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Evolution and Information

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Abstract

The association between life and information is discussed. Evolutionary biologists associate information with the genetic code. It is argued that this should more properly be regarded as *potential* information, rather than information.

Information is considered to be "*a stimulus which expands or amends the World View of the informed*". Using this definition, the standard chain of evolutionary development is reconsidered. It is proposed that the ability to derive information from the environment arose as a direct result of the evolution of organisms that used other organisms as a food source. To survive, they needed some means of distinguishing between what was beneficial and what was detrimental. They therefore needed a simple World View.

Only with the evolution of sexual reproduction did it become necessary for organisms to be aware of others of the same species. It is argued that one of the consequences of the evolution of different sexes is that often, prospective mates had to evolve means of communication. With that development, it became possible for animals to expand their World Views by means other than direct exploration of their environment.

Such reinterpretation of evolutionary thinking has numerous implications for the information scientist. Some of these are discussed.

Introduction

The term ‘information science’ is less than fifty years old, having been coined as recently as 1955 (Wilson, 1999). As a new discipline, information science is still in the process of defining itself. This paper aims to explore links between information science and another, longer established science, that of evolutionary biology. It attempts to bring insights from evolutionary biology into information science (and vice versa). It also attempts to correct misunderstandings that evolutionary biologists have about information.

The paper makes the following assumptions (derived from Meadow & Yuan, 1997) about information:

1. *For there to be information, there must be something or someone to inform.*
2. *To be capable of ‘being informed’, it is necessary to have a World View.*
3. *Receipt of information results in the World View being changed.*

These could be summarized by defining information as

a stimulus which expands or amends the World View of the informed.

A further assumption is made, which is expanded on later.

4. *If something has a World View, it, or its component parts, must be alive.*[1]

Information and potential information

As Meadow & Yuan observe, the word ‘information’ is often used to describe data sets and data streams. This paper, in keeping with their views, considers these to be ‘potential information’. They use the analogy of potential energy in mechanics (p701). If the potential energy of an object is realised, the object has impact. However, certain conditions must be met in order for the potential energy to be realised (i.e., it must fall). Similarly, with information,

> *"A message or set of data may potentially be information but the potential is not always realized… In the information world, impact is what happens after a recipient receives and in some manner acts upon information."*

In the forthcoming discussion, the distinction is important. When discussing evolution, biologists commonly refer to information in association with changes in the genetic code. The first of this paper's two main objectives is to analyse the evolutionary process from the perspective of an information scientist. To achieve this, it is necessary to distinguish clearly between 'potential information' (such as the genetic code) and 'information', as defined in the introduction.

The paper's second objective is to suggest that information science can make a constructive contribution to a number of discussions central to evolutionary biology. It aims to present arguments that are already familiar to biologists, in a manner which demonstrates to information scientists that fruitful collaborations between the two disciplines are possible.

Information and life

The association between information and life is well-established (eg, Debons & Home, 1997, Vickery, 1997). If such an association is accepted, then it should also be accepted that aspects of information must have been subject to evolution. Indeed Maynard Smith and Száthmary have written two books (1995, 1999) in which they develop the idea that

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[1] Given the current state of technology.

"evolution depends on changes in the information that is passed between generations" (Preface, 1999).

It is their view that

"there have been 'major transitions' in the way that information is stored and transmitted" and their aim is *"to explain these transitions in consistently Darwinian terms."* (Preface, 1999).

Implicit in their analysis is a view of information derived from Shannon (1949), which equates information to a signal passed from transmitter to receiver. This would, according to the definitions used above, be an example of potential information. Shannon stated that

"The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point."

Maynard Smith and Száthmary have taken the message to be the genetic code, and the points of transmission and reception to be, respectively, parents and progeny.

Evolutionists' views of information

Maynard Smith and Száthmary make no attempt to define information, beyond stating that

"Information theorists use the phrase 'information is data plus meaning'" (p11).

