CHAPTER 6

Non-verbal and multimodal metaphors bring biology into the picture

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The relationship between multimodality and cognitive effects has become an important topic of discussion in Cognitive Linguistics. A growing number of studies explore the multimodal manifestations of figurative thought in a wide range of domains. However, little research has been done on visual and auditory metaphor in science. This chapter examines (i) pictures from a corpus of publications covering different biology subdomains and (ii) video clips that feature animals and biological processes. The corpus includes expert material and popular science resources. Empirical evidence is provided that visuals, non-verbal sounds, and words work either separately or together to construe metaphors, which have a major role in building scientific theories in biology and in communicating these theories to laypeople and learners.

Keywords: nonverbal and multimodal metaphor, biology, expert and non-expert communication, resemblance and non-resemblance metaphors, productivity, effectiveness

1. Introduction

Academic research in the humanities has shifted from a focus on exclusively verbal text to discourses in which language is but one communicative mode (Forceville & Uríos-Aparisi, 2009, p. 3). In Cognitive Linguistics, this change of perspective has resulted in a wide range of studies that account for the nature of non-verbal and multimodal perception, including pictorial and written signs, spoken signs, gestures, nonverbal sounds, music, smell, taste, and touch.

Importantly, current research addresses the interplay of nonlinguistic modes and figurative thought for meaning creation in different domains. For example, Forceville (1996) contributes to visual metaphor description by discussing pictorial metaphors in advertising. Zbikowski (2009) analyses the musical mode of

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conceptual metaphors and Caballero (2009) studies the interaction of audio and visual devices in winespeak. The interest in semiotic modes other than text has even inspired research on image schemas, involving less studied senses, such as touch (Popova, 2005). Research has shown that image schemas are frequently the anchor of conceptual metaphor (Hampe, 2005; Gibbs & Colston, 2006).

Although multimodality *and* figurative thought have been documented in a wide range of domains of experience, their interaction in scientific communication has been rarely explored. One of the few scholars who have addressed this matter is Núñez (2008), who examines the domain of mathematics to show that gestures by lecturers on the topic supplement textual evidence of metaphoric conceptualisation. However, the great majority of authors who have studied metaphor both in expert discourse and science pedagogy (e.g. Brown, 2003 in chemistry; Temmerman, 2000, 2008 in genetics; Cameron, 2003 in mathematics, *inter alia*; Ureña & Faber, 2010 and Ureña, Faber, and Buendía, 2013 in marine biology) focus on the prototypical verbal monomode to describe the semantic and conceptual underpinnings of metaphor.

Based on authentic (printed and filmed) materials, this study shows that non-linguistic metaphors (i.e. visuals and sound/music) not only figure prominently in scientific communication, but they also interact in order to convey meaning and inform as well as attract the audience. The corpus includes (i) pictures extracted from a set of publications dealing with a variety of biology subdomains and (ii) video clips from documentaries that feature animals and biological processes. The publications that include the pictures are 15 research articles from academic journals and 10 proceedings from conferences on biology. A total of 15 video clips from documentaries have been collected for analysis in this study. All these materials were selected to become a part of the corpus because they are representative of how pictures and videos are exploited in science making and science pedagogy. In other words, these visual materials were chosen because they clearly illustrate the cognitive and semiotic potential of non-verbal and multimodal metaphor for both pedagogical and theory-constitutive purposes in natural sciences. This paper is thus in line with the work by textual metaphor scholars, such as Knudsen (2003), who show that metaphor not only guides scientific observations as well as the development of theories and hypothesis, but is also instrumental to science pedagogy. This claim was originally made by well-known philosophers of science, such as Hesse (1974, 1993) and Boyd (1993).

2. Objectives of the study

Cognitivist metaphor research is in need of rigorous analysis of the role of non-verbal and multimodal metaphors in subject-oriented discourse and specialised knowledge fields. This study focuses on this type of metaphor in biology, putting its significance to the test in both expert-to-expert and expert-to-learner/layperson communicative situations. The following objectives and hypotheses are established:

1. In relation to (1.), in what ways are nonverbal and multimodal theory-constitutive metaphors in the corpus found to be generative in the sense of guiding scientists' actual thinking about the phenomena under study by suggesting hypotheses, and structuring observations? In what ways are nonverbal and multimodal pedagogical metaphors effective, inferential and attractive to explain and illustrate specialised concepts to a nonprofessional audience? In other words, to what extent are nonverbal and multimodal biology metaphors productive with a rich or highly focused inference structure?
2. Are exceptions identified where a nonverbal or multimodal metaphor does not convey meaning usefully, does not map accurately or is misleading? Are such exceptions used pedagogically?
3. Are nonverbal and multimodal biology metaphors largely conventional or idiosyncratic? This highlights the need to examine their degree of entrenchment.
4. Can the dichotomy resemblance metaphor vs. non-resemblance metaphor in scientific terminology (Ureña & Faber, 2010) – that is, specialised language – be easily identified in nonverbal biology metaphors?
5. In what sense can nonverbal and multimodal metaphors make certain aspects of conceptual metaphors salient, which are not, or not as clearly, expressible in their verbal manifestations? (Forceville & Uríos-Aparisi, 2009, p. 13).

To answer these questions, this research is divided into sections and subsections which focus on the specific monomodality or multimodality and the type of mode(s) operating.

3. Monomodality

Differentiating monomodality and multimodality is necessary to effectively conduct a practical analysis of biology metaphors. As Forceville (2009, p. 23) points out, the target and source in a monomodal metaphor are exclusively or predominantly rendered in one mode. In contrast, multimodal metaphors are more complex in nature, emerging from different modes of representation (see Section 4).

One type of monomodal metaphor that has become central to multimodal studies is pictorial or visual metaphor. This section provides evidence that visual metaphor is widely used in the field of biology both to create and structure science and to explain scientific concepts to laypeople. Visuals can be broadly divided into static images (pictures) and dynamic images (movement in body postures).

3.1 Static images: Pictures

Expert science materials were originally thought to only include pictorial representations free of figurative devices since it was generally accepted that they should be clear, straightforward, and precise. Evidence is given in this study that static visuals used by biologists in academic publications (e.g. pictures, drawings, and graphical material) can also have a metaphorical basis to convey science.

3.1.1 *Tree metaphors*

The picture in Figure 1 was on a poster of the Second International Conference of Eugenics in 1921. Eugenics is concerned with the hereditary improvement of the human race by selective breeding. The figure depicts this academic field, which was new at that time, as a tree fed by roots from a variety of disciplines (genetics, biology, sociology, etc.). The aim of the author is to illustrate the eclectic nature of eugenics, which draws on a wide range of (closely) related fields, by means of the metaphors EUGENICS IS A TREE and DISCIPLINES ARE TREE ROOTS. These metaphors allow the author to organise all these disciplines into a harmonious superorganism.

These tree metaphors fall into the category of *conceptual metaphor* in Lakoff's (e.g. 1993) Conceptual Metaphor Theory. Unlike resemblance metaphors (Grady, 1999), which emerge from physical (shape and/or colour and/or size) or behavioural comparison between source and target as material entities, conceptual metaphors rather arise from complex, abstract structure. As Lakoff (1993, p. 229) notes, in conceptual metaphors abstract concepts are understood in terms of concrete concepts directly grounded in bodily (sensorimotor) experience.

On this basis, disciplines – abstract entities – are metaphorically conceptualised as trees and tree parts, which are concrete objects. The arrangement of the disciplines looks like the configuration of a tree with roots, trunk, branches, and leaves. The disciplines that eugenics stems from are represented by the roots, whose function is to feed and support eugenics. Thus, the specific conceptual metaphor disciplines supplementing eugenics are the roots of a tree can be formulated. Eugenics is visually rendered by the trunk, branches, and leaves of the

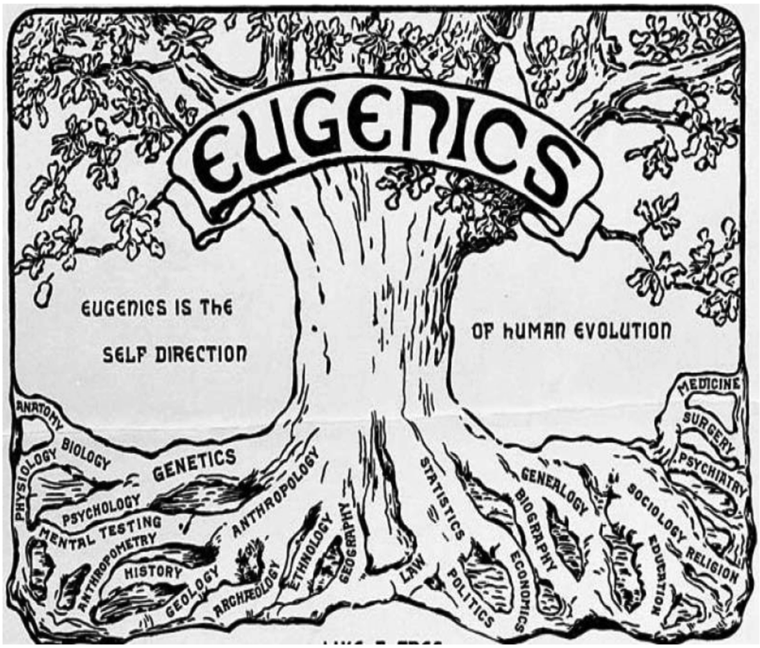


Figure 1. Eugenics as a tree fed by roots from a variety of disciplines

tree. Thus, we can establish the specific conceptual metaphor EUGENICS IS THE TRUNK, BRANCHES AND LEAVES OF A TREE. It should be noted that although the branches and leaves are pictorially represented in the figure, they are not explicitly differentiated as metaphoric sub-mappings. In any case, it can be interpreted, the picture includes a good number of branches and leaves because they are intended to express the idea that eugenics is a multi-faceted discipline with many applications and the power to yield a good deal of positive results to humanity. Therefore, EACH BRANCH (source) could be metaphorically understood as ONE APPLICATION (target) and EACH LEAF (source) ONE POSITIVE RESULT (target).

