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The Development and Design of Science Instruction In the Waldorf School

Giving a satisfactory description of science instruction in the Waldorf School is no easy task. Although the area we touch on there is among the most essential features of anthroposophical pedagogy, it also diverges greatly from many modern ideas about how science should be taught. The fact that we are living in the age of the development of modern science makes it imperative to incorporate the results of the modern scientific world view into modern education and culture. The long struggle to do so is still clearly visible, running like a red thread through the development of our educational system in the past hundred years. The nineteenth century began with a humanistic educational ideal that essentially emerged from German Idealism: the ideal of educating the whole human being. That holistic idea, however, was derived primarily from the world-view of antiquity – specifically, from Greco-Roman culture. What came striding toward it as a result of the further development of modern science, especially in the second half of the nineteenth century, was not incorporated harmoniously into this humanistic, holistic educational system but rather appended to it like a foreign body of some sort.

We can observe this phenomenon in the development of new types of schools such as the German *Realschule* and the Austrian *Realgymnasium* with their emphasis on science and mathematics. Ultimately, it can be traced right down into science instruction in all the grades, even in early elementary school. Rather than being simply a question of whether Greek and Latin are taught, which was how the struggle for and against the so-called "humanistic" *Gymnasium* was framed, the whole educational system is involved. The *Realschule*, for example, resulted not from any unitary idea of education but rather from the somewhat forced integration of new elements – the contributions of modern natural science – into the old system. The scientific aspect of culture, with its earliest precursors dating only to the fifteenth century, is humanity's most recent acquisition. It was attempting to shape its world-view through observation and experimentation, and the big issue was how to integrate it into the old, essentially spiritually based element of Greco-Roman culture. Although the old ideal of education was to educate the *whole* human being, that "whole" was the human being of a bygone cultural era in seemingly new clothes. The new educational ideal did not see this "whole," harmonious human being but aimed only to impart knowledge specific to the newly dawning scientific era. We now have a science that bypasses the human being, especially as a being of soul and spirit, and attempts to see the human body as a product of natural evolution. This monumental struggle has not yet ended; it continues uninterrupted. At all levels of education, from the universities down to the elementary schools, science instruction is a testimony to this evolutionary process. We must indeed incorporate this new element into education, but how can we do so in a way allows the ideal of the "image of the human being" to emerge, an ideal that is justified in standing up to the demands of this scientific worldview?

This is the perspective I have chosen for considering the development of science instruction in the Waldorf School, since it enables me to touch on the essential points that anthroposophy can contribute to education in this field. In its essence, anthroposophy is

characterized by its attempt to apply thinking, as trained by modern science, to understanding the whole human being of spirit, soul, and body in interaction with the world.

When Rudolf Steiner accepted the leadership of the Waldorf School in 1919, he spoke to the teachers about the ideal of the "image of the human being" and presented them with a new goal for education. Their task appeared before them with great clarity: When children and adolescents study the natural world, every natural phenomenon must illuminate the connection to the entire *cosmos* and its great laws on the one hand and to the human being on the other. This cannot remain mere theory but must be implemented on the practical level in every detail. It must become possible to understand the human being on the basis of the entire cosmos and the entire cosmos on the basis of the human being. From how Rudolf Steiner spoke to us teachers about this ideal, we learned: Yes, it is possible to understand nature in a way that allows human beings to find their place within it again. And we set to work, inspired by enthusiasm for this ideal.

First of all, we were faced with the *science curriculum* Rudolf Steiner provided for the first eight grades. What does it actually contain? When all of nature is presented to the children's souls during their first three years of school, the sun, moon, stars, animals, plants, and stones appear as living, soul-endowed figures that talk to each other. The entire cosmos, near and far, is presented to the children's souls as if from a fairy-tale world so they can breathe and move within it.

