Genes and Life: The Need for Qualitative Understanding

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“Which of our genes make us human?” An article with this title appeared last fall in *Science* (Gibbons, 1998). The article reports that there is hardly any difference between the DNA from humans and chimpanzees. Approximately 98.5% of the DNA is the same. A photo of a chimp standing upright accompanies the article, with this caption: “Chimpanzees may adopt the occasional two-legged pose, but they differ dramatically from humans in anatomy and behavior.” Given the similarity of humans and chimps at the DNA level, and the manifold differences at the biological and behavioral levels, we might conclude that DNA has little to do with the essential differences between human and chimp.

But the author of the article comes to a very different conclusion. She states:

> This means that a very small portion of human DNA is responsible for the traits that make us human, and that a handful of genes somehow confer everything from an upright gait to the ability to recite poetry and compose music.

This statement reveals the conviction that DNA is the basic cause of all biological and psychological phenomena: organisms are bundles of myriad separate traits that are determined by genes. It follows from this postulate that all differences between organisms can only stem from differences in DNA. The 1.5% of “unique” human DNA—which may include only about 50 functional genes—*must* be the cause of everything human. Humanness is seen to be genetically modified “chimpness.” Conversely, if scientists knew these “human” genes, they might be able to “convert a default-mode great ape into a human,” as *New York Times* science writer Nicholas Wade put it (October 20, 1998).

Since its advent 25 years ago, genetic engineering of organisms has developed into a paradise for the quantitatively oriented, combinatorial intellect. DNA from any organism can be transferred into any other organism. There are no perceived boundaries; everything appears to have become interchangeable. True, the technical prowess still lags behind the vision of “anything goes,” and in any given experiment there is only about a 1% success rate. But this fact is looked upon as a technical problem to be overcome on the path towards the creation of organisms as custom-made, fine-tuned genetic mechanisms.

Quantities and Qualities

At the gateway to the temple of modern science stands written: banish all qualities, pursue quantity. Galileo, Descartes, and Locke furthered this cause by stating that qualities do not actually exist. Qualities are deemed subjective epiphenomena of reality, which is thought to be quantitative. This conception became the underlying ideology of science: qualities are subjective and there is, therefore, no science of qualities; science pursues the quantitative, because that is the nature of reality.

Even if not all scientists consciously subscribe to this view, in their practice of science they focus on the quantifiable. This reduced approach to phenomena is understandable, since it creates an avenue of clarity into an otherwise seemingly impenetrable thicket of complexity. Quantitative results are easily communicable and the test of falsification through experimentation appears straightforward.

But problems arise when scientists—and the public—begin to believe that the theories and technologies based on a reduced quantitative approach also explain and encompass the qualitative richness and depth of the phenomena that formed the starting point of investigation. The habit of overlooking the boundaries of methodology is widespread and deep-seated in science and leads to short-circuited thought patterns like the one expressed in the search for the essence of humanity in genes.

Any quantitative characteristic or a quantitative change in a living organism is related to the life of this organism in a qualitative way. The mouse's small size is essential to the its activities and its relation to the environment. If a mouse becomes rat-sized through genetic engineering, then we cannot consider only the larger amounts of growth hormone that it produces. With its greater size the mouse can, for example, no longer scamper up the stalk of a wildflower to gather seeds. This is a qualitative change and is related to the mouse as a whole.

As the holistic thinker and neurologist Kurt Goldstein[1] puts it:

> Biological knowledge is not advanced by simply adding more and more individual facts. The facts which are gradually included in the "whole" as parts can never be evaluated merely quantitatively, in such a way that the more parts we are able to determine the firmer our knowledge becomes. In biology every fact always has a qualitative significance. (Goldstein, 1971, p. 30)

Goethe and a Qualitative Approach

One example of the striving toward a science that encompasses the qualitative took place in a controversy at the end of the 18th Century. By that time comparative anatomists discovered that humans and mammals have essentially the same anatomical structure. Finally it came down literally to one bone of contention: the premaxilla. The premaxilla (which is actually a pair of bones, also called the premaxillary bones) forms the outermost (distal) part of the snout of the upper jaw in mammals (see figure 1). When anatomists investigated the human skull, they didn't find the premaxillary bones. Looking at the human skull from the front, the premaxillary bones "should" have been between the two upper jaw bones. Instead, the anatomists saw only the suture where the two upper jaw bones meet.