Interestingly, Figure 1 also includes three primary metaphors, which emerge from the correlation (*conflation*) between two events that repeatedly co-occur in experience (Grady, 1997; Lakoff & Johnson, 1999, p. 49). This embodied aspect of primary metaphors is specifically discussed in Subsections 3.1.2 and 3.2.1. The first primary metaphor, IMPORTANT IS SUPERFICIAL AND PROXIMAL, is my suggestion and a derivation of IMPORTANT IS CENTRAL, provided by Grady (see 3.1.2). IMPORTANT IS SUPERFICIAL AND PROXIMAL is represented in Figure 1 by the fact that essential disciplines to eugenics, such as genetics, statistics and genealogy, are in very close proximity to the ground and/or to the above-ground part of the tree, which represents eugenics. In contrast, the second primary metaphor, ACCESSORY IS DEEP AND REMOTE (also a derivation of IMPORTANT IS CENTRAL), involves disciplines that have less in common with, and thus, are less relevant to eugenics. This is the reason why disciplines such as geology and religion appear as roots furthest down from the trunk.

The third primary metaphor in Figure 1, IMPORTANT IS BIG, which appears in the list of Grady's primary metaphors included in Lakoff and Johnson (1999, p. 50). This metaphor has a pictorial rendering of two types. Both types explain that eugenics is the most relevant discipline in the drawing. Firstly, the importance of eugenics is visually represented by the trunk, whose diameter is significantly larger than that of the roots, representing the rest of disciplines as subordinated fields. Secondly, the metaphor concerns the size of the word *eugenics*, which is written in big capital letters. On closer examination, the degree of importance of all disciplines in the tree is signalled by the size of their fonts. Based on this criterion, the author of the picture establishes three levels of importance: (i) eugenics, (ii) genetics, and (iii) the rest of disciplines. There are examples in the picture where this degree of significance and dependence between disciplines is further narrowed down visually by means of the IMPORTANT IS BIG metaphor. The level of subsidiarity is expressed in the figure taking the width of the roots as a reference. This is the case for the genetics-psychology-biology-anatomy-physiology cluster on the left bottom side of the figure. A bigger root, representing genetics, derives to two subsidiary – and thus, smaller or narrower – sub-roots, representing psychology and biology. In turn, biology feeds on anatomy and physiology, represented in the picture as the narrowest roots in the hierarchy.

All of these pictorial metaphors are complemented in Figure 1 by the conceptual metaphor EUGENICS IS THE SELF-DIRECTION OF HUMAN EVOLUTION,[1] which is linguistically expressed. Being grounded in the sensorimotor experience of seeing an object in motion and following a well-defined pathway in space, this metaphor conceptualises eugenics as a self-contained, autonomous scientific field with the capacity to direct its own way (self-directed). This metaphor is on a par with the LOVE IS A JOURNEY metaphor, firstly suggested by Lakoff and Johnson (1980, p. 45), since both of them are used to understand purely abstract concepts (EUGENICS and LOVE) as physical concepts involving movement and dynamism (SELF-DIRECTION (IN A PATH) and JOURNEY). Even though the visual tree metaphors discussed above and the verbal metaphor EUGENICS IS THE SELF-DIRECTION OF HUMAN EVOLUTION

1. What actually serves as the source of the conceptual metaphor is SELF-DIRECTION, which is a physical and embodied element (as explained in the body text). There is thus one metaphor (HUMAN EVOLUTION IS A CONCRETE ENTITY WITH SELF-DIRECTION/THAT MOVES FORWARD) within another metaphor (EUGENICS IS THE SELF-DIRECTION OF HUMAN EVOLUTION). In addition, and as a consequence, there is one metonymy, where EUGENICS (the part) stands for HUMAN EVOLUTION (the whole). For practical purposes, in the body text I only elaborate on the assumption that eugenics is conceptualised as a concrete entity with the capacity for self-direction.

are essentially different in nature, all of them go to reinforce the claim that eugenics is a self-standing discipline that is central and indispensable to human thriving and development.

The tree metaphor is a clear example of how to use basic models in science for the effective arrangement and presentation of typologies. In fact, this metaphor is extensively used across the full spectrum of scientific disciplines – particularly widely exploited in biology and natural evolution theories (Gruber, 2005, p. 245) – and can thus be regarded as conventional and well-entrenched. This pictorial metaphor usually undergoes a process of simplification whereby the content-rich tree-shape representation of biological results is abstracted into schematic structures, which are easily recognisable because of the metaphor's high degree of conventionality. An instance of schematisation due to entrenchment is the metaphor TAXONOMIES ARE TREES, depicted in Figure 2, which was extracted from a research article in an academic journal (cf. Medina, Jones & Fitzpatrick, 2011). The trunk, branches, and leaves of this tree have been abstracted into simple straight lines (the length and width of the trunk have even been kept to a minimum). This perceptual process is cognitively transformed into a *gestalt* (Lakoff & Johnson, 1980, p. 70), which keeps the structure stable by foregrounding the whole to the detriment of the parts.

For fungus taxonomic reconstruction, TAXONOMIES ARE TREES dispenses with the roots, downplays the trunk, and focuses on the branches (e.g. Chytriomycota) and leaves (e.g. *Allomyces macrogynus*). The possibility of zooming in on different parts of the tree to refer to biological concepts enhances the productivity and inference structure of the tree metaphor, which contributes to the advance of biological sciences. At any rate, the metaphor in Figure 2 is a conceptual metaphor for the same reason as the one that applies to the visual metaphors in Figure 1, that is, abstract concepts are understood in terms of concrete concepts that are directly grounded in bodily (sensorimotor) experience. In this case, the concrete-to-abstract metaphoric mappings involve the concrete source concepts TREE BRANCHES and LEAVES being mapped onto the abstract target concepts PHYLUM, SUBPHYLUM, CLASS, SUBCLASS and SPECIES, which are categories making up the hierarchical structure of biological kingdoms. By virtue of the tree metaphor, these abstract entities are conceptualised as, and visually organised into, an arboreal arrangement.

The phylum (Basidiomycota) in question as well as each specific subphylum (e.g. Agaricomycotina), class (e.g. Homobasidiomycetes), subclass (e.g. Agaricomycetidae) and species (e.g. *Laccaria bicolor*) take a particular position on the tree hierarchy. Specifically, all fungal categories in the arboreal structure are metaphorically understood as branches, except for the species, which are conceptualised as leaves because they have been placed on top of the tree. However, it is the positions (abstract concepts) and not the fungi proper (concrete entities)

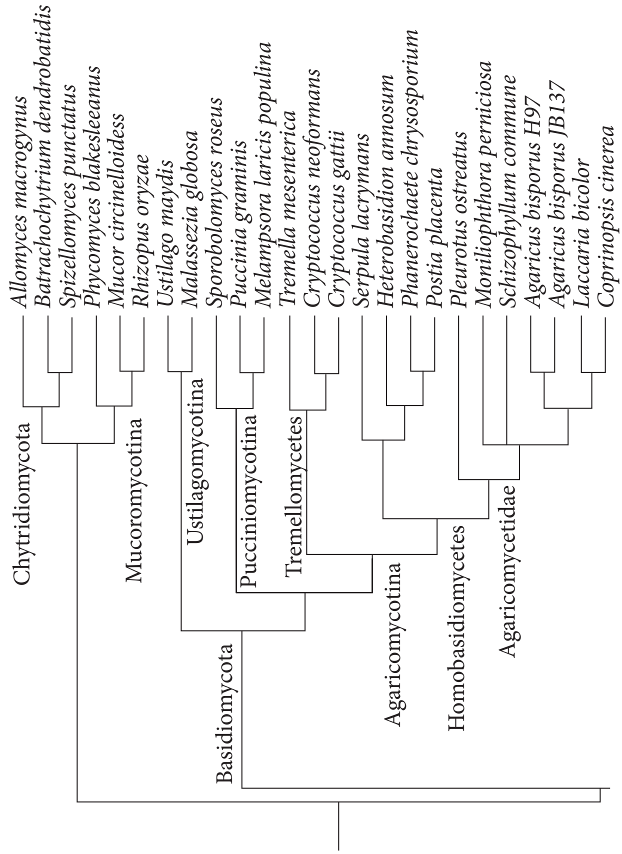


Figure 2. Cladogram of the fungal tree of life (detail)

that actually participate in the cross-domain mappings. In other words, it is not that the physical features of fungi in the taxonomic structure are compared with the physical features of tree branches and leaves (if this were the case, we would be speaking of a resemblance metaphor). Instead, it is the hierarchical locations of the fungi in the cladogram that are compared with the positions of the branches and leaves in a tree. For this reason, it is a conceptual metaphor that is operating here.