Actual instruction in science starts in fourth grade and begins with the human being. While the cosmos still remains imbued with spirit and soul, human beings are the first to emancipate themselves from it and to manifest as independent entities. We point out aspects of the human/world and world/human relationship: how the shape of our heads reflects the cosmic *heavens*; how our limbs and lower body are connected to the earth; how the air that surrounds us shapes the midsection of the human body. Only then do we move on to the animal kingdom, deriving its various forms from the human form. We demonstrate how animal forms emerge through one-sided development of aspects of human nature. In birds, the head is developed above all else; in carnivores, the chest; and in horses and cattle, the limbs and the lower torso, and so forth. We then move on to cover the plant kingdom, followed by the mineral kingdom.

When the children are about twelve years old, we introduce the study of physics and chemistry. These subjects no longer deal with the individual beings of the natural world but rather with the laws of inorganic and organic nature, laws that pervade the entire cosmos and all living things. The first topic of study in physics is *sound*, which we approach through its connection to the familiar artistic element of music. We then move on to study light, heat, and the gaseous and liquid states before finally considering the solid element and *mechanics*, which is the last aspect to be considered in physics in this age. In other words, the laws governing lifeless matter are considered *last*. They are then contrasted with the study of the human being, which is taken up again in eighth grade, showing how the design of the human body, although based on all these kingdoms of nature, nonetheless represents something new and different from them. In the Waldorf School, the children are guided down from the fairy-tale world to the human being and then on down to earth, where they discover the human being again, but now in the total context of how we human beings are connected to the earth and the cosmos.

As the first Waldorf School grew, a new upper grade was added each year, and each year Rudolf Steiner designed a curriculum for it. Looking back over all the grades once the school was complete, we saw that the path of the upper school curriculum was the inverse of grades one through eight. First, the subject matter of grade eight is reconfigured and reviewed in grade nine. Then, in grade ten, the mineral kingdom is considered in connection with the whole earth as an organism. The plant and animal kingdoms are covered again in the next two grades, and finally, in grade twelve, just before the young people leave school, the focus is again on the human being, but this time

as a synopsis of all of the natural kingdoms that presents itself to the young people's souls. Waldorf science instruction begins with the human being and then traverses the entire cosmos to conclude with an enhanced understanding of the human being.

This curriculum with its grand perspectives was certainly capable of inspiring us to tackle great tasks. The timing of each subject is not arbitrary; child development reveals why it must be presented at one particular time and not at another. At first we were only dimly aware of the curriculum's fundamental importance. The full scope of its consequences became apparent only later, as we tried it out and thought about it. In the moment, however, it was up to us to develop the details of our lessons on the basis of these fundamental ideas, and to do that we needed more.

It may seem paradoxical that Rudolf Steiner gave courses on scientific subjects very soon after the school opened. They were aimed at Waldorf teachers, but others interested in science and affiliated with the anthroposophical movement also participated. These courses, which covered the subjects of light, heat, and astronomy, contain countless suggestions for research and many approaches to solving specific problems. Above all, however, the purpose of the courses was to *open teachers' eyes* to how science must be taught once we have truly seen all of nature with new eyes and learned to think about it in new ways.

I still have not forgotten how Rudolf Steiner talked about these subject areas. Whole worlds of insights were revealed to us. First, for example, we heard about contrasting elements such as light and electricity. Light belongs to the extraterrestrial cosmos. It is the opposite of matter (the heavy or earthly element) and is closely related to human consciousness, to the clear, alert conceptual activity that is the "light-filled" element in the human being. The same is true of sound. Although actually also related to the super-earthly element, electricity is bound up with the very structure of matter and struggles to rise from those depths. In human beings, it is related to the unconscious will that works in our limbs. Light and electricity are similar only inasmuch as both can manifest as "light," but in reality they are polar opposites in origin, one coming from cosmic expanses, the other from the depths of matter. Rudolf Steiner distinguished with great clarity between the clear, geometrical, thought-related manifestations of light and the mysterious, dark, almost ghostly manifestations of electricity, focusing on their connection to the human being in particular. We understood that light and sound relate to conscious human conceptual activity whereas electricity relates to the will pole. But heat, for example, lies in between: All of its manifestations mediate in some way between matter and ether, consciousness and unconsciousness, conceptualization and will; as such, they are related to feeling, to the middle aspect of human nature.

