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Fundamental forms of information

ABSTRACT

Fundamental forms of information, as well as the term *information* itself, are defined and developed for the purposes of information science/studies. Concepts of natural and represented information (taking an unconventional sense of representation), encoded and embodied information, as well as experienced, enacted, expressed, embedded, recorded, and trace information are elaborated. The utility of these terms for the discipline is illustrated with examples from the study of information-seeking behavior and of information genres. Distinctions between the information and curatorial sciences with respect to their social (and informational) objects of study are briefly outlined.

Introduction

The objective of this article is to present and justify a definition of information and several fundamental information forms. These forms are capable of, and suitable for, use in the research and theory development of information science. I address common questions and reactions to the definitions in the latter part of the article. At the end of the article, I present several examples to illustrate how these forms can be utilized in the field's thinking, and form the basis for further thought on the fundamental questions of the field.

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First, a definition of information itself is presented and briefly justified. Then the various fundamental forms of information are defined and elaborated. These forms are presented in relation to the work of Susantha Goonatilake (1991), a writer much overlooked both in information science and in the larger scientific community. Goonatilake presents a model of "information flow lineages," which complements the theory being developed here around information forms.

In a companion article (Bates, 2005), I review the literature and present and justify the definition of information in more detail, and in an evolutionary context. There, various theoretical and philosophical issues that inevitably surround such a fundamental concept as information are developed and argued in greater detail, including a discussion of the meaning of knowledge and data as well. Here, the information definition is presented more or less as a given; only the most common concerns expressed by readers and respondents at talks are briefly addressed, in order to focus the discussion primarily on the several fundamental forms.

A definition of information

The word *fundamental* is as important as the other words in this article's title. The effort here is to begin a consideration of information at the most fundamental levels possible. This is done on the grounds that for a word so basic that it defines our field, we need, for a satisfying theory of information, to begin at the beginning, at the root meaning of the term, and build up from there to the more social and other common meanings.

We know that we are continually subjected to a huge range of sensory inputs and internal experiences of sensations and thoughts. In fact, almost anything existing in the universe, that can come into human and other animals' purview, can be experienced as information—a bird call, our friend's "hello," the rock we trip over, the intuition we have about the honesty of someone we are talking to, a book we read. The definition of information used here, therefore, goes to the very basis of any living being's awareness: "Information is the pattern of organization of matter and energy." Though this definition is quoted from Edwin Parker (1974, p. 10), this approach to the concept was endemic at the time. Parker does not elaborate his definition, and no more recent theoretical development of this approach to information has been found. I believe this definition has much undeveloped potential.

Information is the pattern of organization of the *matter* of rocks, of the earth, of plants, of animal bodies, or of brain matter. Information is also the pattern of organization of the *energy* of my speech as it moves the air, or of the earth as it moves in an earthquake. Indeed, the only thing in the universe that does not contain information is total entropy; that alone is pattern-free. Because human beings can potentially act on or be influenced by virtually any imaginable information in the universe, if we want a truly fundamental and broadly applicable definition of information for our discipline, we must begin with one just this broad in meaning and application.

Applications of the term

First, information exists independently of living beings in the structure, pattern, arrangement of matter, and in the pattern of energy throughout the universe, and would do so whether or not any living being were present to experience the information. This is not to claim that we humans have a complete, clear, or "true" understanding of that independent universe, or that it is ultimately understandable in only one way, just that it exists in some form.

Second, the term *information*, as used here, also includes all the patterns of organization of matter and energy in living matter, including in the brains and bodies of human beings and other animals. This information arises from their genetic heritage and is further constructed by living beings interacting with the world, and stored in their sensory, nervous, and biochemical systems. Thus, our subjectively constructed understanding of the world, stored in our minds and feelings, can be viewed from the exterior as well, as one more body of information with a particular pattern of organization. These patterns of organization exist just as surely as the inanimate ones do, except that they are manifested in neuronal connections in the brain, action potentials, and the like. Each construction is conditioned by the animal's current experience and environment, genetic make-up, life history, and information-processing characteristics and limitations. Consequently, any construction animals may make of a given situation may vary considerably from animal to animal.

Thus, the argument presented here is that we can talk about information as an objectively existing phenomenon in the universe, which is also constructed, stored, and acted upon by living beings in countless different subjective ways, each way distinctive to the individual animal having the experience. At the same time, the selection and shaping of the information

to be stored and acted upon by any individual animal or animal species is environmentally and evolutionarily shaped too, so experiences stored across a group of animals will also have many similarities. (Plants can respond to light and other environmental phenomena too, but for simplicity's sake, only animals—with special emphasis on human beings—will be discussed.)

One approach to information (Brier, 1996) draws on Bateson's definition of information as "a difference that makes a difference" (Bateson, 1972, p. 453). A difference to whom or what? Here, I argue that we must begin prior to that understanding, begin even before a sensing animal detects or assigns meaning to an experienced difference. As we shall see, humans and other animals can usefully identify a number of distinct types of information even prior to meaning assignment. Later, we will relate this definition of information to a more familiar understanding of the term, addressing what happens when we *become informed*.

In the end, the fundamental stance taken here is one of scientific observation. The phenomenon being observed is information, the pattern of organization of matter and energy as it exists in the universe and in living beings. The fact that we are observing, however, and claiming the objective existence of patterns of organization such as neurally stored memories, does not imply that *our understanding or construction of that objective existence is true, complete, correct, or the only possible understanding*. Nor does this claim imply that we deny the subjective variations and uniqueness in each individual's perception, extraction, and use of information in their minds and surroundings.

The senses of "pattern"

In defining information in this way, "pattern" is understood to refer both to (1) any kind of arrangement that is not pure chaos or disorganization, such as "*patterns of frost on the window*" and (2) "a combination of qualities, acts, tendencies, etc., forming a consistent or characteristic arrangement: *the behavior patterns of teenagers*" (*Random House Unabridged Dictionary*; Random House, 1993, p. 1423). (These are just two of many senses of "pattern" as typically defined in dictionaries.)

The first definition above implies a first-order pattern. The design we see on the frosted window is not part of any larger whole; it is simply a grouping or spotting of frost on the window that is not totally chaotic—so it does contain information—but nor is it a system. The second definition implies a second-order kind of pattern, one in which a variety of features are knitted together in an overall system or integral design. A pattern of

behavior implies repeated similar cycles of activity, that is, some coherence above and beyond the bunching and scattering of the frost on the window.