Several well-known anatomists declared in their treatises that the human being has no premaxillary bones, thereby distinguishing us from animals. Most of the scientists of those pre-Darwinian times were steeped in the Judeo-Christian tradition and carried the deeply-felt conviction that there were essential differences between the human being and animals. But their scientific studies were showing more and more similarities. The premaxilla was evidently felt to be the last bastion separating humanity from "the lower beasts."

The poet and scientist J.W. von Goethe rejected this view that the concept of humanness could hinge upon a single bone. With vehemence he set out to find the premaxilla, and he succeeded (Goethe, 1988, p. 111ff). He had to look more carefully than his contemporaries had done, since the premaxillary bones can usually only be seen when you look behind the incisors at the upper palate (where you put your tongue when you say "tea"). There Goethe saw, in some skulls, two little bones that lie *between* the upper jaw bones (see figure 1). These are the premaxillary bones. Goethe soon discovered that others had made the same observation long before him. But their studies had been ignored, forgotten or overlooked.

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[1] I have only recently discovered the work of Kurt Goldstein, who died in 1965. I hold him to be one of the deepest and most consequential holistic thinkers and practitioners in the 20th Century. His work has far-reaching implications and warrants greater recognition and further development. He saw his approach as an extension and application of Goethe's methodology. (See Goldstein, 1971 and 1995; Simmel, 1968)

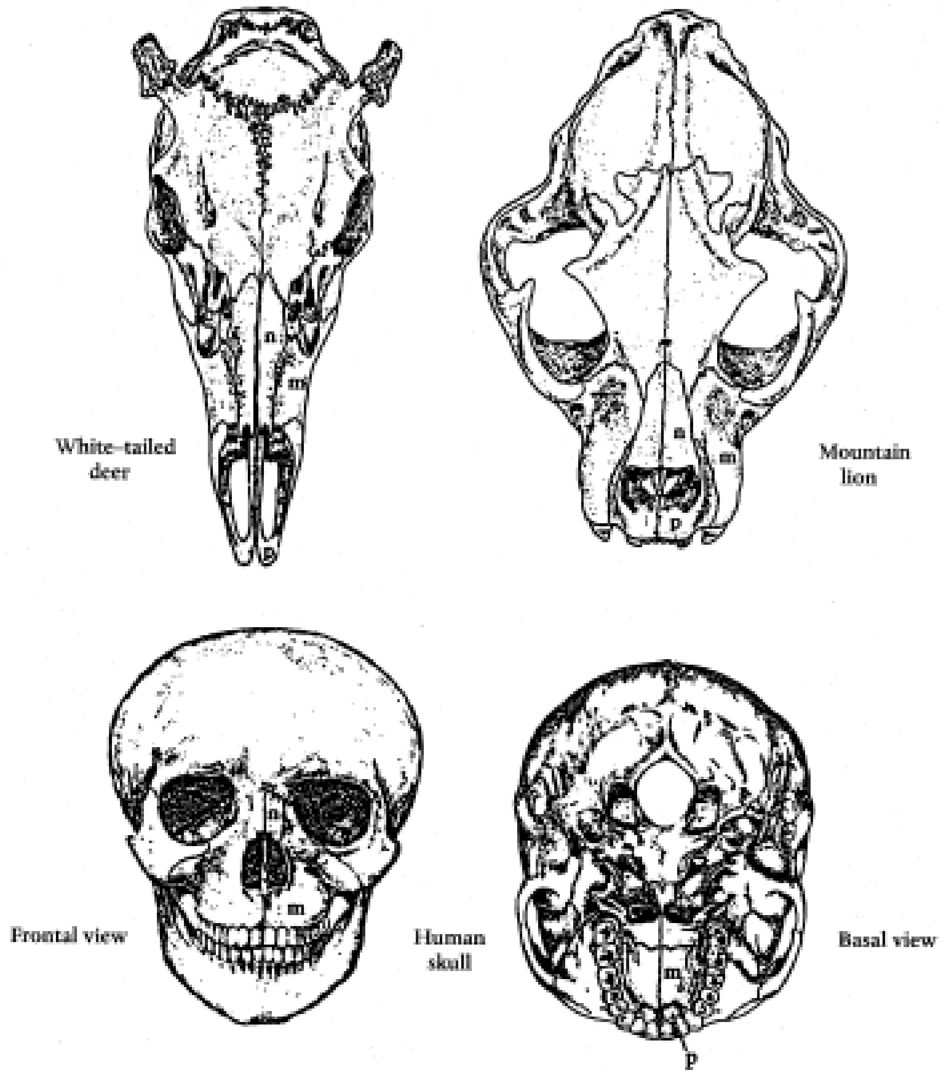


Figure 1. Skulls of the white-tailed deer, mountain lion, and human being. In the human being the premaxillary bones (**p**) are visible only when the skull is viewed from below (basal view). **m**: maxilla (upper jaw bone); **n**: nasal bone; **p**: premaxillary bones.

