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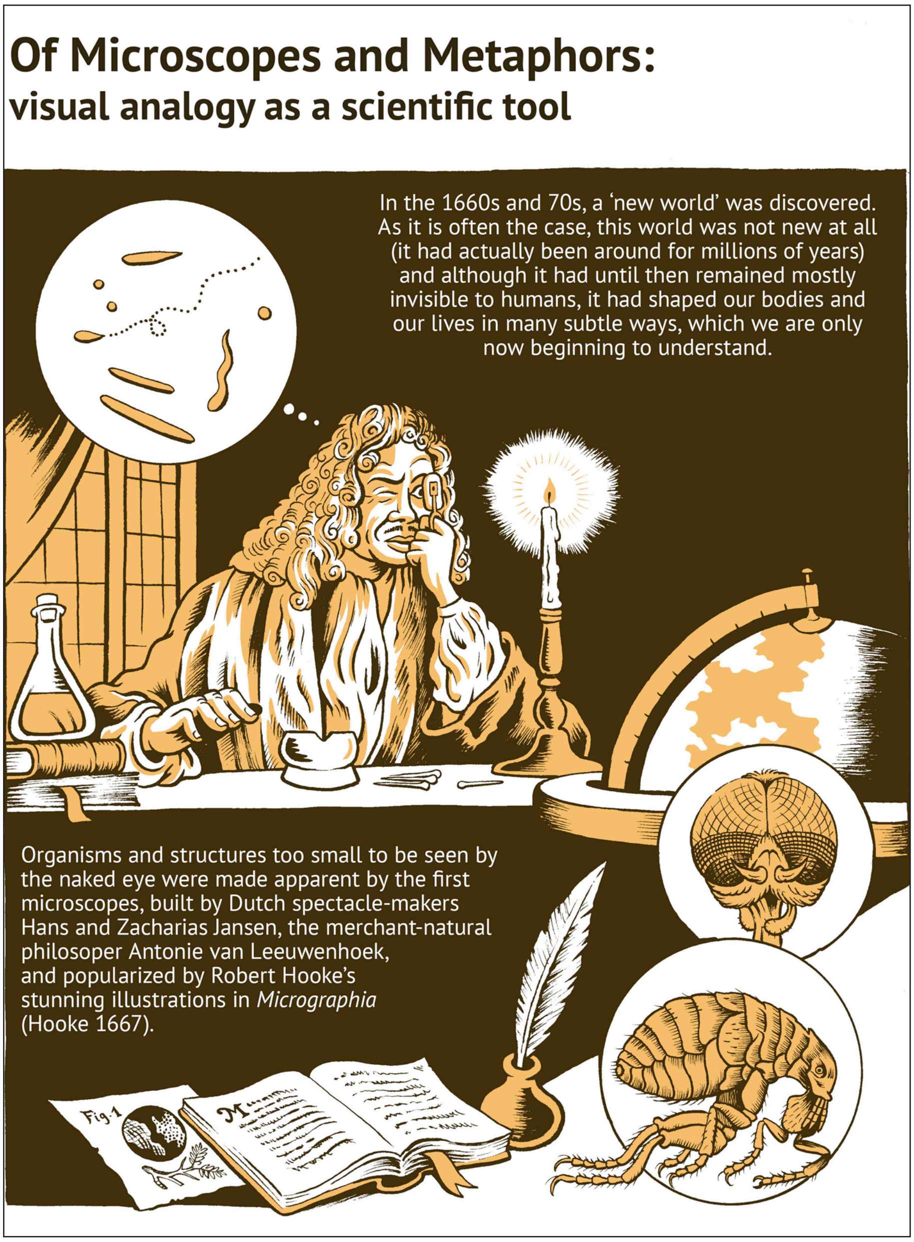
RESEARCH

Of Microscopes and Metaphors: Visual Analogy as a Scientific Tool

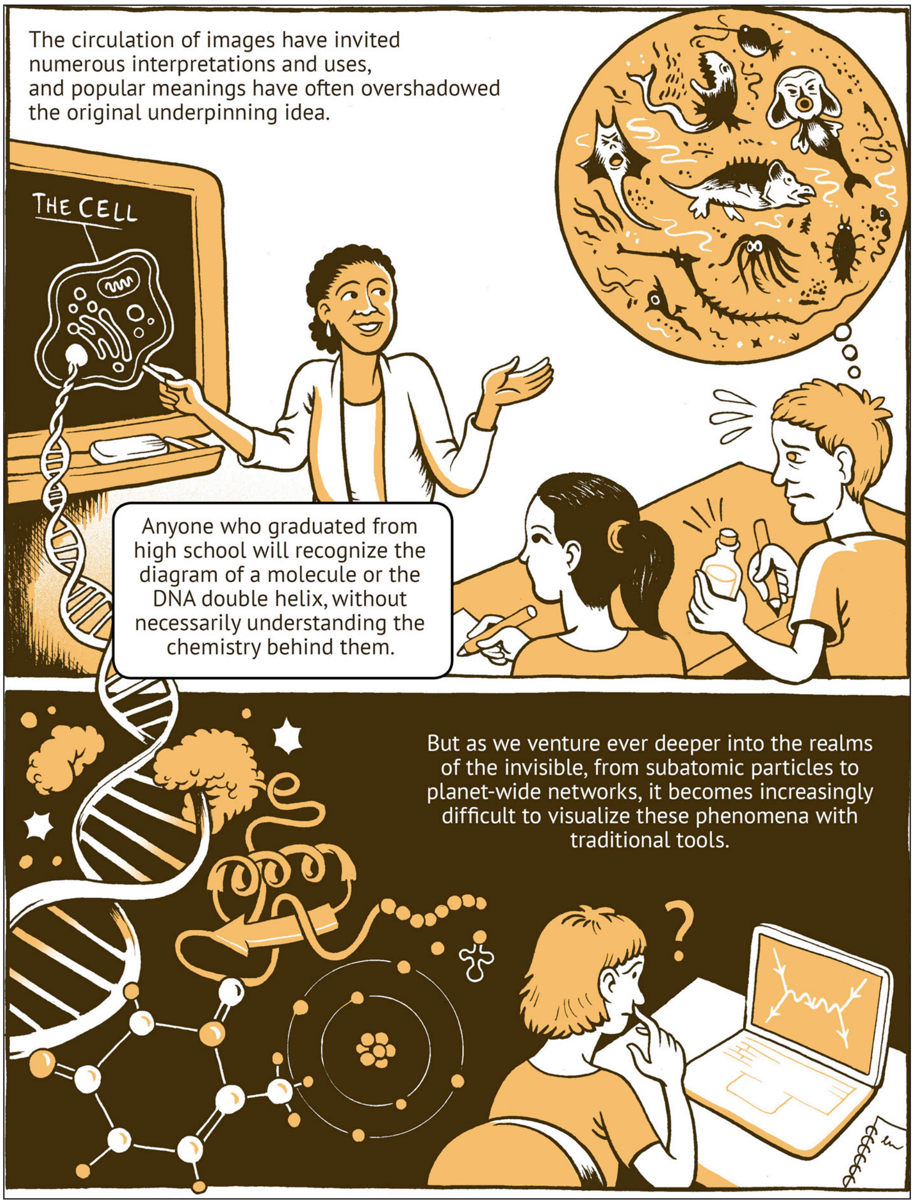
Matteo Farinella
Presidential Scholar in Society and Neruoscience, Columbia University, US
mf3094@columbia.edu

Throughout history, visualizations have played a central role in articulating scientific ideas and innovation. Even though technological systems and tools enables scientists to explore increasingly more 'abstract' scientific domains, sometimes traditional visualization techniques are no longer adequate to guide our understanding. Analogies and conceptual metaphors have often been highlighted as a key component of scientific thinking, especially when dealing with intangible entities and phenomena. In particular, visual metaphors, such as those found in comics, seem uniquely suited to illustrate complex scientific phenomena and promote public understanding of science. This article draws an analogy between microscopes and an imaginary metaphorical apparatus, in order to explore the potential (and limitations) of visual metaphors in scientific research.