A rather more interesting observation is made by Daniel Dennett, another evolutionary theoretician, who, in discussing consciousness (1993:55), observes that

"Nothing but information passes from outside to inside [the brain]*".*

Underlying this observation is a recognition of the importance of boundaries. The idea of boundaries is core to thinking on information systems (eg, Checkland, 1984). However, they are also a vital component of life. Their importance in biology is explored immediately below. The relevance of biological boundaries to information science will be discussed in the subsequent section.

The importance of boundaries

Discussions on the nature of life tend to focus on growth and reproduction. Often overlooked is the importance of boundaries, whether they be membranes, walls, skin or exoskeleton. In 1944, Erwin Schrödinger (1992) gave a classic series of lectures on the nature of life. He addressed the question 'What is Life?' from the viewpoint of the 'naïve' physicist. From that self-derogatory perspective, he asked

> *"When is a piece of matter said to be alive?"* (p69)

His response to his own question is:

> *"When it goes on 'doing something', moving, exchanging material with its environment, and so forth, and that for a much longer period than we would expect an inanimate piece of matter to 'keep going' under similar circumstances."* (p69)

The organism achieves this by

> *"eating, drinking, breathing and (in the case of plants) assimilating. The technical term is* metabolism*. The Greek word (μεταβάλλειν) means change or exchange."* (p70)

Schrödinger argues that these exchanges enable the organism to swap low energy molecules (through respiration and excretion) for high energy molecules. By so doing, the organism is able to maintain an energy level higher than that of its environment: a state which Schrödinger describes as ‘negative entropy’.

Entropy is a confusing concept because a system with maximum entropy has minimum available energy. The first law of thermodynamics states that energy can be neither created nor destroyed. It can however, become dissipated, which means that it cannot be used to power any kind of work. In energy terms, the idea of ‘maximum entropy’ is equivalent to thinking of ‘maximum spread-outness’. When Schrödinger talks about life having negative entropy, he means that it has the ability to gather up some of that dispersed energy, thereby reducing the energy’s spread-outness. If it ceases to do this, it will be subject to the same processes of increasing entropy that affect the environment as a whole. In other words, it will be dead. The organism must therefore protect the concentrated state of the energy it contains. It does this by sealing its high energy contents within a boundary.

As was discussed above however, an organism must also be able to make metabolic exchanges with its environment: a totally impregnable boundary would prevent it from doing so. It is necessary therefore, for the boundary to allow regulated exchanges. To achieve this, the organism must have a means of interpreting its environment in order to make exchanges that are beneficial and not detrimental. In other words, it needs information.

World Views

In the introduction to this paper, information was defined as

> *“a stimulus which expands or amends the World View of the informed.”*

A World View (or Weltanschaung) is generally taken to be a person's perception of his or her physical and social environment (Checkland, 1984). World Views are usually only discussed in association with human consciousness; but in order for any organism to respond to a stimulus, it must have some form of World View, albeit, in most cases, a very simple one. This is implicitly recognized by Checkland who observes that

> *"Judging from their behaviour, all beavers, all cuckoos, all bees have the same W[orld View], whereas man has available a range of W[orld View]s.* p218*"*

Checkland's examples of beavers, cuckoos and bees are all creatures which demonstrate sophisticated behaviour patterns; but even an amoeba demonstrates behaviour which enables it to improve its chances of survival.

If, for example, amoebae were not able to move from areas of low nutrient concentration to areas of higher nutrient concentration, they could not acquire the energy-giving molecules they need to maintain the energy concentration within their boundary (or cell membrane).

The mechanisms by which such detections occur are not relevant to this discussion. What is relevant is that the negative entropy within the amoeba is protected by the cell membrane; but to maintain that negative entropy, the organism must respond to conditions outside the membrane. In other words, the amoeba has evolved a model of a habitable world and uses information derived from its environment to compare its current surroundings to that model. In short, it has a very simple World View.

