are not built to comprehend a lie.
We can neither love nor pity nor forgive.
If you make a slip in handling us you die!

We are greater than the Peoples or the Kings—
Be humble as you crawl beneath our rods—
Our touch can alter all created things,
We are everything on earth—except The Gods!

Though our smoke may hide the Heavens from your eyes,
It will vanish and the stars will shine again,
Because, for all our power and weight and size,
We are nothing more than children of your brain!

Botany Alive

Exploring the Living Totality of the Plant with Seventeen-Year-Olds

by FRANCES WOOLLS

In schools generally today most students go through a course of biology which will include studies of plants and animals in their natural habitats, as well as a detailed study of structure in relation to the functioning of life processes. What one wonders is whether an abiding love and concern for Nature and the Earth are endangered by such biology lessons, with their usual emphasis on dissection and microscopic work.

The curriculum of a Waldorf school suggests courses on botany and zoology in Classes 11 and 12 (ages 16+ and 17+). Here is the teacher's opportunity to introduce these more mature students first to the world of the plants and then to the world of the animals, to show their dependence on each other, and the human being's dependence on both and his increasing responsibility for what happens in the biosphere.

Recently I gave a course on botany to a class of sixteen- and seventeen-year-olds in New York state. There were in all twenty-two young men and women, of mixed ability, and we could reckon on having the first two hours each day for three weeks for our studies.

If one is to experience the plant world, even a fragment of it, one must bring one's powers of observation to bear on the living plant and emphasize its connection with the earth. Repeated looking at a particular plant over its period of growth from seed to fruit will foster intuitive powers of comprehending, which help us to gain a deeper understanding of the living world. So I began by giving each student an Ageratum plant, one in which the inflorescence had yet to develop, and suggested that the plant should be potted, taken home and situated where daily observation would be possible. From time to time drawings would be made, showing the unfolding of the leaves, the lengthening of the stem and emergence of the flower buds.

Meanwhile in the lessons we discussed the significant parts of the shoot—the node, where leaves and side shoots develop, and the internode, where there is contraction and a lengthening of the stem. We drew attention to the central axis, around which there is often a spiraling of stem and leaf arrangements. We had other plants in the room, notably many Cleome spinosa, whose magnificent inflorescence, in shades of pink, was already in bloom. During the days that followed we developed the theme of metamorphosis, showing as Goethe first did, the prime importance of the green leaf and how all other parts of the shoot are modifications of the leaf principle—cotyledon, bract, tendril, sepal, petal, stamen and carpel. Sometimes the carpels may be joined to form a leaflike pod, as they are in Cleome spinosa, or in the velvety pod of the Wisteria and the familiar peas and beans. The discovery of such transformations leads to a fascinating study, but even more significant is the thought structure comprising the living totality of the plant as an organic process of interpenetrating formative forces. This Goethe achieved, as Rudolf Steiner points out in his book *Goethe the Scientist,* by the fruitful combining of idea and experience.

Besides the continuing observation of the single growing plant selected, study was extended to the secondary woodland surrounding the school. This led on to descriptions of the plant covering of the earth as a whole—how it is in desert regions, in swampy lowlands, on the prairies, and on the seaward slopes of the Sierra Nevada mountains, for instance, where one meets such a tremendous growth of stately pine trees, often attaining two hundred feet in height.

There were other lessons in which we studied the characteristics of the trees of the neighborhood and noted the leaf transformations that occur in the sassafras, in red mulberry, and in the ivy that climbs the trees. This change of shape in the leaf can also be seen in the delphinium, buttercup, celery-leaved crowfoot, sowthistle, and so forth. An interesting change of form can be seen in the thick aggregate fruit of *Magnolia grandiflora*. The individual pods are attached to the elongated receptacle, freeing the red seeds which amusingly hang by a thread. One morning we went to look at the rampant growth of the climbing star cucumber (*Sicyos angulatus*), finding its way along the ground in great lengths, up telegraph poles and over trees; its fruit is a solid green star.

I wanted my students to experience every morning another example of plant growth, to live in it intensely and at the same time to be given enough help with technical terms to find a common way of comparing notes with other folk interested

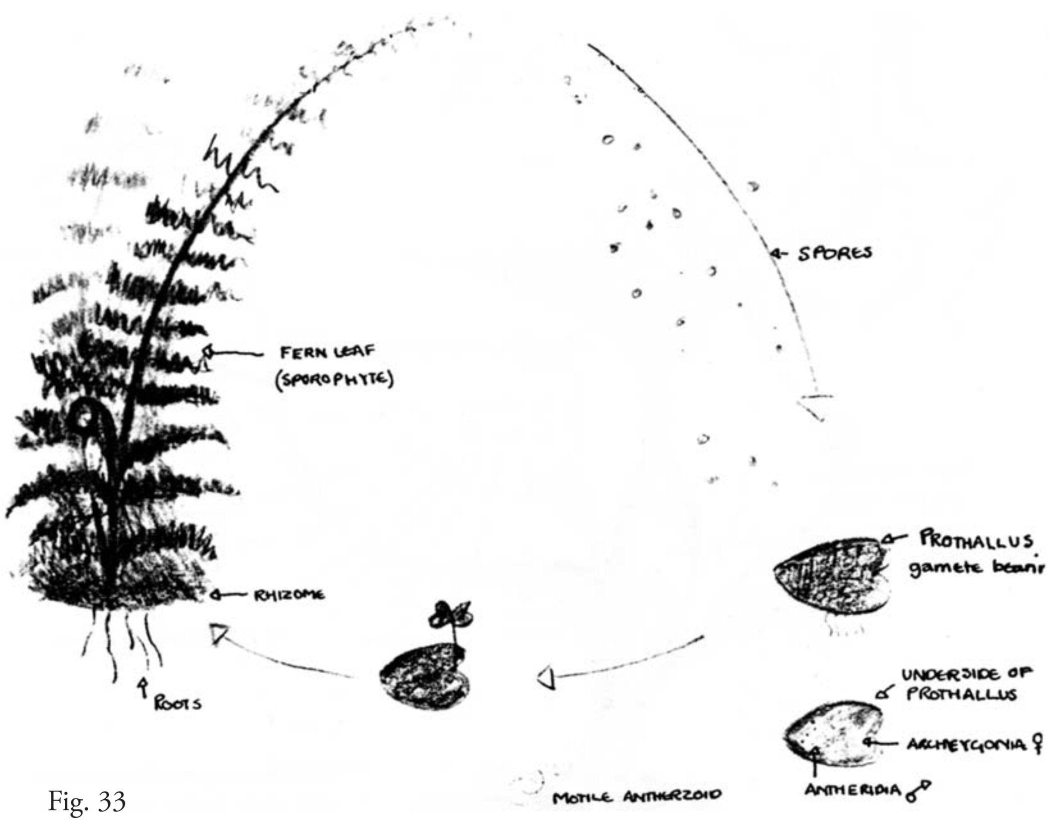

Fig. 33

in botany. There was great interest in the subject of pollination and the relation of the form of the flower to the form of the visiting insect. We contemplated the immense task which bees, wasps, butterflies, moths, beetles and flies carry out in bringing about cross-pollination, and what an enormous debt we humans owe to these creatures. The details of fertilization as revealed by the microscope my class found fascinating.

We certainly also drew on the microscope for our detailed studies of leaf, root and stem structures, emphasizing the differentiation of plant tissues and how these are related to function. It is important to bring out the role of chlorophyll and interesting to compare its structure with that of hemoglobin. This work led naturally to the significance of cell division and a detailed consideration of those wonder-evoking processes which are continually taking place in mitosis and meiosis.

Another phase of the course was an introduction to the way in which plants are named and classified, introduced with a brief sketch of Swedish botanist Carl Linnaeus. We looked at the characteristics of some representative families, and then turned our attention through several days to the nonflowering plants. What a different experience it is to observe in turn the algae, the mosses, the ferns, and then the great conifer trees and to learn something of their life histories. Then come again to the grasses and the grains, and realize the importance of the soil in which they

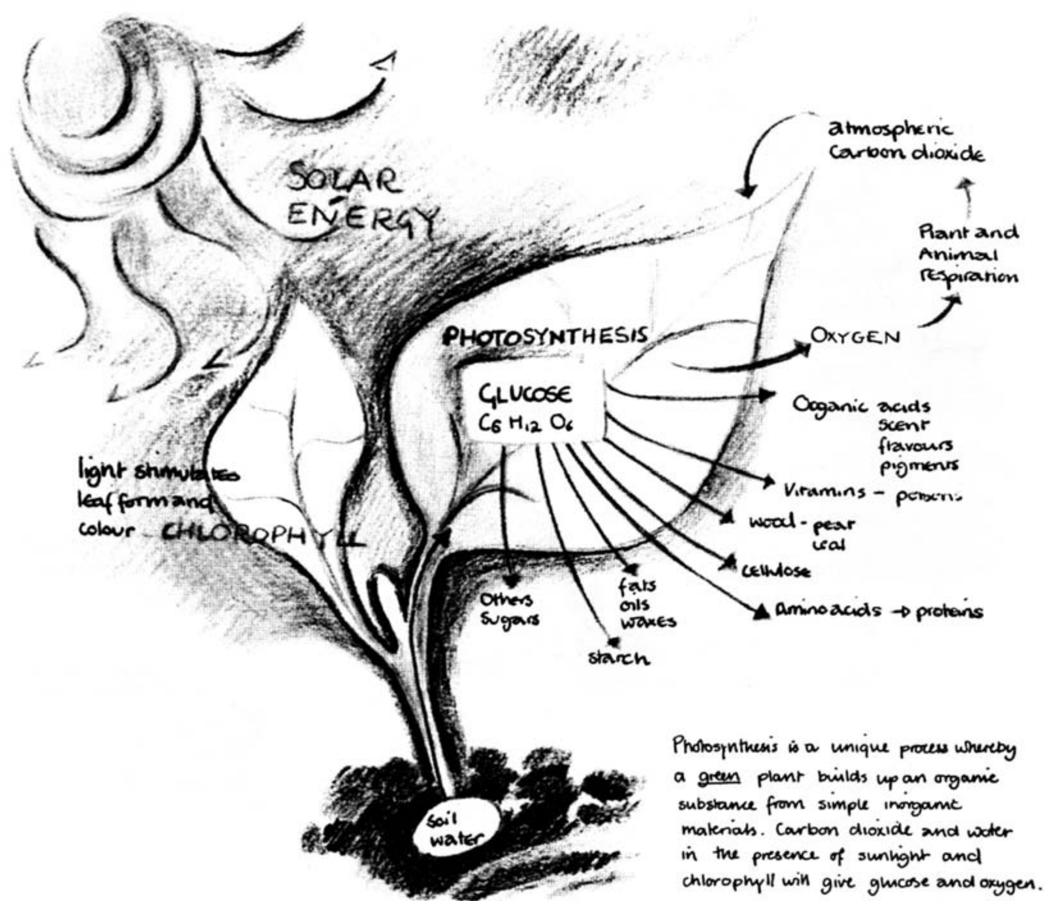

Fig. 34

grow—that soil which Professor N. Berrill in his book *Biology in Action* describes as "precious beyond all estimate." In other botany courses I have found time to do some practical work with students in making soil chromatograms, showing a way of testing the quality of a soil other than a quantitative analysis of the humus content. Practical experiments on photosynthesis and transpiration also have their place, leading to the realization that these are world processes.

During this botany course of three weeks, all students made drawings and notes and wrote essays, the beauty and quality of the work often testifying to the interest aroused. In addition, from discussions in class, students came to realize in a fundamental way that as human beings we have our roots in nature and are utterly dependent on the growing plants.