At this point, insight dawned on us – insight into the role each force of nature plays, both within the cosmic whole and in the human being. For example, we realized that a lesson on light would have be developed very differently from one on electricity, not only in terms of their content (which is self-evident) but also with regard to the teacher's overall tone and attitude. If we view light as only a different manifestation of electrical vibrations, this view will be expressed in everything we present and it will not allow the children to experience that we are dealing with two forces of nature originating in opposite poles of the human organism. But if as teachers we take such thoughts about the essential character of natural forces into account, we are then able to identify the right materials, the right sequence, and the right examples to use in our lessons.

Countless phenomena became comprehensible as a result of such flashes of insight. We also learned to think very differently about the states of matter and their essential nature than we had done before. In the gaseous element, for example, we recognized the activity of forces that are directed out into cosmic space; in the solid element, we recognized the contracting, Earth-oriented forces. The fluid element stands

between them. These ideas cannot be found in any book on physics, but every detail of our lessons can be linked to them. They are seeds for pedagogical activity.

It was similar with *astronomy*. For example, we learned how the starry heavens relate to the configuration of the human organism. In the head, in the shape of the skull, the system of *fixed stars* is revealed, while the midsection of the body with its loop-shaped ribs reflects the *planets'* lemniscatic courses. In the radial orientation of limb development, we recognize the forces of the *Earth*, which are directed toward its center. These perspectives are applicable both to astronomy and to the study of the human being. What is most important is not the specific insight but rather the inner schooling that results from this way of looking at things. If we think from this perspective, we can make ever new discoveries about the connections between heavenly processes and the structure of the human body, and we teach differently when we know about these things.

In effect, therefore, Steiner's science courses were an esoteric school of science for the participating teachers. Rudolf Steiner always aimed to present new views of the essence of the human being and its connection with the cosmos. This shapes and educates teachers, and in a certain sense they become different people. If we take up these perspectives in our preparation, each lesson we present will be different.

The teachers were then charged with implementing science instruction in their classes, whether in the main lesson as class teachers or as specialized teachers in science blocks. At this point, I would like to give a more narrative account of my own experience. In my previous work in chemical laboratories, I had wrestled with the problem of understanding chemical phenomena on the basis of what they reveal directly, one illuminating the other, as they express their essential character. I called this type of observation "phenomenological chemistry." It was an imperfect attempt to grasp nature in the sense of Goethe's statement, "We must not look behind the phenomena; they themselves are the teachings." The methodology of this approach now helped me flesh out the consequences of Rudolf Steiner's very surprising ideas. "The initial foundations of chemistry are best provided by beginning with combustion phenomena," said Steiner tersely in his explanations of the curriculum. It took me years to exhaust the full content of this statement. I began by attempting to demonstrate what a flame is: On the one hand, it radiates light (and heat) out into the world – imponderables returning to the heavens. On the other hand, ash precipitates – dead, material, solidified ash that has become totally earthly. Between these two poles, the air that feeds the flame is active, along with smoke, in which air and water wrestle. The whole phenomenon is what we call a flame. It is where the great cosmic opposites separate: light and heat separate from solid matter, from the salt-like, earthy element. Everything that is alive is combustible. The coloring and fading of leaves in the fall is actually like an extensive development of flames that ascend to heaven, leaving ashes behind. We must view the combustion process as spirit extricating itself from matter. A stanza by Goethe beautifully summarizes what needs to be said about this: "Whate'er a living flame may surround, / No longer is shapeless, or earthly bound. / 'Tis now invisible, flies from earth, / And hastens on high to its place of birth."

This is how we can talk to the children about individual manifestations of combustion. We allow fire, the combustion process, to emerge from nature itself. We show how it develops out of blooming and fading, how dead fire emerges from life. In each instance of combustion we find these same great cosmic contrasts, and the children learn to feel the same toward *every* manifestation of fire. Only later will we talk about oxidation. Oxygen supports ash formation. It is earth-oriented and wants to solidify and condense everything. It takes the opposite direction from light. Through it, everything becomes earthly.