This paper began by noting that, in general, where evolutionists have associated biology and information, what they have described is more properly, an association between biology and *potential* information. It is argued that a concept of information that is more acceptable to information scientists is one which links it to World Views.

Dennett (1993, ch7) describes a process by which consciousness (and therefore, implicitly, World Views) could have evolved. This process is expanded on below in a manner intended to emphasize the role of information in biology (especially zoology).

The first life forms

In terms of the history of life on earth, the amoeba is a relative latecomer. The fossil record indicates that Eukaryotes (true cells) such as the amoeba, did not evolve until around 1.2 billion years ago; some 2.2 billion years after the emergence of the simple bacteria which are thought to have been the first life on earth (Margulis and Schwartz (1998:51).

As Schrödinger noted, for something to qualify as life, it is a necessary, but far from sufficient condition, that it should be able to fuel energy-consuming reactions which create compounds distinct from those found in the surrounding environment. The fuel for such reactions is food. Fossils of the oldest life forms suggest that they were primitive bacteria capable of producing their own food (autotrophic). To survive, they needed to live in a medium which provided access to

- the chemical building blocks from which they synthesized their food, and
- a source of energy (usually light) with which to power the synthesis.

Discussion of ancient life forms is, of necessity, speculative; though the speculation is strengthened by the fact that similar organisms (blue-green bacteria) survive today (Margulis and Schwartz (1998)).

Where the conditions described above are met, blue-green bacteria can survive purely passively, and have no need to regulate the exchanges taking place across their cell walls. In other words, they do not have to act on information derived from the environment.

Seeking food

As has been stated, autotrophs can utilize an energy source available in the environment to produce the high-energy compounds that fuel their negative entropy. As a result, they in turn, are a source of high-energy compounds for other organisms (heterotrophs). These either eat the photosynthesising organisms or scavenge their remains. To survive therefore, heterotrophs need to be able to seek and identify their food. Consequently, unlike primitive autotrophs[2], heterotrophs need information.

Motile bacteria move by means of hair-like appendages known as flagellae or cilia. However, movement uses up energy, so unless the movement leads to circumstances where the bacterium can benefit from a net energy gain, it will be detrimental to the organism. To survive therefore, the motile organism must move in a manner that enables it to offset the energy cost of the movement itself. It must therefore be able to respond to variations in the environment, and to the presence, or absence, of essential compounds.

Recognition of species

It seems somewhat ridiculous to talk about the World View of a bacterium. Nevertheless, bacteria are affected by a range of conditions in their medium, including

- acidity,
- temperature,
- gas concentrations,
- availability of nutrients,
- levels of toxin.

All of these can vary at a microscopic level; so a bacterium needs to be able to read its environment as a series of gradients and move appropriately according to the gradient. Its information-processing skills can probably be summarized in the simple algorithm:

Move in direction that

⇒ *increases energy gain or*

⇒ *reduces energy loss.*

One thing that bacteria do not need to do however, is be aware of other bacteria as being anything other than physical obstacles, or objects with interesting chemistry (and consequently a potential food source or toxin).

The world of a bacterium therefore, does not need to incorporate other bacteria. Colonies form, not because the organisms 'get together', but because there is a supply of nutrients which allows growth and cell division. If the nutrients are in a solution that flows, there are clear advantages to any bacterium that can attach itself to a fixed surface. That fixed surface could be a rock or, just as easily, another bacterium attached to a rock.

Other organisms however, particularly those which depend on sexual reproduction, do need to be able to identify others of the same species. As is discussed below, this is significant when considering information flows because it marks a stage in evolution when information is not merely being derived from the environment, but is being exchanged between organisms.

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[2]It must be stressed that only primitive photosynthetic bacteria are being referred to here. Many autotrophs show a wide range of responses to environmental influences, and are therefore clearly capable of deriving information from their surroundings.