At seventeen the students were mature enough to have a critical look at some of the current agricultural practices which tend towards upsetting the balance in nature, especially with regard to insects; and to appreciate the efforts of pioneers in the Biodynamic methods of farming and gardening. It did not come as a surprise to some of them that recent experiments confirm what people knew intuitively in former times that the moon and even the planets influence plant growth. Not only have the plants an intimate connection with the sunlight around them and the soil beneath them, but the water all over the Earth, having a connection with the Moon,

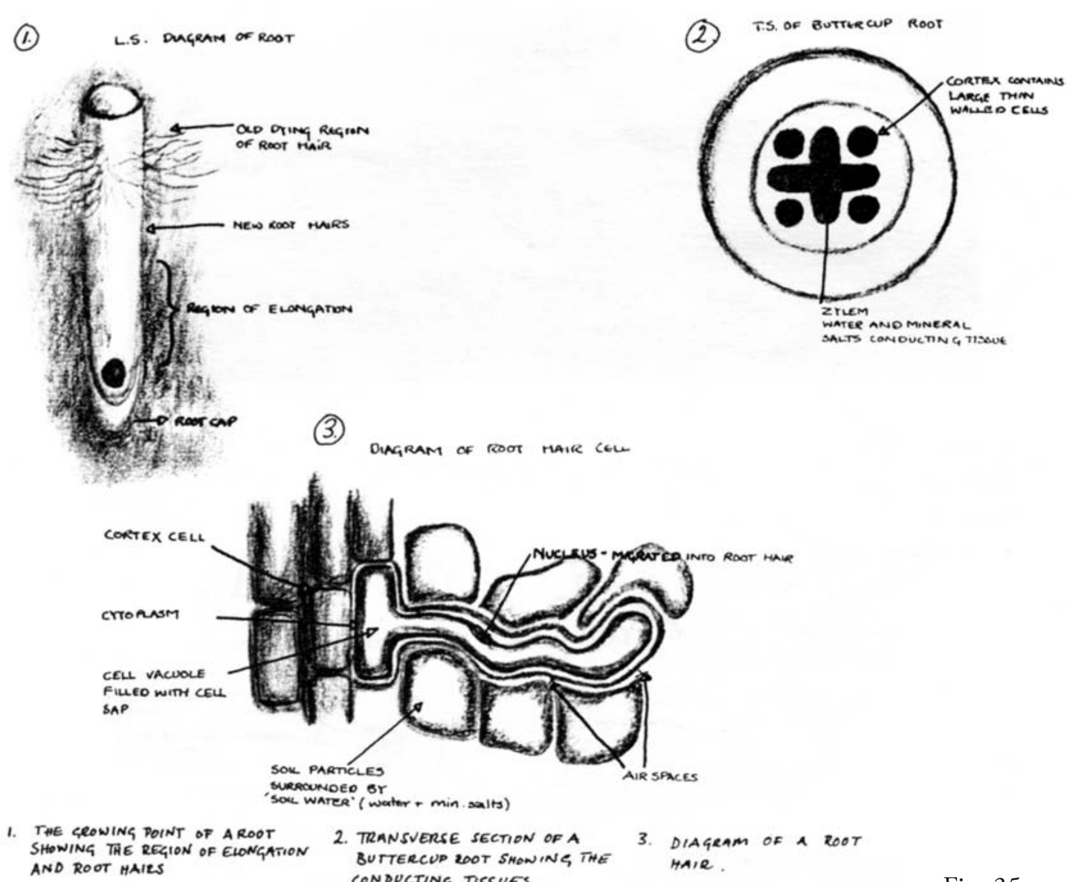

Fig. 35

distributes the lunar forces in the ground and these work from below into the plants. Lunar forces work formatively in the plant saps. Young people sense that the time has come when we need to turn our attention, through experiments carried out scientifically, increasingly to the working of cosmic forces upon the life processes (see figs. 33–35).

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A Thing of Beauty Is a Joy Forever: The Plant

by JANET and DAVID SHARMAN

From time immemorial the plant world, so intimate a part of our planet Earth, has succored the human being not only with nourishment, shelter and warmth but by the raising of his spirits, by speaking to his heart of the wonder and beauty of creation. The glory of the colors, the restfulness of the green leaves, the rhythm of the coming and going of the plant world through the year, all spoke their secrets to man of old as if in a dream. In more recent centuries the human being's growing wakefulness and searching and the development of modern natural science have led to a dichotomy whereby he has become ensnared within the materialistic side of nature and the need for analysis with a growing dependence on theoretical ideas and concepts. Nature and theories about nature are often two quite different worlds—a widening gap exists.

It was most disturbing to read in a recent account of teenage vandalism that sixty-four percent of the young people questioned saw no wrong in the destruction or mutilation of plant life. Yet, no doubt, many of these teenagers will have had some 'science' lessons at school. Obviously the gradual atrophy of the feelings and emotions of young people has been affected by the nature of their education and in particular their relationship to the natural world around them. It was one of Rudolf Steiner's most urgent wishes that young people should not grow up or leave school without a full appreciation and love for the plant world, not only its aesthetic influence, but also the wonder of its very nature, in that through the plant world the human being has a direct link with the cosmos and the influence of the cosmos can reach to us.

It is the challenge of the botany main lesson in the eleventh grade of a Waldorf school to try and close the aforesaid gap—to bring to young people a knowledge of the plant world essential for a modern scientific education and at the same time for an understanding of living nature, the rhythms and forces inherent in the plant world. The stature of a plant is the resultant physical manifestation of many things and we must look and listen to what the plants tell us—for it is by virtue of its form that the plant speaks most eloquently to us, whether the form is there before our eyes, luxurious and colorful, or hidden in the exquisite detail of a tiny seed. This unfolding, ever-changing, pliable form—contracting and expanding, bathed by the forces that form it, showing the rhythms of the cosmos in its manifest substance—this is the plant nature which we must come to understand today. By seeing the universe reflected in the plant kingdom, the greatness of nature can be experienced. In Steiner's words: "The comprehension of nature's rhythms will become true natural science."

The four elements as the Greeks described them—earth, water, air and warmth—can be considered as qualities of life within which the plant grows and develops. The interplay of these qualities will affect the molding of physical substances and call forth the infinite variety of plant forms (see fig. 36). Predominance of water or air can affect leaf form, resulting in metamorphic change. The higher plant grows rhythmically between the darkness of the earth—where it is rooted and wherein the seed rests in winter—and the light—warm radiance of the sun's rays wherein the shoot expands—leaf after leaf in mathematical exactness spreading into the atmosphere where moisture and air circulate to form new grains of substance in the organic functions of the leaf. At the height of warmth and expansion, the blossom appears with color, scent and flavor to bestow its gifts to the human being. Such an 'imagination' can be spoken about with the young people and drawn, while at the same time allowing them to observe the intimate detail of a particular plant body—Shepherd's Purse

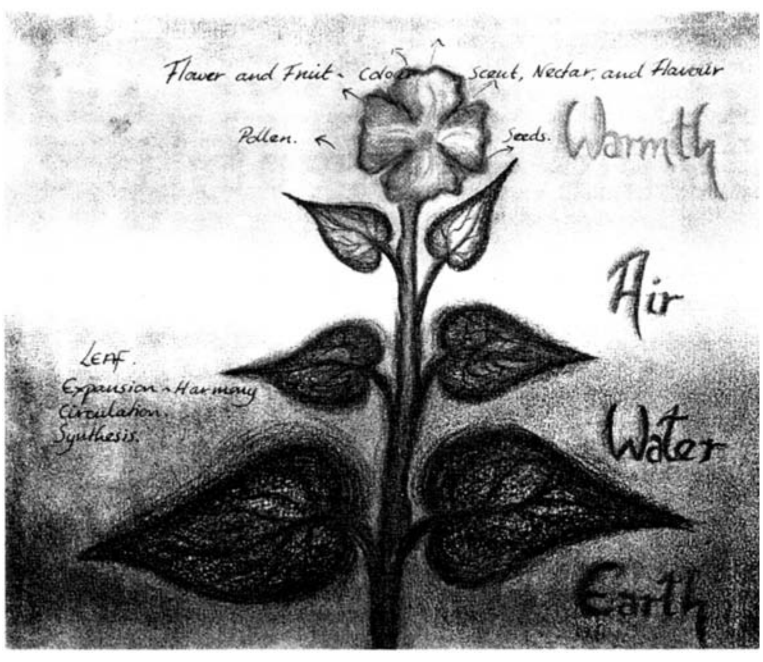

Fig. 36

(*Capsella bursa-pastoris*) and buttercup flower, for example. Here again expansion and contraction in leaf and bud can be pointed out at each node, all expansion arising from the sun's influence, while contraction is ruled by lunar forces. The final overcoming of the heavier watery and earthly forces by warmth produces the flowering shoot—with very rarely a reversal to the vegetable phase. Many discussions can take place here with regard to the influence of seasons on crops, and so forth, as the interests of the young people are stimulated.

At this time pea or bean seeds can be looked at and planted in glass jars to observe the details of germination and the unfolding of the plant in time. This daily observation for several weeks of the growing delicate plant can bring considerable delight and wonder to a teenager, calling up feelings of tenderness and care.

During this school year astronomy too will be studied and a knowledge of the stars and planets gained—perhaps even the wonder of seeing a planet such as Saturn with its rings and moons through a telescope is possible—and a feeling aroused for the great movements of the heavens. Now in contrast, one can turn to the cell, the universal unit of life, and with the aid of the microscope once more discover the orderly working of a creative nature in such a minute and detailed process as cell division and the elaboration of the different types of cells that arise when one describes the diurnal rhythms and working of the stomata in the leaves, where so many questions of ecology and climate can be involved too. What is the secret that raises a column of water to the top of a three-hundred-foot tree?—many theories cannot entirely satisfy one's curiosity.

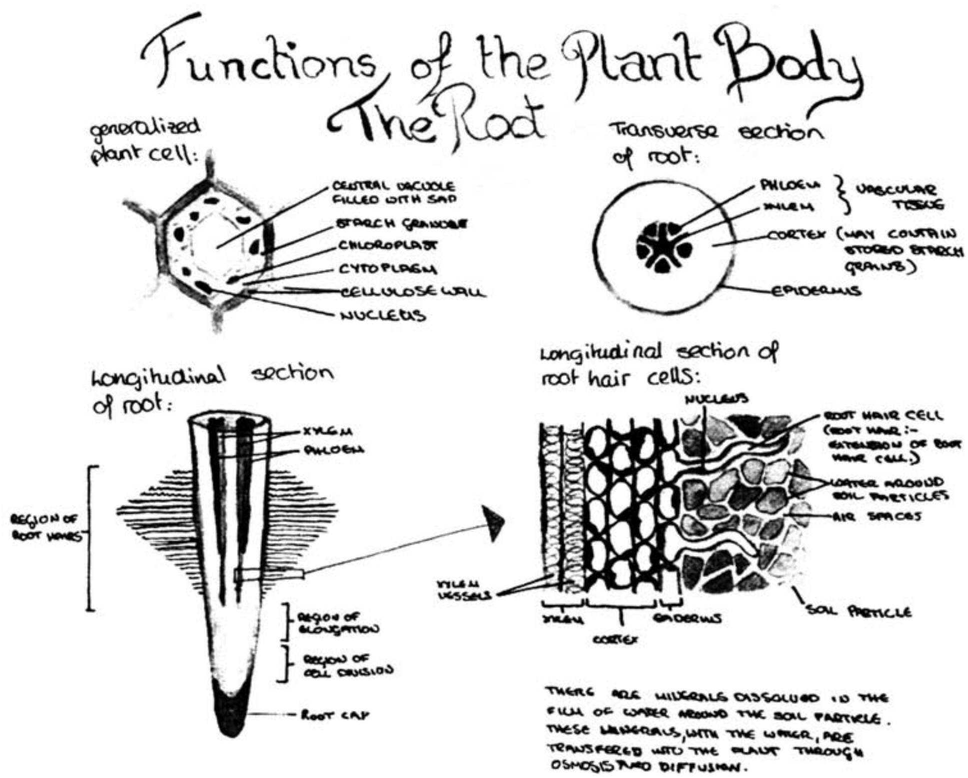

Fig. 37

Together with this understanding, essential scientific processes such as diffusion, osmosis, active absorption of minerals, root pressure, and transpiration must be undertaken, and this is willingly done by the young people who thoroughly enjoy setting up apparatus and making their observations (figs. 37 and 38).