These latter patterns may be characterized as "emergent," meaning that the sum of the elements constitutes something new, a whole with its own distinct qualities. Emergent phenomena are often dramatically different in character from the component elements that go into them. When we look at a chair, we see a (first-order) pattern of light and dark, solid colors and edges. We also are capable, however, of recognizing the chair *as a chair,* an emergent pattern that we can recognize quickly as a whole, because it possesses certain features we have learned to recognize through experience in a culture that uses chairs, and with the help of our inherent cognitive abilities.

This is not to imply that a sharp distinction between first- and second-order patterns is being proposed. Patterns form, dissolve, fragment, etc., in many ways continually, and *are seen* to dissolve, fragment, etc. continually. Rather, both definitions are provided to claim both senses for "pattern" in the above definition. A "pattern of organization," as used here, does not have to imply coherence, though it often does—just something other than pure, pattern-less entropy. (These last four paragraphs taken largely verbatim from Bates, 2005.)

Does this mean, then, that information is merely another word for pattern, or form? No, the crucial phrase in the definition is "pattern of organization." At the physical level, form is often thought of as the outer shape of an object, a three-dimensional concept. Pattern, on the other hand, is often thought of as two-dimensional—though frequently also emphasizing the outer shapes, but in two dimensions. For example, a checkerboard is seen as consisting of 64 squares of alternating colors; thus, it has a *checkerboard pattern*. That is certainly a *pattern*. But, as used here, the pattern of organization of the checkerboard includes everything in and around the board, not just its surface—the pattern of organization of the atoms and molecules of the material of the board itself, i.e., its internal structure, the waves/particles of different colors of light of the checkerboard surface, the pattern of differentiation of the edge of the board with the table upon which it sits and the air around it. The patterns of organization associated with this one checkerboard are multifarious in terms of the physical existence of the board alone.

Numerous additional patterns of organization are involved when we consider the ways observing animals may perceive and give meaning to the sight or touch of the board. Perhaps an insect crawling across the board feels slight indentations in the surface of the board that are invisible to

humans, yet may not even observe the color shift from one square to the next. Someone from a society that does not play board games may see the board and its squares, but not think that they have any imaginable use. An advanced chess player, on the other hand, may ignore the color alterations of the squares and think only of regions of the board that are typically involved in different stages of play of chess.

The patterns of organization of everything in the universe (other than pure entropy or "patternless-ness") involve every physical, biological, perceptual, and cognitive pattern of organization that exists or is extracted by sensing beings. Information is thus not just the outer form, shape, or pattern of something as interpreted by human beings; rather, it includes the physical and biological patterns of organization not sensed by us as well, from the atomic to the galactic, from the virus to the ecosystem. Information, as defined here, includes all physical patterns of organization, all biological patterns of organization of life forms, and all constructed (and emergent) patterns of organization as extracted, stored, and used by living beings.

Breadth of the concept

Information science, or information studies, as it is variously known, is concerned with both animate and inanimate information in a very wide array of forms. Anything human beings interact with or observe can be a source of information. As information scientists, we accept that people create subjective constructions of their experience, and those constructions of information also have an objective existence in the nervous system.

Further, we collect and manage huge quantities of a wide array of kinds of information (patterns of organization of matter and energy), in an ever-growing set of media forms. For this field then, we need a basic information definition that incorporates all these various forms that we research and work with. The definition presented here is broad enough to cover all these kinds of information.

However, it might be argued that libraries and other information institutions do not collect rocks, bird calls, or intuitions. Therefore, is this definition *too* broad? We shall see below that within this encompassing definition, there are fundamental forms of information that distinguish well the focus of the professional activities of our discipline.

Considering the breadth of this definition in another respect, does the definition then imply that information is everything, and therefore not a particularly meaningful concept? The answer here is that no, information

is *not* everything—rather, it is the *pattern of organization of everything*—except for total entropy or chaos, which is assumed to be pattern-free. This distinction between the pattern of organization and the material or energy that constitutes the pattern is crucial. As Wiener has said, "Information is information, not matter or energy" (1961, p. 132). Ours is the discipline that takes this phenomenon—the patterns of organization of matter and energy—as our central focus. (See Bates, 1999, for a detailed discussion of the distinctive character of information science, and Bates, 2005, for more discussion of the philosophical issues embedded in this approach to information.) We shall see that we can build effectively on this foundation.

Using the above definition of information as a basis, we turn now to consider several fundamental forms of information that may be understood to build on the basic definition, and which, it is argued, are useful for the disciplinary needs of information science/studies.

Natural and represented information

Here I introduce and develop the concepts of natural information, represented information, encoded information, and embodied information. See Table 1 for a glossary of terms with concise definitions of all major terms used or introduced in this article.

All information is *natural information*, in that it exists in the material world of matter and energy. Some natural information is distinctive, in that it is involved in representation at some moment of observation. *Represented information* is natural information that is encoded or embodied. Represented information can only be found in association with living organisms.

Encoded information is natural information that has symbolic, linguistic, and/or signal-based patterns of organization. *Embodied information* is the corporeal expression or manifestation of information previously in encoded form.

In the genetic, neural, and biochemical information of living organisms, and in information produced by living organisms, the information exists, actually or potentially, in a duality of embodiment and encoding. Specifically, encoded information may become embodied, and embodied information may become encoded.

Represented information, i.e., encoded or embodied information, can be created only by living organisms. Turning this around, with life begins representation. No effort will be made here to solve the "chicken or egg" problem of how represented information began. Suffice it to say that life does exist on this planet, and with all life comes the *encoded* genetic

TABLE 1. *Glossary of terms*

Embedded information: The pattern of organization of the enduring effects of the presence of animals on the earth; may be incidental, as a path through the woods, or deliberate, as a fashioned utensil or tool.

Embodied information: The corporeal expression or manifestation of information previously in encoded form.

Enacted information: The pattern of organization of actions of an animal in, and interacting with, its environment, utilizing capabilities and experience from its neural stores.

Encoded information: Natural information that has symbolic, linguistic, and/or signal-based patterns of organization.

Exosomatic information: Information stored in durable form external to the body (idea drawn from Goonatilake, 1991).

Experienced information: The pattern of organization of subjective experience, the feeling of being in life, of an animal.

