The Dual Nature of Chemical Substance

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Introduction

According to most philosophers working in the Anglo-American tradition, advances in technology hold no special interest for revealing the rational character of scientific knowledge. Advocates of the Dual Nature Program find this position historically uninformed and philosophically unconvincing. Historical advances in the empirical sciences can be read as progressive improvements of instrumental technologies, laboratory equipment, and experimental instruments. Philosophical insights into the character of knowledge rest on revealing the duality of the scientific world. The Dual Nature Program is very ambitious. According to the principal advocates, Peter Kroes and Anthonie Meijers, all material bodies exhibit the dual nature of technical artifacts:

> On the one hand, we see the world as consisting of physical objects interacting through causal connections. On the other hand, we see it as consisting of agents (primarily human beings), who intentionally represent the world and act in it. *Both conceptualizations are necessary for characterizing technical artifacts* (Kroes and Meijers 2000, p. xxv).

But how can the real world of compounds, molecules, atoms, and electrons exhibit such a duality? According to analytical chemists, properties of chemical compounds are real, not mere technical artifacts. Proposals for a duality of such properties seem, at best, strange, and, at worst, flagrantly false.

I believe that the structure/function duality represents an important insight into the scientific inquiry. Chemical compounds have a structure and a function during inquiry. Moreover, accounts of chemical properties are not incommensurable with their functional descriptions. To explain the duality of substance, without incommensurability, we must resort to engineering design.

Instruments and their design-plans

If technology lies at the core of scientific experience of the world, then we should look to engineering for our philosophical commitments about such experiences. Design-plans for instruments provide experimenters with prescriptions for engaging segments of the environment, based on idealized standards for research. Engagement requires action by human agents, performance of apparatus, and detectable responses. I am not suggesting a philosophy of engineering, but a philosophy FROM engineering, with particular attention given to the designs of experimental instruments.

Design-plans can be read in many different ways, depending upon a reader's purpose and degree of literacy. Manufacturers read such plans as prescriptions for construction, advertisers read them as marketing tools, and experimenters read them as signposts for research. One way for researchers to locate themselves in relation to microscopic processes is by reading design-plans as epistemic maps. As an epistemic map, a design-plan provides landmarks and paths for knowledge-seeking practices by identifying the opportunities for, and constraints upon, inquiry. Such maps produce a mosaic of symbols for an experimenter's orientation, marking out the experimenter's place in the (detectable) world through the skillful use of instruments. A researcher's general orientation to the microworld is revealed in the plans for knowing by doing. Of course, no map is perfect: details are hidden, features are skewed, and landmarks are exaggerated. But an epistemic map offers a graphic agenda for further exploration, guiding researchers in transforming a specimen's character and then monitoring the results. In this respect, a design-plan for laboratory technologies can be read as a channel of epistemic ideas about knowledge-inquiry, dense with meaning about the idealized relationship between a skilled agent (experimenter) and a segment of the world (specimen). By bringing instrumentation to the forefront of attention for a philosophy of experimental research, we can identify epistemic commitments about the interaction between experimenters and specimens.

As instrumental techniques improve, the objects we examine become increasingly distant from us: distant in space and in time; distant – in the end – because of their strangeness with respect to laws of the macroscopic world in which we live (Pomian 1998, p. 228). Many experimental instruments are engineered to overcome these distances. According to the engineering of instruments, any testing apparatus is used as a control process to transform a segment of the environment and then monitor the results. Every machine designed for testing has a general function-structure. A general function-structure refers to a dynamic relationship between machine and environment, a relationship that is defined through processes of manipulation and detection. For any testing device, *information* is received, prepared, compared or combined, then transmitted, displayed, or recorded, for example. This relationship is defined by the kinds of conversions that occur with respect to *energy*, *information*, and *specimen*. In particular, every signal generator of an analytical instrument is designed with the following general function: energy, information, and specimen are converted into information about a specimen's properties. This is be depicted in *Figure 1.*

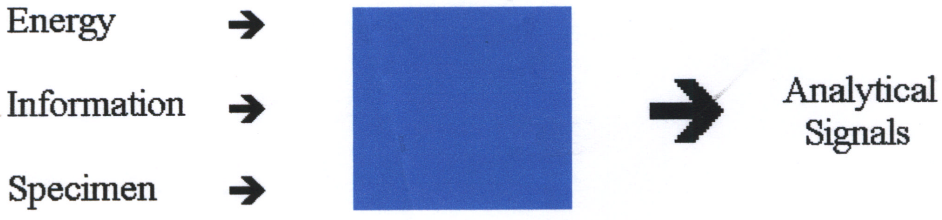

Figure 1. The functions of an analytical instrument.

