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5. A Physicist Discovers Aesthetics

Georg Maier

Looking back over the course of my life, I can make out a certain path along which I have been led by my developing interest in different forms of understanding. I entered a profession with its own specific approach to the world—a profession requiring intelligence and a talent for inventing logically well-formed connections between abstract ideas. Only gradually did I become more open to present appearance, learning to trust it right into the sphere of personal decisions. If at first I had to devote myself fully to abstraction, it was in order later to develop a contrasting appreciation for the specific and unique appearance.

My memory retains certain scenes that appear to be key experiences along this path. What always strikes me as I recall these scenes is that when they were happening I had a feeling they were significant. Moreover, I am beginning to understand earlier phases as prerequisites for later ones. I see how my life owes its special course to people I met. I read my biography as the story of one who was continually spurred on by individuals who accompanied him, none of whom anticipated what would develop from their participation in my life. Of course, neither did I at the time they were my companions. Company, much more than an “inner voice,” turned out to be my guide.

About Playing

A child prefers to play with certain toys. In playing, he or she will often attribute to the things at hand new, unthought-of roles. While serious *work* is expected to depend on expertise in the proper use of things, on keeping to a given set of rules, serious *real life* leaves scope for improvisation. Things acquire new contexts. New rules evolve in playing that may be valid only in a particular constellation. Art, science, and especially social relations *live* on things being done just for the sake of their happening—as every child at play knows very well.

When I was six years old, we moved to a little country village in the Cottswolds in England that had not yet been reached by electric mains. Indoors a paraffin lamp would light up only a part of a room. Outdoors there was no street lighting, so having an electric flashlight at hand was of some help. I must have been about eight when I determined to find out how the working parts in a flashlight—battery and bulb—had to be brought into contact to make the bulb glow. I distinctly remember touching the knob at the top of the battery (which in those times looked golden) with the silvery looking bottom end of the bulb—and *nothing happened.*

I repeated this time and again, incredulous to find that the bulb refused to light. At last, my mother came to my help. She took a piece of insulated copper wire, scraped both ends, formed a tight loop around the trunk of the bulb with one end, and held the other end firmly to the bottom of the battery. To my great astonishment, this preparatory procedure changed the situation entirely. Now what I had been trying to do all the time suddenly succeeded. The filament of the bulb lit up! Of course, I had only old, used-up batteries to play with, which made the bulb glow very faintly. But I soon found out how I could add one battery to another, just as they were arranged inside the body of the flashlight. With a long wire connected to the bulb I could get a brighter glow from a whole row of batteries, none of which were very good. And I even found out that by holding batteries in the palm of my hand I could warm them up and so achieve a yet better result.

Crystal Set

After a few years, at about the age of eleven, I put together far more complicated parts according to one of those books about things a boy could do. I had no idea whatsoever how a "wireless set" actually worked. I saved up for and finally bought the necessary parts from a ramshackle second-hand shop in an alley of the town where an old man with a cat sold all sorts of junk. The place smelled of the cat. Following the instructions in the book, I soon received speech and music in my headphones by sheer luck. That was long before high-purity, single-crystal semiconductor materials were used for solid state components; the transistor was still years off. In those days the simplest receiver worked with a "crystal," a fragment of a metallic-looking mineral in contact with the pointed end of a wire, as a rectifier. In order to receive anything, one had to contact a "good" place on the crystal, which was found by trial and error. But this could be noticed only when a station had already been found by setting the condenser. Both conditions had to be met, but each was contingent upon the other! No electric energy was required to run the receiver, the headphones being activated entirely by the effect of the long antenna.

Electric Bell

Electricity must have come in later during lessons at school. Learning about it was definitely different from playing with it. All the same, I can only remember one thing happening, but it was very important indeed. Our teacher showed us how an electric bell works. We hear it ringing when a little hammer hits it again and again. How does the hammer's repeated movement come about? Finding this out made me feel "initiated." Recounting the phases of the hammer's movement, we were led to discover an ingenious trick: the electromagnet pulls the hammer toward the bell, but ceases to do so even before the bell is hit; nevertheless, the pull of the magnet has given the hammer enough momentum to strike. A spring holds the hammer away from the bell while it is at rest and pulls it back after each strike. After being pulled back, the hammer must again be propelled toward the bell, which is very simply effected by an electric contact that closes as soon as the hammer moves away from the bell and opens again as the hammer is about to strike. The electric current in the electromagnet is switched on when the contact is closed and switched off when it opens, so the hammer will always get the pull of the magnet as soon as it falls back.