Expressed information: The pattern of organization of communicatory scents, calls, gestures, and ultimately, human spoken language used to communicate among members of a species and between species.

Genetic information: Information contained in the genotype.

Genotype: The genetic constitution of a living thing (drawn from standard definitions in the biological literature).

Information 1: The pattern of organization of matter and energy.

Information 2: Some pattern of organization of matter and energy given meaning by a living being.

Knowledge: Information given meaning and integrated with other contents of understanding.

Natural information: All information is natural information, in that it exists in the material world of matter and energy. Represented information (below) is an important subset of natural information.

Neural-cultural information: Information that has been created by, processed in, or disseminated from animal nervous systems, especially human nervous systems. (**Neural information** may also be used for lower animals and/or specifically for the nervous system structures that make memory and action possible in general in animals and humans.)

Phenotype: The genetically and environmentally determined embodiment of a genotype. (Drawn from standard definitions in the biological literature.)

Recorded information: Communicatory or memorial information preserved in a durable medium.

Represented information: Natural information that is encoded or embodied.

Trace information: The pattern of organization of the residue that is incidental to living processes or which remains after living processes are finished with it.

Note. Definitions are the author's unless otherwise stated.

material, or genotype, that can be *embodied* in a living being, known to biologists as the phenotype.

So genetic information is encoded as DNA in the genotype and embodied in the phenotype, the living animal. Neural-cultural information is encoded in the brain and nervous system, and embodied in the experience, actions, and expressions of animals (more below). Exosomatic information, that is, information stored externally to the body, has been developed in complex ways by human beings, and may appear in many combinations of re-encoded and re-embodied forms. Humans may re-encode information as memory or as writing or by other means. These changes occur through natural processes, which may be automatic under certain conditions, or which may be carried out deliberately by a living being.

The use of the term *representation* here refers only to this duality of encoding and embodiment. The term is not used to refer to the various popular senses of an exact replica, model, or other common meaning of the term. In fact, rather than being alike, embodied information and encoded information usually look strikingly different. For example, the encoded strands of pig DNA—i.e., the genotype—do not look at all like the embodied piglets (phenotype) they may produce.

Goonatilake's Three Information Flow Lineages

Susantha Goonatilake (1991) has developed the concept of "information flow lineages," which I use in the following discussion. These lineages are first introduced, then related to the fundamental forms of information developed in this article.

The information flow lineages Goonatilake has identified and defined what he calls information flow lineages through the history of living matter on the planet. He argues that there have been, and continue to be, three lines of information transmission in association with life, which he calls the genetic, the neural-cultural, and the exosomatic "flow lines" of information transmission (1991, summary on pp. 118–120). Genetic information is transmitted through the usual processes of biological inheritance, influenced by natural selection. He states, "Beginning from prebiotic origins a continuous lineage of information and of organized complexity exists as a genetic flow system. As evolution proceeds through time, these lines of genetic information spread out and radiate into new environmental niches" (p. 118). Further, "Metaphorically one could say that the flow line has a 'conversation' with the environment, successful conversations becoming congealed in the genome" (p. 125).

Thus, the characteristics of organisms that promote their fitness, that is, that enable organisms to survive and reproduce in a given environment, are propagated through time in their genetic makeup.

Goonatilake describes the neural element as follows: "To adapt to the changing everyday environment feedback loops exist between the neural system and the environment, influencing the behavior of both" (p. 119). "In the phenotype which is created out of genotypal information, there are other information-producing 'devices' in the form of hormonal and neural circuits. . . . These extra-genetic devices provide also the means by which cultural information is transmitted from generation to generation" (p. 15).

He is careful to distinguish between neural systems, which "can exist without transmissions of acquired information from parent to offspring" (p. 119), and cultural systems in which "/s/uch transmissions across generations, however, do occur . . ." (p. 119). He treats the combined "neural-cultural" as the second flow line. Thus, information can be transferred between the animal and the environment, and from one animal to another through observation or communication in real time. He traces the history of encephalization, or growth of brain size relative to body size in mammals, and points out that some ecological niches demand more and some less brain development (p. 19).

Goonatilake further argues that a third flow line, the "exosomatic," has also developed. This exosomatic line consists of information stored outside the animal as the "externalization of memories" (p. 83). He uses as examples the pheromone trails laid down by ants to guide other ants to food, and even the beaten trails to a water hole that animals follow in a forest (p. 84). (There is some resemblance here to Dawkins' discussion of "the extended phenotype," 1982, not cited by Goonatilake.) The amount and complexity of exosomatic information has grown tremendously over the last several thousand years and has become extremely important for humans. As he points out, books were initially "a repository of men's memories" and later they became memory stores on which brains work (p. 122). Thus, in the third flow line, information can be transferred from one person to another, without the two people ever being in each other's presence, and therefore can skip generations.

He relates the three flow lines, and suggests, metaphorically, why they developed:

> The rudimentary beginnings of these exosomatic information lines can be traced back to even the earliest animals. But they developed and expanded only with the primates and most elaborately only in association with humans. It is only when the

> adaptive limits of the neural-cultural information line begin to be reached that it, in at least some functions 'spills over' into the non-biological; in a similar way, the neural-cultural line developed after 'spilling over' from the genetic. (p. 83)

In other words, neural-cultural transmission is dependent on and arises out of genetic transmission, and exosomatic transmission develops out of the neural-cultural. As human beings used their sophisticated brains to develop dense, informationally rich cultures and learning that they wanted to retain and re-use, they first passed down stories and learning in person (neural-cultural flow line), then discovered and developed means of creating sophisticated external memory stores (exosomatic flow line), with which they could store and pass on vastly greater amounts of information.

Earlier, Brookes (1975) had also used the term *exosomatic* in the same sense to refer to external information stores. White developed the concept extensively also, calling it "external memory" (1992), and Brunk (2001) called a similar concept "exoinformation." At the genetic and neural-cultural levels, respectively, Dawkins distinguished genes and "memes" (1976), and Swanson (1983) defined "biogenes" and "sociogenes." However, I have found no one but Goonatilake who has incorporated these three paths of information transmission into a single model.

Goonatilake "flow lines" in relation to the "fundamental forms of information" The types of information to be discussed in the next three major sections are of my own devising, and were, in fact, developed largely prior to encountering Goonatilake's little-cited book. (Goonatilake defines information as "an organizing mechanism which provides an ability to deal with the environment. It is a symbolic description having modes of interpreting and interacting with the environment" 1991, p. 1.)