Accidental sex

Bacteria attach themselves to surfaces using small, thin protuberances called pili[3] (also called fimbriae[4]). Structurally similar, though somewhat larger protuberances, are known as sex-pili. These form conduits for the transfer of genetic material (Singleton and Sainsbury, 1987:675). Given the tendency described above, of bacteria to attach not only to inert surfaces but to other bacteria, it is likely that sex-pili evolved from the smaller attachment pili.

Bacterial DNA is more loosely organized than the DNA in eukaryotes, where it is surrounded by membranes. Bacteria contain a loose strand of DNA which is often supplemented by additional loops of DNA called plasmids. Plasmids and pieces of DNA broken from the central strand can easily move through a hollow pilus. If that pilus is attached to another bacterium, it becomes possible for an exchange of genetic material to take place without there being any intention on the part of the donor or the recipient of the material. Sexual reproduction could therefore evolve in an organism without that organism having any awareness of others of the same species. This is in marked contrast to the forms of reproduction described below.

Sex and an expansion of World View

From a human perspective of life, bacteria seem unusual in that sex and reproduction are not directly connected: bacteria reproduce by dividing, and so have no need of sex. However, the ability to exchange genetic material is a major driving force in evolution: it allows populations of an organism to respond rapidly to environmental changes.

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[3] Singular = pilus
[4] Singular = fimbria

A clear example of the benefit to bacteria of such genetic exchange is the spread of antibiotic resistance. Mutations are rare and beneficial mutations are rarer still. In a population of billions of bacteria, there may be only one which can survive a dose of antibiotic. That bacterium could rapidly replicate to produce a population of billions; but those billions would be genetically identical. If a second antibiotic were applied, the probability of another appropriately beneficial mutation would be vanishingly small. Because bacteria can exchange genes however, they can swap resistances, so the population remains variable and may acquire resistance to several antibiotics.

For bacteria therefore, it is not surprising that sex is so widespread. However, exchanging genes is far harder for eukaryotes than it is for prokaryotes, such as bacteria. Bacterial DNA is loose, and can move within the organism, whereas eukaryote DNA is held in membranes. Most of it is in the cell nucleus, where it is organized into chromosomes. For it to be exchanged, the nucleus must first divide to produce two nuclei, each with half of the full complement of chromosomes (gametes). Each of these nuclei must then fuse with a nucleus from another member of the species.

This is the basis of sexual reproduction. It is a difficult process which, to the organism, is both risky and expensive. Furthermore, many multi-cellular organisms are quite capable of parthenogenesis (self-fertility), which is both simpler and safer than sexual reproduction. Indeed, even mammalian embryos have been known to develop parthenogenetically, though none have survived beyond the early stages of development (Rougier and Werb, 2001)

The advantage of reproduction without sex is clearly illustrated by the example of aphids, which often reproduce parthenogenetically. The rate at which their populations grow will be familiar to any gardener. Some species of aphid mate occasionally, and so combine the advantage of rapid population growth with the advantage of mixing genes, but some aphids appear to have abandoned sexual reproduction altogether.

They are, however, the exception. The near ubiquity of sexual reproduction amongst multicellular animals suggests that it must have advantages. The opportunity to exchange genes is a clear benefit, but if that were the sole benefit then it is surprising that, for so many organisms, sexual reproduction has become the only means of reproduction instead of just being an option (as it is for aphids). The reasons for sexual reproduction are still being actively debated amongst biologists (Zarkower, 2001). It will be argued below that one of the consequences of the evolution of different sexes is that often, prospective mates had to evolve means of communication. With that development it became possible for animals to expand their World Views by means other than direct exploration of their environment.

Not all sexual reproduction requires direct contact between donors of the gametes, but where such contact does take place, the World View of the copulating organisms must be more sophisticated than that of organisms which reproduce without contact. The World View of the latter need only comprise *things to consume* and *things to avoid*. The former needs also to be aware of *things with which to breed*. As is argued in the next section, the need to breed is linked to a need to exchange information.

