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Characterizing the Three Cultures

The influential British novelist and science administrator C. P. Snow, who had trained as a natural scientist, published a lecture delivered in Cambridge University in 1959 titled "The Two Cultures." The lecture and the fifty-one-page book that followed provoked heated discussion because of its brash dismissal of the humanities as an intellectual mission lacking in rigor and unable to contribute to the welfare of those living in economically underdeveloped regions. Not surprisingly, humanists resented Snow's allegations that world peace and prosperity would profit from training more scientists and engineers and fewer historians, philosophers, and literary critics. Three years later, F. R. Leavis, an admired literary critic at Cambridge University, delivered an unusually harsh, occasionally impolite, rebuttal that caricatured Snow as a failed chemist, incompetent novelist, and social commentator who was ignorant of the world's serious problems.

Snow composed his essay as America was about to experience an extraordinary expansion in higher education that led to a fourfold increase in faculty (from 250,000 to more than 1 million) and a sevenfold increase in students to a total of 15 million, compared with only 50,00 Americans who were attending colleges in 1870.[1] These changes were due primarily to the establishment of new community colleges and rising enrollments in state universities trying to accommodate the many World War II veterans who, assisted by the government's decision to subsidize their education in gratitude for their service, chose to attend college rather than return to the working-class jobs held by their fathers.

There was a proportionate swelling in the funds available for research and in the numbers of scientists, research administrators, practitioners, journalists, and teachers managing, utilizing, disseminating, or teaching the products of science. More than 5 million scientific papers were published worldwide from 1992 to 2002, and 40 percent of that very large number were written by American investigators.[2] Most youths who choose a life in science in 2009 do not appreciate that the term *scientist* (as distinct from a physician or philosopher), as well as the opportunity to pursue a research career independent of one's social class or ethnicity, are less than 170 years old. These facts, combined with a public that had become more skeptical of select scientific claims and the idealistic depiction of scientists as pure of motive in their pursuit of truth, invite a re-examination of Snow's bold thesis.

Although the primary concerns, sources of evidence, and concepts remain the most important nodes of difference among natural scientists (physicists, chemists, and biologists), social scientists, and humanists, the three communities vary on six additional dimensions less pertinent to their epistemologies. (I consider the investigators who study the biological bases for, or evolutionary contributions to, animal or human behavior as natural scientists.) The nine dimensions follow:

1. The primary questions asked, including the degree to which prediction, explanation, or description of a phenomenon is the major product of inquiry
2. The sources of evidence on which inferences are based and the degree of control over the conditions in which the evidence is gathered
3. The vocabulary used to present observations, concepts, and conclusions, including the balance between continuous

properties and categories and the degree to which a functional relation was presumed to generalize across settings or was restricted to the context of observation

4. The degree to which social conditions, produced by historical events, influence the questions asked
5. The degree to which ethical values penetrate the questions asked and the conclusions inferred or deduced
6. The degree of dependence on external financial support from government or industry
7. The probability that the scholar works alone, with one or two others, or as a member of a large team
8. The contribution to the national economy
9. The criteria members of each group use when they judge a body of work as elegant or beautiful

Most intellectual efforts consist of three components: (1) a set of unquestioned premises that create preferences for particular questions and equally particular answers, (2) a favored collection of analytical tools for gathering evidence, and (3) a preferred set of concepts that are the core of explanations. A naïve observer who held no premises about the nature of solid objects might conclude that the bottom half of a pencil resting in a half-filled glass of water had been bent by the liquid. Social scientists and humanists share more premises, analytic tools, and concepts, as well as more of the other criteria in Table 1, than each does with natural scientists. Natural scientists emphasize material processes, minimize the influences of historical and cultural contexts and their associated ethical values, and are primarily concerned with the relations between a concept and a set of observations. Social scientists and humanists resist awarding biology too much influence, rely heavily on semantic networks and, therefore, are often as concerned with the relations among a set of semantic terms as they are with the relation between a concept and evidence, and frequently seek answers that affirm or disconfirm an

TABLE 1. *Comparison of the three cultures on nine dimensions*

Dimension	Natural Scientists	Social Scientists	Humanists
1. Primary interests	Prediction and explanation of all natural phenomena	Prediction and explanation of human behaviors and psychological states	An understanding of human reactions to events and the meanings humans impose on experience as a function of culture, historical era, and life history
2. Primary sources of evidence and control of conditions	Experimentally controlled observations of material entities	Behaviors, verbal statements, and less often biological measures, gathered under conditions in which the contexts cannot always be controlled	Written texts and human behaviors gathered under conditions of minimal control
3. Primary vocabulary	Semantic and mathematical concepts whose referents are the material entities of physics, chemistry, and biology, and assumed to transcend particular settings	Constructs referring to psychological features, states, and behaviors of individuals or groups, with an acceptance of the constraints that the context of observation imposes on generality	Concepts referring to human behavior, and the events that provoke them with serious contextual restrictions on inferences
4. The influence of historical conditions	Minimal	Modest	Serious