Table 2 shows the relationships between Goonatilake's flow lines and my fundamental forms of information.

Genetic information moves through the genetic flow line. My defined fundamental forms of experienced, enacted, and expressed information move through what Goonatilake called the "neural-cultural flow line," and embedded and recorded information move through Goonatilake's "exosomatic flow line." The emphasis in the following discussion will be on neural-cultural and exosomatic information, as well as residue, namely, the information left after animals are done with it—which was not addressed by Goonatilake.

More generally, I believe all pattern of organization in the universe is natural information. *Some* natural information is associated with life—either

TABLE 2. *Goonatilake's information flow lineages in relation to Bates' information forms.*

Bates: Natural information (in all things living and non-living)

Bates: Represented information (associated with living things only)

GOONATILAKE'S FLOW LINES	BATES' TYPES OF INFORMATION PER FLOW LINE
Genetic flow line	Genetic information
Neural-cultural flow line	Experienced information Enacted information Expressed information
Exosomatic flow line	Embedded information Recorded information
Residue	Trace information

Note. Bates' represented information is a subset of natural information. It may be encoded or embodied at any moment of observation. For example, encoded capabilities stored in the brain may be embodied in the actions of an animal. Residue (not addressed by Goonatilake), consisting of trace information, is a flow line in which the information degrades from represented information to, simply, natural information (neither encoded nor embodied). Residue is the flow line of extinction and of the Biblical "dust to dust."

is living itself or was created by the living. That life-associated information is here called *represented information*, and includes genetic, neural-cultural, and exosomatic information, i.e., all the kinds of information that move through Goonatilake's three flow lines. Thus, I define information as both associated with and not associated with life, while Goonatilake dealt only with life-associated information. I further identify information in the process of degrading from life-associated to non-life-associated, that is, *trace information*.

Here, by definition, represented information is either encoded or embodied. Examples of *encoded* genetic, neural-cultural, and exosomatic information are, respectively, the genotype, the nervous system's links and structures laid down through experience (and deriving ultimately from genetic capabilities), and writing. Genetic *embodied* information is exemplified by the phenotype. Embodied neural-cultural information can be seen in the phenotype's experience, actions, and communications; these three all embody previously encoded information. (The interesting complexities of encoding and embodiment with respect to exosomatic

information are not developed in this article.) The following sections provide more detail on several of the named types of information.

Types of neural-cultural information

As noted, neural-cultural information is *encoded* in the brain and nervous system. In animals and, in particular, in human beings, three fundamental modes of *embodied* information are identified: in experience, in actions in the world, and in communicatory expression. Each is discussed in turn in this section.

Experienced information

If we were to look into the brain of a person looking at a classroom chair, we would not see a miniature chair; rather, we would see only neurons firing. However, the person looking at the chair *does* see a chair. The neurons firing in the person's brain, therefore, create *an embodied subjective experience of seeing the chair*, an experience utterly unlike what is going on in the brain to create that experience. A stubbed toe, which produces another round of neuronal activity, is not felt as neurons firing by the person experiencing the incident; rather, that person feels the pain of a stubbed toe—*and in the toe*—not in the brain.

Thus, to feel our own experiences, the brain must create some pattern of neuronal firing that produces consciousness and the associated sense of experiencing life. The question of the nature of consciousness and the mind–brain relationship is one of the most hotly debated questions in all of science and philosophy currently (Chalmers, 1996; Damasio, 1999; Dennett, 1991; McCauley, 1996; Varela, Thompson, & Rosch, 1993, and many others). There is no agreed-upon understanding at this time in those fields, and no attempt is made to solve this challenging question here.

Here, for our purposes, we will simply consider subjective experience, including the experience of remembering, to be the first on a list of kinds of embodied information that result from neural encoded information. Again, all the stored knowledge, life experience, etc. that a person (or other animal) has is *encoded* in neural pathways of the brain. Life as experienced and remembered by the individual is *embodied* in whatever degree of consciousness or awareness that individual has.

One final point about experienced information: We experience our thoughts and activities as a conscious self, while, in ordinary practice, all of

our other knowledge and memories are out of consciousness. Experienced information is not solely what we experience with conscious awareness, however. We can also experience a variety of kinds of out-of-consciousness information that are nonetheless active in creating our current experience. For example, when a pianist is asked by her music teacher to "play with more feeling," she can bring forth a variety of out-of-awareness knowledge and experience that will enrich her playing and give it more feeling. She could not articulate how she does this; she does not know what she draws upon. Yet she can do it—and the student with less training and experience cannot do it. Something in her encoded neural information, therefore, was brought to bear and was embodied in her playing.

Enacted information

We may experience our lives mentally in private, but when we start acting in the world, our genetically endowed talents and life knowledge become visible to the external world. When an animal enacts information, it acts in the world, utilizing whatever capabilities and experience it can from its neural stores. Fish cannot hide nuts and squirrels cannot breathe under water, but each type of animal is capable of embodying many other types of skills or behaviors, which it does lifelong. Animals enact their neural information by carrying out all the activities of their lives. Throughout the history of animals on the planet, much learning, especially that transferred from mother to offspring, has come about by observing and copying enacted information.

Human beings, who possess extraordinarily extensive knowledge, can enact vast numbers of different types of behaviors. Not only do we carry out the usual animal behaviors of eating, birthing, fighting, etc., but we have also developed a huge range of skills, from plumbing to brain surgery, as well as social institutions—religions, the arts, business, government, science. Aside from the physical buildings that often house these activities, the institutions themselves fully exist only when human beings use their knowledge and experience to enact the institutions in real time. Thus, enacted information can occur in isolation or in social contexts, where it becomes a part of the larger texture of social behavior.

Demonstrating how much power and other human relations and choices are embedded within social institutions has been one of the great achievements of the social sciences in the last 20 to 30 years. These social institutions exist by being renewed, reinforced, and gradually changed through time by the people involved in enacting them on a daily basis.

