

HOLISM

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Some people like to build sand castles and some like to tear them apart. There can be much joy in the latter, but it is the former that interests me. You can take a bunch of minute silica crystals, pounded for thousands of years by the waves, use your hands, and make an ornate tower. Tiny physical forces govern how each particle interacts with its neighbors, keeping the castle together—at least until the force majeure of a foot appears. But this is the part I like most: Having built the castle, you step back and look at it. Across the expanse of beach, here is something new, something not present before among the endless sand grains, something risen from the ground, something that reflects the scientific principle of holism.

Holism is colloquially summarized as “The whole is greater than the sum of its parts.” What interests me, however, are not the artificial instantiations of this principle—when we deliberately form sand into ornate castles, or metal into airplanes, or ourselves into corporations—but rather the natural instantiations. Examples are widespread and stunning. Perhaps the most impressive is that carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, iron, and a few other elements, mixed in just the right way, yield life. And life has emergent properties not present in or predictable from these constituent parts. There is a kind of awesome synergy between the parts.

Hence, I think that the scientific concept that would improve

everybody's cognitive toolkit is holism: the abiding recognition that wholes have properties not present in the parts and not reducible to the study of the parts.

For example, carbon atoms have particular, knowable physical and chemical properties. But the atoms can be combined in different ways to make, say, graphite or diamonds. The properties of those substances—properties such as darkness and softness and clearness and hardness—are properties not of the carbon atoms but rather of the collection of carbon atoms. Moreover, which particular properties the collection of atoms has depends entirely on how they are assembled—into sheets or pyramids. The properties arise because of the connections between the parts. Grasping this insight is crucial for a proper scientific perspective on the world. You could know everything about isolated neurons and be unable to say how memory works or where desire originates.

It is also the case that the whole has a complexity that rises faster than the number of its parts. Consider social networks as a simple illustration. If we have 10 people in a group, there are a maximum of $10 \times 9/2 = 45$ possible connections between them. If we increase the number of people to 1,000, the number of possible ties increases to $1,000 \times 999/2 = 499,500$. So, while the number of people has increased by a hundredfold (from 10 to 1,000), the number of possible ties (and hence this one measure of the system's complexity) has increased more than ten thousandfold.

Holism does not come naturally. It is an appreciation not of the simple but of the complex—or, at least, of the simplicity and coherence in complex things. Unlike curiosity or empiricism, say, holism takes a while to acquire and appreciate. It is a grown-up disposition. Indeed, for the last few centuries the Cartesian project in science has been to break matter down into ever smaller bits in the pursuit of understanding. And this works to some extent. We can understand matter by breaking it down to atoms, then

protons and electrons and neutrons, then quarks, then gluons, and so on. We can understand organisms by breaking them down into organs, then tissues, then cells, then organelles, then proteins, then DNA, and so on.

Putting things back together in order to understand them is harder and typically comes later in the development of a scientist or of science. Think of the difficulties in understanding how all the cells in our bodies work together, as compared with the study of the cells themselves. Whole new fields of neuroscience and systems biology and network science are arising to accomplish just this. And these fields are arising just now, after centuries of stomping on castles in order to figure them out.