Sex and communication

Different species undoubtedly derive information from each other. For a predator to be successful it must be able to detect its prey and consume it; while for a prey animal to survive, it must be able to detect its predator and avoid it. In order to survive, both predator and prey need to have their World Views updated concerning the whereabouts of each other, but the transfers of information involved cannot be regarded as exchanges. In each case, the information provided is detrimental to the organism that provides it. The prey does not wish to tell the predator where it is, and the predator does not want the prey to realize that it is being hunted.

The situation is very different where sexual partners are sought. To reproduce in these circumstances, an organism must be able to send out a signal that is recognizable as such to others of the same species. Arguably therefore, information is being communicated.

Partners in procreation often commit different levels of resources to reproduction. One strategy is for the organism investing the least to force a prospective partner to receive its gametes. However, it is clearly to the advantage of the partner investing the most resources if some form of negotiation can be entered into. In many cases, this has led to communities where communication plays a major role in ensuring that the nourishment and protection of any progeny is shared. This is most spectacularly the case with social animals such as bees, ants, termites (Hamilton, 1964) and naked mole-rats (Jarvis, 1981).

On a more basic level though, is the negotiation between males and females that leads to mating. A consequence of this has been the evolution of systems in which prospective mates attempt to communicate their suitability; with the consequent development of some sophisticated displays. These displays may take a variety of forms, involving various combinations of highly visible secondary sexual characteristics, complicated vocalizations, and exhibitionist behaviour. Such displays led to Darwin developing his theory of sexual selection (Darwin, 1897:107).

Mating displays are indisputably attempts to communicate several messages to a prospective mate. Those displaying are not only announcing their whereabouts, but may also convey information about their health, their strength and their ability to obtain food.

Different sexes, different agendas

Many animals are hermaphrodites and therefore perform both male and female roles in reproduction. Where there is sexual differentiation however, there is often sexual dimorphism: i.e., males and females have very different physical forms. Some of the differences are directly associated with their reproductive roles. Many however, are for sexual displays, as described above. It was on these that Darwin focussed when he developed his ideas of sexual selection.

Since it is usually the female that invests the most in reproduction, sexual selection tends to be most apparent amongst the males that compete to mate with her. If they compete successfully, the characteristics that helped them succeed in attracting the female will be passed on to some of their progeny. However, the male will not benefit from having a desirable trait unless he is able to flaunt it. As a result, a form of inter-generational positive feedback occurs, resulting in the evolution of exaggerated and often cumbersome appendages: most famously perhaps, the plumage of certain birds.

The fact that these exaggerated characteristics are frequently detrimental to the long-term viability of the male has often been commented on (Kirkpatrick & Ryan, 1997; Cunningham & Birkhead, 1998). This apparent paradox can be explained, however. A male burdened with some clumsy organ of sexual display may be less able to hunt, forage, escape predation etc, than another, less well-endowed male and so will be unlikely to live as long. However, in his short life, he can expect to attract more mates than his longer-lived rival. Any male progeny that result from these couplings will have a good chance of inheriting their father's encumbrance, and the associated reproductive success.

An obvious question arises however. Why would a female select characteristics which disable her offspring? One reason has been given above: because her male progeny will enjoy greater reproductive success. Another reason though, is that only half her progeny will have the disabling display organs: they will only develop in the males.

Consider the example of the peacock. A male may have a spectacular tail; but to use a non-academic cliché, "*It's not just what you've got, it's what you do with it that counts*." The tail must be displayed. The vigour with which it is displayed helps to inform the female about the male's strength and agility. It is possible that innovative behaviour (new display moves) will also impress her.

The genes that contribute to the male's strength, agility and innovativeness will be passed to female progeny as well as male, but the female chicks will not develop the awkward tail. They will inherit the desirable characteristics, but will dissociate them from sexual display.