Dimension	Natural Scientists	Social Scientists	Humanists
5. Ethical influence	Minimal	Major	Major
6. Dependence on outside support	Highly dependent	Moderately dependent	Relatively independent
7. Work conditions	Both small and large collaborations	Small collaborations and solitary	Solitary
8. Contribution to the national economy	Major	Modest	Minimal
9. Criteria for beauty	Conclusions that involve the most fundamental material components in nature inferred from evidence produced by machines and amenable to mathematical descriptions.	Conclusions that support a broad theoretical view of human behavior.	Semantically coherent arguments described in elegant prose.

implicit ethical ideal. However, the meanings of the concepts used by the three groups deserve special attention because the communities use different sources of evidence.

THREE VOCABULARIES

The meaning of a sentence, for speakers and listeners, is based on the actual events that are named, as well as the network of ideas that was the origin of the statement. The meaning of the declaration, "The bulls were beaten yesterday" depends on whether the referents for bulls were animals or the Chicago basketball team. The three cultures represent language communities that impose distinct meaning networks on their important concepts and, like the dispersed Indian groups of fifth century Meso-America, compete with each other for dominance. One of the insights of the twentieth century, due in large measure to Ludwig Wittgenstein, is that the meanings of most statements are not transparent. Application of this idea to a scientific proposition implies that meaning depends on the specific observations to which a statement refers, and, therefore, the procedure that generated the evidence and the web of meanings that define a theory.

The vocabularies of each culture contain a number of concepts with technical definitions that are of primary interest to only one group (e.g., gluon and transposon for natural scientists, attribution error and gross domestic product for social scientists, and antinomy and historical era for humanists). The vocabulary of psychoanalysts attributed a unique meaning to *energy* that was neither the one implied by the Chinese concept *ch'i*, nor the meaning physicists understood in the principles of thermodynamics. But the three cultures also use terms with exactly the same sound and spelling that have different meanings for each culture, even though the scholars may not recognize that fact. The terms *fear*, *capacity*, *arousal*, *memory*, and *count* are examples. The meaning of "fear" in T. S. Eliot's line: "I'll show you fear in a handful of dust" is not the meaning intended by the social scientist who writes that "The heritability of realistic fears is less than the heritability of unrealistic fears," nor the meaning understood by the biological scientist who states that "Rats that stop moving when they hear a tone that had predicted electric shock are in a state of fear."

Even though the poet, psychologist, and biologist use the same word, each is naming a distinctly different phenomenon. Eliot was naming the subjective feeling that pierced consciousness when he reflected on the value confusion and spiritual emptiness that permeated Europe after World War I. The psychologist was referring to the answers of adults filling out questionnaires asking them about their sources of worry. The biologist was describing a rat's immobility in response to a conditioned stimulus that had signaled an unpleasant event in the past. Eliot could have used the word *angst*; the psychologist could have used the word *worry*, and the neuroscientist could have used the term *vigilant*.

The descriptions of a hypothetical person called Max make this point clearly. Natural scientists would use a vocabulary that referred to features like bone density, glucose level, blood flow, and electrical currents in body and brain. Social scientists would describe Max's identifications with his family, gender, ethnicity, and nation; the shame he feels as an American over the deaths of innocent Iraqi citizens; and childhood memories of family holidays at the seashore. Humanists would refer to his membership in a family that migrated from Ireland to America in the nineteenth century, his nostalgia for summer when the November trees are bare, and the blend of powerlessness and melancholy that pierces consciousness when he reflects simultaneously on his aging father and Dylan Thomas's line, "Do not go gently into that good night." None of these three descriptions can be translated into one of the others without losing some meaning.

The first cohort of economists treated the physicists' meaning of *capacity* in the sentence, "Energy is the capacity to do work" as similar to its meaning in "Money is the capacity to purchase goods." As a result, they assumed that the equations of thermodynamics might be appropriate in mathematical models of the economy. They failed to appreciate that many predicates assume different meanings when they are joined to different nouns because the validity of every declaration rests with a full sentence rather than with a single word. The predicate *fall*, for example, has four distinct meanings in each of the four expressions: "Temperatures fall," "Prices fall," "Apples fall," and "Spirits fall."