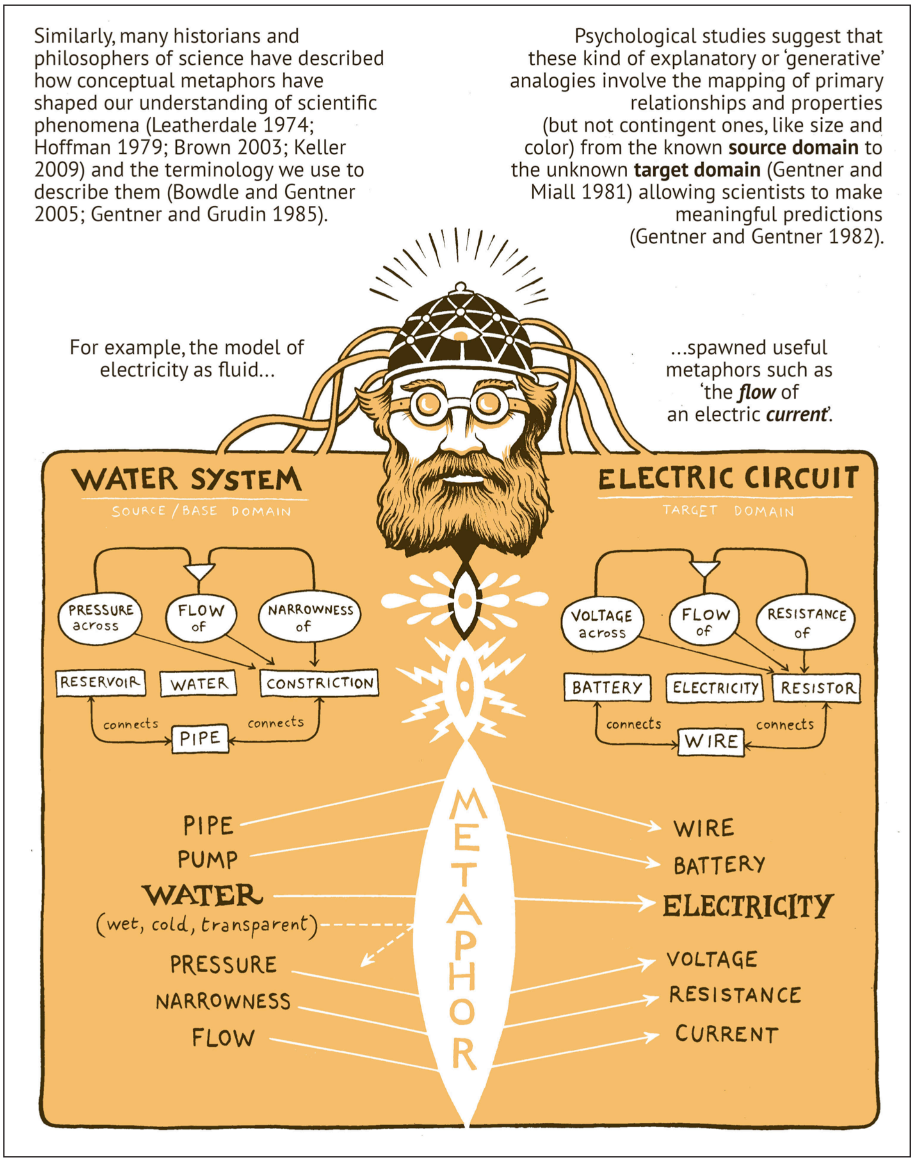
Keywords: Communication; metaphors; psychology; science; visualization

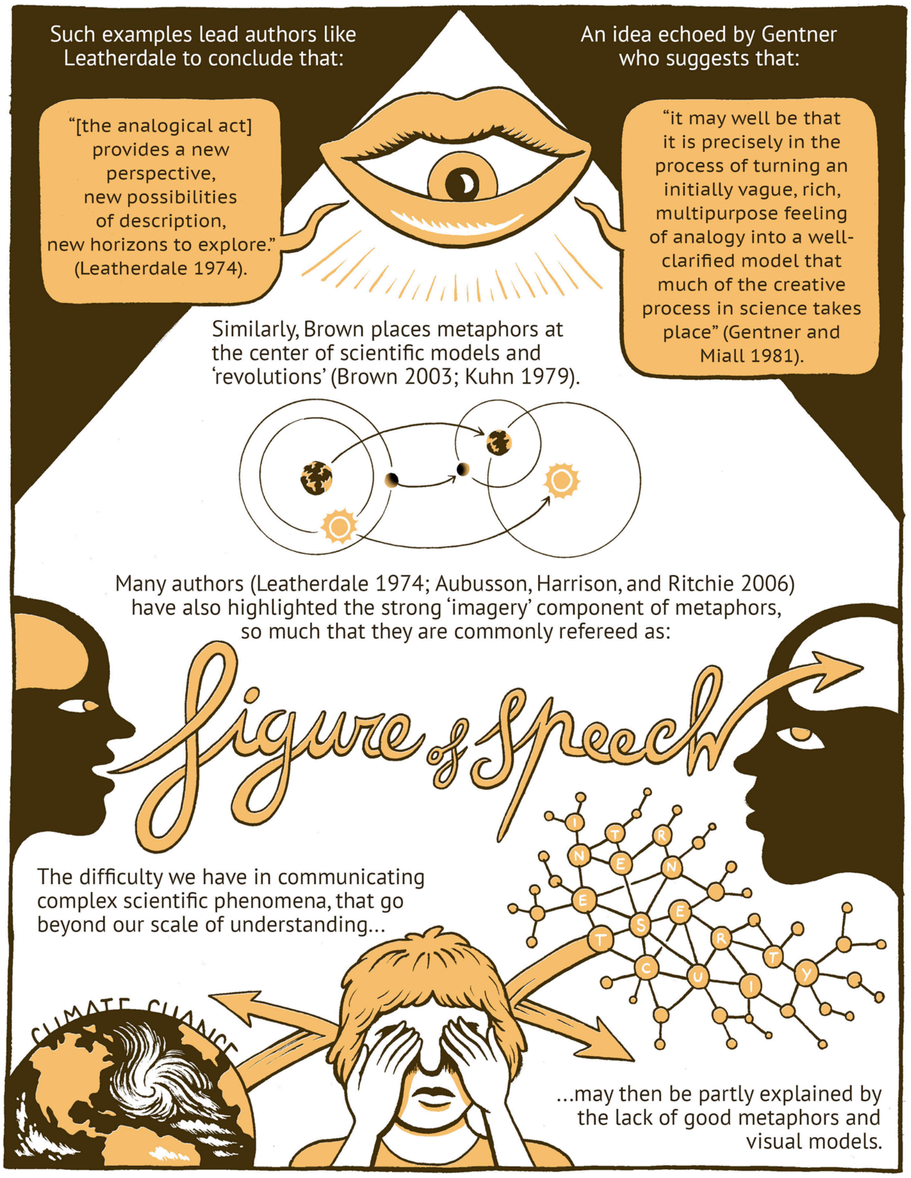

Of Microscopes and Metaphors:
visual analogy as a scientific tool
In the 1660s and 70s, a 'new world' was discovered. As it is often the case, this world was not new at all (it had actually been around for millions of years) and although it had until then remained mostly invisible to humans, it had shaped our bodies and our lives in many subtle ways, which we are only now beginning to understand.
Organisms and structures too small to be seen by the naked eye were made apparent by the first microscopes, built by Dutch spectacle-makers Hans and Zacharias Jansen, the merchant-natural philosoper Antonie van Leeuwenhoek, and popularized by Robert Hooke's stunning illustrations in *Micrographia* (Hooke 1667).