As can be observed, the authors of the article use the tree metaphor to *re*organise and *re*construct fungus taxons. As they point out, "this is the first time multigene families have been used in fungal supertree reconstruction and permits us to use up to 66% of the 1,001,217 genes in our fungal database" (Medina et al., 2011, p. 116). This clearly indicates that the tree metaphor is theory-constitutive insofar as it forms an intrinsic part of the mental and visual model that scientists rely on to classify living beings and organise them into taxonomic hierarchies. Importantly, this metaphor helps to further scientific research in the study of fungi. Furthermore this metaphor was probably applied to the visual taxonomic *re*organisation of multi-gene fungal families even before it was well-supported empirically, which reinforces the effectiveness of the metaphor and makes it even more commonplace. Instances of metaphors that guide investigation before empirical postulation can also be found in figurative terms, as is the case of *DNA barcoding*, suggested by Hebert prior to the broad acceptance and validation of this phenomenon by the scientific community (Larson, 2009, p. 173).

3.1.2 *Other pictorial metaphors*

Self-contained visual metaphors can also work together for scientific knowledge representation and transfer. Figure 3, extracted from an academic journal article, explains the interaction between two wind drifts crucial for specific sea organisms such as white sharks. The picture builds on at least six visual metaphors.

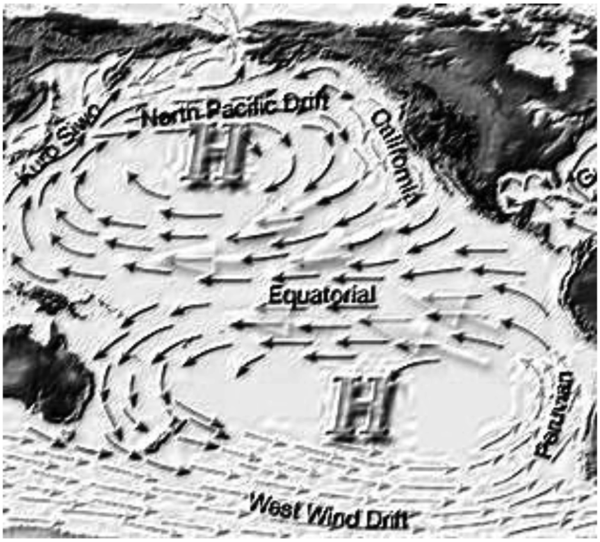


Figure 3. Pictorial metaphors explaining wind drift interactions

The first two metaphors involve the letter *H*, which stands for *high pressure*. *H* is placed at the centre of the wind drifts on the map to visually highlight its importance, since high pressure is a major cause for certain winds to occur. Although the *H* might have been placed on the left or right, the metaphor IMPORTANT IS CENTRAL is operating here. The prominent size of *H* reinforces this by introducing the metaphor IMPORTANT IS BIG. Both IMPORTANT IS BIG and IMPORTANT IS CENTRAL are conventional metaphors and are commonly instantiated diagrammatically by scientists to rapidly structure and convey scientific knowledge, as also shown by the tree metaphor in Section 3.1.1.

Another metaphor included in Figure 3 is MOTION IS LINES/ARROWS. In the picture, the arrows stand for forces/entities in motion, expressing concretely how the wind drifts (black and grey arrows) and white sharks move (white arrows). This metaphor is grounded in our embodied experience of a moving entity/force brushing our bodies or cutting through the air. Movement in space and velocity imply physical projection/expansion and is typically depicted as an elongated line or arrow in scientific disciplines. For instance, Watson, Spyrou and Tall (2003, pp. 74, 78) explain that the reason why arrows are used as visual representations of vectors in mathematics lies in physical embodiment. The dynamicity of the arrows in Figure 3 is evident, even though it is constrained by the mode of representation, which is static. Compare this with visual metaphors depicted by real movement in video clips (see 3.2).

Colours also play a major role in the figurative representation of biological and atmospheric patterns. In the original diagram that Figure 3 is based upon, the black and grey arrows are in reality red and blue, thus standing for warm and cold currents, respectively. This colour distinction helps the reader of the article to easily identify the nature of the winds on the map. The underlying metaphors, COLD IS BLUE and HOT IS RED, have an embodied grounding as well. Firstly, the associations *cold-blue* and *hot-red* are made based on our perception of the colours of fire and ice (partly red and somewhat white-blue, respectively), which are physical features sensed by sight. Secondly, these associations also arise from the visual appearance of the physiological response to cold and hot temperatures seen most clearly in light-skinned human beings; when it is very cold, lips and nails become a bluish purple, and when it is very hot, the skin turns red. The explanation for this is that cold constricts blood vessels, so blood is less visible to the naked eye, whereas heat dilates them, which facilitates blood circulation.

Therefore, COLD IS BLUE and HOT IS RED can be regarded as primary metaphors since they involve conflation or repeated co-occurrences of phenomena in bodily experience. As a matter of fact, it has been shown that instinctive and basic body patterns that give rise to metaphoric thought are intrinsically associated with *experiential correlation* (Grady, 1997, pp. 47–48), an inherent aspect of primary metaphors which consists of establishing a strong conceptual link between two distinct events that repeatedly co-occur. This phenomenon usually gives rise to cause-effect correlation metaphors because after repeated co-occurrences, in experience of the world, we come to conceive one event in terms of another. This structure has also been found in the metaphoric nature of marine biology terminology (cf. Ureña & Faber, 2010). Finally, the white arrows in Figure 3 stand for the white sharks, which normally follow warm currents over cold one. This is so because in contrast to most fish, which are cold-blooded, the white shark is warm-blooded, and can regulate its body temperature (Goldman, 1997, p. 423). Correspondingly, arrows are mapped onto shark movement and sharks themselves, forming a PART FOR THE WHOLE metonymy, specifically WHITE COLOUR FOR WHITE SHARK.

All these figurative devices help experts explain a scientific finding to their peers by giving cognitive and visual structure to its representation. The use of arrows and the pairs *cold-blue* and *hot-red* is so effective and productive that they are found in many other technico-scientific fields. For instance, in the specialised subdomain of thermal engineering, air circulation during gas combustion in direct-vent fireplaces is depicted in the form of blue arrows, standing for motion of outdoor unheated/cold air, and red arrows, standing for motion of indoor heated/hot air.

All the previously discussed metaphors, including the concepts *wind drift*, *importance*, *temperature* (*cold* and *hot*), *pressure*, *arrow*, and *direction*, intermingle to give rise to the compound conceptual metaphor FLOW AND TEMPERATURE ARE ARROWS AND RED/BLUE COLOURS. Having the function of structuring and transmitting specialised knowledge, this metaphor underlies the cognitive context of many academic subject-oriented papers, running the gamut from purely scientific (e.g. biology) to more technical (e.g. engineering) knowledge domains, as has been demonstrated.

Figure 4, extracted from an article in a Spanish-language academic journal, is an example of how widely the metaphorical representation of FLOW is used in pictorial resources of biology research. The figure illustrates the *life cycle* of *Durvillaea antarctica*, a sea alga species. Arrows and circulation are crucial to describe a biological process through a pictorial metaphor. This time, the metaphorical frame is different from the ones discussed above because the arrows in Figure 4 do not indicate motion of a physical force (e.g. a wind drift) in space, but the developmental stages of the alga in time. The underlying metaphor is TIME IS SPACE, which has been discussed in detail in cognitive-linguistics studies (e.g. Lakoff & Johnson, 1999; Evans, 2013). In the literature, this is known as *the Moving Time metaphor* (Evans, 2013, p. 164). Again, an abstract concept (TIME) is conceptualised as a concrete one (SPACE). Specifically, Figure 4 builds upon the sub-metaphor TEMPORAL SEQUENCE IS SPATIAL POSITION ON A LINEAR PATH (Moore, 2006), where the transience of the different stages of algae to becoming reproductive adult plants (target) is depicted as moving arrows at different positions in space (source) in the picture.