For example, the welfare office in a typical United States city exists physically only as a building. Nevertheless, what counts for the people working and seeking help there is the daily enacting of roles and relationships in real time in the interactions among people in that office. If the society sees welfare as unavoidable, and welfare recipients as people who are getting resources they do not deserve—the assumption in much of the United States today—then everyone involved will enact that relationship in countless ways in the daily activity of the welfare office. The office will be dirty and not air-conditioned. Supplicants will be required to wait many hours and will be treated rudely. In resentment, they will react with hostility, leading the staff to become still more negative in their relations, and so on. These unfortunate results do not happen by accident. They arise out of pre-existing collective social assumptions and attitudes, and the people involved carry out the social consensus about the institution of welfare in their daily enactment of work or supplication at the welfare office.

Expressed information

This form of embodied neural-cultural information consists of the pattern of organization of communicatory scents, calls, gestures, and ultimately, human spoken language used to communicate among members of a species and between species. Thus, expressed information has a quintessentially social function. Other than in a few cases, such as a spontaneous cry of pain or fear, all expressed information is intentionally communicative to others in the environment. Animals mark territory with scent, produce mating calls and danger calls; primates gesture expressively. Humans use spoken language and body language to communicate an extraordinarily rich variety of meaning. In humans, communication through expressed information is enormously important, and is supported by brain structures that make language possible. For all these reasons, I have set aside expressed information, technically a subset of enacted information, for independent consideration.

Types of exosomatic information

Exosomatic information, that is, information stored externally to the body of animals, is a type that is core to the interests of information science. Embedded and recorded information are described below.

Embedded information

If we survey all that results from the presence of living things on earth, we find many objects and other visible effects of the presence of animals. The spider makes its web; the bird builds a nest; the human being makes tools, utensils, and other artifacts. Embedded information is that enduring information created or altered by the actions of animals and people in the world. It may be incidental, as a path through the woods, or deliberate, as a fashioned artifact. The changes and added structure found in the nest, the cell phone, or the house all constitute embedded information—information that would not exist without the agency of animals. Because animals act, they leave evidence of their presence. (See also Dawkins' discussion of the "extended phenotype," 1982.)

The study of the embedded information of artifacts has been a prime means of learning about other cultures in the human sciences, especially about extinct cultures. Just as cultures develop socially shared attitudes and institutions that are enacted, so do people develop socially shared design styles and artifacts that are often remarkably stable in character through time and over wide geographical areas. We can learn much about people by studying these characteristics of the enduring physical remains of their cultures.

Though these objects may be seen to carry embedded information, there is only so much understanding the objects can provide. We can deduce, perhaps, how a flint knife was made, but may not be able to determine how a lost pottery-glazing technique was carried out. In short, the embedded information is generally not left by its creators to be informative, but rather is informative as an incidental consequence of the activities and skills of the people leaving the artifacts. We deduce what we can, and often must forego some other knowledge we might wish to extract.

Embedded information is not limited to earlier cultures, however. Quite the contrary, the impact, in embedded information, of the current human cultures on the planet is beyond measure. Every building, every object, every plowed furrow that human beings have left on the planet is a kind of embedded information.

Recorded information

Recorded information is communicatory or memorial information preserved in a durable medium. While an animal scent mark in the woods may be

thought to be intended to communicate "This is my turf; stay off," I will limit the discussion of recorded information here to human products.

The use of symbols is primary to human beings (a symbol is "[s]omething that represents something else by association, resemblance, or convention. . . ," *American Heritage Dictionary*; Houghton Mifflin, 2000), and constitutes a powerful and extensively used capacity on our part. Written language is an obvious form of communicatory information, but over the centuries, people have used our symbol-making capacity in countless ways. See, for example, Wilkinson (1994), who characterizes nine broad classes of symbolism in Egyptian art, only one of which is related to language (examples of others are form, size, color, action). Recorded information may have begun with drawings or carvings; however, the most revolutionizing form of recorded information was almost certainly the technology of writing, which was followed in later years by musical and mathematical notation, and other sorts of recorded information (compare Hjørland, 2002). Other forms of recorded information, such as photography, film, audio recordings, and many more, need to be incorporated in a general theory of recorded information for information studies.

Relationships among the forms of information

The crucial difference between embedded and recorded information is communicatory intent. The activities of the animal—enacted information—produce embedded information, the durable effects of action. (There are many nonenduring effects as well, such as the displacement of air past my legs as I walk.) The activity of using language, or other communicatory means—expressed information—has its enduring equivalent in recorded information. (Along these same lines, Heilprin and Goodman [1965] distinguished "short-duration" and "long-duration" messages. This is not to make the simplistic assumption that writing is simply spoken language written down. Written language is generally formulated differently from spoken language.)

Enacted information creates embedded information as its durable result, and expressed information leaves recorded information as its durable result. Further, just as expressed information is a communicatory subset of enacted information (as there are many noncommunicatory forms of action), so also is recorded information a communicatory subset of embedded information because there are many noncommunicatory (that is, not intentionally communicatory) forms of embedded information. Though written language is central as a form of recorded information,

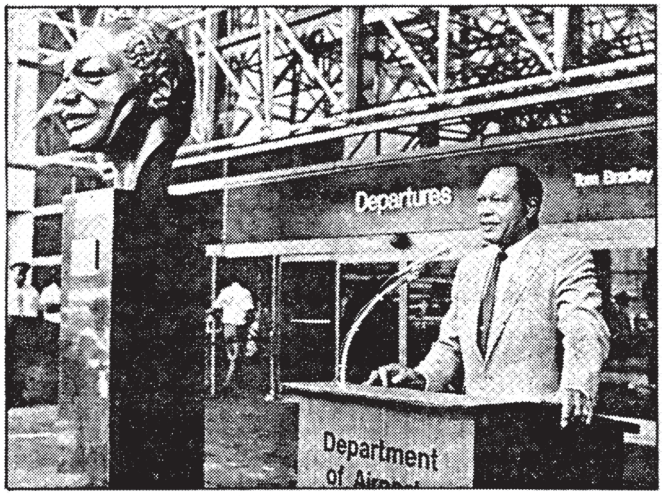
it is not the only form. A monument to a battle, for instance, may be intended primarily as a statement about the event, and only secondarily as a work of art. Embedded and recorded information may appear in or on the same artifact.

Recorded information is distinguished here from expressed information because the invention of writing and the development of the technologies to produce durable recorded information appear to have had an immeasurable impact on human cultures and on the speed of development of those cultures. No longer do humans have to try to memorize all that their culture knows; now a lot of that information can be kept in durable form outside the body. The durability and storage efficiency of such information have enabled a great leap in human information processing. The impact on human cognition of written records has been discussed at length by Ong (1982), Havelock (1980), and others.

