1

Human and Animal Communication

We, modern humans, find ourselves swimming in an ocean of information. If we were to get out of town to escape from the hubbub our fellow beings create, it may not be calm that awaits us in the forest. The forest has its own din, unceasing and of countless types. This is nature speaking to itself. Now, why should there be so much information being circulated, and so much time and energy being used up? This chapter discusses these questions, starting with the human case before going on to other languages in nature.

1.1. Language, that amazing thing

There are several ways in which *Homo sapiens* stand out from other species. Humans are bipeds, masters of fire, practitioners of art, makers of tools and weaponry, live well past the age of reproduction, impose rites of passage on each other between the stages of their life and so on. The human being is unique for many of these reasons. We differ from other primates in that we do not suffer from hirsuteness, and we walk on our rear limbs. However, there is another difference that, though rarely mentioned, is perhaps the most fundamental and the least anecdotal: *Homo sapiens* are information specialists. That is what this chapter is about, and we will also consider why this is the case.

Scientists of the 19th Century understood that *Homo sapiens* had not been created apart from other living beings, but was simply one among several species. Some, however, did not give up trying to find reasons for upholding our uniqueness, one way to try to regain our lost position. Many

thoughtless assertions, such as “the human being is the only one to ...”, have since been refuted. No, we are not the only ones to make tools; we are not the only ones to have a culture; we are not the only ones to know how to count. Chimpanzees and gray parrots can do some of these things. Saying that we do these things better, or that we can do more things than these, will not help save our ego as a species. The vanity evident in such beliefs is clearly unhealthy. It is a bit like the immaturity a child displays when they have not learnt that while they are unique, they are also equal to other children. In principle, difficult as it might be, the scientific approach should guard itself against the supposed uniqueness of the human species. At the same time, there is one striking fact we should not overlook.

Humans possess a characteristic that we may fail to notice, just as some of us may miss the elephant’s trunk when we look at the animal or the activity of the dam-building beaver. *Humans talk*. They talk a great deal. In fact, talking or listening take up one-third of our waking time, that is more than 6 h a day. On average, we speak 16,000 words daily. The males of some bird species perhaps do better quantitatively, but our words, endlessly repeated, create meaning; they produce information.

In the context of language, information has a somewhat precise intuitive meaning: we know whether what we are hearing is interesting or boring. Even though such a subjective feeling does not by itself provide a usable measure for the quantity of information contained in a particular portion of speech, it does point out a significant lead. It is by modeling how we spontaneously measure the appeal of another individual’s utterance that we can develop a general definition of the notion of information. This definition, though conceived in language, has applicability that extends well beyond.

1.2. The mechanics of language

Human communication is “monstrous” in several aspects, not only by the prohibitive amount of time devoted to it. Communication has requisitioned our memory and our intelligence. We know by heart tens of thousands of subtle shades of meaning found within words and expressions learnt during the course of our life. Any one of us can make an unlimited number of meaningful sentences using this lexicon, most of which may never have been uttered before. While we may be able to do this without much effort, we must not underestimate the intricacy of the mechanism involved. Language

depends on incompletely understood processes, a study of which would be fascinating. The sentence “Last year, the alarm sounded when the birds flew overhead” provides illustrations of some of them. When we analyze the acoustic signal that reaches our ears, our brain recognizes some phonemes of English, the “l” of “Last”, then the long vowel “ɑ:”, then the “s” and so on. The sentences contain about 30 phonemes. Some of them, like “s”, appear several times. These phonemes are drawn from a very limited set. English dialects offer a gamut of three dozens of them.

Why is it that there are so few phonemes? If there were more, every phoneme would have carried more information, our words would have been shorter and we would have been able to express numerically more ideas per minute. But this would have been at the cost of risking mounting confusion, because if we were to populate the accessible acoustic space of pronunciation with more phonemes, there would necessarily be a reduction in the acoustic contrasts that separate them. Then, why not enhance the acoustic contrast by utilizing fewer phonemes? After all, any computer scientist will tell you that two phonemes would do, as in Morse code. Yes, but then the words would grow longer, and they would flow more slowly. The English word “wonderful” is pronounced /’wʌndəfʊl/, and has eight phonemes, namely /w/, /ʌ/, /n/, /d/, /ə/, /f/, /ʊ/ and /l/. In the dot-and-dash Morse code, the word would read: dot dash dash space dash dash dash space dash dot space dash dot dot space dot space dot dash dot space dot dot dash dot space dot dot dash space dot dash dot dot, that is, 26 Morse signs and eight spaces. It is obvious that the two-phoneme code calls for a much longer stretch of time to transmit the word than the code composed of several phonemes within the acoustic space that our articulatory capacity allows us to access.

Phonology is a *code* that allows us to represent words in the form of sounds. Writing and sign languages are other codes that enable a representation of words. A code enables a transition from the domain of signs to the domain of meaning (Figure 1.1). The word “wonderful” may be coded by nine letters in writing, or by movements of the hand in the British sign language (both hands open, the index finger touching either side of the mouth, then moving forward and slightly outward). The meaning generated by these codes is the same.

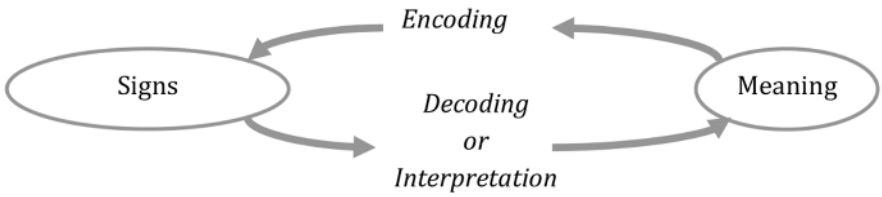
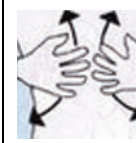
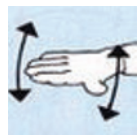


Figure 1.1. *A code enables a transition from the domain of signs to the domain of meaning*

Some codes are *word-for-word* codes. This is the case with the code used by underwater divers (Figure 1.2). Here, the code has about 10 different gestures, each with a very precise meaning. For example, "I have just exhausted my reserve of air". If there were no homophones in English, such as "hoard" and "horde", or synophones, such as "fare" and "fair", the phonological code would have been word-for-word.

 "Everything is fine" or "signal received"	 "I cannot open my reserve"	 "Everything is fine" (Area signal)	 "I am out of breath"
 "Come up" or "I am coming up"	 "There's something wrong"	 "Everything is fine" (by night)	 "Come closer" or "regroup"
 "Go down" or "I'm going down"	 "Distress signal" (Area signal)	 "There's something wrong" (by night)	 "I'm cold"

 "I've opened my reserve"	 "I have no more air"	 "Stop" "stay there" or "I stay there"	

Figure 1.2. *The principal signs and their associated meanings in the code of underwater divers (http://www.aurel32.net/plongee/signes.php)*

The divers' code is not only word-for-word, but also *holistic*. In a holistic code, each sign is self-contained. It is not possible to break down the divers' code into elements that could then be reassembled into new gestures to form another code. Most codes of communication among primates appear holistic, and cries used for different meanings generally do not have common parts (Cheney and Seyfarth 1990). We shall have more to say on this aspect later. Holistic codes, however, show one limitation: an entirely new sign needs to be invented for each new meaning. It happens that nature invented a far more efficient system that is at work in our languages, and also in the biology of our cells: combinatorial codes.