It is the phylogenic (i.e. evolutionary development and history of a particular species) *cycle* of an organism that is visually represented, which means that this process is *repeated* uninterruptedly across individuals in the same species as they are born and die. For this reason, the timeline featuring such a process is represented not by straight but by curved arrows tracing a closing circle.

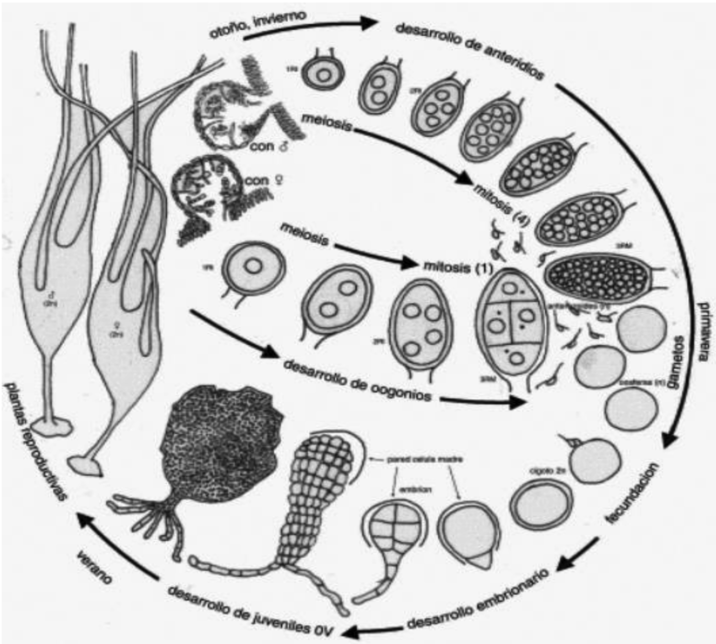


Figure 4. Life history of the alga *Durvillaea Antarctica*

3.1.3 *Summary of contents*

This section has given empirical evidence that conceptual metaphors involving TREE, ARROW, BLUE AND RED, and CIRCLE as source domains are commonplace in the scientific knowledge field. These metaphors are particularly habitual in natural sciences research studies, where they operate to present biological entities and processes through pictorial devices. The TREE, ARROW, BLUE AND RED, and CIRCLE metaphors are non-resemblance in nature, which makes evident how useful they are to visually express abstract concepts through pictorial resources in expert-to-expert communication. This reinforces the value of metaphoric thought and conventional visual metaphors in specialised circles.

Being non-resemblance metaphors, the pictorial tree metaphors are effective in visually representing and organising abstract aspects or dimensions, such as, in examples given above, the degree of significance and embedment of a set of branches of knowledge with respect to a certain discipline and the fine-grained arrangement of fungi into taxonomic categories. The tree metaphors are also highly generative, irrespective of their level of abstraction: despite lacking leaves and roots and having highly schematic branches, the fungi tree may be judged as effective and inferential as the discipline tree, with its well-defined branches and roots. Interestingly, the tree metaphors discussed emerge from a number of primary metaphors, which are directly anchored in our sensorimotor experience, where two events always co-occur on a cause-effect basis.

The FLOW conceptual metaphor divides into two types of target-source mappings: FLOW-TEMPERATURE conceptualised as ARROWS-BLUE/RED COLOURS (e.g. wind drift interactions) and FLOW-TIME conceptualised as STRAIGHT/CURVED ARROWS (e.g. developmental stages of the *Durvillaea Antarctica* alga). As explained above, the pairs *cold-blue* and *hot-red*, being a part of the circulation/flow schema, are mapped from physiological and perceptual bodily experience, and subsequently from features of the environment. As a whole, the depiction of both types of conceptual mappings crucially assists biologists in presenting their peers with specialised concepts and phenomena in academic papers. We can thus conclude that the metaphor vehicles ARROWS and RED/BLUE COLOURS are sufficiently inferential to guide scientific investigation.

Despite their success in explaining science, static images are less effective in featuring and exploiting conceptual metaphors. The next section turns to visual metaphors found in *dynamic* images featuring different animals, and highlights the value of these images to get scholars' messages across not only to other specialists in academic communicative situations, but also to non-experts in pedagogical environments.

3.2 Dynamic images: Animal body language

The figurative grounding of human gestures and body postures is currently widely discussed (e.g. Cienki & Müller, 2010). Nevertheless, little has been written about the metaphoricity of zoosemiosis – i.e. communication within and across non-human animal species – from a cognitive-linguistic point of view. Evidence is provided in this paper that animal physical signification, representation, and communication, the three pillars of zoosemiosis (Martinelli, 2010, p. 1), can be figuratively interpreted. As will be explained, the application of metaphoric structure to the animal world raises interesting questions among expert biologists and cognitive psychologists, and has positive implications for non-specialist readers' understanding and consolidation of specialised knowledge and for their amusement in learning.

3.2.1 *The Brazilian wandering spider*

A good example of the metaphoricity of animal body language is the characteristic threatening position and movement that the poisonous Brazilian wandering spider (genus *Phoneutria*) adopts to scare away potential predators. Expert documents provide evidence of this behaviour. Specifically, the spider's body posture is illustrated in Figure 5, and described by biologists Martins & Bertani (2007, p. 1), who write that for this defensive display the spider holds its frontal legs high after lifting its body to an erect position, and performs swinging lateral movements. Unfortunately, no video clips could be retrieved from specialised sources to show this movement. Nonetheless, this dynamic behavioural pattern is clearly evident in the Youtube® video clip at http://www.youtube.com/watch?v=-zfzY14l23g.

Figure 5. Threatening posture of the Brazilian wandering spider

From a cognitivist perspective, two primary metaphors can be argued to emerge from this instance of kinaesthetic or body language. As is well known, the embodiment approach to metaphor (Lakoff & Johnson, 1999) sees kinaesthetics as the foundation of basic, primary metaphoric models that are acquired early in life by means of conflation/co-occurrence of two events (see examples of experiential correlation in 3.1.2 and below in this section). The first primary metaphor, CONTROL/POWER IS UP, builds on the spider's erect position and lifted frontal legs, which expose its venom-loaded fangs. In regards to humans, psycholinguistic research (Schubert, 2005) shows that the concepts of power, dominance, and status are partially mapped onto the physical vertical dimension, which implies that the metaphors LACK OF CONTROL IS DOWN and CONTROL IS UP are embodied. Linguistically speaking, these metaphors are reflected in sentences such as *He is at the bottom of the social hierarchy; His power is on the decline; I am on top of the situation*; and *I have control over Paul, so he will do whatever I order him.*

These paradigms can be applied to the wandering spider from a cognitivist *human* perspective. Applying humans' responses to danger, it can be interpreted that this animal is attempting to gain an up-high vantage point, which should intimidate its opponent and give the spider a sense of superiority over it. It is quite the same effect made by cobra snakes when they raise their bodies upright if threatened. An example of the reverse interpretation involves a dog crouching its body low and putting its ears and tail down to show submission to a stronger conspecific or to any other more powerful animal. The fact that a primary metaphor is rooted in the spider's body posture is hardly a coincidence. Specifically, again, we can speak of a visual primary metaphor, which is thus grounded in experiential correlation (cause-effect structure). Accordingly, it may be interpreted that by *raising* its body and legs (cause), the wandering spider has learnt to gain a physical, and eventually, psychological advantage over its enemies (effect). In the metaphor, the source UP is mapped onto the target CONTROL/DOMINANCE. This conceptual pattern evidently makes correlation metaphors, one type of non-resemblance metaphor, different from resemblance metaphors, which emerge from physical appearance and/or behavioural comparison.

Specifically, the CONTROL IS UP metaphor complies with Grady's (1997) central claim about primary metaphors. According to this claim, the distinction between target and the source in primary metaphors is the *degree of subjectivity* rather than how clearly delineated or how abstract the target concept is (Evans & Green, 2006, p. 304). On this basis, CONTROL, a subjective (difficult to measure or quantify) concept, is understood in terms of UP, an objectively measurable perceptible unit.

In any case, visual metaphors of this type can also support Conceptual Metaphor Theory's (e.g. Lakoff & Johnson, 1980; Lakoff, 1993) major tenet that conceptual metaphor facilitates for scholars and students the understanding of abstract concepts (psychological advantage) in terms of concrete ones (rise of the body). In fact, what the spider makes is an *abstract referential gesture,*[2] which contrasts with an *iconic gesture* (cf. Cienki & Müller, 2010). In the abstract referential gesture, the abstract referent itself cannot be represented iconically since what is being referred to lacks a physical structure that can inherently be depicted with the limbs. In our case, dominance is an abstract concept/referent that fails to have perceptual properties. Consequently, this type of gestural sign corresponds to the non-resemblance metaphor category. An example of iconic gesture in biology involves the dark-footed ant spider (*Myrmarachne melanotarsa*), which purposely stretches its frontal legs forwards and horizontally, in an unnatural position, in order to mimic the antennae of a real ant (Figure 6). This spider species bears a stunning resemblance to an ant *per se*, but the leg stretching performance enhances the ant imitation model even further.