There are fire processes within the human body, too, but where are they? They are in the movement of our limbs, in actions in which the will is at work. Your will, your moving limbs, are filled with living, soul-imbued flame! This is where the outer process of burning

can be found within, although totally transformed. And where is the ash? It is found in the human skeleton, in the structure of bones, and most especially in the human head. So we see that the human body is an inverted flame that burns in the metabolic/limb system, with the ash "precipitating" into the head. This flame, too, lives on air – the air of human breathing, which houses our human soul life.

It is different in plants. In their life process, they burn from below upward toward the heavens. Colorful flowers ascend from green leaves like flames; ash accumulates in the roots and in the bark of trees. Leaves, which breathe and hold water, are located between these poles. When ignited, each plant reveals a flame that is an image of its outer form. The flame from a burning blade of grass is different from that of a broad leaf or a flower. Animals are like hot, air-driven flames that crackle passionately, greedy for air. Human beings overcome this aspect to a certain extent, and the human "flame" is inverted because we walk upright. These ways of thinking are already familiar to the children from a different perspective: From studying the human body, they know that uprightness orients humans in cosmic space like inverted plants, with the horizontally oriented animals occupying the middle ground.

The basic phenomena of all of chemistry lie concealed in explanations of this sort. For example, in class we can experiment with heating plant matter of some sort in a hermetically sealed container, as in "dry distillation" of wood, to produce coal gas. The gas "blooms" upward; while down below in the retort, the charcoal (which will contain the ash as combustion continues) "takes root." Between these two poles, all sorts of fluid components develop and can be condensed, especially if leaves are burned instead of wood. Burning flowers produces more flame; heating bark, more charcoal. Even dead plant substance, therefore, produces a plant-like formation under the influence of fire. Coal gas, composed largely of methane and hydrogen, develops in the top of the retort. The children learn how hydrogen "grows" out of the combustion process when air is excluded and then ignites or "blooms" as it rises. They understand that hydrogen is part of the materialized manifestation of the plant's striving toward the heavens. When they then learn the chemical properties of hydrogen, they are not surprised to discover that it is so light, expandable, volatile, flammable, warming, and unstable or that its distinctive activity is always the opposite of oxygen's. Hydrogen is directed out into the cosmos, oxygen toward the earth.

Once we have laid the foundation so carefully, it is then tremendously meaningful to the children to discover that water can be transformed into hydrogen and oxygen. They are already familiar with water as the mediator than connects opposites wherever it is found. It is the bridge between heaven and earth, between acid and base, between gases and solids, in human blood circulation, between peoples and nations, and so forth. Now they understand why this is so: Within itself, water binds together the fiery, volatile element of hydrogen and the solidifying, earthly element of oxygen, which would turn everything to ash. As an experience, this is totally different from confronting the children very early on with the fact that water consists of two atoms of hydrogen and one atom of oxygen and that its chemical formula is H_2O. Instead, we want them to understand on the level of feeling and thinking *why* the laws of the entire cosmos require water to have the specific inner makeup that corresponds to this formula.

Of course an essay such as this can provide only partial indications, but all the facts children learn in other schools can be approached in this same way at any level of instruction, always building on what came before. It is important to emphasize this point because it would be easy to give the impression that Waldorf children do not learn the facts they need to know, which is not the case at all. It is only a question of *how* they learn about the same facts they would have to learn otherwise. For example, when I talk about salts, the whole tone of my lesson must be different than when I talk about the combustion process. Salts are the solid element that crystallizes out of fluids, acquiring form,

condensing, and becoming earthly. *Salt processes* are the opposite of *fire processes*. That is why ashes contain such high concentrations of salts. Water, however, actively mediates between and unites these two poles.