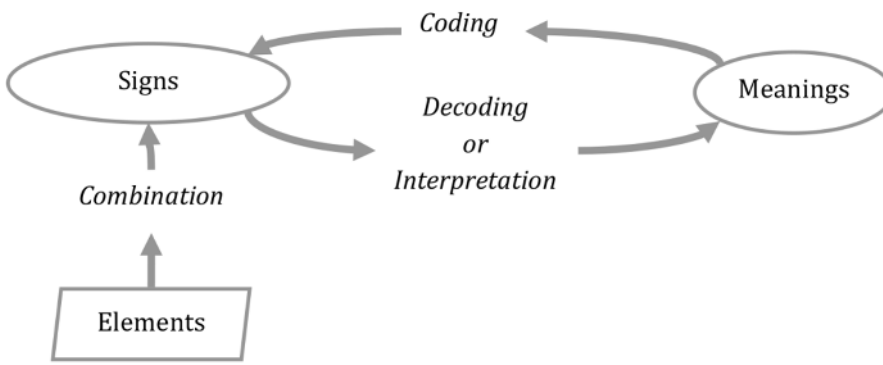


Figure 1.3. *Combinatorial coding*

In a *combinatorial* code, signs result from combinations of basic elements (Figure 1.3). The mechanism of combination is potentially capable of manufacturing a large number of signs. The phonological code is

combinatorial: it manufactures its signs by combining phonemes. The word "wonderful" is encoded by a sign, /'wʌndəfʊl/, a combination of eight elementary phonemes. The system of traffic signs is combinatorial (Figure 1.4). The red circle stands for actions that are disallowed, the blue square for what is permitted and the red triangle warns of cyclists and other types of road user.

Figure 1.4. *Examples of partially combinatorial code: traffic signs © Crown copyright*

Computer codes use combinations of bits (a bit taking either of the two values 0 or 1) as elements to form "words" that encode instructions to the processor or addresses in the memory. Binary words such as these used to have 8 bits in the earliest personal computers, but are generally encoded with 32 or 64 bits in present-day machines. The elements of the genetic code (Chapter 2) are the four molecules denoted as A, U, G and C, and these constitute RNA.

It is possible to superimpose several levels of codes. This is the case with human language. The sets of phonemes or, in writing, the sets of letters encode words, or more generally morphemes – carrier units of meaning. The word "speaking", for example, has two morphemes – a free morpheme *speak*-, the root, and a bound morpheme *-ing,* signifying a gerund form or a present participle. Sets of morphemes encode words according to the laws of morphology. In the above example, the two phonemes *speak-* and *-ing* together form the word *speaking.* Words, in turn, become elements of another code, the signs of which are phrases (nominal group, verbal group, etc.) and sentences. The hierarchy continues at higher linguistic levels: sentences go on to form discourses.

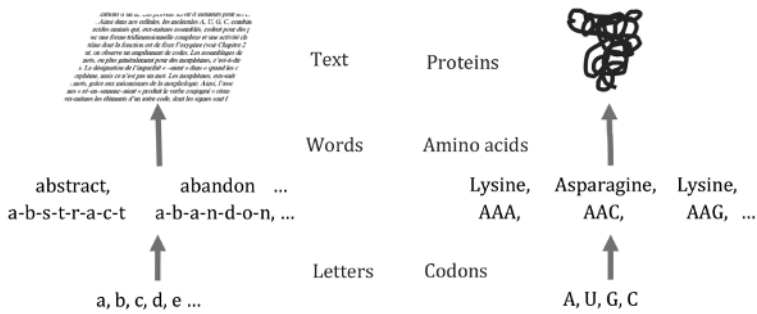


Figure 1.5. *Illustration of the parallel between the combinatorial hierarchies of written language and the living*

Figure 1.5 illustrates the principal levels of the combinatorial hierarchies that characterize written language and the living, placing the two alongside the combinatorics of molecular biology. The molecules A, U, G and C, constituents of RNA, are "read" in threes in our cells. This then results in the detection of codons that encode for amino acids, which in turn compose proteins. The proteins are molecules with the ability to assume a complex, three-dimensional form, and to perform a chemical activity. They carry out an essential part of the intelligent work within the cell (see Chapter 2).

The superimposition of combinatorial levels poses a problem, because such an action must be matched with a superimposition of the levels of code in order to set up a link between signs and meanings for each level. Figure 1.6 illustrates this notion for the decoding, and Figure 1.7 for the encoding. Consider the sentence "Last year, the alarms sounded when the birds flew overhead". The reader's brain analyzes the groups of typographic signs and isolates them: L-a-s-t y-e-a-r…, which it decodes into letters of the alphabet. It then composes the letters into words as "Last", "year" and so on. These words become the elements of a composite sign of a higher order, now made up of groups of words, and no more of letters. We have just carried out a complete turn of reading (Figure 1.6). Let us do a second round. The analysis of the groups of words isolates the words "when", "the", "birds" and so on, and our brain interprets them. It forms, for example, an image of birds; it associates the determiner "the" with the following noun, and sends out a simultaneous instruction for the word "when". It then composes meanings to form more complex representations, such as an image of birds in flight. These representations form a composite sign from a higher

level. A third round of decoding will enable us to combine the images to portray causal relationships, for example. A fourth round will then allow us to have an understanding of the meaning of the complete story.

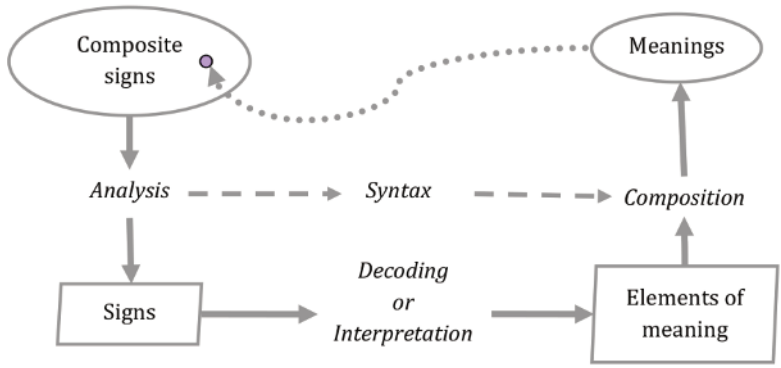


Figure 1.6. *Combinatorial decoding. The curved arrow shows how meanings at a level can serve as elements of a higher level*

Figure 1.6 illustrates the message–decoder–environment (MDE) principle discussed in the Introduction. The environment comes into play during the decoding of signs. When its role prevails, we would prefer the term *interpretation*. In its most basic form, the environment introduces errors or noise. However, it includes the decoder itself, its state and its history. In the case of a human listener or reader, their past knowledge and what they are looking for will exert a significant influence on how they understand a message. It must be remembered at the same time that it is impossible to determine what constitutes "relevant context", the constitution of which determines the result of the decoding. The sentence "There is water" will produce widely differing responses according to whether the respondent is an individual suffering from thirst in a desert or someone who has spotted a leak in his bathroom. We shall see, in Chapter 2, situations in which the presence of certain molecules in a cell, or the prior expression of certain portions of DNA, can significantly change the decoding of cells.