Leg-stretching is a defence strategy against ant-averse predators and as a camouflage technique to go unnoticed, which enables the spider to gain access to and eat the eggs of other spider species (Nelson & Jackson, 2009). From an

2. Although they are intrinsically linked to human communication, gestures should be broadly understood in this context as part of the more general category of kinesthetics, i.e. the movement of the body in three-dimensional space (Koller, 2009, p. 64).

Figure 6. An ant-looking spider enhances impersonation by stretching its frontal legs forwards, so that they look like an ant's antennae.

anthropocentric point of view, this gesture constitutes a visual resemblance metaphor, which involves concrete-to-concrete mappings between two entities (i.e. the spider and an ant), based on physical comparison. As can be seen, the use of visual metaphors can be extremely useful to consolidate the knowledge of learners of biology about particular behavioural patterns and specific physical features of species. In other words, establishing stimulating and amusing comparisons between different animal categories draws students' attention, which may help them better remember details of the survival strategies of a particular species. This strategy is thus an aid to memory.

The second primary metaphor is CONTROL IS (SWAYING) MOVEMENT. Again, the wandering spider sways its body sideways (cause) to gain a physical vantage point and intimidate its enemy (effect), which ultimately enables the spider to take control of the situation. This behaviour is like a boxer's, who tries to gain control and expresses intimidation by swaying from side to side before his opponent to confuse his attack and finally find a good angle to punch him. The conceptual metaphor SPIDER BEHAVIOUR IS BOXER BEHAVIOUR can thus be formulated. Not surprisingly, the metaphor CONTROL IS (SWAYING) MOVEMENT has a clear linguistic correlation in Spanish expressions such as *Deja de vacilarme!* [Stop teasing/intimidating me!], where *vacilar* literally means *to sway*.

Let us elaborate on why it is worth using the spider metaphors to build scientific theories on animal behaviour and cognition or to bring specialised concepts to learners. If we ask ourselves under what circumstances a nonverbal or multimodal metaphor can be construed, the answer in this case is that the spider metaphors may help biologists make structuring inferences, resulting in comparing, contrasting, identifying, and classifying differing animal species, as well as in forming hypothesis about the biology and ecology of such species. In addition, these metaphors provide evidence to cognitive linguists that embodied cognition is also applicable to animal description, which expands the applicability of metaphor studies to other knowledge fields. These metaphors also assist cognitivists in describing primary, and thus highly instinctive and hard to identify, cognitive mechanisms in zoosemiotics.

Importantly, applying the spider metaphors to the animal world also brings up the question of the existence of metaphoric thinking in non-human animals. This thought-provoking hypothesis concerns ethologists, cognitive semioticians in cross-species studies, and experts in animal cognitive psychology. Suggesting that the conception of mental events in animal cognition is rooted in conceptual metaphors is currently too challenging. However, once demonstrated that specific brain structures are activated during metaphoric processing in humans (Rapp, Leube, Erb, Grodd & Kircher, 2004), neurobiological experimentation in animals could be initiated in this direction. In fact, there is a burgeoning strand of zoosemiotics, known as *the pluralistic view of zoosemiotics* (e.g. Martinelli, 2010, 2011; Maran, Martinelli & Turovski, 2011; Ureña, 2014), which leaves the door open for the existence of sophisticated mental life and superior psychic faculties in non-human species (Maran et al., 2011, p. 14). This is known as *comparative anthropological zoosemiotics*, which makes comparisons between human and non-human semiosis with a view to establishing potential connections between the two codes (Maran et al., 2011, p. 9). Ureña (2014), for example, applies image schemas, which are fundamental constructs of human cognitive psychology and (applied) cognitive linguistics, to the complex and potentially reflective behaviour of the mimic octopus (*Thaumoctopus mimicus*) when it engages in imitation of other sea organisms, such as a flatfish and a lionfish, for survival purposes.

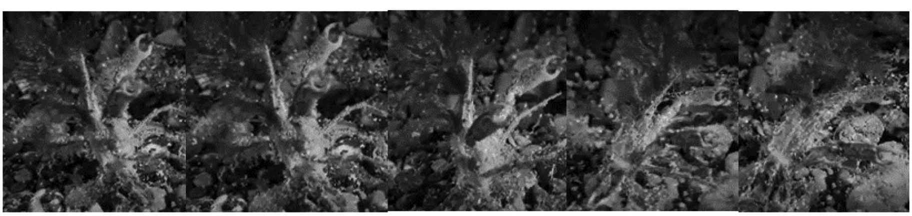
Describing and illustrating the Brazilian wandering spider metaphors with the visual support of video clips is also useful to biology learners in a classroom and to laypeople in any other pedagogical environments. These metaphors assist in:

i. making explanations of animal behaviour and cognition more appealing and amusing to the non-specialist audience since premises of cognitive psychology are normally cumbersome to laypeople; this is done by mapping human psychological states (in this case, intimidation and impression) onto animal responses (in this case, very specific bodily postures and striking physical enactments) to scare antagonists off;
ii. making biology learners value the wide scope, applicability and great pedagogical potential of metaphors; in fact, they are meant to aid students' memory of specialised concepts and phenomena (e.g. the way certain species behave and interact with antagonists for survival purposes).

3.2.2 *The Gibb's sea spider*

All three dimensions of zoosemiotics (animal physical signification, representation, and communication) need not necessarily be at work at the same time. The analysis of the survival strategy of the Gibb's sea spider (*Pisa armata*), a type of crab, shows that this crustacean seems to make use of physical signification (reflective use of a semiotic sign) and representation (the way the animal would construct sense), but not of communication (interaction between the sender of the message and its receiver). I am hedging my statements because openly attributing cognitive capabilities to a lower animal is not tenable by all non-human behavioural cognitive theories. Thus, we are limiting ourselves to the cognition of human observers for the value of human metaphorical understanding. In any case, as mentioned in Section 3.2.1, these metaphors encourage ethologists, cognitive semioticians and behavioural biologist to raise hypotheses about the actual scope of animal psychic faculties and reasoning, as done by scholars in the pluralistic approach to zoosemiotics. It should also be pointed out that the analysis conducted in this subsection does not address the linguistic metaphor *sea spider*, which emerges from the physical comparison between the long and thin legs of the crab and the legs of a spider.

The documentary film sequence at http://youtu.be/sp2X-IErKrY?t=15m28s features the Gibb's sea spider. The images make explicit the metaphorical nature of the appearance and behaviour of this animal from a human perspective. Concretely, its hairy protuberances look to us like the branches of an epipelic (attached to the sediment) alga in shape and colour. In addition, the crab even seems to imitate the gentle movement of the alga (behaviour) by swaying as if at the mercy of the waves; this seems to the human observer to enable it to escape the attention of predators. So, this interpretation prompts behavioural biologists and researchers of animal cognitive psychology to ask themselves whether the *Pisa armata* draws on physical signification (to go unnoticed) and representation (to sway like an alga), while avoiding *inter*action (i.e. communication) with its predators. Figures 7–11 are stills extracted from the documentary film of the swaying movement of the crab stuck to the seabed.



Figures 7–11. Sequence depicting the alga-like appearance and swaying movement of the crab *Pisa armata*.

The figurative grounding of this physical-behavioural pattern challenges Grady's (1999) dichotomy of image metaphors vs. behaviour-based metaphors, defined as mutually exclusive, watertight categories based on motionlessness (it is the physical appearance of two entities that is compared) and dynamicity (it is the behaviour of two entities that is compared), respectively. The Gibb's sea spider's description involves a metaphor that is located in a transition zone between purely static (alga-like protuberances) and dynamic (alga-like movement) images because it emerges from both types of comparison. This was also found by Ureña & Faber (2010) when they examined the semantics of marine biology metaphorical terms, and thus, their method goes from lexis to thought – that is, they first note lexical evidence of the metaphors, and next, adduce their meaning and the underlying thought. Contrast this with the visual sequence in the documentary film of the Gibb's sea spider. The visual sequence supports Conceptual Metaphor Theory's premise (Lakoff & Johnson, 1980, p. 4) that metaphoric thought, as complex as it may be, precedes language. This is further reinforced by the fact that the metaphor-based visual characterisation of *Pisa armata* has not yet even been lexicalised by biologists or reported in their literature.

Despite its lack of lexicalisation, the figurative description of the *Pisa armata* ecology is a crucial constituent of the imagery of biologists since it helps them to identify certain biological patterns, recognise the same patterns in other animals (e.g., the orangutan crab, *Achaeus japonicus*, which has also been found to sway like algae to camouflage for survival), and finally, make species classifications. In other words, this metaphor is used to enhance theory on animal behaviour. It can thus be argued that the manipulation of visual mental images in dynamic sequences is involved in aspects of creative thought in science-making, particularly during the discovery of novel or emergent properties of living beings. It should be noted that the Gibb's sea spider metaphor started out as an idiosyncratic metaphor, and preserved this status until researchers showed this crab's behaviour to be a common pattern across crab species. At that point, the metaphor became conventional, resulting in the formulations SEA CRABS ARE ALGAE, as the generic metaphor, and SEA CRAB BEHAVIOUR IS ALGAE MOVEMENT, as the specific metaphor.