I not only must have understood the trick, but, more than that, must have understood that I had been given the ability to understand! And this is what gave me the feeling of an initiation. I was impressed to discover that the inventions of the time were within my reach. I felt myself promoted from the status of a child who just plays with things to the rank of a person who is growing able to *know how to invent*.

Chemistry and Physics

Upper school led into science, which I enjoyed as a way of playing with ideas. One day, our chemistry teacher let us participate in preparing hydrochloric acid. I cannot recall how it was done, though of course I have since learned how it must have been. But this does not seem to have been all that important. What struck me on that occasion was that we had prepared a substance that is useful in real life, and so laboratory work moved me into the realm of serious activity in the world. This feeling must have surprised me, for chemistry acquired a new flavor I had not tasted before.

While science appealed to me, I remained shy in my relations with people. Professional life should not engage me too deeply with people! I imagined that in science human relations would not be so important. Later this certainly turned out to be all wrong, but such a feeling was then governing my image of my future.

Not long before the end of school I received advice about future studies. I visited a cousin, twenty-two years older than myself, a really great physicist who was later to become well known. I think it was the first time I met him. I must have told him about science at school and presumably about my liking for chemistry. He tested my likings and by the time I left him I had changed my mind. Comparing physics and chemistry, he had pointed out that in physics you may solve a problem by thinking it over, while in chemistry you depend on practical know-how, you have to know a great deal, and you will still be obliged to find out even more by gaining specialized experience. His argument for creative mental activity and against dependence on empirical findings appealed to the stronger leanings in me at the time, of which I had not been consciously aware up to that moment. Chemistry was out.

You Are No Good at Chemistry

Chemistry was part of the physics curriculum at university. In one phase of laboratory work we were given a mixture we were to analyze qualitatively. By applying the appropriate tests we were supposed to find evidences for certain ingredients. When we decided to stop our search and offer our results to the instructor, we were by no means certain that they were either correct or complete. So the drawbacks of chemistry I had been told about really were true. The instructor had to examine us after each task to check our knowledge of the chemistry of a certain group of elements. I had to rely heavily on shrewd guessing, mainly trying to deduce my answers from the structure of the periodic table of elements. Of course, the instructor could not be deceived, and one day he told me, “You don’t really know anything about chemistry, but you’re good at thinking!”

Diploma Thesis

For my diploma thesis I was given a “chemical” problem (in the sense of this narrative). It had just been discovered that crystalline layers of certain copper compounds exhibit most interesting spectroscopic phenomena at very low temperatures. I was to prepare one such substance with traces of a second, and then look for spectroscopic results. Not being good at chemistry, I could only prepare samples with traces in the range of percents instead of parts per million. This turned out to be a great stroke of luck, for my samples showed a new, unexpected effect that supported certain expectations about the mechanism underlying the spectroscopic phenomena. My professor told me, "Now we ought to publish your results in the form of a letter to a scientific journal." What actually happened? To my surprise, the letter that was written revised history by implying that we had made the experiments because we expected them to add support to the accepted theoretical model!

The difference between chemistry and physics had proved to be true. Certainly unexpected empirical findings proved rather important in this line of research—and also rather beneficial for my personal success! It turned out that this windfall could easily be recoined to give the necessary results for my doctoral thesis.

Alternative Research

What I had experienced was brought home to me forcefully by a project I pursued immediately after my professional training. I spent an apparently fruitless year working on experiments aimed at effects that were supposed to be outside the scope of conventional science. The person I decided to work with had a certain experimental setup in mind, which, as he expected, should bring previously unknown forces within reach of humankind. Full of the best belief, I sailed into my work. Soon I found effects in my apparatus. Things seemed to be going well. But these interesting effects turned out to be explainable by conventional, that is, trivial, physical mechanisms. So I had to modify the experiment by insulating it against the influence of its immediate physical surroundings. This course of events continually repeated itself. My experimental findings were never in keeping with expectations. Slowly but surely it became clear to me that the whole quest kept me in a state of contradiction to experience. I would lose interest in my results as soon as they became explainable. Much later, I would learn that comprehension of an appearance can always be deepened. Explanations are only temporary steps; if taken with too much finality, they can even endanger the deepening of understanding. So, looking back, I could recognize this experience as being of the greatest value for future undertakings. But at the time what I needed was a new job.