You may have difficulty appreciating Goethe's enthusiasm for the discovery of this bone—an enthusiasm he expresses in letters to his friends Herder and Knebel (quoted in Schad, 1985, my translations):

> I have found—neither gold nor silver, but it gives me the greatest joy—the premaxilla of the human being… It is like the keystone to the human being; it's not missing; it's there! But how! (to Herder)
>
> The difference between the human being and animals is not to be found in any given particular….The agreement within the whole makes each creature what it is, and the human being is a human being just as much through the

> form and nature of the upper jaw as through the form and nature of the last two bones of the little toe. (to Knebel)

The discovery of the premaxilla supported Goethe's view that what distinguishes the human being from animals does not lie "in any given particular." For Goethe the presence of the premaxilla did not make the human being into a "mere" animal, nor would its absence have guaranteed a distinction between human and animal. What was important was not *that* the bone was present, but *how*, "since the agreement within the whole makes each creature what it is." He saw that the premaxilla—if viewed with an eye directed toward understanding the whole organism—could reveal humanness, just like any other bone. This insight was the source of his deepest joy.

Can we see how a single bone is related to the organism as a whole? Long-legged, long-necked hooved mammals like the deer also have elongated skulls, and the premaxillary bones are long and slender (see figure 1). The same is true for the other bones of the front part of the skull: the nasal bone, the upper jaw (maxilla) and the lower jaw (mandible) are all long and taper towards a point. Just as the front (distal) part of the skull is elongated so is the distal part of the limb: the foot and toe bones are especially long. The deer stands on the tip of its two hoofed toes and the heel is halfway between the ground and the torso. This part of the leg is mainly tendon and bone, while the shorter upper leg bones are surrounded by muscle. Similarly, the rear part of the skull and jaw are embedded in muscle, while the snout is bony.

By contrast, the mountain lion has a much more compact skull, which is mirrored in the shorter and broader premaxillary bones (see figure 1). The mountain lion—as is typical for the cat family as a whole—also has a more compact body than does a deer. Its neck and legs are relatively short and muscular. It stands not on the tips of its four toes, but on the first toe joint. Just as the mountain lion latches onto and penetrates through the skin of its prey with its claws, so does it pierce and tear flesh with its sharp and pointed canine and cheek teeth. Clearly, head and limb fit together.

What about in the human being? Goethe realized that the way the individual bones—including the premaxillary bones—are formed in the human being is an expression of our upright posture (cf. Schad, 1985). In the human skull the facial and jaw bones do not protrude forward. Developmentally this fact is expressed in the rapid closing of the upper jaw bones that grow over the premaxillary bones, which themselves remain undeveloped. Since the skull is short and round it can balance on the vertical spine. In the four-legged mammal, the brain case remains small and sits behind the protruding face and jaw, reflecting the animal's overall horizontal orientation. By contrast, the human skull has a large brain case, which rises above the face and jaw, mirroring the vertical orientation of the whole human body. The fact that we have no snout is related to our ability to speak and also express our emotions and thoughts through facial expression. The large cranial vault is an expression of the inwardness out of which we can act.

In contrast to the deer or mountain lion, in the human being the femur—the body-near, proximal part of the leg—is the longest bone in the leg (and in the whole body) while the feet and toes are short; the heel rests on the ground. Mirroring this relation in the head, the brain case, as the part of the skull closest to the body axis, expands, while the facial cranium remains small. Now we can see how justified Goethe was in writing: "A human being is a human being just as much through the form and nature of the upper jaw as through the form and nature of the last two bones of the little toe."