Apart from its theory-constitutive role, the Gibb's sea spider metaphor has a clear explanatory function. Once there is agreement that visuals greatly assist experts in explaining and describing specialised concepts (Fernandes, 2004), the documentary sequence shows that this also holds true for biology pedagogy. The dynamic images of the alga-like crab gently swaying immediately triggers a crab-alga comparison in the viewer's mind, who quickly learns about the survival strategy of this animal. Interestingly, at no time does the narrator make this metaphor explicit. He limits himself to describing the crab's swaying movement and to explaining its purpose (i.e. to escape the attention of possible predators), with no reference to algae as the element of comparison (in cognitivist terms, the source of the metaphor). We can thus infer that the narrator puts the viewers to the test, and assumes that they will be able to project cross-domain mappings in order to gain and consolidate knowledge.

This discourse strategy is possible because the source domain of the metaphor (ALGA) is not present in the visual, but only the target (GIBB'S SEA SPIDER) is. This is a typical aspect of real-life dynamic images involving resemblance metaphors, such as the Gibb's sea spider itself or fish imitating a loose leaf or another lifeless object that drifts side to side in the tide (cf. e.g. https://www.youtube.com/watch?v=TUgkGGIM7HY)). In contrast, in visual primary metaphors, such as those involving the Brazilian wandering spider, only the source (ERECTED BODY AND LEGS) is visible since the target (CONTROL/POWER) is abstract and more subjective in nature. Interestingly, as we will see in Section 4, the visual constituents of both the source and target of a good number of multimodal metaphors are visually represented in the video clips to enrich the metaphors and make the argumentation and explanation of biological processes and behaviours more attractive to the audience.

3.2.3 *Summary of contents*

The previous subsections make a case for studying the role of dynamic visual metaphors that underlie the behaviour of animals both in specialised and pedagogical environments. Metaphors are shown to be abundant not only in their verbal mode (in other words, in the taxonomic nomenclature of non-human species, such as *ant spider*), but also in their purely visual (and imagistic) mode to attract a non-specialist audience and for the understanding of sophisticated animal behaviour. Evidence is also given that resemblance metaphors are an often-seen type of metaphor in biology. For their realisation, they may find support in primary metaphors, which are primitive cognitive constructs that ultimately tie in sensorimotor experience with the metaphorical conceptualisation of animal enactments. This is the reason why LACK OF CONTROL IS DOWN and CONTROL IS UP, operating behind the Brazilian wandering spider metaphor, are conventional primary metaphors commonly found in the analysis of biology visuals. Because they arise from concrete-to-concrete mappings, visual resemblance metaphors are perceptually – and subsequently conceptually – more salient and identifiable than primary metaphors. Therefore, resemblance metaphors may be said to be more useful pedagogical-wise; however, primary metaphors are, on many occasions, the building blocks of resemblance ones.

From a specialised scientific perspective, dynamic visual metaphors in biology are interesting because they may prompt scholars to redress their investigation, suggesting hypothesis about animal cognitive psychology and leaving the door open for the existence of complex and reflective mental life in non-human species, along the lines of the pluralistic view of zoosemiotics. Within this framework, new research lines might emerge that sought evidence for the psychological reality of metaphoric patterns governing the behaviour of non-human animals.

In teaching and pedagogical circles, dynamic visual metaphors make the presentation of abstract concepts (such as dominance, threat and intimidation) and their intriguing connection to specific bodily responses more amusing and attractive to biology learners and laypeople interested in this scientific field. Especially effective from a pedagogical point of view is the strategy followed by some TV documentary narrators not to use certain conventional metaphors, such as SEA CRAB BEHAVIOUR IS ALGAE MOVEMENT, but instead present the viewer with documentary contents. By exclusively relying on the narrator's description of the behaviour as a swaying movement and its corresponding images in the visuals, the viewer is deliberately left alone to construct a metaphor out of the comparison crab-alga by him/herself. This ludic effect adds to the promotional appeal of the documentary and showcases the inferential power of visuals to produce metaphoric reasoning in the audience.

The next section elaborates on the incidence of multimodal metaphors in the popularisation of natural sciences. These metaphors do not exclusively arise from visual cuing, but from the conflation of at least two different modes of representation.

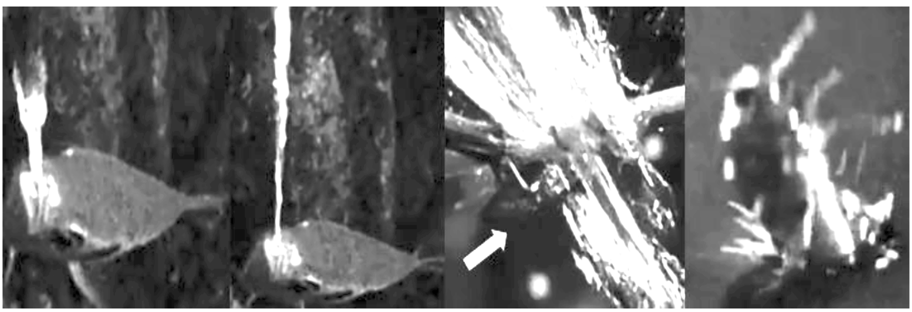
4. Multimodality

Forceville (2009, p. 24) writes that multimodal metaphors are metaphors whose target and source are each represented exclusively or predominantly in different modes. He also regards as multimodal those metaphors where the source is cued in two or more modes simultaneously. The biology examples discussed below fall into this second category. Accordingly, the target domains are conceptualised by different modes of the source domains. Among these modes are sound and music, which have only recently started to be explored (Forceville, 2009, p. 384).

4.1 The archerfish

Around three decades ago, the metaphorical basis of the archerfish (*Toxotes chatareus*) was verbally explained in a biology research article. Dill (1977, p. 169) found that "archerfish spit droplets of water at aerial insect prey, knocking them onto the water surface to be eaten […] the fish must deal with potentially severe refraction effects at the air-water interface". This finding had implications for ichthyology since it prompted biologists to make additional observations and refine their theories about the visual apparatus of some fish and how they find, capture, and eat their prey. In the verbal mode of expression of *archerfish*, the source and target are ARCHER and FISH, respectively. In addition, ARCHER is a WHOLE FOR THE PART metonymy, specifically ARCHER FOR ARCH, since it is the mechanism and shot of an archery bow that is compared to the spitting mechanism of a fish's mouth.

Popular science materials, especially documentaries, pick and choose diverse representation modes of metaphoric thought with a view to being as illustrative as possible and catching the viewer's eye. Accordingly, this subsection explores how the source domain of the metaphor *archerfish* is conceptualised, depending on whether it is cued by a verbal (speech) or non-verbal (sound effects) mode in a pedagogic setting. The focus of analysis is on the documentary video clip at http://www.youtube.com/watch?v=fhBZ40jIo4Q, which features the archerfish. Figures 12 to 15 are stills extracted from the video that sequence the predatory strategy of this fish.



Figures 12–15. Sequence of waterjet going out of the fish's mouth (11), cutting the air (12), and impacting on the insect (white arrow) (13), which falls down to the water (14)

The narrator's speech includes a number of words, such as *archerfish*, which is a technical term, and thus, a well-entrenched lexical item, and the expressions *expert in ballistics*, *weapon*, *water pistol* and *gun barrel*, which are novel sources that are recruited on-line to characterise *Toxotes chatareus*, the target, as a weapon user. This means that ARCHER, the original source coined by experts (see above), has been expanded to the broader domain WEAPON by the narrator for *promotional* (Nelkin, 1994) purposes. This expansion is also realised by the sound effect of a projectile cutting the air to characterise waterjets as arrows or bullets (see minutes 0: 12 and 0: 33, for instance) for the same purposes. Surprisingly, there is no visual realisation of the source domain – for example, the image of an arch(er) or a gun(ner) to be mapped onto the image of the fish, which is the target.

The promotional value of both the linguistic and auditory sources of the metaphor is evident, since they are intended to attract the audience. However, it is necessary to consider the question of what is pedagogically valuable about these novel sources as distinct from their entertainment or promotional value. Since the sound effect chosen is fairly generic, it may designate any type of arm and projectile. For this reason, this mode assists the terminological, and thus, conventional metaphor *archerfish* in describing the fish as an archer. This is a clear example of how a multimodal metaphor makes salient certain aspects of conceptual metaphors (in this case, the auditory facet of the source, which substantially enriches and supplements the whole weapon metaphor structure) that are inexpressible or backgrounded in its verbal or visual manifestation.