Neutron Optics at Nuclear Reactors

In my next step I entered a field in which kinds of forces that had been unknown when I was born were being put to use. A new tool of research with nuclear reactors was being established. The reactor process is governed by the flux of neutrons associated with the fission of uranium, and the neutrons, as they issue from the core of a reactor, can be used for research.

First experiences tend to be strong, persisting in memory. The day I had my interview as a possible future coworker in the Swiss Federal Institute for Reactor Research, the director of the department I was to work in took me on a detailed tour of a reactor installation that was to be put into operation shortly. Since there was as yet no radiation hazard, we visited places that would soon be inaccessible. I was able to see and feel the massive structures necessary to contain the high radiation that would surround the process. At gateways I received a first-hand sense impression of the thickness of the walls of the vaults we entered. I looked through heavy glass "windows" of unimaginable depth. That evening I had to tell my friend and future wife about everything that had so deeply impressed me.

In the routine of daily life that followed, the hall around the reactor was my usual workplace. Here one had to provide for all the experimental details necessary to the research projects. Here, too, many important discussions with co-workers took place— not only on professional matters. On special occasions when things went wrong, my strong first impression of the thick walls and their significance was expanded and intensified. But this never gave me a feeling of danger. The place was the accepted scene of professional effort. Only later, after leaving this field of work, did I begin to contemplate my experiences. Eventually I was led to a negative personal judgment about the industrial use of nuclear energy.

The field of science I had entered utilized leaked-out neutron flux to get information about materials. Everything depends on how the materials being tested *scatter* the neutron flux. I will try to explain what is meant. In a neutron optical experiment, when all is said and done, one always counts events. If the reactor is not running, practically no events are to be detected. When, on the other hand, there are many events, the experimental set-up lets these events form a kind of image of the material you are studying. You can think of neutrons as *particles* where they originate and again when it comes to counting events. And in between you are dealing with neutron *waves* that you must imagine to be embracing the probe material extensively. The apparatus, which must give the neutrons alternative ways of being scattered, puts "questions" to the neutron flux. The answers it receives always fall within the scope of the questioning framework—just like our answers to multiple choice questions. You must specify a set of alternative models, and you give the material you want to study a chance to express itself within this context. The kind of answer you get is that the distribution of counted events implies different probabilities for the various alternatives you have suggested.

As a beginner, one still felt that events "happened." But with experience, one realized that a single event or bursts of two or even three in short succession meant nothing whatsoever. Events of this sort must be taken in their statistical averages. I remember watching counters count and gradually conceding that what seemed to be happening in the present was not yet to be taken as a reality in the context of our work. Somehow, we were simultaneously participating in two different realms: one in which our senses could still participate, and another in which probabilities emerging in numerical terms were what really mattered.

It is hardly surprising that computers for data processing were the other novel instrument beside the reactor that one needed for this kind of research. It is interesting that both technologies were invented and developed at the same time. So what we see in the reactor hall as the neutron optical instrument is to be understood as part of a system of which the computer is an integral part. The research workers direct the "attention" of the system when they design the physical installation and also when they write programs for the computer.

After seven years in which I gained practical experience in a field of artificial sensing at the very time it was evolving, I was fortunate enough to be given the opportunity to move into the field of percept-based science. What I did not know when I made the change was that *understanding based on perception is the original meaning of "aesthetics."*

Watching Waves: An Exercise in Observation

From the old bridge across the Birs (near Dornach, in Switzerland) one can look down onto the surface of the flowing water. It has actually come almost to a standstill due to being dammed. The old bridge is built of limestone masonry; it has two spans and above the middle pier is a baroque sandstone statue of Saint Nepomuk. The road across the bridge no longer carries any traffic; its cobblestone surface is reserved for pedestrians who can look back to the old houses of Dornachbrugg, then look to the north a little further downstream where the river flows through the "Dornach Canyon" after driving the turbines, or upriver where ducks often swim in groups. One morning, while waiting for a shop to open, I looked upstream, saw the ducks and watched their wakes in the form of a V behind them. It was obvious to me that I was not perceiving the slight ups and downs of waves directly. What appeared was a "waving" of mirror-like reflected images taken from the visible surroundings. The phenomenon was so intriguing because the images were moving, and it was hard to grasp the principles governing their order. But there is no doubt that what was happening helped make the scene look “watery.” The subject occupied me for a long while afterward. I still like to get people to watch what is happening when they “see waves” on the surface of a gently undulating pond.