All of our anatomical, as well as our mental and spiritual capacities, can be seen in relation to the upright posture. Goethe's friend Herder recognized this connection clearly, and expressed it precisely and beautifully:

> Because the human being has to learn all things, because it is our instinct and calling to learn everything like our upright gait, we learn to walk by falling and come often to truth only through error. The animal is carried forward

> securely in its four-legged gait; the more strongly expressed proportions of its senses and drives are its guides. The human being has the advantage of a king to look to far horizons, upright and with head held high. Of course, we also see much darkly and falsely. We forget our steps only to be reminded when stumbling on what a narrow basis the whole head and heart edifice of our concepts and judgments rests…. The human being is the first to be set free in creation. We stand upright. The balance of good and evil, of false and true hangs in us. We can search, we shall choose. Just as nature gave us an overviewing eye to guide our gait, so also do we have the power not only to place the weights, but—if I may put it this way—*to be the weights* on the balance. (Herder, 1982, p. 65)

Herder's description can give you an impression of how far it is possible to go in relating seemingly mundane biological facts to the inner nature of humanity. When we see how each aspect of a being tells us something about it as a whole, we are no longer thinking quantitatively. The part is not an isolated "thing." It is a revelation and realization of a larger context. As Hegel might have phrased it: the part of an organism goes beyond itself to become what it is in essence, namely, a member of a whole. When we begin to see the same tendencies, the same gestures in different parts, the whole begins to speak. What speaks is not a quantity, not a thing, but a quality—that of the specific wholeness of human or chimp. Nothing is interchangeable. The chimp is through and through chimp. The human is through and through human.

This understanding is direly lacking in a genocentric view that hopes to discover the difference between human and chimp in 50 genes. It is not only lack of insight, but also hype to give 1.5% of the genome credit for human biology—let alone credit for the ability to recite poetry and compose music. The secret—the "cause"—of humanness or chimpness is not to be discovered in our genes, although some day it may be possible to discover how genes themselves relate to the integral nature of a being.

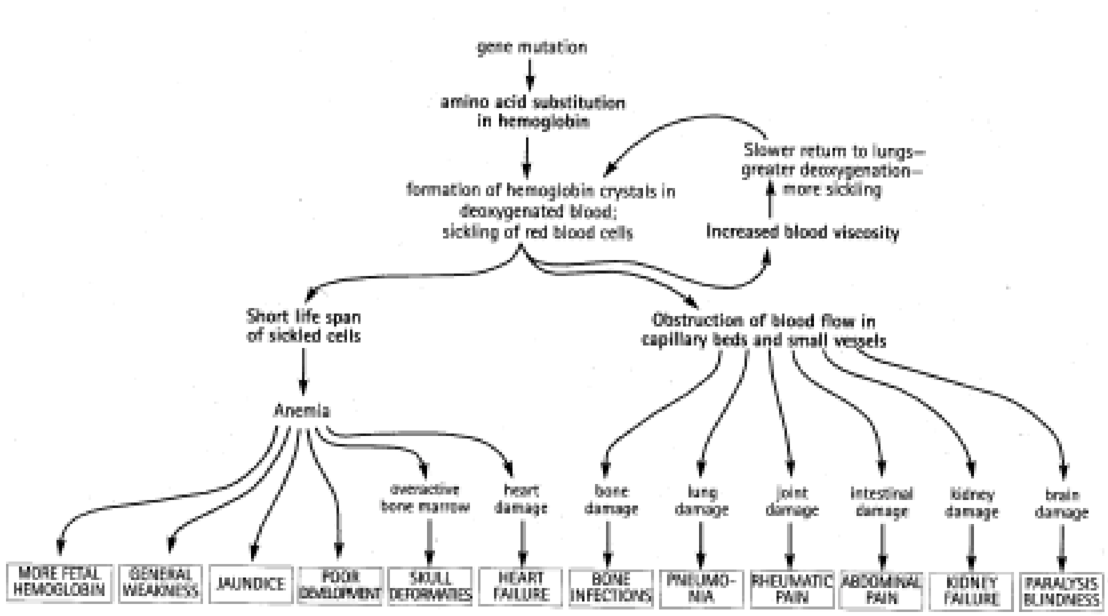
The Isolating Procedure and Genes

In order to adequately grasp the inherent nature of a living being, we *must* think qualitatively. This is what organisms tell us. Once we gain a sense for the organism as a qualitative whole in which all aspects hang together, we realize how essential it is to be aware of the process of analysis, which dissolves the whole organism, separating it into parts. Kurt Goldstein expresses the problem clearly:

> If the organism is a whole and each section of it functions normally within that whole, then in the analytic experiment, which isolates the sections as it studies them, the properties and functions of any part must be modified by their isolation from the whole of the organism. Thus they cannot reveal the function of these parts in normal life….If we want to use the results of such experiments for understanding the activity of the organism in normal life (that is, as a whole), we must know in what way the condition of isolation modifies the functioning, and we must take these modifications into account. We have every reason to occupy ourselves very carefully with this condition of isolation. (Goldstein, 1971, p. 10)

All of genetics is based on this isolating procedure—from the mental abstractions of independent traits and genes to the concrete products of physical isolation in breeding experiments, cytological investigations, and biochemical analyses (for a detailed consideration see Holdrege, 1996). Unfortunately, little thought is given to the consequences and limitations of gaining knowledge this way. If scientists were as aware of the isolating procedure as they are of the products of this process, we would find much more careful formulations about the relation of genetic findings to the whole organism. Instead, we "know" that genes determine the characteristics of an organism.