Eighteenth century German poet and scientist, Johann Wolfgang von Goethe pointed to the polar opposites of light (yellow) and darkness (blue) working in harmonious activity together, out of which arises the color green. This same polarity is there in the living plant where the roots are trapped in the earth's darkness while blossoms reach for light and warmth. In the green leaves a harmonious activity exists where the miraculous creation of virgin substance takes place.

Air-permeated water with sun's rays striking through it makes the rainbow; the same elements of light, air and water bring about carbon assimilation in plants. May we then think of the plant as an enchanted rainbow through which the creative process works to produce material substance in the world of nature?

With such an imagination before them—the plants as a bridge between heaven and earth—the students can go on to look more precisely at the unique and wonderful process of photosynthesis (fig. 39). Photosynthesis is that process whereby the light of the sun becomes the source of energy used by plants to build first glucose and, from that, all further organic substance, and in this process providing the vital oxygen for our aerial environment. Once again, scientific experiments can be easily set up by students to see the differences between photosynthesis and respiration.

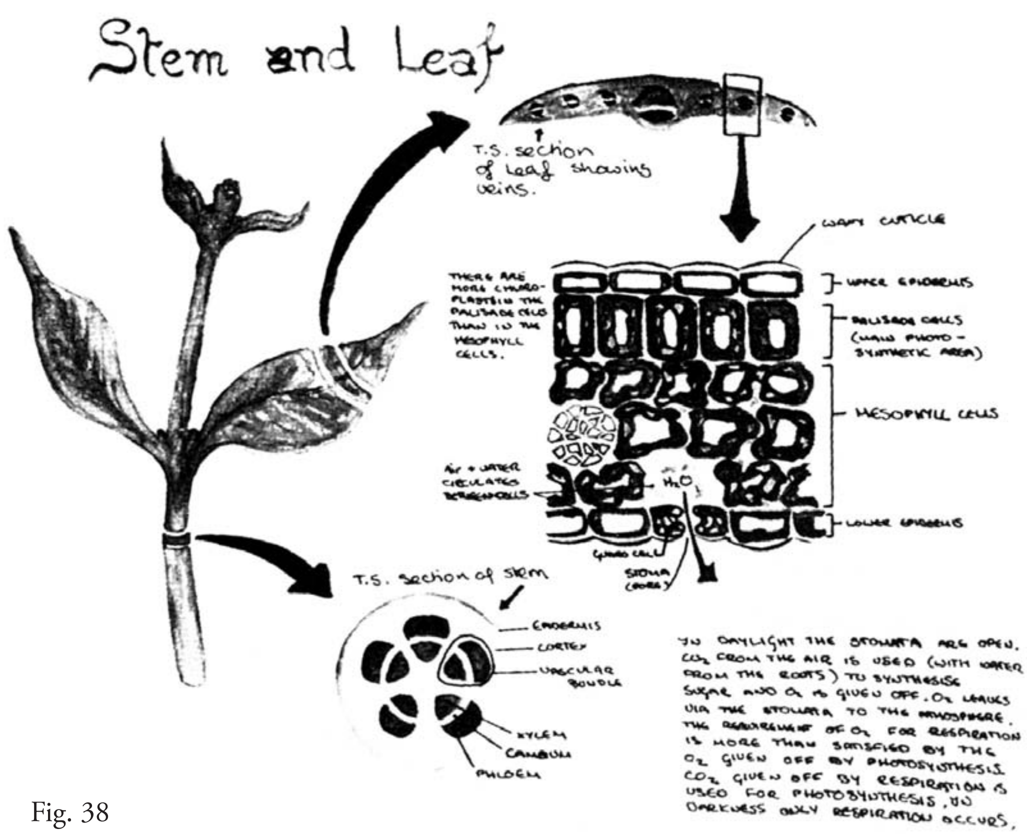

Fig. 38

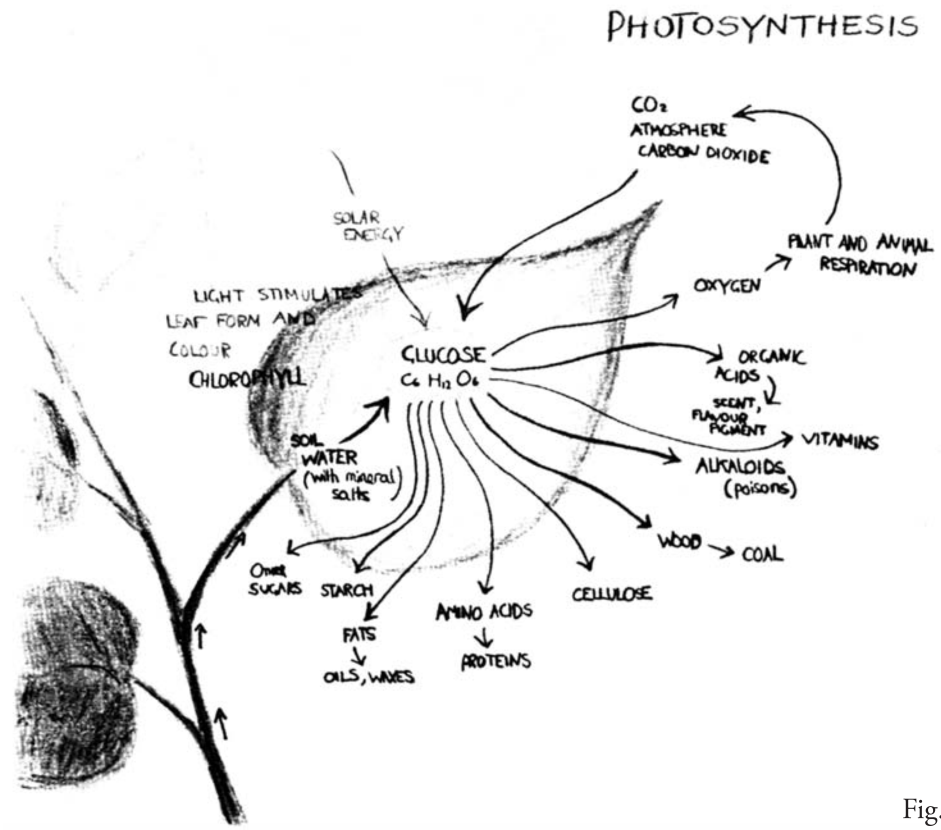

Fig. 39

Some work on organic substances will have been done in the ninth grade organic chemistry, and this knowledge can be drawn on in talking about plants and the substances they produce using modern chemical terms.

A project to encourage independent work and research on a particular plant of the student's choice can be set. Here botanical detail together with substances produced and used by mankind and their effects can stimulate discussion—and it is also good education for the teacher! Tobacco, cannabis, opium poppy and coffee were amongst those projects presented by one class, giving rise to lively discussions. By this point the students have painted a picture of the dominant flora of our planet, the higher flowering plants and the intimate way their life relates to the human being, the earth and the cosmos.

In *The Metamorphoses of Plants,* Goethe describes the process of plant growth in a metric form which can sometimes be used in recitation with the class. (A translation by Edgar A. Bowring was published by George Bell and Sons in 1874.) (See fig. 40).

Our environment is characterized by a richly diverse plant kingdom, on which the human being is dependent for his very existence. Members of the plant kingdom are found throughout all regions of the land and sea. Even in the most inhospitable places, some forms of plant life have been able to survive, e.g. in the tundra and on mountain heights. The subtle activities of the non-green plants (fungi and bacteria) are of considerable importance in the biological world.

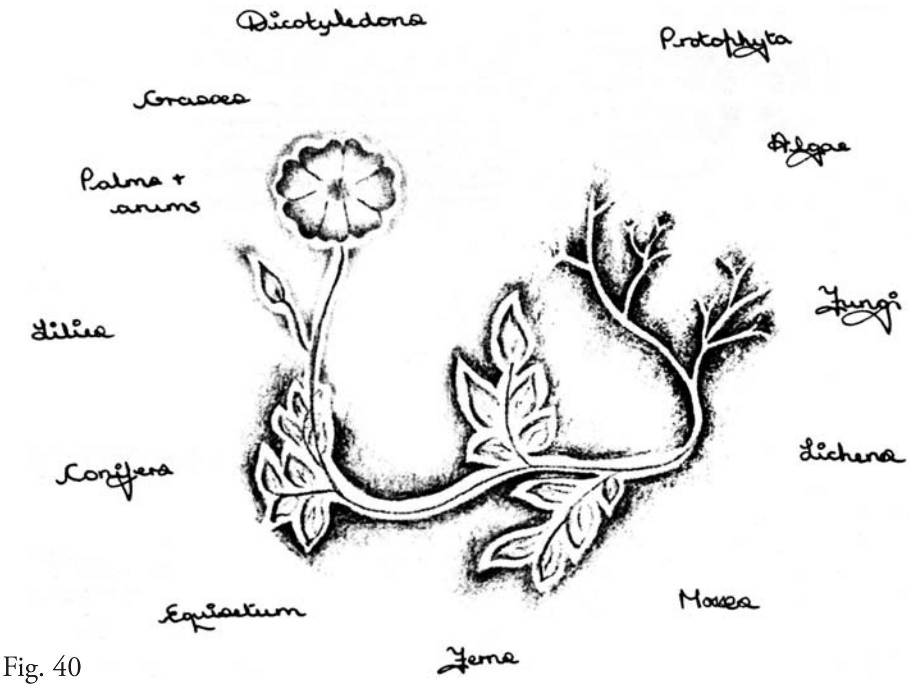

Fig. 40

The order in which we look at the plant kingdom reveals a world of increasing complexity. Here two imaginations at once strike us: the tremendous unity of the plant world in its greenness and devotion to life and at the same time the incredible diversity of forms as a result of the formative forces playing into the molding of their substance according to the environment in which they grow. Diversities of structure and function are best explained as manifestations of gradual change or evolution (fig. 41, at end of this chapter).

This grouping of the plant kingdom in the plant circle is a natural or phytogenic one in which relationships are considered and in which the life history of the individual recapitulates the life history of the race—in scientific language "ontogeny recapitulates phylogeny." This is shown in the imagination, by drawing the higher plant on the inside of the circle.

I Protophyta (fig. 42)

Protophyta (flagellates, desmids and diatoms) consist of floating masses of microscopic single celled plants, the phytoplankton or "pastures of the oceans"; their domain has never been invaded by plants of multicellular construction. It is estimated that they contribute half the photosynthetic productivity of the earth and ultimately support all the animal life in the oceans. Some are found in fresh water too.

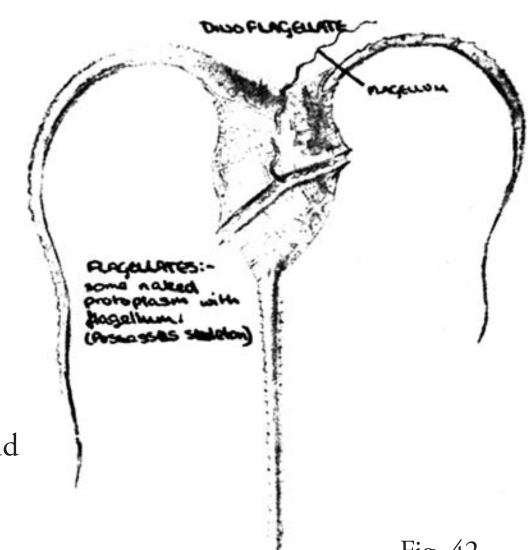

Fig. 42

Ancestors of these forms may have trapped the sunlight in the seas of long ago so that today we can exploit the great deposits of mineral oils.