In the context of this report, it must be stressed that I did not treat the phenomenon in the way a physicist would tend to do. I did not derive the phenomenon from the obvious model of reflection by a mirror bent in wave form. Rather, I tried to discover how the observed image resulted from a transformation of the image that had been apparent when the ducks were absent. Straying off the path I had chosen as a high school student, I let experience instruct me in finding the appropriate concept.

A Search for a Characteristic Gesture for the Reactor Process

The nuclear power plant at Kaiseraugst to the east of Basel was never built. For years a continuous opposition was kept up to prevent it from ever happening. At the height of the conflict the site was occupied by people who stayed there day and night. Frequently, demonstrations were held there during weekends. Although the demonstrations were serious protests, they were strictly peaceful affairs with an atmosphere of joy that so many interesting people were around. I remember one occasion when the two sides claimed widely differing numbers of participants. With a twinkle in the eye, one would point out that there was one objective number to be taken seriously, which was the very large number of grilled sausages sold and consumed. Such good humor remained part of the atmosphere, despite the fact that a serious power struggle was taking place—after all, people were putting their civic reputations at risk.

My experience gave me reason to opt against this technology. The pros and cons of nuclear energy were supposedly discussed in public strictly on the basis of “objective science.” And, indeed, I became aware that both sides used the kind of logic that had bred this technology. The only difference seemed to be in the way personal risks for the local population were felt. I sensed that what moved the large section of the public, who were opposed to the project, was a feeling for the *gestures of the reactor process.* I suspected that certain images, seldom alluded to, were of important moral content—just as the image of a power plant that ran on practically no fuel must have been an incentive for the development of nuclear energy. (And it still seemed to offer cheap power; the problem of disposal of nuclear waste was greatly underestimated by the pronuclear camp at the time. Since then nuclear energy has turned out to be just too expensive.) So the "official" logic of the discussion was one thing and the driving forces on both sides were quite another. Those opposed could not voice their true misgivings, since these could hardly be expressed in the language of efficiency, which is to say, the language of cost and profit.

I began to ask myself: what image of the reactor process had been forming in *me* while I had been taking advantage of it in my professional career? With the experience I had been granted, I should have been able to characterize the nuclear reactor process in terms of *gestures of a being*. I felt myself committed to the task. The memories of the vaults that impressed me so deeply began to unite with the logical principles that govern the reactor process.

The part neutrons play in the reactor process is comparable to the role of heat in combustion. In a wood fire, for example, the flux of heat from the flames roasts the wood, driving burnable gases out, which in turn nourish the flames. In the reactor process this sort of continuity depends on the neutron flux. The flux ensuing from fission of the special uranium isotope is transformed in a moderator, such as water, so as to cause further fission of uranium. While combustion works on the basis of air being taken in and exhaust gases continuously being returned to the atmosphere, the reactor process needs its surroundings only as a cooling agent, for the heat generated in the reactor process generally has a detrimental effect on the process itself. We must keep in mind, that the reactor contains all the material that it needs to feed its process. If, in combustion, a source of oxygen is admixed to the oxydizable fuel so that it can burn in isolation, then the process of combustion can accelerate to an explosion. And the reactor-process is related to such combustion— both can accelerate.

The elementary theory of reactor dynamics treats the uranium in the fuel elements and the moderator in which these elements are submerged as a single unit. When the parts of this unit are properly arranged, a neutron flux sets in at a certain point, which must be found empirically. This flux is linked with fission in the uranium. Each fission event results from a neutron of low energy being absorbed, and in turn produces a number of high-energy neutrons. While traversing the moderator, neutrons will lose almost all their energy. The theory follows all the possible fates of a freshly emitted neutron that will prevent it from triggering a subsequent fission event. The probability of avoiding all these fates multiplied by the average neutron yield from a single fission event is the index of criticality. If this number is unity, the neutron flux remains at a constant level. As the index depends almost only on this arrangement's *size, materials,* and *form*, control of the reactor can be exercised by changing these mechanically. If the index is greater than unity, the process will increase exponentially in time, and the reactor is said to be "supercritical." You must keep in mind that the average time span of a generation of neutrons can be extremely short, so there is always a threat of the neutron flux quickly rising from an immeasurable level to a dangerous "excursion" (as we called it) of power.