In a faculty meeting devoted to determining the chemistry curriculum for grade eleven, Rudolf Steiner said something like this: “Talk about each substance in a way that allows the class to recognize that its effects are distributed throughout the natural world, that it also works within the human body, and that the substance itself is only the solid-looking part of a living process.” That’s all he said. We had to take it from there. For example, when I had to talk about sulfur, I attempted to make it clear to the class that it is only one part of the earth’s Vulcan or fire process and that it also works in the same way in plants, animals, and humans. It promotes growth, digestion, and all metabolic processes; it is at work in the caustic plant oils, in human metabolism, and in all forms of rot; as a medication, it initially re-inflames old disease processes, and so forth. In short, sulfur is only a small part of a comprehensive *sulfur process* that pervades and fuels all living things. As such, all substances are the corpses of *living processes*. When we grasp these processes, we stand in the focal point of nature’s creative activity and from there gain access to the entire cosmos as well as to the human being.

Similar lessens can be developed around any substance. For example, young people must know that *calcium* is inseparably linked to processes in *animals*. All calcium is actually the product of animal life in various stages of transformation. The element of *potassium* stands in a similar relationship to *plants* and *sodium* to *minerals*. Our understanding of calcium is inadequate if we fail to realize where its process takes root in the living, natural world. This is the only way to understand all outer processes (including technological processes) that involve the use of substances.

In one lesson on combustion, I showed the children various examples and also demonstrated how sulfur, for example, forms an acid when it burns whereas other substances form bases. Rudolf Steiner was sitting in on the class, and after listening for a while, he said to the children, “Now that you’ve seen all this, think about what goes on inside your own body. Something acidic always forms when you move your arms and legs, but when you sit very still and only your head is working hard, something like a base develops in your brain.” So the children sensed the connection between the process taking place in the beaker and processes in their own bodies. Rudolf Steiner often offered support of this sort for teachers, suggesting directions for further work.

He offered similar suggestions in other areas, too. Once when I was preparing to teach *zoology* in grade twelve, it became evident in a faculty meeting that there would be only twelve to fourteen days available for that block. I asked Rudolf Steiner how I could possibly hope to cover the subject in such a short time. Always in favor of economy in teaching, he didn’t hesitate a bit but said as if it were the most natural thing in the world: “Twelve to fourteen days! That’s just right! There are twelve groups of animals, so you can talk about one each day and still have a little time left to sum it all up.” I was astonished. “Twelve groups of animals?” “Yes, I’ll write up the list for you by tomorrow,” Steiner said, and he did. The next day, I had the names of the twelve animal groups and my real work began, namely, researching the characteristic features of each group. By the time I finished teaching that block, I knew how to teach zoology because I realized that those twelve groups, taken together, accounted for the entire human being. And moreover, combining those twelve groups into three larger groups of four each revealed that the first four are repeated on a higher level in the second four and on an even higher level in the third four. For example, in all its attributes, *polyps* or jellyfish manifest as lower forms of worms and worms as lower forms of snakes or other *reptiles*. Or insects (seventh group) reveal themselves as an imperfect level of birds (eleventh group), and so forth. In short, the entire animal kingdom appeared wonderfully structured and in the closest possible

relationship to the human being. I realized this not through speculation but as a matter of direct perception when I had finished teaching about the twelve groups.