How these early plants arose is still shrouded in mystery but one thing is certain: Their forms are most beautiful and of an infinite variety—they gave infinite joy to the Victorian microscopist! In conjunction with the zoology in Class 12, a plankton net can be made and, if a suitable boat can be found, a 'plankton excursion' made (fig. 43).

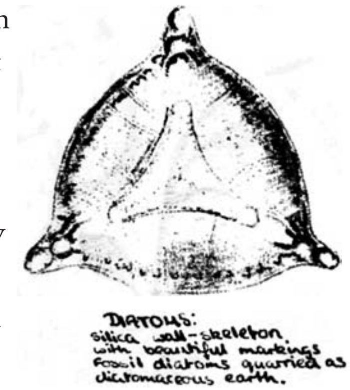

Fig. 43

II Algae (fig. 44)

The march of evolution has gone a stage further and given us plant bodies mostly of multicellular construction, and known as a thallus, again of infinite variety—filaments, plates, colonies and large thalli—all seem wholly dependent on a watery environment. These are the marine seaweeds and their cousins the freshwater 'pond scums' and weeds. A beautiful organism for our young people to observe in this category is Volvox, a microscopic rolling green ball of many cells—a plant colony or unified plant soma. A plant that moves?—an enigma of beauty. The zonation of the seaweeds by color and distribution on the seashore can make an excellent ecological excursion if you are near the sea—be sure to go at low tide! Again, there are many seaweeds which have a 'story' which can be interjected as time permits.

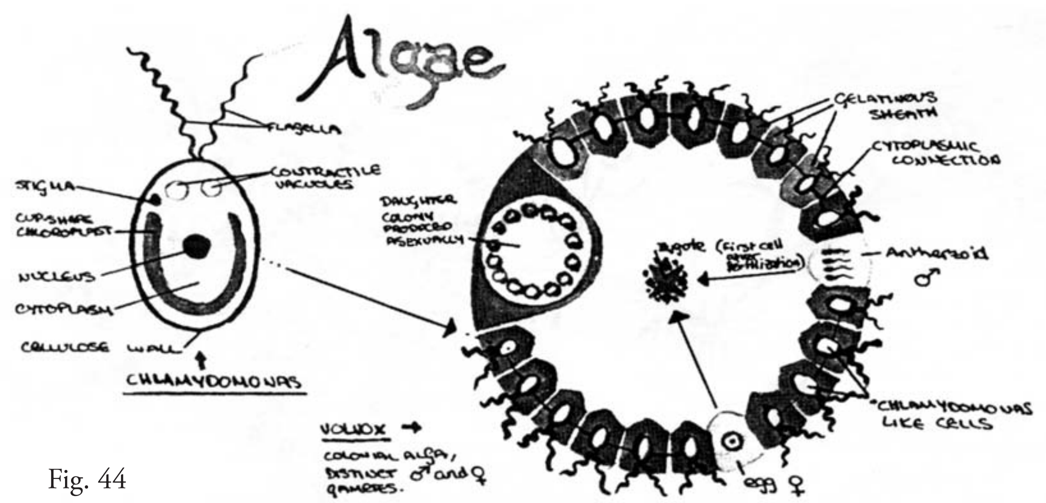

Fig. 44

III Fungi and Bacteria

The fungi show certain characteristics which distinguish them from all other plants. They lack chlorophyll and therefore seek out a different form of nutrition although they still retain some common features with green plants—a cellulose cell wall and certain reproductive cells. They have, too, a strange affinity to the animal world in some of their processes of nutrition and the fact that they can produce animal organic substances such as glycogen. A large group—molds, mildews, toadstools, mushrooms, and many plant diseases—they are the great scavengers of nature by virtue of their mode of life. Some are deadly poisonous, while others are sought for their culinary properties, and yet others are beneficial in other ways.

The structure of these plants is very simple: the Mucor (pin mould) can be grown to show this. The larger fruiting bodies collected from the autumn woods can lead to a good artistic exercise. Again, there are individual species with interesting stories to touch on, e.g. yeast, penicillin, and so forth. In the Edinburgh school a supplementary microbiology main lesson is given in which the study of some of these organisms and the history of their discoveries are gone into in more detail.

IV Lichens

Lichens form a large group of small plants found from pole to equator, from mountain top to sea level. All are dual organisms (alga and fungus), displaying the phenomenon of symbiosis, a living together for mutual benefit. Lichens are natural indicators of industrial pollution of the air and have long been a source of natural dyes, litmus being originally obtained from lichens.

These first four groups all display the quality of *root nature*. Their plant bodies shows very little differentiation, while life processes and absorption are carried out over the total surface.

V Mosses and Liverworts (fig. 45)

These are the most primitive of the green land plants; they are small in size, have no true roots, and the shoot may be a simple stem and leaves, or remain thalloid. Evolutionarily they form an isolated group not closely related to higher

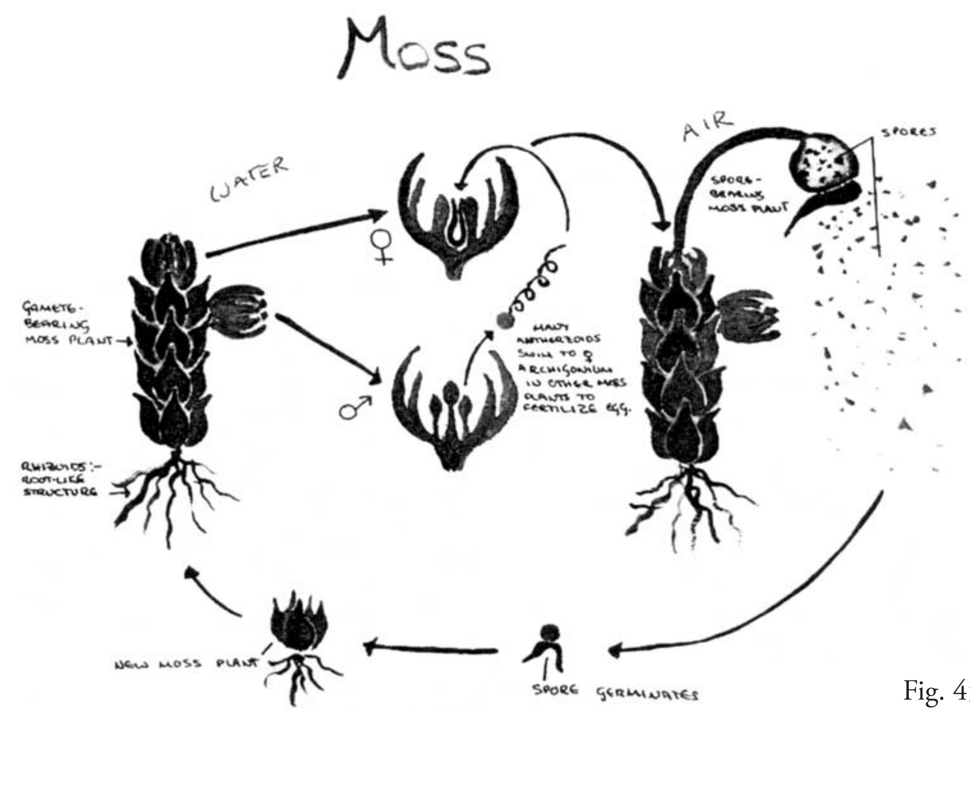

Fig. 45

plants, as can be seen in their life cycles where the gametophyte is the main plant. They rarely occur as individual plants but form extensive groups or colonies which help to maintain the humidity they need. They are true terrestrial plants, colonizing bare earth and rocks, and, though dependent on water for part of their life cycle, equally dependent on dry air for their spore dispersal. Observing mosses and liverworts in the laboratory can give us an experience of the harsh drying nature of the aerial environment on a delicate organism not fully protected against it—a low-power binocular microscope can reveal to us some of the delicate features.

The next six groups are all *vascular plants*, the true land plants, capable of surviving the harsh terrestrial environment by virtue of their internal conducting tissues and their external waxy cuticle. By these means an internal environment is maintained and large forms can develop such as the trees. True roots are now very important in securing for the plant its supply of water and mineral salts. Stem and leaves develop in a galaxy of forms—annual, biannual and perennial, but now always commencing from a diploid zygote—the result of the union of gametes, and thus the dominant plant is the sporophyte. The further march of evolution brings about the development of the true seed, a further elaboration in the drying and warm conditions of earth evolution. Vascular plants are classified thus:

- Seedless plants: ferns and equisetums
- Seed-bearing plants:
  - Gymnosperms: naked seeds, e.g. conifers
  - Angiosperms: enclosed seeds:
    - Monocotyledons
    - Dicotyledons

VI Ferns and Equisetums

These are moisture and shade-loving plants, usually growing in damp ravines and woodlands. The dominant organ is the leaf, and their economic value lies in the aesthetic appeal of their foliage. They perennate by an underground rhizome, and the leafy crown uncoils in characteristic fashion each spring—Canadian fiddleheads, for example. The life cycle still has a watery phase for fertilization which is a limitation to its success.

Today there is but a single genus in the equisetum group, though in coal measure times there were plants of tree size dominating the swamps and forests. Equisetum, sometimes called horsetail or scouring rush, has a very characteristic mode of growth which gives it a jointed appearance, and it is highly impregnated with silica which gives it its rough texture. It is a plant of ancient lineage, having been described by Pliny, Albertus Magnus (twelfth century) and Nicholas Culpeper in his *British Herbal*; and has been ascribed medicinal properties since earliest times. Steiner recognized the qualities of equisetum and suggested its preparation as a wonderful remedy for plant diseases. If a plant is diseased it means that the normal balance of plant and universe is disturbed; often water is too abundant and then insects and pests will attack. A preparation from equisetum with its silica and warmth element can be sprayed on to redress this state of affairs and re-establish the right balance (see: *Agriculture of Tomorrow*, L. Kolisko). The life cycle of this plant is similar to the fern, and specimens pose a difficult task for observation and drawing.

VII Conifers

Here the true seed habit is established and at no time in the life cycle is the plant dependent on an external watery phase. Now the earthly environment can be conquered, although the seeds as yet are only borne in cones.

Today coniferous trees are among the dominant forest trees of the world. Majesty and grandeur are their right. Soaring like spears into the blue skies, these mighty giants of the North American west coast, from California to British Columbia, some two- to three-hundred feet high and a thousand years old—humble the spirit that views them. Once again there are many trees with many stories. One which made a wonderful link for us when we taught in Vancouver was the Douglas fir, indigenous to the rain-soaked coasts of British Columbia. It was discovered and collected by the Scottish plant collector, David Douglas, who was plant-hunting in North America for the Royal Horticultural Society in 1823–1824. From seeds brought home to his master at Scone Palace in Scotland, he grew the first Douglas fir (named after him) in the UK, and it is said that all subsequent plants are descended from this tree, still to be seen in the Scone Arboretum. Douglas fir has a bright future as it is unsurpassed by any other conifer in quality of wood. The tallest tree in Lynn Valley, North Vancouver, in 1902 was 415 feet and 14 feet in diameter. The human being's greed, however, has caused severe problems in the devastating clearances of whole areas through indiscriminate logging—the gap is gaping wide! Environmental pressures are now being brought to bear and reforestation is taking place—but it needs thousands of years to heal such wounds.