The decoding of the genome in our cells follows a hierarchy of mechanisms (Figure 1.5) that is organized as shown in Figure 1.6. We may describe the first analysis–decoding–composition cycle as follows: the RNA from the transcription of a portion of our DNA is analyzed by specialized molecules as a sequence of basic signs, that might be A, U, G or C, and is

decoded as such. This decoding operation leads to a composition of these elements in sets of three and produces a meaning: the codon (there are 64 codons possible, see Chapter 2). The codons become the elements of a higher level decoding operation in which the codons are decoded in the form of amino acids, themselves compounded in the form of proteins. We can keep on traveling through the cycle, as shown in Figure 1.6: sets of proteins get analyzed, and then get interpreted by the cell in the form of their chemical affinities with other molecules. The meaning produced by the combination of these affinities is a graph or a network of chemical affinities. The higher levels of this decoding, which would see the networks of chemical affinity interact with one another, are still little understood. Modeling these levels of decoding will, however, be needed to establish a link between DNA and the overall structure of the cell.

A fundamental difference between human language and genetic code is that only the former is reversible. To put it another way, the cellular machinery is capable of extracting a meaning from the genetic sequence it reads in our DNA, but cannot write into it any meaning whatsoever. To create meaning, nature relies on random mutations and natural selection that places mutations in competition among themselves. Human language, at the same time, has the remarkable property of being able to encode meanings that can then be decoded. In order for this to work, the encoding and the decoding mechanisms must be similar (Figure 1.7).

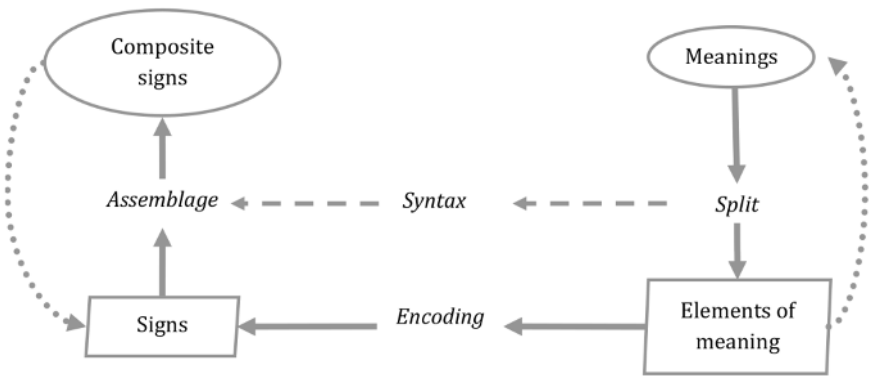


Figure 1.7. *Combinatorial encoding. The curved arrows indicate transitions in the hierarchic level*

In Figures 1.6 and 1.7, the link *syntax* represents the rules utilized in the structural assemblages. The simplest syntax consists of a simple juxtaposition. The phonemes or the codons are simply placed end to end during the operation of composition. However, the syntax can be much more sophisticated, as in the grammar of human languages.

1.3. What is syntax?

Combinatorial codes are generally characterized by constraints. In English, for instance, a *t* is not preceded by a *z* (*Aztec* is an exception, however it is not a native English word). In French writing, a *b* is not preceded by an *n* (except in the word *bonbon*). With some 30-odd phonemes that the language possesses (compared to the 44 that linguists assign to English), one can, in theory, produce unlikely sounds such as *k-d-k-d-i*. However, there are limits to how far such a process can go. Pronounceability is a factor that comes to mind. It is hard to conceive of a French speaker who can pronounce the word "kdkdi". Then there are rules governing pronunciation. As an example, the pairs of vowels *é-è, eu-e* and *au-o* follow a strict rule in the French spoken in southern France: they are open except when the vowel terminates the syllable. Consequently, words like *kerique* and *kelrique* can only occur in the French of southern France if they are pronounced "ké-rique" and "kèl-rique", the *é* and the *è* representing closed and open vowel sounds, respectively. Every language, every dialect and every accent possess their own phonological rules.

Phonological constraints reduce the throughput of information. The bar on closed vowels in the syllables *-kél-*, *-keul-* and *-kaul-* in the French spoken in the south diminishes the informational character of the vowels used. In the extreme case, if there were a single possibility for the vowels, it would be that they provide zero information, as their presence would be mandatory. If phonological constraints have the effect of diminishing information throughput, why should such constraints be there in the first place? Their existence is perhaps unrelated to any aspect of information, but has to do with ease of pronunciation or of learning.

When we speak or listen, we do not content ourselves with just recognizing the words uttered. We assign particular meanings to groups of words. "Last year" and "Next year" bring to mind different meanings. Words are therefore elements of a code of an upper hierarchic level in which signs

are sentences (Hauser 1996), or sometimes those which are not quite sentences. A string such as “Birds fly look” may have a meaning in certain contexts, but an English speaker could fault it on grounds of syntactic correctness. This is because language places certain constraints on combinations of words.

What is the purpose of *syntax*? A short answer would be that syntax is a set of rules governing the way words are used, and this implies certain constraints on how they are uttered or written. An observable effect of syntactic constraints is to limit the range of possible word combinations. While one may say “When flew the birds” (obviously sounding literary), one may not say “Flew when the birds”. Syntactic constraints are strict. The 10 words of the sentence “Last year, when the birds flew overhead, the alarm sounded” can be combined in 3,628,800 different ways, but only a handful of them are considered syntactically acceptable.

Syntax does not owe its existence to its role as censor for the forms it considers incorrect, even though some of them might make sense. It has a higher task, which is to enable an encoding-decoding operation with sets of words (Figures 1.6 and 1.7). The sentences “Peter hit Paul” and “Paul hit Peter” both have the same words, but do not mean the same thing. Syntax guides us to an understanding of (in this example) who did what and to whom. More generally, syntactic structure introduces asymmetric dependencies between words or groups of words. The difference in meaning between “the cousin of his neighbor” and “the neighbor of his cousin” arises from the order of the groups of words. If such order were absent, the interpretation of the combination “cousin/neighbor” would have been arbitrary. The prepositional phrase “of his cousin” depends on the noun phrase “his neighbor”. Our capacity for interpretation uses such asymmetric dependencies in order to build meanings.

1.4. Meaning

Language code is not word-for-word. The semantic decoding of a sentence, that is, the determination of its meaning, presupposes the execution of a process of interpretation that researchers in the science of language have not modeled completely (Dunbar 1996). Consider the sentence: “Last year, the alarms sounded when the birds flew overhead”. One interpretation of the temporal relations of this sentence would be that there were several flights of

birds and that the alarm sounded several times, probably at the moment of each flight. We might even imagine a causal relation between each flight of birds and the sound of the alarm. Collecting the meanings of the words "birds", "flew", "alarm" and "sounded" will not be enough if we are to properly interpret the sentence. It is not as if we were playing with a building-block set. We have to carry out a calculation, taking into account the typical duration of birds' flights and of the ringing of the alarm, and comparing them to a particular year, before we can decide whether this particular episode was a repetition of an earlier one. Consider "Last year, when I was repairing my roof, my car's petrol tank sprang a leak". Here, in this example, the two episodes referred to may be unique ones and may not have any causal relationship. The construction of the meaning of a statement (Figure 1.6) impacted its interpretation, not so much its decoding. The reason for this is that knowledge outside the statement, in the form of the environment and the listener or reader, entered the scene.

The calculation of a meaning is an instinctive process, most often performed without much effort. What is the result of that process? These questions have engaged the attention of philosophers for a long time. Cognitive sciences have cast some light on them, and this has had the merit that testable theories have emerged, alongside devices that successfully reproduce the human capacity for interpretation, though admittedly modest in scale at the present time. From a cognitive point of view, there is no difference between the natures of meaning and perception. The interpretation of "The book that is on my desk, on top of the pile" is a perception, relatively limited for someone who has not seen the said desk, but possibly clear enough to enable him/her to find the book in question. The person tasked with bringing the book back will have to adjust two perceptions: the direct view of the desk in a state of disorder and the perception created by the statement. The interpretation of "… when the birds flew …" also made use of our capacity for temporal and spatial perceptions.