Even some terms in the vocabulary of natural scientists have different meanings. The meanings of mass, space, and time in Newton's equations are not synonymous with the meanings that Einstein understood. Nonetheless, Newton's concepts work well for an apple falling from a tree and Einstein's terms explain the energy emitted from a fissionable uranium atom. Acceptance of relativity theory and quantum mechanics during the last century, which altered the traditional meanings of time, space, and objects, allowed both philosophers and scientists to appreciate that the meaning and validity of every proposition are restricted to the language system to which it belongs, and might not be valid in another system.

A tolerance toward multiple meanings for words belonging to distinct language systems allows us to believe, simultaneously, that physicists writing in the mathematical language of quantum mechanics are correct when they declare that there are no stable objects in the world, and psychologists are correct when they state that the world consists of solid objects like cups, that can be touched, moved, and filled with liquid. We accept both statements as true without the disturbing feeling of cognitive dissonance that accompanies logically contradictory ideas because they belong to separate language systems. This principle allows neuroscientists to use the word *fear* to describe a pattern of neuronal activity and psychologists to use the same word to describe a person's judgment of his or her subjective experience, even though the term *fear* has different meanings in these two language networks.[3] Unfortunately, many scientists experience more cognitive dissonance in this instance than they do in the case of the reality of cups.

The evidence gathered by biologists and psychologists awards different meanings to the term *aroused.* Most adults report that the color red induces a feeling of arousal or excitement, whereas blue reduces the intensity of subjective arousal. However, the brain wave profiles that are indicative of enhanced arousal of cortical neurons occur to blue rather than red. Thus, neuroscientists should not equate the arousal that is defined by a pattern of cortical activity with the psychological experience of arousal.[4]

This same argument applies to *memory*. A group of Chinese adults who had been exposed to Chinese during early childhood, but had consciously forgotten their first language after learning English as a second language, indicated whether the second word in a sequence of two English words was or was not semantically related to the first; for example, dog and cat are related but dog and crayon are not. The neurons of the temporal lobe generate a distinctive wave form in the electroencephalogram when a second word is semantically unrelated to the first about three-tenths of a second before consciousness recognizes that the second term is incongruent.[5]

The bilingual Chinese who were convinced that they lost their childhood knowledge of Chinese showed a smaller than expected wave form when a second word was unrelated to the first in English, but happened to share a Chinese character. The English words *train* and *ham* are unrelated, but share the Chinese character *huo*. Thus, when the word *ham* appeared after *train*, the bilingual Chinese person showed a smaller wave form to ham than did monolingual English speakers, even though they were totally unaware of the fact that their brains had responded to a shared meaning that was unavailable to their consciousness.[6] This fact implies that their brains had preserved some feature of the meanings of the Chinese characters and, therefore, the terms *memory* and *remember* have different meanings when a brain response or conscious detection of meaning supplies the evidence. Psychologists invented the concept of implicit memory to account for this fact.

The term *count* provides a third example of the conceptual confusion that occurs when neuroscientists use brain profiles to define a concept that is essentially psychological. Although this term was invented originally to represent the ability to arrange the cardinal numbers in an ordinal sequence, two neuroscientists concluded that brains can *count* because the profiles of activation were different for displays of 20 compared with 30 dark circles.[7] However, the brain was responding to the perceptual difference in the spatial distribution of distinctly contoured elements and not to their number. A person gazing at a shelf containing eighteen books sees an array of objects varying in height, width, and color, not eighteen objects. Infants see the protuberances on their hands; it will be several years before they learn that each hand has five fingers. The blood flow patterns that are normally activated when people are counting were dissimilar to two displays of three objects in different spatial arrangements (one array grouped two of the objects close together and the other did not). If the neurons in this area were counting, the blood flow patterns should have been the same because both arrays had exactly the same number of objects.[8] Moreover, the areas that are active when people are looking at arrays of discrete objects are different from the areas that are active when people are reading numbers.[9] The brain would respond differently to clocks set at 6:00 and 3:00 o'clock, but that does not mean that the activated neurons were responding to the concept of time. Number and time are acquired concepts imposed on experiences, and appreciation of their meanings relies on circuits involving distinct brain sites.

Most living forms, including algae, display a regular twenty-four- to twenty-five-hour cycle of metabolic activity, but biologists do not suggest that algae are "counting" the passing minutes of each day. Neither are foraging bees, whose dance on returning from a bed of flowers to their hive varies as a function of distance between the hive and the flowers, counting the meters between the two places. It turns out that their nervous system is registering the amount of contour they fly over on their visit to the flowers and the accompanying variation in neural activity determines the quality of the dance.[10] Bees also scatter the pollen of the plants they visit, but that fact does not mean that they are altruistic or "good Samaritans." The hair cells on the basilar membrane of the inner ear respond differentially to sounds of varying frequencies, because of the inherent variation in