The ferns, equisetums and conifers represent the evolution of the dominance of the *leaf form*. We come now to the *flowering plants:* the angiosperms, the glory and triumph of the plant kingdom. A flower is a shoot modified and refined by a long evolution in an atmosphere so dry that the warmth of the sun becomes the dominant factor. Its parts are modified leaves, the whole is much condensed, so parts are borne on the receptacle in a tight spiral or in cyclic whorls. Varied as may be the vegetative green leaves of the plant world, a world of metamorphosed wonder is revealed in the floral leaves, and nature surpasses herself in the colors and forms that now arise. Sepals, petals, stamens and carpels are all subservient to the life of renewal and arise in mathematical precision and number according to the family characteristic.

The last four groups of our plant circle describe the development of the flowering plants in an ever-increasing response to the conditions of the evolution on earth (fig. 46).

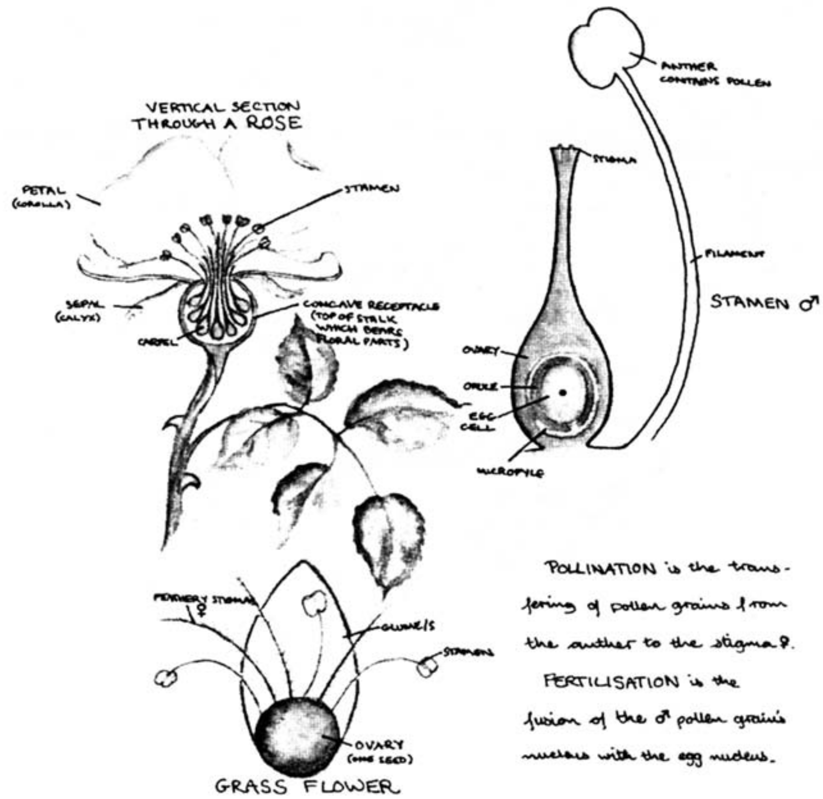

Fig. 46

VIII Lilies

These are large, fragrant and watery, and are built on the plan of three in their flowers. They have narrow, simple leaves and never harden into woody forms. They are predominantly herbaceous, a bulb being a typical life form.

IX Palms and Arums

This group is characterized by its inflorescence being enclosed by a spathe—the only British indigenous species being *Arum macculatum* (Lords and Ladies or Cuckoo Pint) though many plants of economical importance belong to this group, e.g. banana, date, coconut, and so forth.

X Grasses

Though still belonging to the monocotyledons, the grasses have warmed to the influence of the sun and air. Wind pollination reduces the floral parts to the essential whorls and no colorful corolla appears. The rooting system is vigorous and strong and forms in many cases a dense moist turf, from which shoot up the narrow, sharp silicia-impregnated leaves. In ancient times it was from these plants that man developed his staple grain plants. In class, if time permits, the seven grains can be related to the seven planets—their qualities in nutrition, and so forth, can be discussed. These often make good examples too for the botanical project.

XI Dicotyledons

Having contrasted the general characteristics with the monocotyledons, the family *Rosaceae* is taken as an example of highest perfection and beauty, together with a comprehensive pattern of growth in its other members: trees, shrubs and herbaceous plants. The flower built on the five-part principle in many members ripens into fruits of many kinds; and it is a family which allows wide discussion. The rose, itself a plant of perfect balance, is a fitting plant with which to complete our studies, and bring us full circle to the flowering plant again.

Thus, the plant circle is concluded with the angiosperms which exceed all other vascular plants in range and diversity of plant body, habitat and usefulness to mankind. Among the gifts they bestow are foods, textiles, drugs, oils, perfumes, timber, cork, honey and beauty.

Class 12 and the Constellations of the Zodiac

Fig. 41

by NORMAN DAVIDSON

The illustration in figure 47 shows the position of the planet Jupiter at its brightest in 1989 (end of December) among the stars of Gemini, the Twins. When the students now in Class 12 in Waldorf schools had entered Class 1, Jupiter was in almost the same position; in the intervening years it moved one complete circuit of the zodiac. When the students were in Class 6, Jupiter was only half way round the zodiac and stood among the stars of Sagittarius. Then, they were about to have an introductory lesson in observational astronomy, making them familiar with the zodiacal constellations, among others, and with the basic laws of the turning sky.

In Class 12, when Jupiter has stepped through the entire zodiac and returned to its position at the feet of the Twins, the students are ready for another major study of astronomy, apart from any supportive studies of the subject there may have been in the years between. For Class 12, Jupiter and the zodiac parallel the progress of the student through the school years. The zodiac itself stands as a complete circle in space and time, imaging the totality which the final-year student is brought, by the Waldorf curriculum, to experience in every subject and to experience in the sum of all the subjects put together.

Figure 47 is a map by Albert Dürer showing the zodiacal stars and others, seen as if from 'outside' the starry realm, looking back on a celestial sphere of constellations. The positions of Jupiter at its brightest for the past twelve years are marked by dots on the circle (ecliptic) running through the center of the zodiac. The positions of Jupiter at its brightest in 1977 and 1989 can be seen close together at the feet of the Twins.

In this map by Dürer the line at top right showing the end of the segment marked with the symbol 'X' cuts through the body of Pegasus the horse. The position of the line is correct for Dürer's time, but today must be shifted clockwise by about seven degrees towards the head of the horse and the constellation of Aquarius. Why is this? To answer the question in Class 12 is not only to grapple with the technicalities of observational astronomy, but also to raise into clear consciousness something which is often enshrouded in cloudy, *pseudo*-occult thinking today, i.e., the Age of Aquarius, brought about by the precession (moving forward) of the spring equinox position of the sun through the zodiacal stars over thousands of years.

The students can discover that there are at least two zodiacs—one comprising the actual stars and constellation figures, called the *sidereal zodiac,* and the other division of the circle (ecliptic) into twelve equal parts starting at the sun's spring equinox point, this point being considered the beginning of Aries. This is the *tropical zodiac* of the sun's seasons. The tropical zodiac is found to shift slowly, century by century, against the background of the fixed stars, so that the spring equinox point makes a complete circuit of the *sidereal zodiac* in about 25,770 years. Dürer's equally-divided circle therefore makes one complete revolution clockwise in that time through the circle of constellation figures he has drawn.

If one now divides the fixed stars into twelve equal lengths along the ecliptic (not done in the illustration) with the star Aldebaran at the center of the arc occupied by the constellation of Taurus the Bull (as the Babylonians are understood to have done), then the spring equinox point stood at the center of the constellation of Taurus in 3000 BC, of Aries in 852 BC, of Pisces in AD 1295 and will only reach culmination in Aquarius in 3442. As for the spring equinox point 'entering'

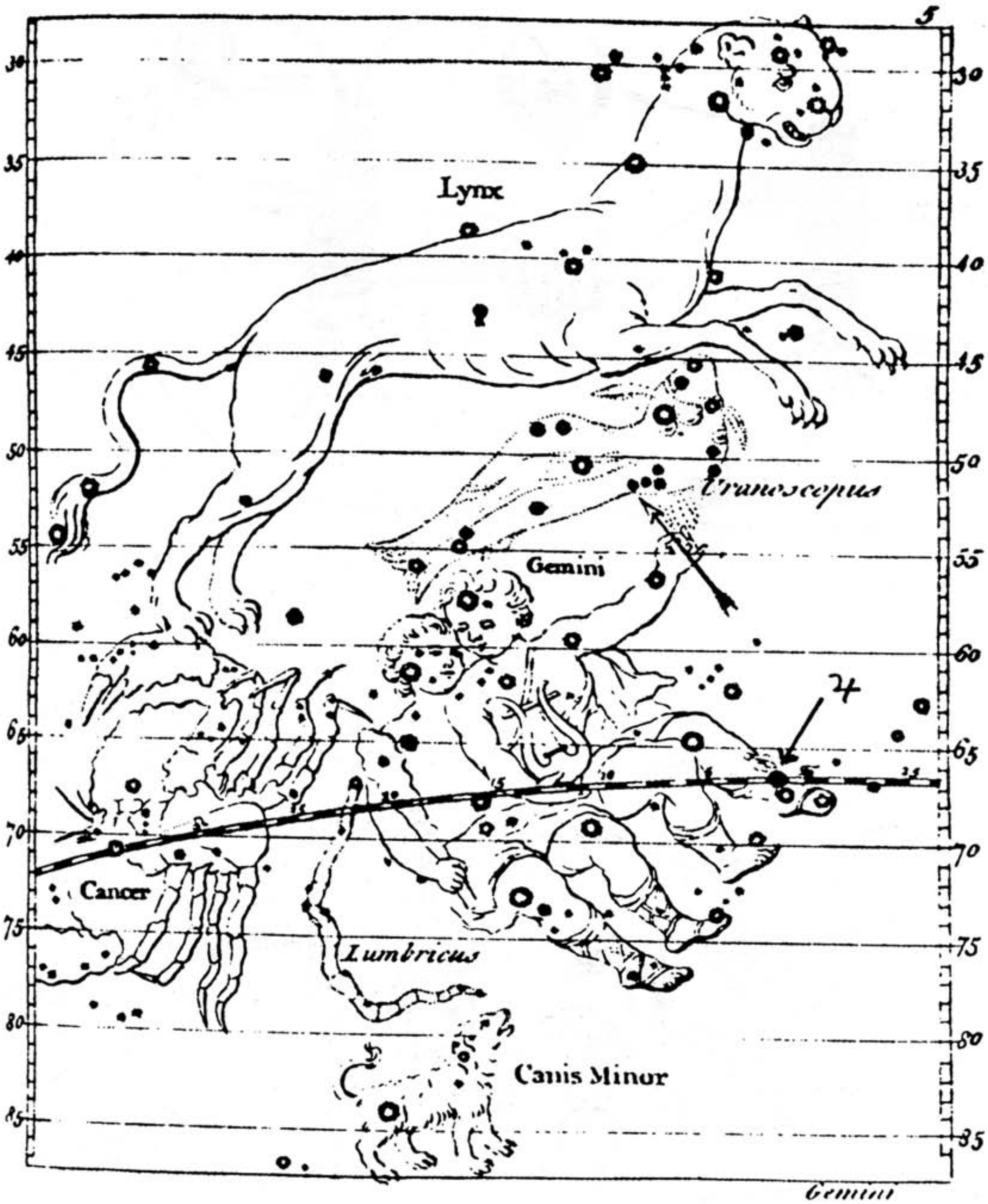

Fig. 47 *This star map, now in the British Museum, was designed by John Hill, eighteenth century English writer on scientific subjects. It contains fascinating additions to traditional star lore. Between Gemini and Cancer is 'Lumbricus,' representing an earthworm, and between Gemini and Lynx is 'Uranoscopus,' or stargazer—"a sea fish of peculiar figure, and has its name from its eyes being in such a position that it always looks upwards."*

Aquarius in the equal-constellation scheme, this will not happen until 2368. An age of Aquarius may be said to have dawned, but will not be entered into or reach culmination for some time. In 2368 the two zodiacs will be shifted from each other by exactly one constellation. In AD 221 they exactly coincided.