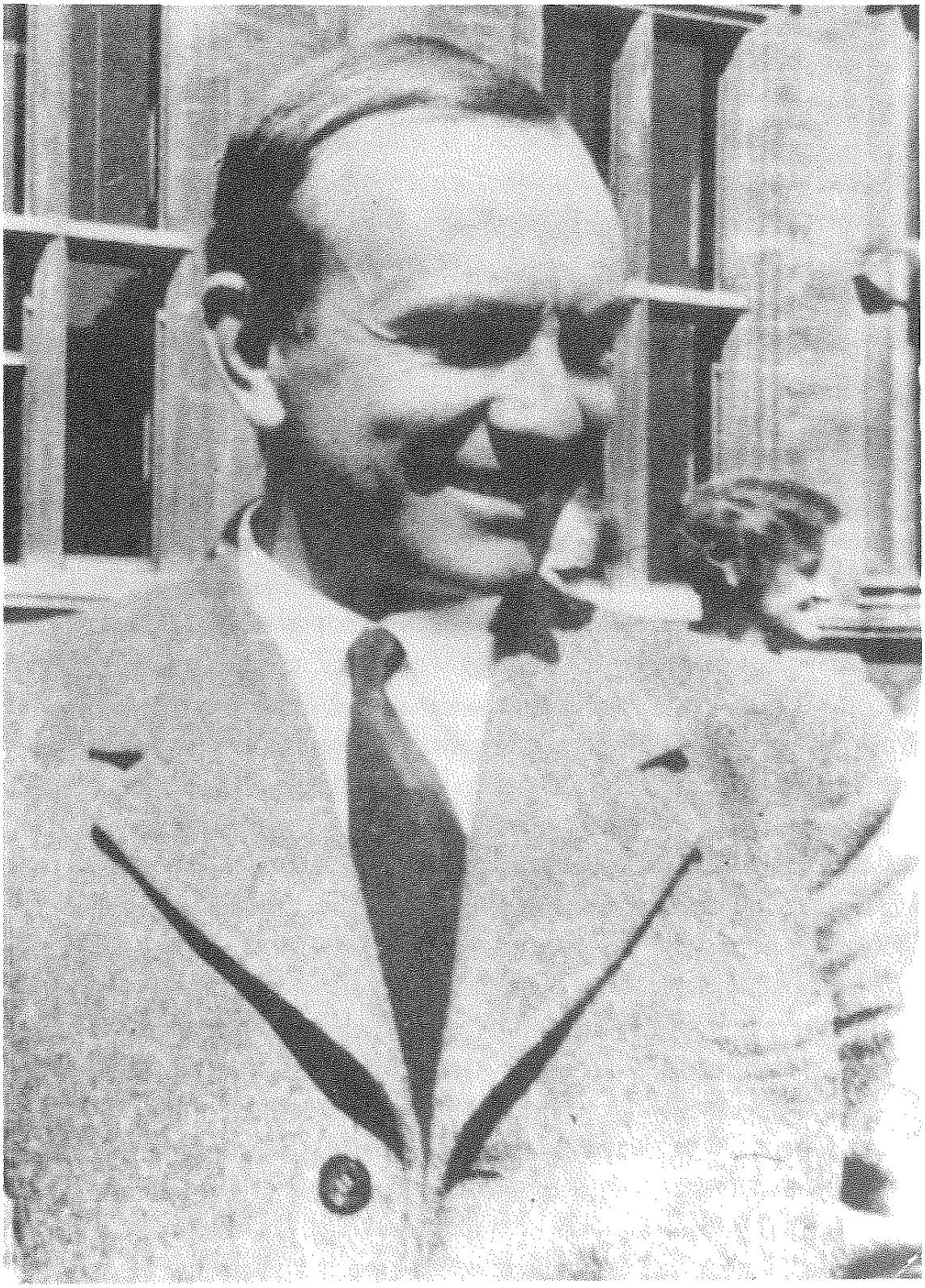
Of course the actual *study of the human being* is a natural focus and is taught repeatedly on all levels, so it developed in unique ways. The guiding light for teachers is Rudolf Steiner's principle of the *threefold human being*, which was one of the first contents of Steiner's original teacher training course. Having spent some time teaching in the way described here, it is difficult to imaging studying the human being without this view of human threefoldness. The study of the human being overlaps with all other subject areas, and in this sense teaching science becomes the common property of the whole school. How can we talk about the human being without beginning with the distinction between the head (the waking, conscious part of the body that serves cognition) and the unconscious limbs and metabolism? When we cover the nervous system, we find the same division: the *brain*, which is completely at the service of our waking, conscious psychological activity; the *spinal chord*, which is totally devoted to reflexes and semi-dreaming actions; and the *sympathetic nervous system*, which is totally unconscious and involved with digestion and the internal organs. The same subdivision is also apparent in the limbs: down below are the legs, totally subject to gravity; above, the jaws (the head's "limbs"), completely incorporated into the roundness of the head; and between these poles the arms, freely mobile and accessible to rhythm and to the gestures of speech. The upper human body is shaped by cosmic forces, whereas the lower port, which serves nutrition and locomotion, is shaped by the earth; the midsection with its rhythmic system mediates between these extremes. These truths, however, are not taught to the children exclusively in blocks on the human body but also appear (more or less consciously) in all other subjects. Isn't this threefoldness present as a self-evident active principle in eurythmy, gymnastics, or art – or for that matter, in every other subject? The children sense this unity running throughout the entire school. The study of the human body is the foundation of the entire art of education.