In contrast, the verbal items, such as *water pistol* and *gun barrel*, are at odds with the terminological metaphor, since they refer to *fire*arms. Broadening the source domain from BOW to WEAPON involves inaccurate mappings if the source domain *archer* is taken as a reference for the metaphor. For instance, *gun barrel* is mapped onto *the fish's mouth spitting water droplets*, which does not actually fit in with or does not make sense to the metaphorical term *archerfish*. Inaccurate mappings of this type are deliberately prompted by the narrator in order to enrich the whole metaphorical structure and make it more appealing to the audience; however, this strategy does not necessarily make the metaphor more instructive. In fact, it might be considered misleading. This case supports the claim that in the interest of public understanding, scientists and science educators should sometimes restrain promotional tendencies that lead to oversell (Nelkin, 1994, p. 30).

4.2 The velvet worm and the harvestman

This subsection describes auditory, visual, and linguistic metaphors included in the documentary video clip available at https://youtu.be/3DOvo2V8XIY?t=4m46s, which features two arthropods, the velvet worm (*Onychophora*) and the harvestman (*Opiliones*). Although these are metaphorical terms used by experts to refer to individuals of the Phylum *Onychophora* and the Order *Opiliones*, none of the documentary metaphors analysed here has anything to do with the metaphorical basis of such terms. The video contains both monomodal and multimodal metaphors.

One monomodal metaphor arises from auditory perception. From 4: 52 to 5: 03 in the video, a light and relatively high-pitched sound of violins can be heard as the images show the quick and dynamic marching pace of the velvet worm and harvestman along a tree branch. The choice of the high-pitched sound of violins is not random at all. In fact, this sound is the source of the metaphor, which maps onto the images of both animals making their way at a light pace, which is the target. This is a parallelism which the author of the documentary consciously establishes between light music and light pace, probably meant to be unconsciously interpreted as such by the viewer. This is a conventional strategy that is used in different settings, particularly in films as cinematic metaphors. What is novel with respect to the previous case studies is that both the source and target domains in this case, which belong to distinct modes of perception, are made explicit to work simultaneously. Thus, this is an example of *simultaneous cueing*, according to which, if two things are signalled in different modes, metaphorical identification is achieved by saliently representing target and source at the same time (Forceville, 2009, p. 31). In this case, simultaneous cueing adds liveliness and precision to the images, and is intended to help the viewer realise or be aware of the metaphor.

The light sound of violins – together with complementary sound effects, such as a sort of alarm (5: 05) and a brief clashing sound that is repeated at short time intervals, also helps to create an intriguing and disturbing environment, intended to draw the viewer's attention to a dangerous encounter between two animals. There are two factors that should be analysed here. The first factor is the high-pitched sound, which is embodied insofar as it keeps the viewer's expectancy up. This is a complex case of embodiment, which can be traced back as follows. First of all, the physical source domain UP is mapped onto the emotional state domain EXPECTANCY/INTRIGUE, since people tend to be on their feet at a moment of uncertainty (for example, in a forest, lost people vigilantly stand on their feet because they may be attacked by a beast).

The ensuing metaphor, INTRIGUE IS UP, is the opposite of RELAX IS DOWN. Subsequently, since a high-pitched sound causes emotional tension (e.g. the famous bath scene in Hitchcock's film *Pyscho*), a cross-domain mapping is established between the source domain HIGH PITCH and the target INTRIGUE, from which INTRIGUE IS HIGH PITCH arises. More specifically, we can speak of a co-occurrence (primary) metaphor since both elements (INTRIGUE and HIGH PITCH) co-occur in time. Accordingly, thanks to film watching experience, hearing a repeated high-pitched sound involves or anticipates an intriguing or dangerous scene. Being a primary metaphor, the distinction between INTRIGUE, the target, and HIGH PITCH, the source, is first and foremost their degree of subjectivity. INTRIGUE, a more subjective (hard to measure or quantify) concept, is understood in terms of HIGH PITCH, an objectively measurable unit. The production of feelings and emotions by sound/music is an effect that verbal metaphors cannot achieve so readily and effectively.

The second factor to be considered is the cadence of the violin sound, which follows a pattern of repetition at short intervals (a set of three-second long sequences starting at 4: 52 and ending at 5: 07). These quick sequences of repeated sound also contribute to creating a disturbing atmosphere. This effect has a physiological explanation: the more nervous we feel, the faster the rhythm of our heart beats. Accordingly, the QUICK MUSIC SEQUENCES are mapped onto the VIEWER'S HEART BEATS, which keep up with the rhythm of the music, thus producing a feeling of uneasiness in the viewer. If we link this mapping to INTRIGUE IS HIGH-PITCHED SOUND, the result is the compound/complex metaphor INTRIGUE IS REPEATED HIGH-PITCHED SOUND. As Grady (1997) claims, compound metaphors are constructed from the unification of primary metaphors, which are foundational.

The last metaphor emerging from sound also involves the mapping LIGHT SOUND – LIGHT PACE. Occurring almost at the end of the video at 7: 53, a short piano sequence of light notes can be heard as the velvet worm swiftly hides behind a rock. Each note on the piano seems to map onto each step that the worm takes to strengthen the sense of rapidness and lightness. This auditory device adds to the promotional, free-and-easy style of the documentary, which ultimately seeks to grab the viewer's attention.

The video includes verbal monomodal metaphors. The narrator uses lexical items such as *weapon, slime guns, razor sharp mouthparts, spiky armour,* and *chemical warfare* to list the number of defence and attack skills of the velvet worm and the harvestman. These expressions, which are not biology-specific terminological units, are closely linked to the vocabulary and the auditory strategy discussed in Subsection 4.1, including *archerfish*, *water pistol, gun barrel*, among other expressions, and the projectile sound effect. Far from being a coincidence, this convergence gives evidence that the biology discourse heavily relies on the WEAPON conceptual macro-metaphor to explain biological processes, especially in exegetical and educational contexts, where deliberate creative metaphors can be easily exploited. Based on all this evidence, we can be safe in suggesting that the entire video is built around the idea of a fight about to break out, where animal behaviour is compared to a battle (the Youtube clip title is even called *Monster Bug Wars*) or a boxing match (note the table typical for boxing that pops up at 5: 10 and compares the profiles and strengths of both contestants as if they were boxers). WAR/MATCH is thus the overarching metaphor theme – instantiated by visual, auditory and verbal cues – that substantiates and articulates the narrator's argumentation throughout the video clip.

It should be noted that the terminology of biology also draws on this conceptual metaphor in the form of terms such as *archerfish*, *sentinel organism*, and *evolutionary arms race* (cf. Ureña, 2011, where textual evidence is provided of the existence of the metaphor LIFE/SURVIVAL IS WAR). This means that sometimes the border between conventional metaphors and idiosyncratic ones is difficult to draw, particularly when conventional metaphors have idiosyncratic extensions (Forceville, 2009, p. 26). As Knudsen (2003) highlights, in addressing the general public, scientists use the 'closed' metaphors of expert discourse as 'open' metaphors in order to achieve their rhetorical goals.

Finally, the video contains a case of multimodal metaphor. In this metaphor, the target, the physical collision between the velvet worm and the harvestman, is cued by two sources belonging to different modes of representation. The first source is visually realised at 6: 01 and 6: 05 in the form of artificial flashes of light when both animals collide. Figure 16 and Figure 17 are stills extracted from the documentary film. Figure 16 illustrates the emergent flashes the instant at which the worm and the Opilion enter into frontal physical contact. For visual clarification, the worm's body as well as the harvestman's long legs are pointed by white arrows.

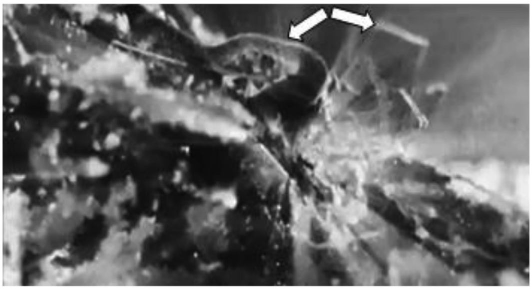


Figure 16. Emergent flashes of light at collision

Figure 17. Flashes during collision

These flashes are accompanied by brief percussion sounds, which are the second source of the metaphor, mapping onto the COLLISION target as well. Both auditory and visual effects are included by the author because of their spectacular nature, and thus, they have a promotional purpose.

4.3 Summary of contents

Based on authentic materials, the previous sections show how multimodal metaphors are used to popularise natural sciences among laypeople. Multimodal biology metaphors in documentaries normally include both auditory and visual artefacts, a combination that is intended to bring the appealing power of documentaries to full potential. Indeed, these metaphors are deliberately exploited by documentary narrators to draw audience attention. Particularly common in this type of pedagogical environment are resemblance metaphors, since comparison between concrete entities in shape, colour and/or behaviour are especially productive and easy to understand by nonprofessionals, and non-resemblance metaphors, which mostly involve acoustic effects.