The interpretation of a statement does not end with its meaning. To be able to understand the statement on the birds, the listener will need to form an image of birds flying by the volumetric detector of the alarm in the narrator's house. However, the listener will go beyond that point, and probably infer a causal relationship between the flight of the birds and the triggering of the alarm.

1.5. Beyond meaning

Production of meaning is not the first function of statements. If it were, we would have been passing our time uttering long strings of stupid, but completely meaningful, statements of the type "The carpet is gray/there are four lamps in this room/it was night when the sun set". Meaning is only a means in the service of a much higher object, which is to raise interlocutors' interest. This notion of interest is critical in defining the concept of information (Dessalles 2013).

Our natural speech is composed of sounds that enable us to recognize morphemes. Morphemes in turn combine to make recognition of words possible, and words are arranged so as to form sentences, which in turn go on to create meaning. How does *meaning* come about? In spontaneous human conversation, meaning is generated by two principal activities: the evocation of an event and the production of an argument. These two conversational behaviors, narration and argumentation, cover more than 90% of our time in spontaneous speech. Narration consists of reporting events, that is, the where and when of happenings, putting in perspective the facts of given situations and of the protagonists concerned (Galtung and Ruge 1965). Argumentation is quite different. It does not resurrect a situation, but deals with problems, that is contradictions contained in statements made, involving observations, beliefs or wishes.

Language is thus a "game" that possesses two aspects, sometimes overlapping but largely independent, on the cognitive plane: evocation and logic. The two corresponding behaviors, namely narration and argumentation, are found in extreme and ritual forms in news and debates that different media have (Galtung and Ruge 1965). News items are stories relative to events, recent most often, while debates deal with problems that result from conflicting beliefs or intentions. The word *information* is naturally associated with the two aspects of language: on the one hand, the events may contain information, while, on the other, the element that enables a resolution of a problem may also be called information.

Information, in the sense of the word that we are going to adopt, covers both of these aspects. Information brings about a change in the observer's access to the situation that he/she is considering. It is through language that we try to modify the cognitive state of our interlocutors. They measure the

interest, and therefore the information, that our discourse holds based on the magnitude of this change (Galtung and Ruge 1965; Dessalles 2013). However, this should not create the impression that the notion of information only applies to human discourse.

1.6. Non-human languages

In mathematics, the word *language* designates the type of combinatorial code described in Figure 1.1. A formal language utilizes elements that may be combined into signs (we are speaking here of *words*) such that they may be made subject to rules of grammar. Clearly, this definition applies to *natural* human languages. It would apply even better to artificial human languages, such as Java, C++, Prolog or Python. Would it do equally well describing communication among the living?

Living beings, animal or vegetal, complex or unicellular, produce and acquire information. The cells in our bodies send signals, in the shape of hormones, to other cells; butterflies emit pheromones to attract sexual partners; ants have a huge armory of substances that they leave on the soil for their sisters. Communication among the living can use all the dimensions for which the sender has available to the recipient: chemical, visual, olfactory, vibratory and so on. What about language? As far as we know, communication among ants is not combinatorial. As in the case of divers, their chemical signs do not lead to systematic combinations. Pheromones are easily analyzable, like molecules or atoms, but they are essentially chance assemblages. The purists will refuse to talk about the language of ants, except metaphorically.

Combinations are widely found in animal communication. The male nightingale, for example, has a repertory of some 200 songs that can be analyzed into superimposed combinatorial levels: the bird emits a sequence of calls, “the context”, made up of “packages”; each packet is a memorized combination of “songs”, which are composed of simpler elements, “sections” (Hauser 1996, p. 286). The multiple combinations evolved to the present level of complexity because the females of the bird species are able to decode the presence of each package, each song and each section when setting the males competing. Likewise, male birds being able to borrow

stanzas of their neighbors' songs show that they have already decoded them. We may therefore quite legitimately talk about language here.

We can hear the critics already. The language of nightingales is not semantic: it does not carry specific meanings beyond: "I am the superb male" or "This territory is mine". We may retort that every sign has a meaning when it is decoded. It is true, of course, that contrary to what humans impose on their language, the nightingales' calls are not expected to evoke perceptions. Their calls may apparently say nothing about the tree or the pond or a neighboring nightingale. This type of referential communication, able to evoke perceptions, is indeed present in nature, if not among nightingales. Historically, it was a study of bees that showed this to be clearly true.

Since ancient times, beekeepers have known that bees communicate among themselves about the location of food sources. However, so long as the code they used remained unknown, the ability to do this appeared magical. What, by the way, is the "language" of the bees? An answer became available in the 1940s when Karl von Frisch cracked the code of the language of the bees (Von Frisch 1953), a discovery that brought him the Nobel Prize. A bee visits the cupful of sugared water that the investigator has placed at some distance from the hive. She returns to the hive and performs a characteristic dance for her sisters on the honeycomb in the darkness of the hive. The dance follows a straight line along which the bee rapidly swings her abdomen back and forth. Then she returns to where she started from, turning right and left alternately, and then resumes her swinging in a straight line. The entire series of movements produces a characteristic trajectory (Figure 1.8). Now, what is remarkable is that the angle formed by the path of the dance movement with the vertical line mimics the angle formed by the sun's direction with the direction of the path to the source of food. Even more remarkable is the fact that the dancing bee, seeking to enlist her sisters in the foraging for food, might carry on dancing for several minutes or even hours. The position of the sun will have changed while this goes on, but the bee keeps pace with every change by varying the angle of her dance. In the 1990s, researchers were able to send bees into predetermined locations by placing miniaturized robots that simulated the oscillating dance (Kirchner and Towne 1994). Thus, we had evidence of having understood the code of bees.

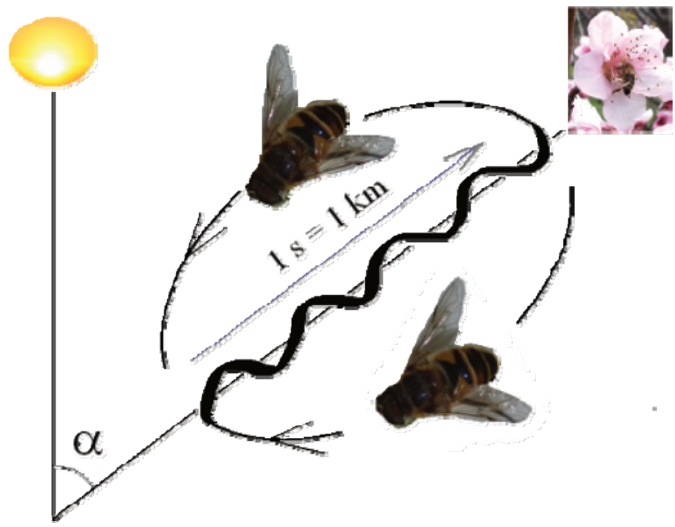


Figure 1.8. *Illustration of the trajectory of a bee in her hive, which she uses to show to her sisters a source of food (http://commons.wikimedia.org/wiki/File: Bee_dance.png). For a color version of this figure, see www.iste.co.uk/gaucherel/information.zip*

Does the way bees communicate among themselves constitute a language? The signs that show the directions to take in foraging for food form a continuum, with the values of the angle between the axis of the dance and the vertical varying continuously. This is a rich way of communication, even if it has not been formed by a combination of simpler elements. A language theorist may only see in it a holistic code, but the code of the bees is in fact much more than that. It is an *analog* code, that is a continuously varying code. Some sign language also show gradual properties. The sign for falling can also include signs relating to the speed or trajectory of the fall. Spoken language offers instances of an analog code: "These children are *impppossible*!". The analog code of the bees shares a characteristic with human languages, namely arbitrariness. In this language, the vertical replaces the direction of the sun and the direction of the path of the dance takes the place of the direction of the flight. These arbitrary choices recall the arbitrary character of our own words.