The power of any machine to generate movement rests on the *conversion of energy* into something useful. A signal is a form of energy in which information is conveyed. Information can be transferred, or stored in data banks for example. Information can be given in various forms, such as a magnitude display, control impulse, or data entry (Wallace 1977, p. 22).

The use of instruments in chemistry

Instrumental techniques require both manipulation and analysis: experimenters manipulate, agitate, and transform a segment of the microscopic world, then analyze, monitor, and distill the results. This combination of doing and thinking is rigorously defined in the design of laboratory instruments. To compensate for the gradual distancing of the chemical substance from actual measurements, chemists have devised techniques for transforming a specimen's properties into analytical signals. Properties of a material substance are converted into information, in the form of the peaks whose shapes contain data. Present-day chemists 'handle' information as much as they handle material change. "These electrical ghosts stand for the real material samples," as the eminent chemist Pierre Laszlo writes (1998, p. 31). In this respect, the segment of the world under investigation exhibits the kinds of capacities that are attributable to our own creations, that is, signals. Consider for example, an absorption spectrometer, commonly deployed in studies of analytical chemistry. When this device is used, a specimen is manipulated by bombarding photons, which emanate from an artificial energy-source. With a transformation of the specimen's dynamic properties, certain experimental phenomena are 'carriers' of information. The resulting signals are then enhanced and transformed in preparation for the inscription of marks at a read-out (Rothbart and Slayden 1994).

Researchers treat a specimen as a tool of inquiry (Dewey 1960, p. 118). The specimen has a function, as if it were a tool used for acquiring knowledge. A specimen functions as one of nature's machines, with capacities to generate movement when sufficiently agitated by mediating technologies: instruments.

The metaphor of nature as machine has captivated scientists for centuries, and retains its hold on experimental researchers to this day. The machines of the 17th century were characterized by their powers to transmit, or modify, actions initiated from some other (mechanical) source. Mechanistic philosophers of the modern era found in Nature's machines capacities to transmit, or modify, action initiated from an external source. According to Robert Hooke, the Grand Watchmaker created the universe as a Cosmic Machine, in which smaller machines are embedded in larger ones. In the 18th century, the mechanical, clock-like images were replaced by such technical advances as the steam engine and in electronics. Today, the conception of nature as a generative mechanism continues to command attention. The revolutionary advances in biochemistry of the 1950s perpetuated the allure of organism-as-machine. For the mechanism of DNA replication, for example, the DNA double helix unwinds, exposing slightly charged bases to which complementary bases bond, eventually yielding two duplicate helices. With the machine-metaphor in mind, Nancy Cartwright reduces the entire physical world to a composite of nomological machines. Each machine is defined by its capacities to generate movement in other bodies. In classical mechanics, attractions, repulsion, resistance, and pressure are capacities manifested when a machine is running. But Cartwright does not recognize the technological influences in the notion of substance.

During an experiment, a pure specimen functions as a technical artifact, that is, a machine of nature whose capacities remain stable during a sea of change. A machine's capacities endure, even as its states evolve. But which capacities are exploited during an experiment? The answer is revealed by the specimen's function. A specimen functions as a source of action, causally responsible for movement, or states, of other bodies. A specimen's capacities are revealed in the new beings, states, events, or products that are brought into existence during an experiment. A specimen is not passive; it reacts to technological inducements. In analytical chemistry, a specimen functions as a coded machine, that is, a stable source of signals, ready for decoding through instrumental manipulations.

Underlying a specimen's function is a purity of structure. But the notion of purity demands attention to purification techniques, purging a subject matter of contaminants and annulling experimental sins of individuals. A specimen could be dissected, manipulated, heated, cooled, separated, or synthesized with other compounds. To remove impurities, a researchers must have some idea of a specimen's defining properties. In preparing a sample for instrumental analysis, an experimenter isolates and'ìputs on display' certain attributes of a compound, exposing its 'nature' properties.

So, by reading the epistemic maps of instrumental designers, we discover the dual nature of material bodies. *During research a specimen functions as a machine of nature, and its physical properties are revealed through acts of purification*.

Today, we confront new domains which challenge traditional distinctions between machines and non-machines. For example, nanostructures provide insight into both the emergence of life and the fabrication of new materials. But why should we be surprised that the machine/non-machine duality has been challenged with the advent of new technologies? Throughout history, no single demarcation criterion between machines and non-machines has withstood the onslaught of major technological innovations. Our understanding of non-machines is inseparable from technological advances. In this respect, the detectable world can be known by exploiting the kind of properties that we attribute to our own creations, and revealed in the technical artifacts of laboratory research.

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