Let me give an example. Sickle-cell anemia is the classic textbook case of a single-gene disease. A point mutation in DNA is thought to "cause" all the pathological symptoms that make up the disease. The following scheme illustrates the presumed causal connections (from Mange and Mange, 1980):



If this scheme represented reality, then all individuals with this point mutation would have the same symptoms and problems. Clinical studies give a very different picture, since individuals with an identical molecular lesion display a greater than expected variation in their clinical course…at one extreme are patients with virtually no medical problems other than chronic hemolytic anemia [destruction of red blood cells] and at the other are patients incapacitated by repetitive bouts of crippling pain or organ failure due to infarctive damage….The physical examination may be normal or display all or most of the features typically associated with HbSS [sickle-cell anemia]….Counts of irreversibly sickled cells also did not distinguish mild and severe HbSS….The hemolytic component of HbSS has little effect upon the severity of disease….It is ironic that HbSS, one of the first disorders of man to be identified and understood at a molecular level, is still poorly understood in terms of its pathophysiology. (Steinberg and Hebbel, 1983)

There is no simple sense in which we can say that a gene mutation causes sickle-cell anemia. What we often forget is that in any illness the organism as a whole is reacting to a changed situation. Normally the production of fetal hemoglobin ceases soon after birth, but in the case of sickle-cell anemia, its production continues in compensation for the lack of adequate adult hemoglobin. Similarly, the overactive bone marrow and the enlarged heart and spleen are also part of the compensatory action of the whole organism. Such changes are symptoms of the disease as well as an expression of the organism's attempt overcome it.

It is not a matter of the gene "giving commands," determining all changes in the organism. Rather the genetic change brings about a qualitatively—and individually variable—new situation for the organism, which responds as a whole, in an individually unique (and therefore always somewhat unpredictable) manner. This shows how absurd it is to think one could deduce an illness as a cascade of cause and effect change reactions originating in the gene. We can only understand the gene in the context of the whole organism—even in the most "simple" diseases. The boundaries of a reductionist view of disease becomes even more glaring in so-called complex diseases (like coronary artery disease). As Sing et al. (1992) state the problem:

> Most investigators readily acknowledge that multiple genetic and environmental factors interact to determine risk of these diseases, but seldom is the implicit biological complexity considered when designing and interpreting genetic studies.

Genetic Engineering

The prowess of genetic engineers arises from their ability to ignore the organism as an integrated, interactive being, while gaining a knowledge of isolated substances and small-scale biochemical processes. When scientists think of an organism as a genetic mechanism, then there is every reason to try to exchange parts in order to "improve" the mechanism's function. The ideal of genetic engineering is to create and control the smoothly functioning, predictable bioreactor—the plant that is resistant to pests and herbicides, the farm animal that produces meat or pharmaceutical substances with maximal efficiency, the human being genetically vaccinated against an array of infectious diseases.

For example, if larger, faster-growing pigs are desired, why not implant growth hormone DNA from, say, cattle into pigs? Government, university, and industry scientists have been working on this task for more than a decade (Pursel, 1998). There are now transgenic pigs that produce large amounts of bovine growth hormone. These pigs grow faster, utilize feed more effectively, and have less carcass fat than their normal cousins. This is more than the researchers had hoped to achieve, since they didn't expect the pigs to produce leaner pork. But these are not the only changes that take place. The pigs are also very susceptible to stress, have a high incidence of gastric ulcers, dermatitis, arthritis, lameness, and renal disease, and the boars often lack libido. Because of these (and other) "side-effects," such transgenic pigs have not yet become marketable.

This example is not an isolated case. Genetic engineering experiments often produce unexpected, negative results. Once we learn to see organisms as the integrated beings they are, where every part and process is related to every other part and process, then we begin to expect such unexpected results. They are not "accidents," even if they cannot be foreseen. The transgenic organism reacts as a whole to the foreign substance (DNA). Sometimes the reactions are subtle, often they are crass and harmful. In addition to the changes described above, for example, the transgenic pigs stop the secretion of their own porcine growth hormone, partially balancing out the effects of the genetic manipulation (Pursel et al., 1987). As in the example of sickle-cell anemia, we see a compensatory activity of the organism.