Another reason that leads us to view the code of the figure of 8 dance of the bees as a language is that it is compositional. Compositionality is a property of some combinatorial codes. In a compositional code, the meaning of a combination of signs may be deduced from the meaning of the signs that exist in its components (Figure 1.6). Human languages are compositional: the meaning of a sentence can be deduced from the words that constitute it even when the context intervenes. There are exceptions. Certain idiomatic expressions, such as “kick the bucket”, “pass the buck”, “get the sack” and “keep one’s shirt on”, have meanings quite different from the sum of the meanings of the individual words used. This is especially the case when their etymology has been lost. Idioms are therefore not compositional. The code of the bees has compositionality of a particular type: the length of the straight path of the dance provides the measure of the distance to be traveled. This indication is to be combined with the indication of the angle to obtain the location of the source of food.

Closer to home in the genealogy of species, there are examples of codes both referential and compositional at the same time. Many varieties of macaques emit alarm calls when they see a predator. Vervet monkeys emit calls that differ with whether they have spotted an eagle, a snake, a leopard or another troop of Vervets (Cheney and Seyfarth 1990). Another species, Campbell’s Mona Monkey, combines the same vocal signals for such different events as the fall of a branch, the presence of a leopard or the presence of another troop of its own kind (Zuberbühler 2006).

1.7. Types of language

We have just identified some properties that languages may possess. Some languages, even the most developed, such as the nightingale’s song, only produce a single meaning, generally continuous, that corresponds to a certain quality that the signal permits to be registered. Other languages, such as the alarm system of Vervet monkeys, produce several meanings. Then there are languages that rely on a production of combinations. Table 1.1 contains some examples of languages classified according the following criteria: *unique* or *multiple* meanings, combinatorial signal system, presence of a *syntax*. A signal, such as the call of the deer, produces a continuous index that is evaluated by the females of the species (Figure 1.9(a)). Signals with the same meaning can be combined. This happens with secondary sexual traits of the domestic rooster: his colorful comb, plumage and song

combine without producing any meaning other than an assertion of the quality of maleness (Figure 1.9(c)). The song of the nightingale also produces (as far as we know) a single meaning, a performance level other nightingales can measure. The song is combinatorial, combining as it does a collection of simpler elements, and obeys a syntax that makes it characteristic (Figure 1.9(e)). It is essentially digital, being constructed of elements that the bird has the option to insert or omit. The complex nuptial routine that birds (such as ducks) must go through before mating obeys a similarly strict syntax, even if its meaning remains simple and unique.

In systems of multiple meanings, combinatorial signals match the range of meanings. The alarm calls of Vervet monkeys apparently lack any combinatorial character (Figure 1.9(b)) (Zuberbühler 2006). The dance of bees produces several meanings pertaining to locations by combining the angle of the path of the dance with length and the number of oscillations (Kirchner and Towne 1994). A similar combination of meanings is seen in the pidgins which are languages without syntax produced when adults need to communicate with the help of a vocabulary of a language that is not their own (Bickerton 1990). Thus, “Demain moi retour campagne” (“Tomorrow me return country”), said in Tai-boi (a pidgin of Indochina), carries the same meaning regardless of the order of the words. A language is called *compositional* if meanings depend, and depend uniquely, on a combination of signs (Figure 1.9(c)). The dance of the bees and the pidgins appear to be compositional codes. This statement is valid, however, only if the constraint “depend uniquely” is applied without insisting on rigor. When the interpretation involves the context (the environment in the MDE schema), the code ceases to be compositional in a strict sense. We may consider that a language is compositional when different meanings can be deduced from different combinations of signs. With this more flexible definition, pidgins can be seen to be indisputably compositional. A language that has expressions with multiple meanings, but is not compositional, is called *holistic*: it must have a distinctive sign (or a sign with only incidental resemblances to other signs) for every meaning (Figure 1.9(b)).

In a compositional language, syntax not only governs the structure of combinations, but also establishes the link between this structure and the meaning produced (Figure 1.9(f)). In human languages, meanings possess a structure. If we imagine that Peter hit Paul, we believe that Peter is the actor, and Paul the patient of the action of being hit. These relations occur in a syntactic structure: the actor is here designated the subject, the patient the

complement, while the action (the predicate) is indicated by the verb. Note that the syntax–semantics correspondence is not always quite as immediate, if we recall the example of the flight of the birds. In a compositional syntactic language, such as a human language (but not a pidgin), the structure of the message provides information on the structure of the meaning.

Unique meaning	*Non-combinatorial*		Deer's bell
	Combinatorial	*No syntax*	Collection of secondary sexual traits
		Syntax	Song of a nightingale courtship displays
Multiple meanings	*Holistic*		Cry of alarm
	Combinatorial (compositional)	*No syntax*	Dance of bees Pidgin
		Syntax	Human language

Table 1.1. *Classification of types of language*

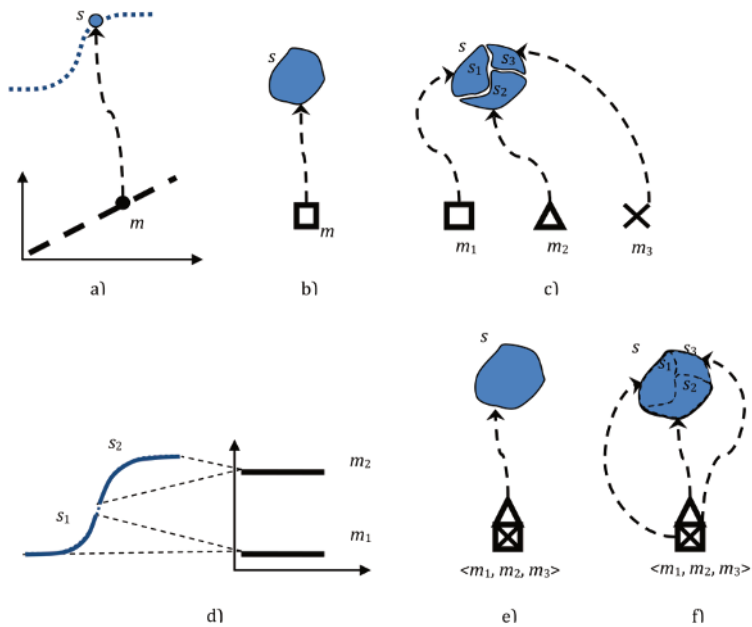


Figure 1.9. *Pictorial representation of types of signifier–signified relations. a) Analog type: the variation of the signifier (m) is in correspondence with the variation of the signified (s), b) holistic type: a signifier for each signified, c) compositionality: the signified is inferred from the juxtaposition of the signifiers, d) quantization: discrete signifiers for a continuous signified, e) non-compositional syntax and f) compositional syntax. For a color version of this figure, see www.iste.co.uk/gaucherel/information.zip*

Of the greatest interest to linguists and computer scientists is the type of syntax that governs the structure of sign combinations. The syntax of the call of a bird can be represented using a simple procedure (called *finite state machine*) that requires little memory, while the syntax of human languages makes significant demands on memory (we are speaking here of central recursion, Hauser *et al*. 2002). For example, in the sentence "My cousin's neighbor who lives in Paris is an engineer", the subordinate clause "who lives in Paris" is embedded in the noun phrase "My cousin's neighbor who lives in Paris", which is itself part of the global clause "My cousin's neighbor … is an engineer". As far as we know, human language is the only one that uses nestings or embeddings as this example shows.