It is not only physical characteristics and movements that are used to convey information about an animal's suitability as a mate. The ability to make sounds also plays a part, and is subject to the same processes of selection. In the next section it is argued that complicated vocalization formed part of a pattern of sexual display behaviour amongst the ancestors of humans, but that it became dissociated from that context. Instead, it provided a general means of communication, rather than solely a means of conveying information related to reproduction.

Sex and language

What has been written above takes well-established arguments in evolutionary biology and examines them from the perspective of an information scientist. It is hoped that the exercise will have stimulated information scientists to consider how our discipline may impact on others. It is also hoped that it will generate interest in information science from other scientists. The section that follows is more speculative. It considers recent research which supports the suggestion above, that language was originally the result of sexual selection. The ideas are still relatively new, but they are presented here on the assumption that any debate on the development of language will be of relevance to the study of information.

Humans, like other primates, are sexually dimorphic; although we have avoided the extremes of sexual selection for physical characteristics such as those discussed earlier (Lindsey, 1997). Sexual selection of physical features is therefore less important to humans than to many other animals. However, as has been stated, displays and vocalizations are also important, and sexual selection for such behaviours might have been (and may still be) a factor in human evolution (Crowe, 2000).

The idea that language is instinctive and is associated with heritable characteristics is well-established (Pinker, 1993). In addition, the idea that vocalization is associated with sexual selection in humans is advocated by both Miller (2000) and Crowe (2000). Miller, in a discussion on Verbal Courtships (ch10), implies that language is equally important in sexual selection for both sexes. Crowe by contrast, presents evidence which suggests that language originated in a mutation on the chromosome that determines maleness in humans (the Y chromosome). Further evidence relating language to sexual display by males comes from recent research at Manchester University, where tests demonstrated that testosterone can improve men's verbal fluency (O'Connor, *et al*, 2001).

Given such findings, it is not surprising that women are attracted to men of exceptional linguistic and vocal ability. While there is no single formula for guaranteeing that someone will be attractive to the opposite sex, there are certain key components which differ in importance according to gender. The research cited above helps to explain why male poets are romantic figures; but the same (to the chagrin of Dorothy Parker) cannot be said of female poets. Looks are undoubtedly important to both sexes; but where male musicians of unprepossessing appearance can attract female interest because of their vocal displays, their female counterparts tend to be marketed as much on looks as ability (Lindsey, ch13).

Such findings therefore, indicate the possible importance of language in conveying information about a man's availability and appropriateness as a mate. However, it is clearly the case that language does a lot more than this. If, as Crowe suggests, language did evolve as a mutation on the Y chromosome, then at some stage the necessary gene or genes crossed to other chromosomes and spread throughout the whole hominid population. Just as the hypothetical peacock discussed above, disseminated strength, agility and innovativeness to progeny which did not use those qualities in sexual displays, so the ability to create a range of sounds and pitches may have become ubiquitous amongst pre-human hominids, leading eventually, to the evolution of a system of oral symbols which allowed those hominids to represent and communicate their World Views. If this hypothesis is accepted, then it is somewhat ironic that, in modern humans, women appear to be more competent users of language than men (Ridley, 1994:249).

Exchanging and recording information

The power of language as a means of representing and comparing World Views is clear. Language not only allows us to share contemporaneous observations on the world, it also enables us to store observations and inferences by such means as writing. The transmission of ideas and technologies from one generation to another therefore becomes far more reliable.

Diamond (1997:21) makes the interesting suggestion that people from technologically primitive societies may, in general, be more intelligent than people from technologically sophisticated societies. They are subject to immediate problems of survival, such as the need to find food and live through conflicts; and the possession of intelligence confers a clear advantage. In technologically sophisticated societies, such problems have largely been solved by our forebears. The technology that is often seen as providing evidence of greater intelligence therefore, owes more to effective means of information storage and retrieval, which enable solutions to be passed on to generations beyond those that developed them. Diamond (pp312-3) cites evidence to show how easily technologies are lost in societies where no system of recording exists.