In this description, concepts of extremely disparate character have been suggested. One can hardly imagine the "fates of the neutrons" to stem from any authentic experience of fate on the part of the neutrons. We form our pictures of such events by relinquishing the terms of first-hand experience. In order to construct morally significant representations of the process in question, we must carefully visualize the various abstract functional *relationships* and the physical conditions giving rise to them. Then we can assess the relevant gestures:

The process depends on no outer agent whatsoever. S*elf-excitation* sets in, caused only by the physical arrangement's *size, materials,* and *form*. And this self-excitation of the physical object occurs within a confine sealed off from the world at large, *locked away from life* in nature. And likewise in the future: accumulated radioactive waste must be kept locked away from the circulation, the whirl, of life. These relevant gestures characterize the way the process acts; they are found in experience, just as we get to know the behavior of a living being we become familiar with. This characteristic behavior becomes extremely lucid once we compare it to the fundamental processes of plant and animal life and their intimate interrelations. Then it becomes striking how *autistic* the nature of the reactor process really is. When we refer to a behavior of this sort, we are really alluding to a Being, not given in Nature but brought to existence through the activities of cooperating Human Beings.

I began to see that my own convictions about nuclear power resulted from awareness of such characteristic principles of the process. These principles are far removed from the interpenetrating and integral contexts of living processes. And I was further convinced that there must be some common element in various people's perceptions of the reactor—that the significant gestures must indeed be felt vaguely even by the man in the street.

Discovering Aesthetics: The Hidden Aim of a Long Journey

All the while, no decisive agreement to give up the project had been reached between the government and the prospective builders of the power plant. The construction equipment could resume work any time, so the opposition remained on the alert. One day, I was told of a group that met regularly in Basel to discuss topics connected to non-violent resistance. It was there that I soon met and got to know a philosopher whom I had already heard speak at a discussion after the Chernobyl catastrophe. Hans Rudolf Schweizer (1932 – 2001) turned out to be *the* specialist on and translator of Alexander Gottlieb Baumgarten (1714 – 1762), who had coined the word "aesthetics" when envisaging an alternative mode of cognition. Thanks to this encounter, my work on phenomena-based science gained a much wider context. I learned that Baumgarten had conceived "aesthetics" as a name for *all fields of science* based on first-hand experience given by the senses—on images and mental pictures, as opposed to *logic* and analytic reasoning applied to generally accepted knowledge.

Looking back, it is becoming clearer to me that I had been engaged in finding my way between these antagonists all my life. I see my cousin explaining the pros and cons for chemistry and physics, and using arguments for which Baumgarten had coined the appropriate terms. As a high school student, I had opted for logic, fully convinced of its superiority. Later, in doing experimental work for my diploma thesis, I had worked with and mixed materials, which led to surprises. I was gaining know-how from sense percepts, just the way my cousin had warned me. In doing "chemistry," I found myself beginning to practice the mode of cognition that Baumgarten had envisaged as aesthetics! When my discovery was written up, the professor insisted on putting the whole story into a "logical" framework: we wrote that the experimental work had been undertaken with the aim of supporting the established theoretical understanding.

What were the characteristics of the new science as Baumgarten originally conceived it? Aesthetics was certainly not just a theory of art, or worse, a theory of the production of pleasing impressions. Baumgarten coined the name from *aistheta,* the Greek word for "sense percepts." Aesthetics as a *new mode of cognition* was to combine two activities: perceiving and representing. That is, Baumgarten was interested in the passive sense impression as expanded by expressive activity. In this book it has become apparent that we engage in expressive activity even *while* we perceive—this being the only way to grasp anything at all. In the following chapter we will begin to compare the methods of logic and aesthetics. This will lead to an assessment of stages in the process of aesthetic cognition. As it will turn out, we will also find that attending, organizing through *intentionality,* and then participating in the appearance are the valid realization of Baumgarten's vision of a science based on experience.