In these time spans an historical- as well as astronomical-type rhythm can be detected, and connections found with sequences of cultures studied in earlier classes (notably Classes 5 and 10). Students are probably familiar with aspects of language, art, consciousness, and so forth, which feature in a development through Ancient India, Ancient Persia, Babylonia/Egypt, Greece/Rome and the present, in stages of about two thousand years each.

The above could form a background to presenting the zodiac in an astronomy course in Class 12, but a background only. Students of this age are due a rigorous, modern treatment of the subject, and this part of the sky should be understood in terms of astrophysics and three-dimensional space as well. Distances of stars from the earth/sun system can be ascertained, first using the parallax method of the angle between earth, star and sun—just as in triangulation in surveying. One has thus carried the earth's laws of space into the cosmos. Then the two-dimensional, flat band of the zodiac dissolves into three dimensions—and sometimes surprisingly so when one discovers that the brightest stars are not necessarily the nearest. Six stars in the zodiac are among the brightest twenty-five stars in the sky, yet none of these is among the nearest twenty-five. Of these six, Antares in Scorpio is brighter than Castor in Gemini, but much further away.

It can also be pointed out that 'fixed' stars do actually have their own motion in relation to each other—a fairly early discovery in the history of modern science, being first made by Edmond Halley in 1710, when he compared the then-known positions of Arcturus, Procyon and Sirius with their positions given by the astronomer Ptolemy hundreds of years earlier and found them to be significantly different.

Then there is the important subject of the physical constitution of stars as determined by analysis of their spectra to deduce chemical elements in the light. Here not only geometrical instruments have been extended from earth into the sky, but whole chemical laboratories. Much pioneer work in spectrum analysis was done during the last century by the English astronomer William Huggins, who wrote about his researches taking place around 1860: "Then it was that an astronomical observatory began, for the first time, to take on the appearance of a laboratory. Primary batteries, giving forth noxious gasses, were arranged outside on one of the windows; a large induction coil stood mounted on a stand on wheels so as to follow the positions of the eye end of the telescope, together with a battery of several Leyden jars; shelves with Bunsen burners, vacuum tubes, and bottles of chemicals, especially of specimens of pure metals, lined its walls. The observatory became a meeting place where terrestrial chemistry was brought into direct touch with celestial chemistry."

Huggins spoke of the 'worshippers' of this New Astronomy and of its emerging scientists as "a knightly band, who have shown their knighthood by prowess in discovery … in chivalrous quest for Truth." Huggins himself pierced another time-honored shield when he announced to the world in 1868 that there was a connection between a shifting of certain lines towards the red or blue end of a star spectrum and the recession or approach of the star. He calculated Sirius to be receding at twenty-nine miles a second (faster than the modern estimate). Yet this episode in astronomy is made more interesting and important today by the fact that one of the world's prominent astrophysicists, Halton Arp, has questioned the recession (redshift) theory by apparently showing in his book *Quasars, Redshifts and Controversies*[1] that certain seemingly remote 'galaxies' cannot owe their extremely high redshifts to velocity of recession alone, and that the added factor may be the creation of new matter which is ejected from the centers of nearer galaxies, posing the question of whether these galactic cores "involve the normal terrestrial physics that we know about."

Lastly, to return to a zodiac related to the measure of the human being, one cannot omit the phenomena of eclipses which give the *ecliptic*, or apparent yearly path of the sun, its name. The word means 'circle of the eclipse,' for only when the

Fig. 48 *National Gallery of Art, Washington DC*

moon approaches the sun's path can eclipses of the sun or moon occur. And when they do occur, it is with breathtaking mathematical order and with rhythms which repeat themselves in the life of the human being.

Several examples relate the Class 12 student (who is around eighteen or nineteen years old) once again to the phenomena of the zodiac. The geometrical arrangement of the earth, sun and moon has it that in 18.6 years, one particular variety of eclipses (say, solar eclipses in which the moon crosses the ecliptic from below upwards) has spread itself around the entire zodiac. After eighteen years and ten or eleven days, the earth, sun, moon and moon's nodes (where its path crosses the ecliptic) stand in the same relationship to each other. During this latter period, as many solar and lunar eclipses take place as there are years in the normal life span of the human being. Also, single eclipses occurring eighteen years and ten or eleven days after each other form a series *Saros* with again as many eclipses in it as years in a human life. And after nineteen years *Metonic Cycle,* sun, moon and stars repeat the same relationship to the earth so that the same phase of the moon takes place against the same background of stars. As above, so below.

Endnote

1. Published by Interstellar Media, 2153 Russel Street, Berkeley California 94705.

Nibbling, Piercing, Grinding: Animal Dentition and Diet

by JANET and DAVID SHARMAN

The human being has many views on teeth. Some find them beautiful enough to use them for adorning themselves; others view them with fear at the thought of their sinking into their flesh; yet others find their shapes and adaptations of particular interest when studying the animal kingdom. Like so much in nature, teeth have an appeal of their own in their beautiful forms and reveal the reality of the forming forces in different animals. They are the hardest and most dense part of the physical body; they line the jaws and are well designed to obtain food of a variety of kinds. The showing of teeth often expresses a sign of aggression and menace, yet in contrast a smile of human friendship can be enhanced by shining teeth. Could they be the jewels in the crown?

When one considers the animal kingdom, a major challenge is to find a comprehensive picture of the great diversity which presents itself. Order out of chaos can be gained by looking at the major division or phyla presented in the comprehensive classification work of Linnaeus.

Another way is to take the upright, balanced and unspecialized form of the human being as a starting point and see how the mammals, for instance, represent one-sided developments of a particular feature. If we look at the human skull, rounded and embryonic in shape with its balanced dentition (see fig. 61), and compare it with some mammalian skulls, we see how the animal is specialized and locked into its particular nature which equips it wonderfully to cope with its own way of life—it has a specialized dentition for a specialized diet. In this way dentition and diet make a considerable contribution. 'Man' has a well-balanced and unspecialized dentition suitable for an omnivorous diet. His front cutting incisors (four up and four down), canines or 'eye' teeth on either side (four in all), and eight premolars all appear in the young child as 'the milk dentition' destined to be exchanged after the seventh year.

In his development, the human being is marvelously slow! He is born helpless and must gradually learn all his skills, even from the start, in walking, speaking and thinking. Thus he progresses through three seven-year periods of development: 0–7, 7–14, and 14–21 years of age. It is interesting to note that, at the end of each seven-year period, four new teeth appear in the back of the mouth—these are the true molars, never to be replaced. Thus, at about ages 7, 12–14 and 18–21 (wisdom teeth), these molars are added to make up the permanent adult dentition.

Teeth come in three main types: incisors, canines and molars. Each type has its own particular function: the front ones bite, the canines pierce and hold, and the back ones grind. This forms a threefoldness which can be elaborated by dividing the animals in the following way.

TYPE OF TOOTH ACCENTUATED

Incisor	*Canine*	*Molar*	
Rodent e.g. beaver, mouse, rat squirrel	Carnivore e.g. lion, tiger, cat, wolf, dog	Herbivore e.g. cow, deer, horse, camel, moose	*Mammalian group*
Fats & oils, starches, grains & nuts	Protein – hunts other animals	Cellulose – grazes vegetation	*Type of food*
Nerve-sense function	Rhythmic function	Metabolic function	*Predominant life process*

It may be surprising to learn that nearly three quarters of our mammalian species can be pigeonholed very easily by the specialization of their dentition. Furthermore, teeth are the heralds of the digestive system that follows, and in each group one type of tooth predominates.

What is seen in balance and harmony in diet, in dentition and life processes in the human being, becomes separate and brought to single perfection in each group. The rodents need foods rich in energy that can be easily digested. These small mammals are always busy nibbling with their dominant incisors and sensing their surroundings, alert for immediate action. They sleep in short spells in order to be wakeful again.

In direct contrast the herbivores have generally large, powerful and heavy bodies. They spend most of their time feeding, grazing on vegetation, followed by a long digestive process. Their food is rather poor in nutrients; a main constituent is cellulose which is very hard to digest. Their dominant teeth are the large ribbed molars which grind vegetable matter small enough for the digestive process to succeed. Many of these hoofed animals chew their food twice, the second time being the chewing of the cud. It is because of this strong and efficient digestive system that these animals have become so successful (see fig. 49).

There are one or two interesting anomalies in the mammals: for instance the boar, elephant and hippopotamus are all herbivores, yet all have large canine teeth! Also Wolfgang Schad in his book *Man and Mammals* (1977) mentions an interesting correlation between the growth of canines and antlers. If one examines the primitive South and East Asian deer, the musk deer of the Himalayas and the Chinese water deer, there are no antlers, but instead they possess unusually long upper canine teeth, which hang outside the mouth! In contrast we find red deer and moose with large impressive antlers and canine teeth reduced to short stubs or absent. There is evidence that the root of the canine and the antler connect, which can be clearly seen in the skull of a Muntjac, or rib-faced deer. What does all this mean? Perhaps it is that in these hoofed mammals the antlers and horns are a sign of surplus metabolism and possibly the extra large canines in this group might be considered thus.

Looking at the skulls and dentition of some aquatic vertebrates (shark, seal

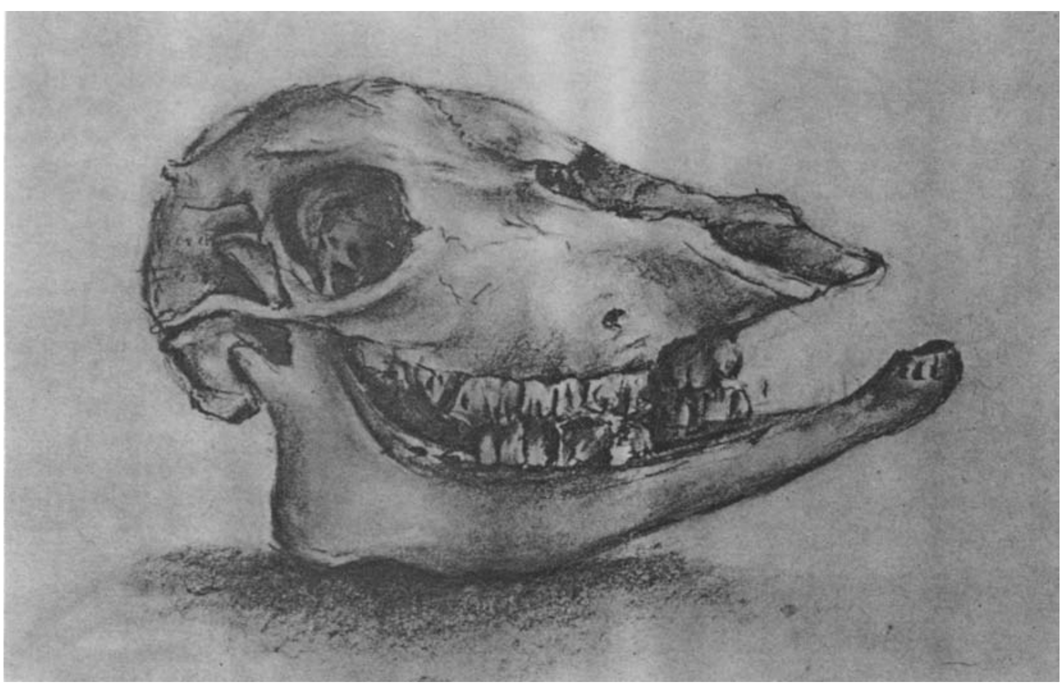

Fig. 49 *A 16-year-old's drawing in which black and white bring out sharply the characteristics of a sheep's skull. In adolescence, faculties of imagination partly transform into those of precise observation and causal thinking.*

and porpoise), one is struck by the lack of differentiation of the teeth: all are similar and slant inward, possibly to prevent the escape of their slippery prey (see figs. 50–52: *Three aquatic vertebrates*).