Table 1.1 does not contain all the distinctions that exist among languages. An interesting difference is that between the analog language (Figure 1.9(a))

and the digital language (Figure 1.9(d)). Table 1.2 shows these differences in the case of combinatorial languages. Digital combinatorial languages depend on combinations of fixed elements. This is so in the case of words that are sets of phonemes, and sentences which are sets of words (or of morphemes). Conversely, the language of bees gives an indication of the direction in an analog manner, since the angle concerned varies with the direction.

Analog	Angle of the path of the bee's dance
Digital	Nightingale's song Words of a human language Sentences from a human language

Table 1.2. *Analog and digital compared*

One of the essential qualities of a digital code is that it resists being copied multiple times. It is therefore not surprising to find digital characteristics in human languages, in which messages are tossed about by word of mouth, and similarly in the transmission of molecular heredity (see Chapter 2), in which messages are transmitted from one generation to another. Another purpose digital codes serve is to prepare for a combination in which each element is either present or absent.

Figures 1.6 and 1.7 show, respectively, the structure of the decoding hierarchy and reversibility, elements that were excluded from Table 1.1. Another difference between languages, just as fundamental as the others, relates to the arbitrary character of the signs. This property presupposes a radical independence between the sign and its meaning. Some codes are not arbitrary. This is particularly so with indicators of quality that are competitive signals (the bellow of a deer or the plumage of a peacock) for which there must be a link between performance and meaning (or quality). Analog signals are never wholly arbitrary, because there remains an iconic relationship with the signified. For example, in the case of the dance of the bees, the choice of the vertical direction to represent the path of the sun is arbitrary, provided that the variations of the angle are necessarily linked to the indications of the direction of the flight.

Some of the properties we have just mentioned logically come before some of the others (Figure 1.10). An arbitrary code, for example, will result from an iconic code by drift. A digital code may evolve by quantization (thresholding) and simplification from a simple analog code. Quantization may operate in any gradual field (sound amplitude, frequency, duration, etc.). The elements of a holistic code may, in principle, be split, that is cut in time; if the resulting fragments can be rearranged in different combinations, we obtain a combinatorial code: this is how the complex song of a bird can become progressively more complex from simpler song elements. This mechanism, though, has little chance of being able to produce a compositional code, because it would involve the splitting of the signifier and the signified at the same time. A compositional code has a better chance of evolving through a superimposition of referential designations, each relating to a part of the designated position (Dessalles 2010). The two systems, the combinatorial and the compositional, may both use digital elements (Figure 1.10). Lastly, a syntax may develop simply because the combinatorial system producing the signal is constrained: this may be the case with a non-referential code, such as birdsong. For a referential code, and for the relationships among signals, a syntax will emerge to express a preexisting structure in the designated situation.

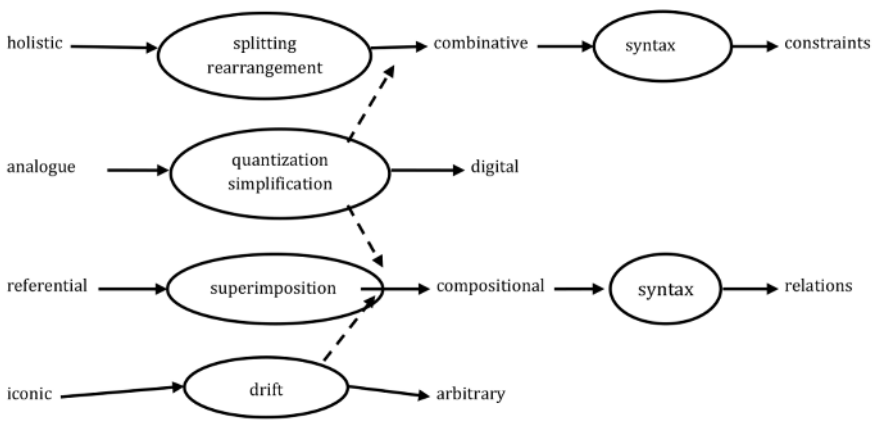


Figure 1.10. *Derivational relationships between codes*

1.8. Why give information?

Information is a useful thing to have when it is reliable and useful for whoever decodes it. But why should it be good to give it? The answer is simple in the case of two sexual partners: the interests of the sender and the receiver coincide at least partially. Members of a family similarly share common interests. We can understand what drives bees to communicate with one another: the fact that they are sisters. While remaining within the framework of natural selection, we need to only think at the level of genes, and not at the level of individuals, to convince ourselves of the benefit for which the bee performs her dance. A genetic mutation that enables a more precise performance will not be of much use to the bee as an individual, as she would lose more time doing a higher level of dancing. However, the mutation may spread because the beneficiaries of the information are sisters of the dancer, and most of them will have had a similar mutation. In other words, the mutation is beneficial to copies of itself. Likewise, the alarm call of the black-and-white colobus benefits his family (Zuberbühler 2006). As in the case of bees, the genes that determine patterns of behavior in the face of danger are transmitted to the offspring of colobus, even though the one issuing the alarm lowers his/her chances of survival by attracting the predator's attention.

The community of interest between sender and receiver is more frequent than generally thought. It might even exist in unexpected contexts, say between predator and prey. It explains the behavior, strange at first sight, of a Thompson's gazelle within sight of a lion. The gazelle will naturally take flight, but will first perform some spectacular leaps in the air (stotting). Most of us have seen photos of these gazelles in Africa jumping to great heights, and expending their energy in the act. That amount of energy would certainly have been more useful in the animals' flight, and therefore for their survival. Ethologist Amotz Zahavi has analyzed the scenario in an original manner (Zahavi and Zahavi 1997). According to him, the gazelle, in leaping up into the air, is sending the lion a signal that can only be characterized as honest. The lion has every reason to believe the information that its potential prey has provided. According to Zahavi, that information is that the gazelle is fully fit, and that the lion would in all probability be wasting its time engaging in a chase. This information is honest, because the gazelle could not be lying, if only because she has vaulted to the height that she could reach. An individual not at the peak of fitness could not accomplish such a feat, and a mediocre performance would send a very clear message to the

lion: “Chase me!” We can see here how natural selection produces an honest communication between prey and predator, granting that their interests diverge on all other planes.

A strange phenomenon, pointed out by biologists John Krebs and Richard Dawkins, can also arise in the evolution of a communication, where the sender and the receiver do not have the same or similar interests (Krebs and Dawkins 1984). The receipt of information by the receiver is a good starting point for a study of this phenomenon. Let us say there is a male dog that senses that another dog is about to pounce on him and bite him. He has thus gathered information about the intentions of the second dog. The second dog, quite unexpectedly, has a certain power over the first, in that he can manipulate him, lead him to believe that he will launch an attack, while in fact he does not intend to. It would be in the first dog’s interest, then to wait for reliable indications of the second dog’s intentions, such as flexing his legs to prepare for an attack or baring his teeth. The second dog would find it in his interest to mimic the first dog’s behavior, even though he may not have intended an attack in the first place. Such a reading/manipulation association evolves into sufficiently exaggerated signals to put off the least credulous observer. We have passed from a discreet flight of information to a clamorous climax in manipulation. For Krebs and Dawkins, the exaggerated signals met with in nature would lead to such a dialectic of reading/manipulation. It comes back to a dual operation, namely use of the sender by the receiver and vice versa. The song of the nightingale, the peacock’s plumage and even some human rituals, at least in part, could have resulted from this mechanism.