When genetic knowledge and technology are re-introduced into the arena of life, they enter a realm where context is everything. If there is one thing we can be sure about, it's that unexpected problems *will* arise. That's the most certain prognosis. This fact makes the blatant undervaluation of the way transgenic crops will affect other organisms and the environment as a whole especially insidious. Many crops (soybeans, corn, potatoes, cotton, etc.) are being genetically modified to become resistant to herbicides and pests. In 1998 about 30% of all soybeans planted in the USA were genetically engineered for either pesticide or herbicide resistance. Recently scientists genetically engineered a weed (*Arabidopsis*, the workhorse of plant genetics) to become herbicide resistant. Completely unexpectedly, many of the transgenic plants changed their reproductive behavior (Bergelson et al.,1998). Normally *Arabidopsis* is self-fertilizing, but after the genetic manipulation many of them started to cross-pollinate. The researchers have no idea why this happened and how it is related to their manipulation. But they do recognize that such an unexpected result should give us pause to stop and think about transgenic crops. Soybeans, for example, are normally self-fertilizing. If anything comparable happened to them, then the herbicide resistance could spread via pollen to plants that are not genetically engineered. Imagine the predicament of the organic farmer whose neighbor plants transgenic soybeans.

Of course no one knows if soybeans will change in this way, but at least there should be concern. Most ecologists are urging more stringent practices and better oversight of transgenic crops. But the USDA has actually *reduced* the oversight of field trials and commercialization of transgenic crops, playing into the hands of the large biotech companies that produce the seeds as well as the herbicides.

The Need for Qualitative Understanding

The producers of transgenic organisms, and very often government agencies as well, would like to capture us in their vision of complete control, and to have us believe that laboratory experiments and clearly circumscribed field tests "prove" the efficacy and safety of their products. But neither genetic thinking, nor the techniques themselves are adapted to the complexity of life; they are maximally effective only under maximally controlled conditions. Life is not about isolation; it is about interpenetration and mutual dependence.

The tendency within science and genetic technology is not to change the approach, but to find ways to increase control when problems arise, counteracting the problems already created by using more of the same kind of methods. It might be possible, for example, to build stalls to support arthritic, lamed pigs that can hardly walk and carry their body weight. Or couldn't transgenic pollen be modified to self-destruct when it reaches the air? (But what if a few don't?) Precisely such "solutions" show the grotesque nature of viewing and treating organisms as objects to be manipulated and completely controlled. This approach can only lead to the creation and perpetuation of more unhealthy conditions.

The quantitative approach can continue to feed our desire, and increase our ability, to control aspects of life. But it is also starkly reflected in the mirror of unhealthy side-effects and the continual race to solve problems we have caused with solutions that cause more of the same kind of problems. Following this path, organisms will increasingly come to reflect our disregard for the integrity of living processes. Organisms are resilient, but can they withstand indefinitely the onslaught of manipulation based on combinatorial, mechanistic thought?

A shift to a qualitative approach in science can help lead us beyond this dilemma. This shift is radical and difficult, since it entails cutting through hype and sacrificing our will to power. But we *can* leave behind the desire to control, striving instead to acknowledge and understand the integrity of our fellow creatures. When we begin to see organisms as qualitative wholes in which even a seemingly insignificant bone carries the signature of the whole, then the organism starts to come alive for us. We establish a relation from being to being. The more our understanding becomes centered in the other, the more we can develop ways of action that take the integrity of that being into account. How else is responsible action possible?

As long as scientists view organisms as mechanisms in a world separate from them, there is no real question of responsibility. Ethical considerations in this case are after-the-fact and viewed as being outside the scientific process. For this reason they are also usually ineffective. Only when we incorporate the qualitative into the scientific process—when our way of viewing consciously includes the other being from the outset—can we begin to heal this split. Responsibility involves an inner relation to the world that is bracketed out of a quantitative approach.

Although genetic engineering is clearly a proof of the efficacy of modern science, its results show just as clearly the necessity to change our ways of viewing and treating life. It is as though transgenic plants and animals were shouting at us to stop viewing and treating them like inanimate objects that can be modified according to our wishes and desires, and to earnestly begin to acknowledge, understand, and deal with them as the beings they are.

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