Evolution and information

In the preceding paragraph, the phrase ‘evolutionary advantage’ is used. It is Darwinian evolution that is being referred to. The genius of Darwin was not in suggesting that life could have evolved, but in proposing a mechanism for that evolution. Darwin would have been well aware of the fact that there were other theories of evolution prior to his own.

One such theory was advocated by the French naturalist, Jean-Baptise Lamarck. He proposed that characteristics acquired by an organism in its lifetime could be passed on to its progeny. He cited as an illustration, the example of the giraffe which

> *“is known to live… in places where the soil is nearly always arid and barren, so that it is obliged to browse on the leaves of trees and to make constant efforts to reach them. From this habit long maintained in all its race, it has resulted*

> *that the animal's fore-legs have become longer than its hind legs, and that its neck is lengthened"* (Lamarck, 1914).

As a model for biological evolution, Lamarckism was discredited a long time ago. The discovery of genetic principles in the 19th century supported Darwin's hypothesis, and Lamarckism has come to be regarded as an interesting, but misguided contribution to biology. However, as a model for the way in which human societies evolve, it is highly appropriate. Where the philosophies and technologies of one generation are available to be inherited by a later generation, that generation can build upon the thoughts and ideas of its ancestors. The adapted thoughts and ideas can, in turn, be transmitted to a subsequent generation. Where a culture has writing, the process of transmission becomes significantly more reliable.

Summary

The idea that information and life are intrinsically linked has been developed by exploring the kinds of information processing that would be needed by organisms of differing levels of sophistication.

Life probably began as a self-perpetuating set of reactions fuelled by a steady source of energy. The simple organisms in which such reactions took place could merely exist, more or less as a by-product of the energy source. Their environment was sufficiently stable for them to maintain the negative entropy of their contents, without having to regulate exchanges across their boundary.

These simple autotrophic organisms in turn, provided energy to organisms that evolved to feed on them or their remains. However, the autotrophic organisms were by no means a steady source of energy. Instead, they needed actively to be sought; so the subsequent heterotrophic organisms had to evolve mechanisms for finding them. It therefore became necessary to derive and use information in order to identify food sources.

The information they needed would have related solely to nourishment and survival. There would have been no need for them to respond to other organisms of the same species, except as either an irrelevance or an obstacle. With the evolution of sexual reproduction however, the need arose for information to be communicated between organisms. Sexual selection led to the evolution of specialized appendages and behaviours specifically for the purpose of conveying information related to reproduction. It has been suggested that language evolved in humans to serve such a purpose.

The evolution of language facilitated the reliable storage of information, allowing it to be passed on from generation to generation. As a result, human culture is now subject to Lamarckian evolution.

Implications for Information Science

Information processing is a fundamental characteristic of most forms of life. If this is accepted then it becomes clear that there are potential insights to be gained by applying concepts developed in the information sciences to the biological sciences.

One such insight is implied above in the section headed ‘Exchanging and recording information’. If it is accepted that human societies are subject to Lamarckian evolution, it becomes clear that many differences attributed to race owe more to factors affecting information storage, retrieval and exchange than they do to genetics.

It is true that isolated communities will display characteristic features determined by their genetics, but much of their culture will be determined by their World View. For such societies, that World View will be dictated largely by information derived from their immediate environment.

Writing makes possible the development of ‘textual communities’ (Stock 1983:90), groups of people, not bound by geography, who make

> *“parallel use of texts, both to structure the internal behaviour of the groups’ members and to provide solidarity against the outside world”.*

Most obviously today, they include adherents to the world’s major religions; but legal codes, written constitutions, bodies of rules, and the standard texts of many academic disciplines, produce other examples of textual communities.

This being so, what could be the consequences of depending on systems that place emphasis on the rapid and effective circulation of information, but neglect its systematic storage?

An association between information science and the biological sciences raises the possibility of interesting collaborations across the disciplines. As an example, the discussion above on possible links between information exchanges and sexual reproduction in animals raises many questions to which the information scientist could usefully contribute.

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