The multimodal metaphors discussed above are good examples because they combine the verbal, auditory and visual modes. The verbal mode manifests as the terminological – and thus conventionalised – metaphors *archerfish*, *velvet worm* and *harvestman* and as nonconventional lexical metaphors, such as *water pistol*, *gun barrel* and *slime guns*. The narrators come up with the latter in a strategy where the conventional metaphor theme WAR/GAME is extended to associate a metaphorical term used by expert biologists with novel or idiosyncratic metaphorical expressions for explanatory purposes. This fact illustrates the great productivity of the WAR/GAME metaphor. It should be noted that this is a rare strategy to see in specialised biology research articles (see Ureña, 2016 for a detailed discussion of novel metaphors in scientific publications), but very frequent in popularising contexts. The metaphors *water pistol* and *gun barrel* are at odds with the terminological metaphor *archerfish*, since they refer to *fire*arms. Broadening the source domain from BOW to WEAPON involves inaccurate mappings if the source domain ARCHER is taken as a reference for the metaphor. Although clearly used for pedagogical reasons, *water pistol* and *gun barrel* do not convey meaning faithfully, and therefore, they might be misleading for the audience.

The auditory mode in the archerfish metaphor also involves expanding the WAR theme by relying on sound effects made by firearms, which is then equally appealing though potentially misleading to the viewer. Falling back on auditory metaphors to explain biological concepts and phenomena is also very rare in expert communication, but a common strategy in instructive and exegetical settings because they attract biology learners and laypeople and richly complement the visual and verbal metaphors. One metaphor in the acoustic mode in the velvet worm and harvestman documentary is LIGHT PACE IS LIGHT MUSIC, which may be unconsciously interpreted as such by the viewer. This interpretation is interesting in terms of the promotional value of the documentary because it draws on people's universal psychological responses to light and intriguing music and sounds. The level of entrenchment of this auditory metaphor in popularising videos of science is high, underlying a conventional type of music that is used not only in documentaries but also in films as a cinematic metaphor because of its great effectiveness.

The visuals that are metaphorically represented in the velvet worm and harvestman video clip are also intended to arouse interest in the non-expert audience. The intense flashes of light are artificially introduced in the video as a figurative manifestation of an unfriendly physical encounter or collision between two insects. Because of their unreal and sensational nature, these flashes achieve a degree of spectacularity, which assists the narrator in getting their message across to the viewer. Despite not being necessary to communicate scientific concepts, this multimodal device is extremely useful in pedagogical contexts because its spectacularity cannot be attained by the conventional verbal metaphors *velvet worm* and *harvestman* alone. For this reason, multimodality is highly instrumental to popularising scientific knowledge through metaphoric thinking.

An alternative metaphoric interpretation to LIFE/SURVIVAL IS WAR in the velvet worm- harvestman video clip is LIFE/SURVIVAL IS DRAMATURGY. In fact, most viewers/students of this type of biology documentaries are accustomed to seeing video dramas that include various sensorily-stimulating audio/visual devices that naturally map onto the observed features of the target LIFE/SURVIVAL. This high level of familiarity buttresses the pedagogical and promotional value of the SURVIVAL IS DRAMATURGY metaphor. The video clip includes staged interactions of actors with roles played out in scripted fashion (the AGGRESSOR is mapped onto the VELVET WORM, whereas the VICTIM is mapped onto the HARVESTMAN). Within this framework, there is also a hierarchy of status (DOMINANT-VELVET WORM and SUBMISSIVE-HARVESTMAN). The staged interactions of actors are featured by means of alternating sequences of the animals' SLOW AND RAPID MOVEMENTS and COLLISIONS, which are metaphorically interpreted in terms of SOFTER AND HIGH-PITCHED MUSIC and FLASHES OF LIGHT. The music, sounds, and light flashes map onto the rise and fall of the viewers' emotions, which are typically stirred while watching drama performances. Importantly, there is a narrative underlying all of these metaphorical mappings and comparisons, that is, survival of the fittest.

These visual, auditory and multimodal metaphors crucially reinforce and contribute to the dominant metaphor SURVIVAL IS DRAMATURGY, providing the narration and the story behind it with thematic cohesion and structure. Being sensational and attention-grabbing, these metaphors are also key to promoting the documentary.

5. Conclusions

This paper provides textual, visual and auditory evidence that nonverbal and multimodal metaphors are well integrated into the construction and teaching of biology sciences. It shows how different semiotic modes, including static and dynamic (body language) images as well as sound/music, work separately or together to construct figurative meaning. The resulting metaphors reveal aspects of biological patterns that cannot be readily accessed through terminological metaphor. Some of these metaphors – mostly visual in nature – are theory-constitutive, which means that they are conventionalised metaphors that help (re)structure and classify scientific findings, enhance theories, and eventually, further science. The tree metaphor is a good example since it permits scientists to organise knowledge and biological elements in a structure, where scientific disciplines are hierarchically arranged as roots, related to each other in terms of relevance and degree of connection to a main discipline. For this reason, tree metaphors can be said to have a particularly rich and productive structure, which fosters interconnections between specialised concepts, and have inference structure.

Some tree metaphors, such as EUGENICS IS A TREE and DISCIPLINES ARE TREE ROOTS, are readily identifiable because the source domain is visually portrayed. Non-resemblance metaphors are also common, and can be easily distinguished from resemblance ones. This is the case for the non-resemblance metaphor IMPORTANT IS SUPERFICIAL AND PROXIMAL, which subserves the tree metaphors EUGENICS IS A TREE and DISCIPLINES ARE TREE ROOTS.

Inference structure is particularly useful because it stimulates further observation of natural entities and processes. For example, by setting the metaphor SEA CRAB BEHAVIOUR IS ALGAE MOVEMENT, biologists can search for animal behavioural patterns similar to the specific behaviour of the crab species *Pisa armata* (e.g. some fish imitate loose leaves that drift side to side in the tide), and then make comparisons and associations, and establish contrasts. These metaphoric comparisons feed imagery and boost imagination, which assists scientists in inferring or hypothesising why and how this biological/ecological paradigm occurs across animal types, extending or restricting the paradigm.

From a pedagogical point of view, metaphors such as the one mentioned above make explanations of animal behaviour and cognition more appealing to the laypeople since principles of cognitive psychology are normally difficult to understand by a non-specialist audience. Biology teachers and scholars using metaphors of this kind incite learners to value the wide scope, applicability and great popularising potential of metaphors. For example, the metaphor DOMINANCE IS UP, attributed to the Brazilian wandering spider, is meant to encourage students to somehow identify animal species with humans, which attracts their attention and makes learning specialised concepts and phenomena (in this case, the way some species behave and interact with antagonists for survival and predatory purposes) more amusing.

Moreover, sophisticated animal behaviour also raises questions about the actual complexity level of animal cognition. An insight into the bodily postures and responses of certain animals to predators from a metaphor-based perspective should encourage biology scholars to open up new lines of investigation towards finding evidence of reflective, and perhaps, metaphoric reasoning in non-human species. There is evidence of the activation of specific brain structures during metaphoric processing in humans (Rapp, Leube, Erb, Grodd & Kircher, 2004). This type of reasoning could be put to the test in experimental neurobiological studies of non-human animals, especially because the scientific community continues to be in need of psycho-cognitive experimentation that painstakingly looks into the ecological and cognitive-semiotic grounding of imitation patterns in animals. Findings in this direction would crucially contribute to construct path-breaking theory in the burgeoning field of comparative anthropological zoosemiotics, which makes comparisons between human and non-human semiosis with a view to establishing potential connections between the two codes (Maran et al., 2011, p. 9).

Other metaphors are deliberately used by educators to explain biological phenomena to laypeople incorporating auditory devices for clearly promotional purposes. Specifically, the effective and sensational effects of visual and acoustic resources cannot be produced by terminological metaphors alone, hence the significance of multimodality in pedagogical contexts. Metaphors of both types can emerge from resemblance and non-resemblance patterns. Non-resemblance metaphors are mostly primary metaphors or are based on them. Visual resemblance metaphors are mostly unconventional/idiosyncratic as well as highly imagistic. Because of their creative nature, the use of metaphors that do not map accurately is not uncommon in these communicative situations. For example, the verbal metaphor *gun barrel*, used by a documentary narrator to support the visual representation of the metaphor *archerfish*, does not actually fit in with the latter (GUN IS A FIRE WEAPON). Even though it may be misleading, using *gun barrel* to explain and describe the behaviour of a fish species may nevertheless be beneficial overall, because it enriches the whole metaphorical structure and makes it more appealing to the viewer.

The evidence provided in this paper is a contribution to the study of facets and types of metaphor that are all around us, but which have been rarely addressed in research. As has been shown, nonverbal and multimodal metaphors play a major role in helping biology experts pursue their science more effectively and in attracting natural sciences learners and nonprofessionals by explaining abstract and complex concepts in an amusing and striking manner.

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