Turning to a consideration of the origin and development of mammalian teeth, we find that the teeth rudiments are formed in the early embryo from primary germ layers: the outer skin (ectoderm) is destined to form the enamel, and the middle layer (mesoderm) destined to form the dentine and pulp cavity. An upside-down cup-like structure is formed which grows inside the developing bony jaws. A third material, cement, holds the tooth in place and serves to bind it to neighboring structures. The central pulp cavity is alive with blood vessels and nerves and nourishes the tooth until it reaches its final and finished form.

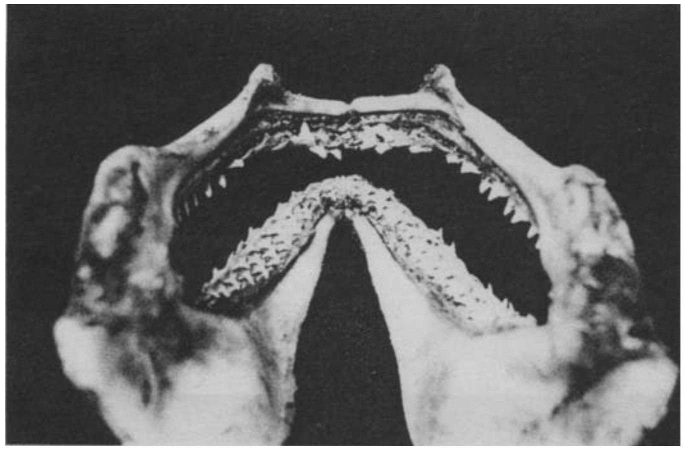

Fig. 50 *Shark*

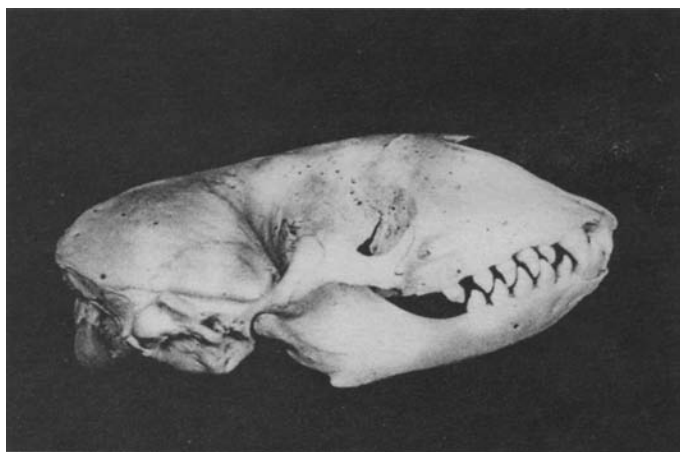

Fig. 51 *Seal*

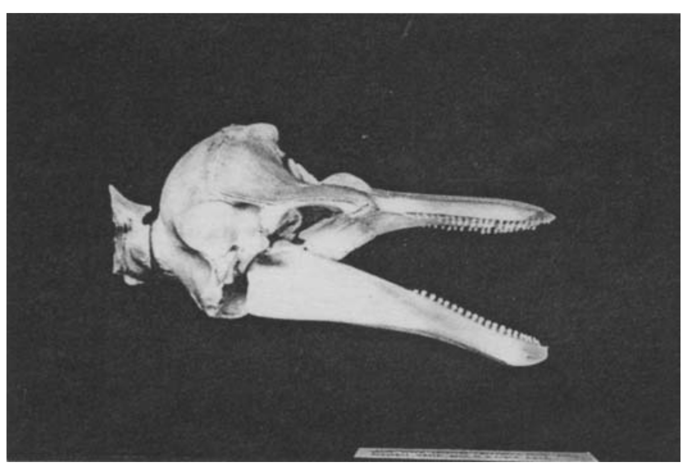

Fig. 52 *Porpoise*

Some animals have teeth that grow continuously; these have a permanently wide-open pulp cavity and no roots. This condition is seen in the incisors of the rodent and the grinding molars of the herbivores (see figs. 53–55: *Three animal skulls that demonstrate the 'specialty' of each species*).

Like the human being, mammals have two sets of teeth, 'the milk teeth' and the permanent dentition. However, unlike the helpless newborn human child, young mammals

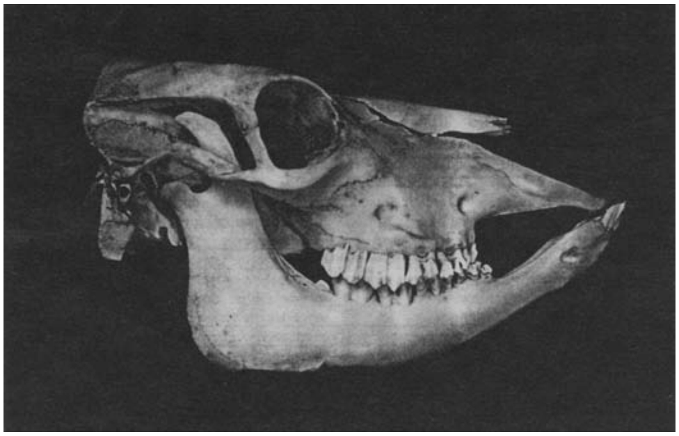

Fig. 53 *Cow: herbivore, with strong molars*

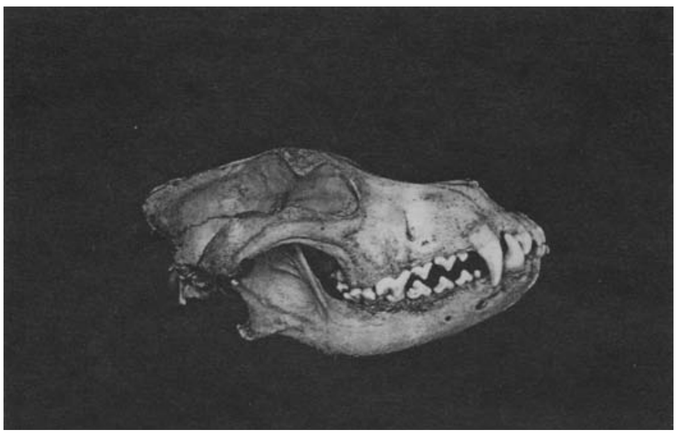

Fig. 54 *Dog: carnivore, with protruding canine teeth*

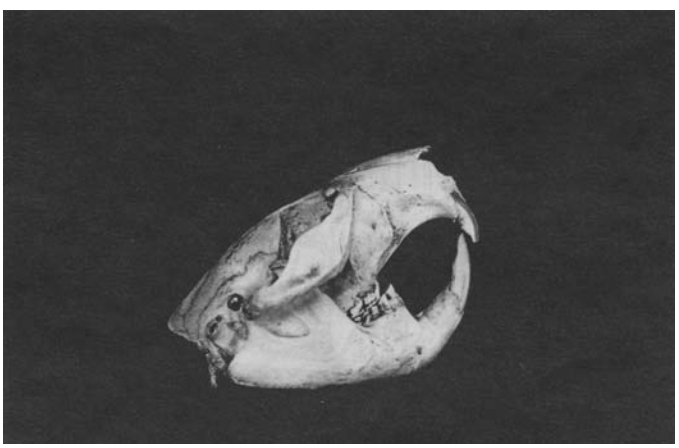

Fig. 55 *Beaver: representative of the rodents, with magnificently developed incisors*

at birth quickly proceed to acquire their physical abilities, evidenced by the young calf or foal which can stand and run within hours, and lambs which gambol and play. This is reflected in the dentition too when the milk teeth show an immediate and continuous replacement with no time lapse before the adult dentition takes over. The diagram shows the exposed jaws of a young cow, one and a half years old, with erupting adult dentition (see figs. 56 and 57).

In a comparison of three pig skulls—neonatal, seven weeks and one and a half years old—we can see clearly how the formative forces quickly and strongly work on the young animal. The young sow within two years has completed her development, is mature and capable of reproduction, while the young round skull is lost to a large angular shape (see figs. 58–60).

Through the 'incompleteness' of the young human being and through the long time taken in reaching adulthood, there remains time for the ripening of the spirit. This potentially raises the human being's status beyond the reach of the rest of the animal kingdom, an ennoblement which carries with it responsibility.