In many situations, the interests of the sender appear to be non-existent, so that communication remains a mystery. The Vervet’s call of alarm is intended for the entire troop. Why is it that the Vervets are not content to benefit from the alarms sent by other species that would have guarded them from the attention of the predator? Zahavi, who has studied the desert-dwelling Arabian babbler species for decades, explains the strange behavior of the members of a species while communicating among themselves as an act of publicity (Zahavi and Zahavi 1997). The Arabian babbler species has the habit of mobbing predators. If a snake appears, the little birds form a ring around it, and threaten to attack it with their beaks. Such behavior can hardly be safe, since the snake’s mouth is not far. In sound Darwinian logic, one would have expected each bird to leave the job of mobbing the predator to its companions, a behavior that ought to have disappeared after several

generations. However, this has not been the case. According to Zahavi, the harassment inflicted on the snake is not intended for the reptile, but is in fact meant for members of the flock! In the act of daring the predator, each member of the flock is showing off its courage. The information such displays convey is crucial in the world of this species: every member of the flock now knows who are the brave ones when it comes to choosing one's friends and allies.

Figure 1.11. *An Arabian babbler (Turdoides squamiceps). For a color version of this figure, see www.iste.co.uk/gaucherel/information.zip*

This is not an instance of anthropomorphism. The lifespan of an Arabian babbler is at least 60 years, which it spends in the shelter of one of the scarce shrubs that thrive in the desert, thereby escaping from raptors. Outside that shelter, the bird's lifespan drops to under 2 years. The worst enemy of the Arabian babbler is not the raptor: the main danger to the bird comes from other Arabian babblers that may dislodge it from the bush it occupies. The first thing the bird must do is team up with brave fellow birds capable of taking risks in defending their bush home from invaders. If one were to follow Zahavi, the behavior the birds show toward the snake is very much a signal, and the information it conveyed is social in nature. This could prove to be a costly signal, as there is high risk in harassing a predator. The worst losers are those who abstain from action, because by not offering information about their courage they may fail to be recruited, and consequently risk being excluded from all bushes in the area.

The story of the Arabian babbler should serve to alert us about the operation of the numerous types of animal behavior, and even human behavior. The alarm call of the Vervet monkey may well have a social function, such as making known the individual's suitability for sentry duty, something that might incline its fellow Vervets toward keeping it in the

troop. What can we say about human inclinations toward providing information?

Individuals of our species are extremely fond of information. They pay to receive it, and at the same time they are in a hurry to dispense it. The nearly 16,000 words we utter on average each day are evidence of this. Why do we behave in this way?

The web is a product of our appetite for information. Its beginnings date back to the 1990s. The scientists who brought into being the first web pages were simply looking to facilitate access to technical documentation within their group. The story would have ended there. The Minitel in France carried out this function of providing access to information. There was one essential difference, however: users of the Minitel could not *provide* information, but only receive it. Though unintended, the stroke of genius of the inventors of the web lay in offering to each individual, and in particular to the scientists who had computer access, an opportunity to create a page of their own. And what an explosion that caused! Instead of putting out simple technical manuals, scientists could now make use of the system to display their articles. Then it was the turn of the public. Everyone could provide information and benefit by displaying themselves. The rest is history: an explosion in the number of web pages, appearance of blogs and the arrival of social networking platforms.

The Twitter network is a perfect example of how information is exchanged in our species. A Twitter subscriber can post short messages that are received by "followers", i.e. other subscribers wishing to receive what the first has to say. And that system has been working. Subscribers devote a prodigious amount of time in posting messages about events they have personally witnessed, and to forward messages they receive and find interesting. This type of network is the best propagator of news and current rumors. Twitter subscribers are not paid for their labors. This is not strictly an exchange, since the majority (80%) of the follower–followed links are asymmetric (Kwak *et al*. 2010). Twitter subscribers, like all other human beings, provide information because they like to do it. Twitter broadens the narrative function of language by enabling users to minimize the passage of time between an event and narration. How should one explain this narrative reflex, unique in nature because of its scale and systematic character?

After having long ignored the issue of treating language activity as a necessary corollary of intelligence, scientists recently recognized the importance of the problem. They had earlier believed that information was the subject of cooperation, or of a swapping arrangement, or a matter of give-and-take. “If you scratch my back, I’ll scratch yours”. This description is obviously not valid when applied to the provision of information, as opposed to the performance of a service. We generally do not behave like spies, or punters, or speculators on the stock market, who exchange information worth money on the basis of a perfect reciprocity. People not only dispense information willingly, but compete with one another to do so. The important thing is to be the first. What is more, such information most often relates to trivial matters. Take a look at Twitter. Human communication has little to do with a give-and-take type of exchange, but much more to do with showing that we are the first to know and tell.

Where did this behavior come from? The analogy of Zahavi’s Arabian babblers may contain an answer. We provide information to our fellow beings, not for its own value, but as a means of flaunting our ability to acquire it, much like how the birds show off their courage in teasing their potential predator. It still remains to be explained how this ability has a social value in human society.

Primatologist Robin Dunbar observed that language is deeply involved in the establishment and preservation of social relations (Dunbar 1996). His studies led him to hypothesize that language would have replaced grooming, a practice that plays the role of cementing relationships among numerous species of primate, including those closest to us. Instead of spending time picking through the fur of other members of the troop, which is what the primates do, human beings spend their hours together talking. Could it be that language is the human equivalent of grooming among primates? It certainly makes for an appealing hypothesis, but there should be added room in it to accommodate an explanation of why human conversation largely consists of narration of events, rather than a series of synchronized grunts.

Here, the parallel of the Arabian babbler may turn out to be useful, if we bear in mind certain traits of our species. The Arabian babbler adopts an entire series of costly behaviors, starting with the harassment of its predator, so as to form alliances and so protect others in the flock. The bird’s situation is not unlike ours. As the Latin dramatist Plautus observed over 2,000 years ago, man is wolf to man, and this suggests an even more dramatic scenario.

For the first time in history, our distant ancestors had found a means of killing their fellow beings without particular risk to themselves. Having discovered weapons such as stones and pointed sticks, the hominids were able to kill their congeners by surprise. The discovery inevitably upset the inherited social order of the primates that was founded on superiority of muscles. In the case of chimpanzees, the alpha male, that is the male at the top of the hierarchy, fathers between 30% and 40% of the next generation (Reynolds 2005). Imagine in this context that killing without risk is possible. The male ranked third in the order can easily rise in rank, using surprise to kill the alpha male and the beta male, and then becoming the one to procreate the most progeny. That would be a possibility, unless of course he got killed instead!

The only safeguard against the eventuality of murder by surprise would be to surround oneself with friends able to ensure protection against danger. This is perhaps why in our species information has replaced muscle. By displaying to those around us the most surprising events, we are showing all through the day our superior ability to acquire information, marking us out as good potential allies or friends. As in the case of the Arabian babblers, we parade a quality that will make us look good in the eyes of our congeners. This quality, this informational capability, has become crucial because of the particular "political ecology" of our species. This explanation of the importance of information in our case is one of the few that has the merit of being consistent, on the one hand with the reality of language and, on the other hand, compatible with the constraints of Darwinian theory.