Teaching science in this way is an ongoing living, growing process that must constantly be shaped by the community of teachers. In the first Waldorf School, for example, when a teacher succeeded in developing a specific subject block for one of the upper grades, those efforts were not wasted but was shared with other teachers who would cover it later, on either the same level or a very different one**.** Still, of course, every teacher had to prepare for the block anew, since no two classes and no two teachers are alike. Waldorf teachers engage in a unique form of pedagogical work when they develop the methodology they need for a specific class by applying the sum total of Rudolf Steiner's indications, the practical experiences of colleagues, and publications that have appeared in the meantime, ultimately arriving at a way of teaching chemistry or a topic in physics that is unique to that class. Conventional textbooks are of little help in this approach. They usually present only a very small fraction of the subject matter, and much of what they do include is unusable, so we teachers must laboriously compile much of our material from a wide variety of books. Where would we ever find a single book that gives a complete description of the effects of silica and lime? We might find one aspect in a book on human physiology, others in botany or zoology texts or in older works by Goethe's contemporaries, for example, who developed similarly comprehensive concepts of nature as a whole.

Today we also owe a great deal to scientific works by anthroposophical friends, who have covered a wide variety of subjects in the past ten years, offering teachers a wealth of stimulating ideas to draw from. For example, when *Guenther Wachsmuth'*s book on etheric formative forces in the cosmos, the earth, and the human being appeared, it also gave a great boost to activity in the schools because it provided teachers with countless possibilities for teaching at any age level. Anyone who has read this book and then has to teach a class about geography, weather, the course of the sun, or the earth as a whole will bring the subject to the children very differently from before. And when *Hermann*

Poppelbaum's book "Man and Animal" was published, it struck me that it made available a tremendous amount of material that would help teachers prepare to present the Earth's evolution in ways appropriate to the children's souls. What good does it do to talk about spirit if what we convey to the children is an image of the earth in which the human race appears as nothing more than the highest among animal species? Formerly, it was possible to avoid this dilemma only by laboriously compiling the geological and paleontological facts discovered by the natural sciences and then comparing them to Rudolf Steiner's "Esoteric Science," struggling to combine the two. A few indications were available, but what we had was, on the one hand, scientific presentations with endless lists of facts but no spiritual content; on the other, humankind's evolution in spirit and soul. We knew that each list of scientific facts had to be understood anew in conjunction with the contents of "Esoteric Science." And after that, we still had to adapt everything to the needs of the children. The availability of so many stimulating ideas in the writings of anthroposophical researchers certainly does not mean we should not use other literature, recent scientific publications, and so on in our preparation. But we need more than just those, and that "more" could only be developed as described above. Even today, there are still no children's science textbooks; we have had to compile them ourselves.

In short, a totally new way of teaching science had to be developed, and perhaps it is justified to say that this new way of teaching is beginning to live up to the ideal presented at the beginning of this discussion. It really does integrate nature into human cognition in ways that allow us to acknowledge that the human being subsumes all the forces of nature and transforms them into something higher. In turn, however, the human being is what makes the natural world understandable for us. In the context of education, therefore, science uses modern insights into nature to vindicate the "image of the human being," the ideal that must present itself to humanity's view today.



Outside the school in Stuttgart, circa 1925.