Residue

In Table 1, *Residue* was listed as the fourth and final information flow channel (not named or discussed by Goonatilake). However, information does not cumulate in this channel as it does in the other three. Rather, residue represents the trace or deteriorating form of prior genetic, neural-cultural, or exosomatic information. The flow here is of a different sort—the Biblical "dust to dust"—in which structures previously associated with life recede back into their natural, inert forms. Trace information is that information that is degrading from being represented information (encoded or embodied) into being natural information only (neither encoded nor embodied). Trace information includes the no-longer-used wasps' nest, waste heaps, carrion, disintegrating ancient scrolls, and so on. Trace information is included here to acknowledge that all living processes produce waste, and degrade eventually, according to the law of entropy.

After a fire has leveled a house, for instance, most of the information in it—including the pattern of organization of the building materials, the arrangement of rooms, the structure of the furniture, the texts of the books, magazines, and so on—has been consumed and cannot be restored, without bringing in new materials. There may be traces of information left, but not anything like the amount of information—embedded and recorded information—that was there before the sudden degradation of the house by fire. Eventually, embedded information (as well as all other kinds of represented information) degrades to a residue of its former



GEORGE R. FRY / Los Angeles Times

Bradley times three—Los Angeles Mayor Tom Bradley speaks Friday during unveiling of a bronze bust of himself at Bradley International Terminal at Los Angeles Airport. The work by Russian-born artist S. Sarkis made its debut on third anniversary of terminal's opening and completion of other major improvements.

FIG. 1. *"Bradley times three," photo by George R.Fry,* Los Angeles Times, *June 20, 1987, part II, p. 1. ©1987. Los Angeles Times. Reprinted with Permission.*

self, then ultimately loses all trace of representation and becomes simply natural information.

Collecting the information forms

A summary example of information forms

Figure 1, "Bradley times three," illustrates the information forms discussed here. Former Mayor Bradley of Los Angeles and the other human beings in the photograph are the phenotypic expressions, or embodiments, of their genotypes, their encoded genetic information. We may assume that the Mayor is conscious of his own experiences in the moment (experienced information). Further, he is carrying out a physical action of standing at the podium, and a sociocultural action of dedicating the bust of himself (enacted information). He is speaking (expressed information). The statue, the terminal, the podium—all the human-made objects around him—carry embedded information. The words on the terminal entryway and on the

plaque on the face of the statue's pedestal are recorded information. Had an empty candy wrapper been visible on the floor of the terminal entryway, it would be an example of trace information.

Other categorizations of information

Clusters of writings, principally in the management and knowledge management literatures, have dealt with different categorizations of knowledge. Tacit versus explicit knowledge is greatly discussed (Baumard, 1999; Davenport & Prusak, 1998), and some efforts have been made to create even finer distinctions. Blumentritt and Johnston (1999) have collected over 25 differently named types of knowledge, drawn from the literature. Among the terms included is "encoded knowledge" (Blackler, 1995, p. 1025), used similarly to "encoded information" here. "Embedded knowledge" and "embodied knowledge" are also used (Blackler, 1995; Collins, 1996), but with different meanings from those used here for information. The referenced definitions are, of course, all for the concept of knowledge, not of information, and are not structurally related to each other in the way they are here.

Common issues raised regarding the definition

The ideas presented here go against some common assumptions in the field, and evoke various reactions in readers and audience members. In this section, I will address the most common of these reactions. (Consult my 2005 article for more detailed discussion of some aspects.)

First, let us discuss three seemingly disparate issues:

- Is information a "sign," as used in the theory of semiotics?
- What is the relationship of information to knowledge?
- In this article's terms, what does it mean to "be informed"?

Briefly, *semiotics* is "the study of signs and sign-using behavior" (Encyclopædia Britannica Online, n.d.). The American father of the field was C.S. Peirce, who conceptualized the world of signs in the following way: There is (a) a "representamen," that is, a sign vehicle, or form, which the sign takes, (b) an interpretation, or sense, made of the sign, and (c) an object (material or conceptual) to which the sign refers (Chandler, 2004).

For example, to most English speakers, the letters "tomato" on a page are a sign. This comes about because we *interpret* ("b" above) the *sign vehicle* of the letters ("a" above) to represent tomatoes (*object*—"c" above). Thus, to us, "tomato" is a sign.

Chandler also notes that "[t]he sign is more than just a sign vehicle. The term 'sign' is often used loosely, so that this distinction is not always preserved." However, the "*representamen* is the *form* in which the sign appears (such as the spoken or written form of a word) whereas the *sign* is the whole meaningful ensemble" (Chandler, 2004). Nothing is a sign unless it is interpreted as a sign (Chandler, 2004). To Peirce, a sign thus stands for something to somebody in some respect (Chandler, 2004; Hoopes, 1991).

The interaction of sign vehicle, sense, and object is called *semiosis* (Chandler, 2004). Semioticians emphasize the dynamic nature of semiosis, as a social and linguistic process in which meanings and associations shift through time and with changing circumstances (Lidov, 1998; Taborsky, n.d.). Semiosis is thus a broader and more encompassing process than individual acts of interpretation of signs.

We can mark out a relationship between signs and information. To interpret a pattern of organization as a sign, an animal must have some association, either derived instinctively or through learning and experience, between that sign vehicle and the object to which the vehicle is interpreted as referring. The marks on a page that make up the sign vehicle "tomato" do not automatically or inherently refer to the object to which we English speakers give that name; rather the object, the sign vehicle, and the interpretation of the vehicle have been linked through time in the development of one particular language. Likewise, a certain kind of strutting in the male birds of a species is not automatically and inherently a courting display, i.e., a sign of a desire to mate, by the male to females. Rather, that association has been developed over time through natural selection (see also Hoffmeyer, 1997).

In the language used here, information can be seen as the raw material, the fodder, that goes into the process of semiosis, as well as into individual acts of interpretation. For example, in various cultures over the years, waving a hand toward oneself has come to mean "come here." Thus, a long-term semiotic process has resulted in that association being present in many human beings' minds. My culture shares that association. When, at a party, I interpret that hand motion from a friend across the room as a sign to come join him, I am selecting out a certain subset of all the information around me. From all the patterns of organization of sound, sight, smell, and touch that I experience in the room, I separate out the hand motion and read it as "come here," and then heed the call.