1.9. The autonomy of information

The propensity of human beings to peddle information creates a space in which certain information appears, circulates and then vanishes. According to an analogy suggested by Richard Dawkins, information travels between brains a little like genes within generations or viruses among individuals. In this analogy, the substrate consisting of the accumulation of humankind's brains serves as the biotope for a particular fauna that Dawkins calls "memes" (Dawkins 1976). Memes are elements of information of different types: events, beliefs and opinions, all capable of passing from one brain to another, as if by contagion. This movement of information is the theatre of a form of selection, a mirror image of what happens to living beings. The more infectious the memes, the better they propagate. Opposing memes fight for

supremacy. Some memes will sink into oblivion, and die, while others may mutate as a result of wrong transmission, and so on.

The theory of memes, like all analogies, does have its limitations, but it is an interesting source of inspiration. Its defenders will say that the theory is itself a meme, having shown itself as particularly infectious since its invention by Dawkins in 1976. One of its limitations is that it ignores meme hosts and their cognitive constraints. The informational value of memes depends on cognitive computations that our brain most often carries out unconsciously. Knowledge of these cognitive processes will undoubtedly make better predictions about the spread of memes than is possible with the simple analogy of contagion. We will examine some of these processes to better understand the specificity of the information of human origin.

In the 1960s, some journalistic studies attempted to identify the factors that make information interesting. The result was a catalog of factors such as the unexpected, reference to personages from the elite, cultural proximity, and intense character. A cognitive approach would reduce the catalog to two principal factors: emotional value *a priori* and unexpectedness.

The emotional value *a priori* gives the scale of interest to which reference is made. The semantics of the event tell us whether we are talking of life or of death, of lay-offs, or a win of 10 euros. We are interested in events in each of these scales without comparing them. However, emotion *a priori* is insufficient to generate interest. Every moment, there is a death, or someone loses her job, or someone wins 10 euros. We do not consider these events as subjects of information. There is one essential ingredient missing here: the interest we have in information as necessarily due to our perception of *unexpectedness*.

Intuition tells us that unexpectedness implies low probability. An accident happening to a loved one, a birthday coincidence, an explosion in the neighborhood, a fire on the Eiffel Tower and a celebrity in a restaurant, all of these situations interest us, and we speak about them. They constitute for us and our near ones information. Subjectively, we perceive these situations as improbable, and therefore unexpected. The probability concept is not adequate in dealing with the unexpected, because probability theory does not take account of the egocentric character of unexpectedness. As we shall see in Chapter 4, unexpectedness is measured by the abnormal simplicity of the event to the observer. We all know the saying, “accidents

only happen to others". The others, who are anonymous by definition, are hard to describe. If it is a colleague who is a victim, even a colleague you may not have known personally, concern and emotion grow with their proximity to you, whether they work in the same company, in the same building, in the same service, or have the same birthday as you. Likewise, the Eiffel Tower or celebrities are well known enough for the events concerning them to have emotional impact, and therefore to possess information.

The same phenomenon explains why information is a perishable good. Few individuals take the trouble to read newspapers older than 3 days. An old event, say the assassination of President Kennedy, is not information anymore, because its cognitive reach has become complex. This event has receded into the lists we maintain in our memory: the chronological list of events, the list of historic events arranged in order of importance, the list of the presidents of the United States and the list of assassinations. At the time of the 15th anniversary of the death of President Kennedy, the event has become a piece of information, only because access to it has become easier – a half-century is simpler than say 47 years 3 months and 2 days. The anniversary thus creates a shortcut in the access to the memory of the event, and our interest in it is automatically awakened.

Life and the spread of information depend on purely cognitive factors. Dates of anniversaries have nothing to do with the contagious nature of the meme. Among the cognitive factors that influence information, and often threaten its existence, there is, of course, critical thought. Information has credibility that may vary across time and with individuals. Information that is no longer credible loses its informational character. We doubt certain information because we possess the ability to spot logical inconsistencies. We would, for instance, find it difficult to believe that Cuba was able to provide to the United States important information on Venezuela, because such news would contradict our knowledge of the current diplomatic relations between these countries.

This ability to detect inconsistencies between facts and beliefs is a typically human faculty, and probably quite unique among the living. It may have evolved in our species as a protective mechanism against deceit. We owe to it, among other things, our ability to reason. Without it, all the information available at any given time would be worthless. Without logical tests of consistency, the only information we would turn our attention to

would be that directly verifiable through our senses. The world would then become one of here-and-now. Such a world, that might have been the world of our ancestors, stood shattered with the emergence of our critical capacity. Unverifiable information attracted interest since it could be examined for credibility. At some point in its evolution, our species entered a world of elsewhere (in time and space). As we shall see in the following chapters, the ability to withdraw ourselves from the local world and the current moment is also a feature of biological and ecological information.

Because of our logical abilities, we only verify, visually, a tiny part of the information that we accept. The information circulating on the cerebral biotope of the human species is placed on a narrow (though infinite) fringe, that is constituted of facts that are both unexpected and consistent with the known. In every case, information is conveyed by language, and only exists in the eye of the beholder. Is it possible to generalize this concept of information so as to cover cases in which the human being and its language are not involved?

1.10. Language and information

For a mathematician, a language is grounded in a combinatorial code. The code of the bees is hardly combinatorial, and yet we happily speak of the language of the bees! The signal sent to her predator by the jumping gazelle, or the signal the Arabian babbler sends to his congeners as they mob a snake, may be seen as the beginnings of language. Still, we can see in them more than just foreshadowing of codes: we see an indication of good health in the gazelle, and an index of courage in the Arabian babbler. Could we say then that there is language here since information is transmitted, no matter whether such transmission is based in a code? There is a clear need to define the concept of information.

Despite its importance in our lives and our understanding of the world, a clear definition of the concept appears to have so far eluded us. We shall consider several definitions in Chapter 4. For the present, we only say that information modifies the state of whoever receives it. This remark, apparently self-evident, implies that information must exist for a given observer. However, there is no indication here that the observer is to be human. It is enough that the observer is able to decode what interests him/her/it. Furthermore, we shall say that the effect of a piece of information

is to *simplify* an aspect of the functioning of the observer. This is intuitively easy to understand. The lion has his choice simplified when he sees the gazelle staging her beautiful leap: he knows that he is not going to set up a chase. The bee about to go foraging receives information from her sister's dance. Her choice of the direction of flight is simplified to the point of determining it. In general, the quantity of information transmitted is measured by the magnitude of the simplification it has caused.

There can be information even when there is no language. The sun does not speak to us to tell us that the day has dawned. Conversely, the languages of nature in which we are interested in this book exist because some entities take the trouble to provide information to other entities able to decode it. If the living world is buzzing with the number of languages surrounding it, it is not merely because of the flow of matter and energy. It is because information plays a fundamental part in the process. If nature *speaks*, it is because information circulating within it favors, in one manner or another, entities transmitting it and those receiving it. The actors who exit the information game cease to exist. As information experts, human beings may be allotted a degree of centrality in the living world. By an accident of evolution, they became experts in a field that serves as the unifying principle for all of life, from society down to the molecule through the ecosystem. The language of human beings is only one very particular form of transmission of information, which they use to improve their social value. Most may not suspect that at each second the trillions of macromolecules that constitute their body are also engaged in the process of exchanging information.