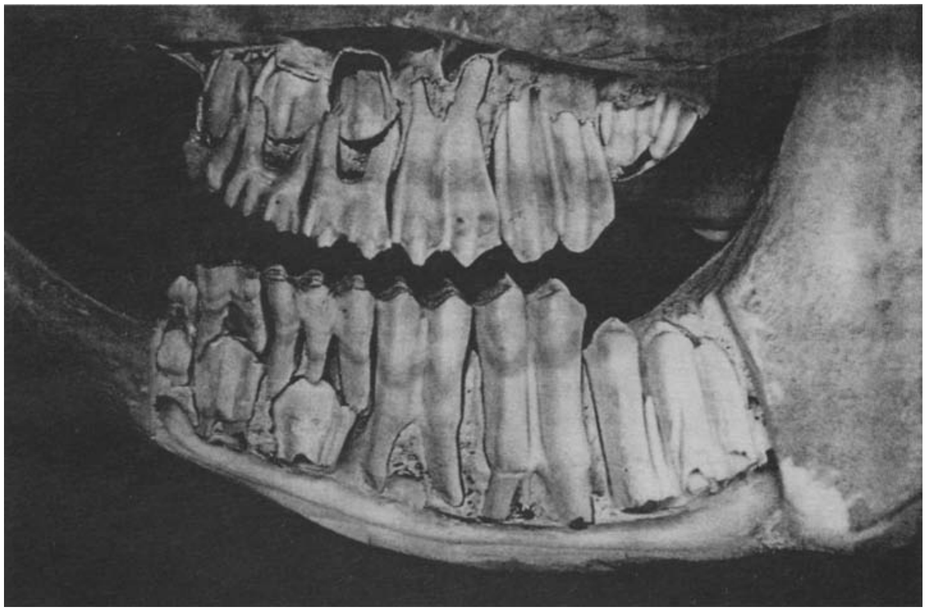

Fig. 56 *Photograph showing the jaws of a young cow, with molars exposed*

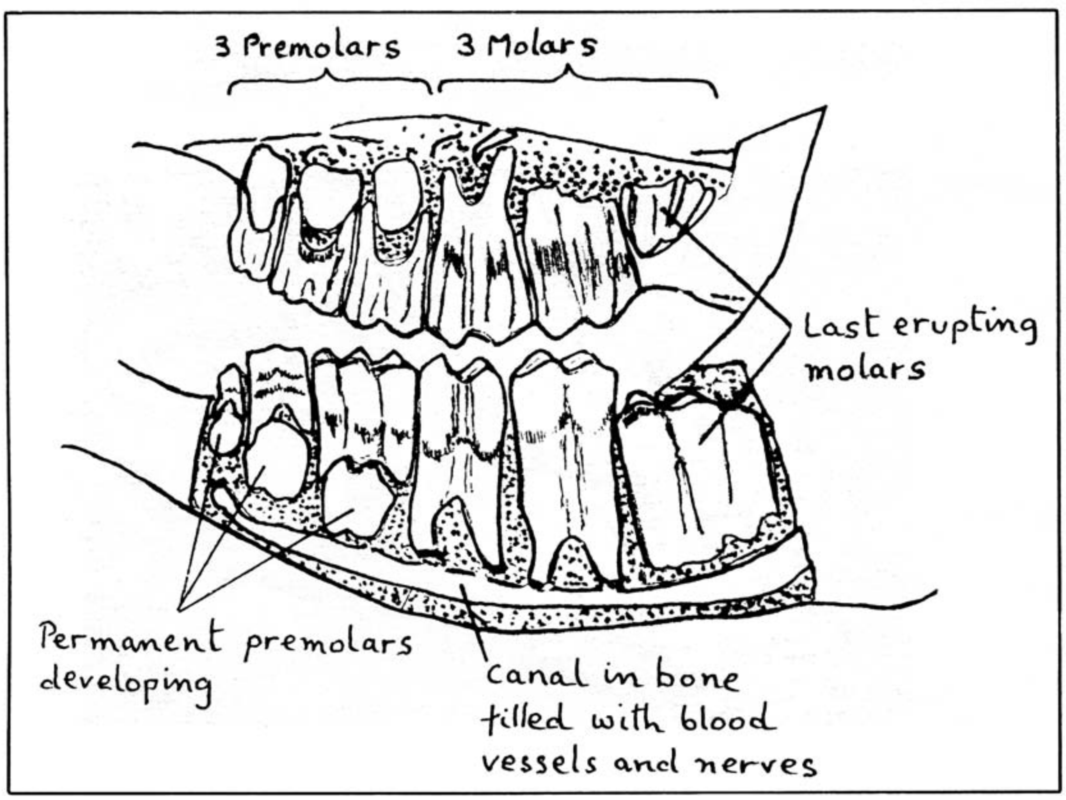

Fig. 57 *Corresponding diagram*

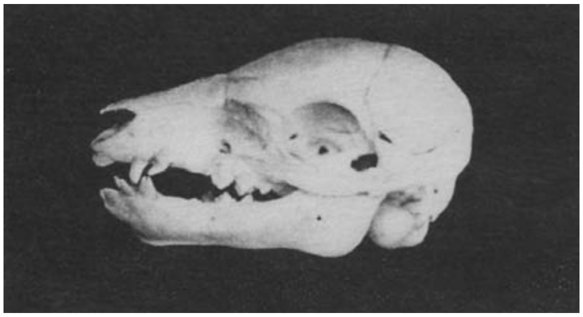

Fig. 58 *The development of the pig's skull: neonatal*

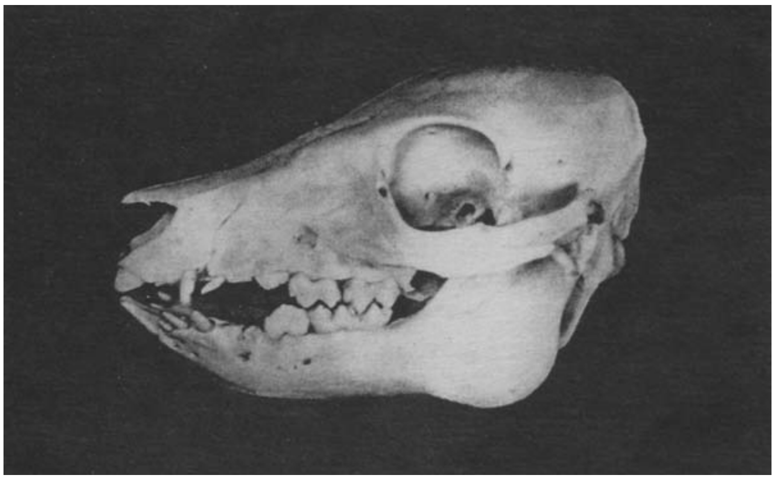

Fig. 59 *The development of the pig's skull: at seven weeks*

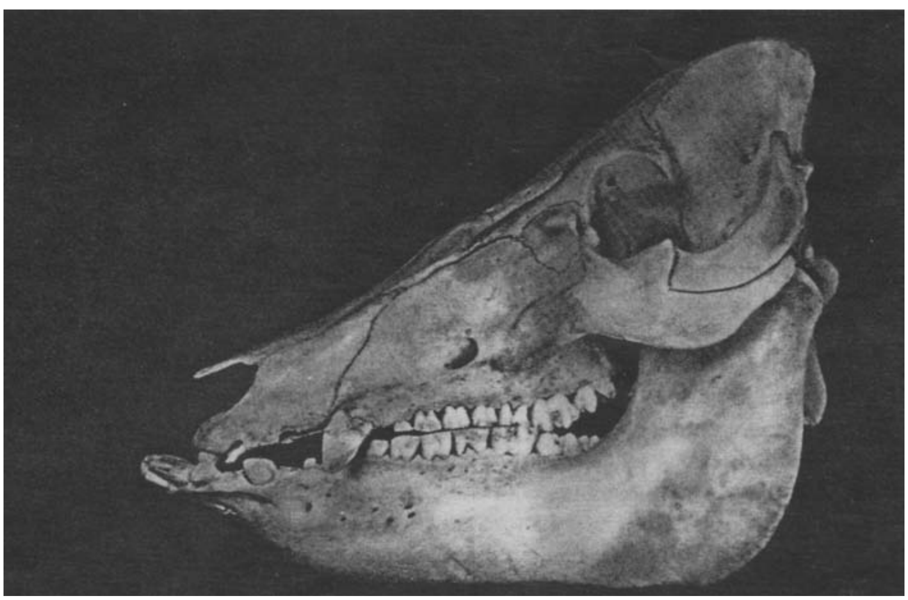

Fig. 60 *The development of the pig's skull: the mature sow (not to scale)*

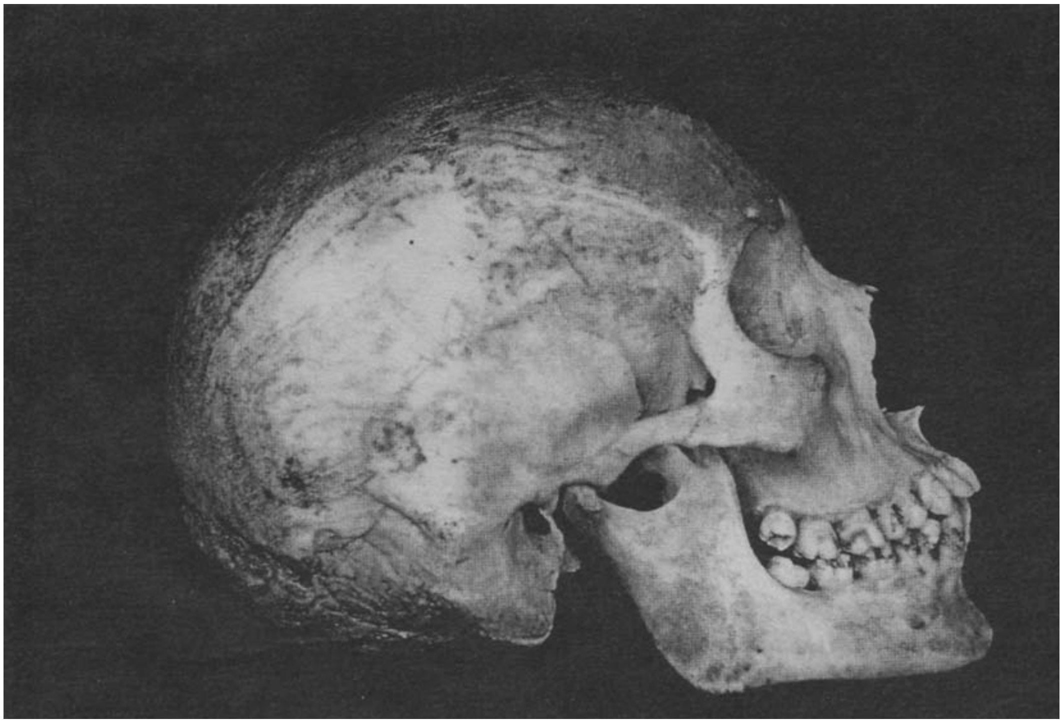

Fig. 61 *The human skull reveals a threefold balance in the arrangement of molars, eyeteeth and incisors.*

Biographical Notes

The following (deliberately very brief) notes have been extracted from the original biographies that appeared alongside the respective articles in Child and Man, though details were not always included in the archives. Hence, the information was correct at the time of publication of the article(s). Where more recent information has been available, it has been added.

Horst Adler: a Waldorf parent and computer scientist in industrial research.

John Burnett: After being a class teacher in Wynstones, Gloucestershire, UK, for 16 years, he became involved in teacher training and educational advising; and course director of the Waldorf program in Plymouth University.

Peter Clemm: metallurgical engineer before gaining class teacher experience at Green Meadow School, NY, and The Pine Hill Waldorf School in Wilton, NH.

Norman Davidson was a high school teacher in Kings Langley and Michael Hall, UK, before becoming involved with adult education in North America.

L. Francis Edmunds had both class teaching and high school experience before founding Emerson College, Forest Row, UK. His publications include: *Rudolf Steiner Education: The Waldorf Impulse*, London: Rudolf Steiner Press, 1962.

Lawrence Edwards was a class teacher and Upper School teacher in Edinburgh before retiring to devote himself to research.

Roland Everett: a class teacher for very many years at Elmfield Rudolf Steiner School, UK

H. Friedberg: no information available

Hans Gebert was a high school physics and math teacher before becoming involved in teacher training in North America. His publications include *Has Science Let Us Down?* Toronto: Mercury Press.

Dolores Graham: a Waldorf parent in North America, with much teaching experience

Alan Hall: a science teacher in the high school at Wynstones

Hans Heider: His article "Natural Science and Human Freedom" was printed in *The Faithful Thinker*: Centenary Essays on the Work and Thought of Rudolf Steiner, 1861–1925, published by Hodder and Stoughton, London, 1961.

Eileen Hutchins: a founding teacher of Elmfield where she taught as class teacher and in the high school.

K.M. Jones: a Waldorf high school science teacher in Edinburgh, Scotland

Graham Kennish: a science teacher in Wynstones and a co-founder and lecturer of the high school science teacher training course there.

J.D. (David) Lanning: both class teaching experience and high school science teaching at Michael Hall.

Ernst Lehrs: science teacher at the original Waldorf school, Stuttgart

Brien Masters: class teacher and high school teacher at Michael Hall before becoming founder and course director of Waldorf teacher training courses in London and at Michael Hall.

David Mitchell was a class teacher, high school life science and chemistry teacher, and adult educator. He is currently chairman of AWSNA Publications and co-director of the Research Institute for Waldorf Education in North America.

L.F.C. Mees: a Waldorf parent in Holland, medical doctor, and international lecturer

Norman Niven: Waldorf parent and senior dental officer (orthodontics) in The Ministry of Health.

Robert Oelhof was a high school teacher at Hawthorne Valley School, Harlemville, NY.

Gordon Purdy: tutor in the general arts program (Oassics) in the Open University before becoming a class teacher at Michael Hall.

Martyn Rawson: experienced Waldorf teacher; founding teacher and class teacher at York, UK; currently language teaching in Germany and lecturing around the world

Dorothy Salter: high school and middle school biology, chemistry and mathematics teacher in Holywood, Northern Ireland

M. Sergeant: no information available

Janet and David Sharman: Upper School sciences, Edinburgh, Scotland. David was formerly a marine biologist in Fisheries and Research in Aberdeen, Scotland.

A.R. Sheen: class teacher and high school mathematics teacher, Michael Hall.

E.G. Wilson: no information available

Michael Wilson: founder of the Goethean Science Foundation, Clent, Warwickshire; authority on Goethe's Color Theory

Frances Woolls: Upper School science teacher at Wynstones, before lecturing in teacher training courses on both sides of the Atlantic.