In the conventional usages of information studies, we take the above as an example of *being informed*. I now know something I did not know before—he wants me to come join him. We can make countless other such examples: Jane tells Joe that his suitcase has arrived, that the ship has run aground, that the Red Sox have won the World Series, that he got 100 on his test, etc. All these involve before and after moments, not knowing something, learning it, then knowing that something.

Looking on from the outside, we can say that something in my or Joe's nervous systems changed, the neural patterns of organization changed after we were informed. So the nervous system information changed in the sense in which information has been discussed to this point in this article.

In ordinary parlance, however, and in information studies as well, we use "informed" to refer not only to a new pattern of brain matter, but also to a change in meaning or understanding in our experience. Although not stated explicitly, information as defined to this point is without meaning, is meaning-free. Living beings can *assign meaning* to information, but patterns of organization of matter and energy are not inherently meaningful. Thus, how do we account for the "meaning-free" sense of information as well as the "meaning-full" sense of information given meaning, as in the above examples?

As noted earlier, any information in the universe can potentially be informative, so we began with a definition of information broad enough to encompass all that potential information. At the same time, we study "information-seeking," where people have a specific need that has meaning, and seek to meet that need with information that likewise has meaning for them, i.e., it matches or fills the stated need.

Let us then define the following terms for use as needed in the field:

- Information 1: The pattern of organization of matter and energy.
- Information 2: Some pattern of organization of matter and energy given meaning by a living being (or its constituent parts).
- Knowledge: Information given meaning and integrated with other contents of understanding.

We can thus unite the several issues discussed in this section by saying that Information 1 is the basis upon which semiosis acts over the long term, as well as the basis upon which individual acts of interpretation of sign vehicles operate. Taking the above example again, I have learned through participation in my society that a certain hand wave means "come here." Assuming my friend succeeds in moving his hand in a pattern sufficiently

close to the generally understood features of that hand movement, and I see him when he is waving his hand, then I am able to read the movement as a sign with that meaning. I now feel informed that my friend wants me to join him. My interpretation of the hand movement—Information 1—has yielded Information 2, some pattern of organization of matter and energy given meaning in my mind.

As the receiver, I have made the linkages, i.e., I have constructed an understanding and am informed. As many have pointed out in recent years, information does not move, like a physical substance, unaltered, in a pipeline from the mind of a sender to the mind of a receiver. Rather, meaningful Information 2, assembled by a sender from knowledge stores, is disseminated via speaking, writing, or other means, and directed to a receiver. The receiver initially receives the message as Information 1, perhaps as sounds, or marks on a page. These sign vehicles remain meaningless until given meaning by the receiver through interpretation, thus constructing an understanding of the message as Information 2. As we know, the Information 2 constructed by the receiver may be very different from the Information 2 that the sender intended to communicate. Eventually, the constructed Information 2 is integrated more or less permanently into the receiver's knowledge stores, and disappears as a separate entity in the individual's experience.

This is not to imply that "being informed" is a situation that occurs solely at the level of a single act of interpretation in relation to a single sign. Rather, in most cases when a person feels informed, numerous interrelated acts of semiosis have occurred, both simultaneously and sequentially, within a context of complex social and cultural meaning-codes that can be very elaborate in the case of human beings (Chandler, 2004).

When needed, Information 1 and 2 can be distinguished in discussion in the field; otherwise, the term *information* is understood to refer to one or both senses.

Meaning is *ascribed* to some of the Information 1 in the world by living beings, that is, living beings interpret some of the information in the universe as signs. An enormous part of all the Information 1 in the universe, however, has never been interpreted as a sign by any living being.

By the way, "informing" always takes place between living beings, because, as far as we know, only living beings (or their constituent parts) can engage in sign production and interpretation. The tomcat marks its territory to communicate to and ward off competitors; however, the waves do not "inform" the beach by moving sand particles.

Note that truth is not a requirement of knowledge as described here; knowledge is a kind of meaningful belief. We may or may not be able to

offer various kinds of evidence to support such beliefs, and we may or may not be able to claim fairly, by the understandings of our culture, that these beliefs are true to the reality of the world.

There is just one final point; I have included the discussion of semiotics here to respond to reviewers, and to demonstrate the general relationship between semiotics and the information definition presented here. However, the linkage, though interesting and promising, is not necessary to the argument made here. One can think and talk about Information 1 and 2 and knowledge as described herein, without any reference to semiotic theory, and without loss to the model presented here.

Applications and implications of information forms in information science

There are numerous potential applications and implications of these fundamental information forms for information science. Three broad areas will be addressed here, as examples of the still broader possible uses for this approach to the concept of information.

Research in information seeking behavior

In this section, I will illustrate the value and applicability of these concepts of information by applying them to the sub-field of information-seeking behavior. Ultimately, it is desirable to apply these terms throughout information science.

An illustrative example can be found in the work of Edwin Hutchins in his book, *Cognition in the Wild* (1995). Hutchins studied a group of people working together who were relatively isolated physically from the rest of the world; they were the crew of a U.S. Navy vessel. His orientation was that of the book's title—How does cognition work in the real world, as opposed to the laboratory? However, we can study his work from the standpoint of information seeking with equal benefit. Hutchins studied the way the crew handled navigation, including an emergency incident, on the ship. He found that their collective production of successful navigation arose out of a wide range of sources, not just the training of the crew, though that was part of it. The very layout of the ship and the design of the bridge promoted the smooth flow of information from the exterior of the ship to the crew and among the crewmembers. Each crewmember took on a distinct, but coordinated, role. Critical information was posted at just the right locations for use. Likewise, navigation practices required that not one,

but two crewmembers have certain crucial pieces of information at the same time to reduce the likelihood of error. Posting of critical information at the right locations for use, redundancy of information in the crew's knowledge and in the materials they worked with, and a variety of other information factors in the situation promoted the effective coordinated response. Even the format design of the forms the crew filled out made it easier for them to complete their work successfully.

Though Hutchins was studying collective cognition, he also produced groundbreaking work relevant to information studies, because he incorporated *all* the forms of information that were supporting the crew's performance, not just the forms that we conventionally label "information" (see, for example, Hutchins, 1995, pp. 263–285). People get information not just from paper sources, not just from other people, but also from the physical layout of their workspaces, from the design, not just the content, of informational genres, and above all, from the interaction of these various factors in a real situation. All the patterns of organization of matter and energy—cognitive, physical, architectural, social, linguistic—are informative. Therefore, to understand fully this information seeking and use situation requires the identification of the roles of all these forms of information.

The terms defined in this article can be seen as an initial effort to identify the various information forms needed for the study of people in their information milieus. In the example of the ship's crew, it would be possible to distinguish the nature and role of *experienced information*—what the crew was perceiving and thinking about, *enacted information*—what they did, and observed others doing, at each step of the process, *expressed information*—what they said and understood from their own and others' verbal and body language, *embedded information*—how the architectural layout and design of instruments and documents affected their information use, and *recorded information*—the documentary resources used.

Information genres

Distinguishing genres of information has been a long-standing necessity for library catalogers, who wish to include information type within their descriptions of various kinds of documents (Wilson & Robinson, 1990). However, while much work has gone into the making of definitions for practical cataloging, there has been no larger established theory of genre types within library and information science. Recently, the advent of new informational forms on the World Wide Web has provoked another round of interest in genre in information studies (Bates & Lu, 1997; Crowston &

Williams, 2000; Vaughan & Dillon, 1998, among others). In a completely different realm, genre has also been a focus of interest in literary studies, the arts, and other fields, where a given genre can be seen to be an expression of, and a vehicle for, a particular kind of communication (Ingarden, 1989; Trosborg, 2000).

Perhaps the information types described in this article can provide the basis for a more theoretically grounded understanding of genre. For example, within the humanities we can see the performing arts (dance, theater, music) as the disciplines of expressed and enacted information, the plastic arts (painting, sculpture) as the disciplines of embedded information, literary studies as the disciplines of recorded information, and so on. Starting with a consideration of these fundamental differences and distinctions in the *object of study* by the practitioners of these disciplines, perhaps we can develop a taxonomy of the material culture of the arts and humanities that has a novel basis. This taxonomy may also be useful for grounding the development of a suitable classification of genres for library work as well.

The information and curatorial sciences

Of late, there has been much interest in the relationship between library and information science, archives, and museum studies. In the digital era, all of these disciplines are involved in digitizing parts of their collections, and the challenges facing these fields appear to be converging. Museum collections management databases are being revamped and made available to the public online, just as library catalogs have been for some years now.

I believe that the distinctions made in this article among types of information can help clarify just what the relationship is and should be among these disciplines. They are all what might be called *collections disciplines*, as their primary purpose is to create collections of objects, that is, to bring together objects of social interest for research, learning, and entertainment, and make them available to an audience. All these disciplines create some sort of organized access to their collections, and house those collections in institutions of a certain type and organizational design.

Those institutions, the library, the archive, and the museum, arose for different purposes, however, and have different traditions. The different purposes arose around the collecting of distinct types of objects. In other words, *collections sciences are distinguished one from another by the kinds of objects of social interest that they collect*. Though digitization makes for some similarities in the challenges these disciplines face, it should also be

kept in mind that each discipline arose around, and is designed to meet the needs of, the underlying social objects collected.

Libraries house published recorded information, archives house unpublished recorded information, and museums house various kinds of embedded information, from works of art to archeological artifacts. Natural history museums house embodied genetic information, that is, partial or whole (and no longer living) phenotypes. Still other museum-like institutions, specifically, zoos, aquariums, arboretums, and gardens, collect and house living phenotypes, also embodied genetic information.

The distinctions among types of information detailed here may be used as a basis for analyzing and distinguishing various sorts of collections sciences. Those that collect recorded information of various types are among the information sciences, and those that collect embedded objects and embodied phenotypes are part of the curatorial sciences.

Summary and conclusions

Information is the pattern of organization of matter and energy. All information is natural information, in that it exists in the material world of matter and energy. Represented information is natural information that is encoded or embodied. Encoded information is information that has symbolic, linguistic, or signal-based patterns of organization. Embodied information is the corporeal expression or manifestation of information previously in encoded form.

Goonatilake's model of three broad streams of information transmission over the history of life on the planet is utilized; he calls the streams "information flow lineages." These are the genetic, neural-cultural, and exosomatic flow lines (Goonatilake, 1991). I have proposed several fundamental forms of information and have assigned them to the Goonatilake flow lines. These are genetic information in the genetic line; experienced, enacted, and expressed information in the neural-cultural line; and embedded and recorded information in the exosomatic line. Genetic and neural-cultural information are *encoded*, respectively, as the genotype and as nervous system structures and action potentials. Genetic and neural-cultural information are *embodied*, respectively, as the phenotype and as experienced information (experience, consciousness), enacted information (actions), and expressed information (communication).

Exosomatic information, that is, information stored externally to the body, has been developed in complex ways by human beings, and has been differentiated here as embedded information (the pattern of organization of

the enduring effects of the presence of animals on the earth) and recorded information (communicatory or memorial information preserved in a durable medium). Recorded information is the chief focus of the information professions, and embedded objects and embodied phenotypes are the chief foci of the curatorial professions, including museum studies and zoo management. Examples have been provided to illustrate the relevance of these terms to two further areas of information studies, namely, information seeking behavior and information genres. It should be possible to develop comparable examples for other areas of information studies.

Information deteriorating from its former relation to the living back into inert natural information is called trace information. Trace information, seen as ignored detritus in most other disciplines, takes on immense significance in information studies, archival studies, history, archeology, and the curatorial disciplines.

Finally, a distinction has been made between Information 1, the pattern of organization of matter and energy, and Information 2, some pattern of organization of matter and energy given meaning by a living being (or a component thereof). Knowledge has been defined as information given meaning and integrated with other contents of understanding.

This perspective and corresponding terminology have been developed to provide a fresh conceptualization of some of the classical issues in information science/studies. The discussion of Information 1 enables us to start at the root of all information description and information seeking—the patterns of organization in the universe, including those generated by other living beings—that animals and humans respond to and use in interpreting and giving meaning to their experience.

Having begun at that foundational level, we found that we could also identify several distinct forms of information of value to our and related collections disciplines. These terms provide a larger vocabulary than we had previously to describe the various kinds of information that are important to information science/studies. Perhaps we are now just a little closer to being able to build a more principled understanding of our and related disciplines.

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