Fig. 1

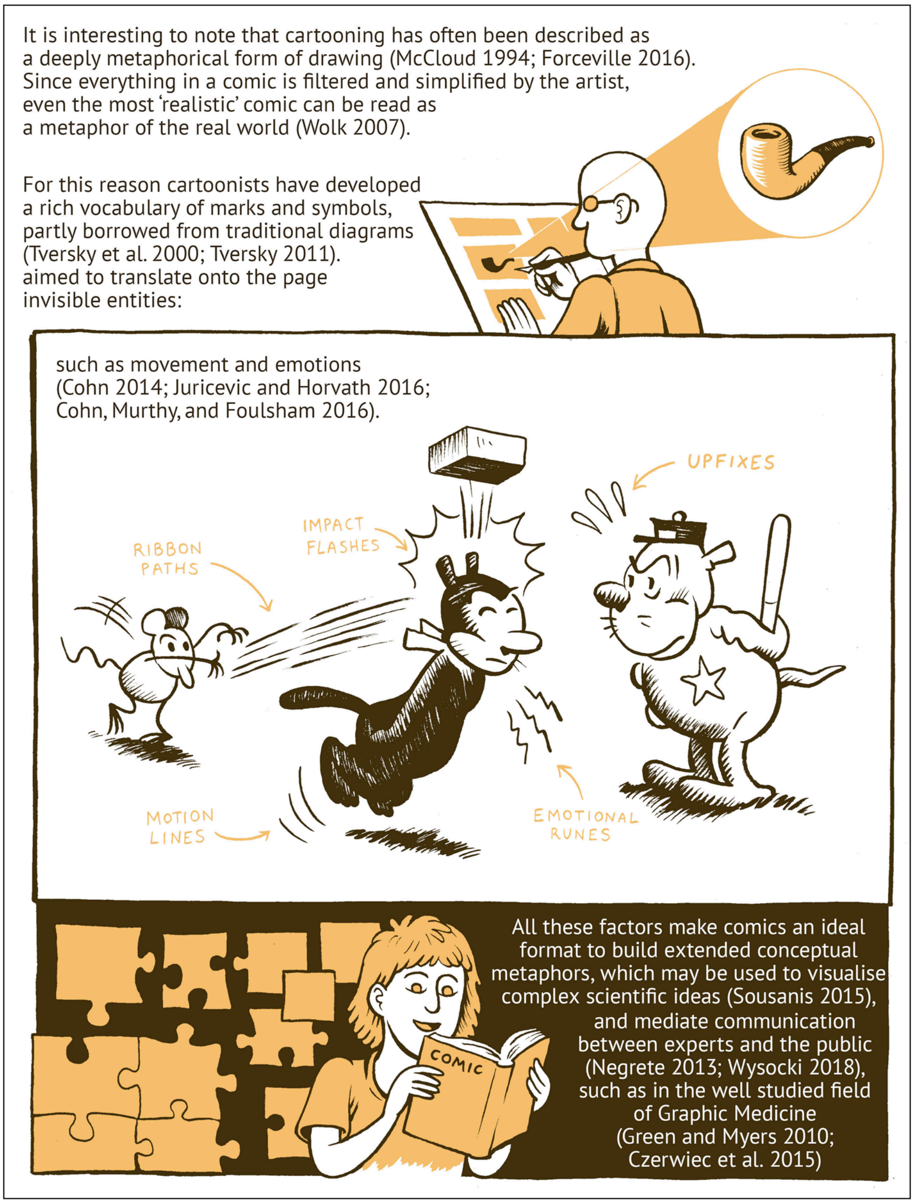

Microscopes are just one of the most striking examples of how visualization techniques can facilitate and trasform scientific resarch, opening entire fields of enquiry (L. Pauwels 2006).
The evolution of microscopes in the following centuries completly transformed the language and precision of scientific knowledge.
Many natural philosophers explored the world revealed by the lens of a microscope through incredibly elaborate illustrations.
Moreover, visualizations played a crucial role in articulating concrete and abstract knowledge in science education, scientific communities, and non-expert audiences (Gilbert, Reiner, and Nakhleh 2007).

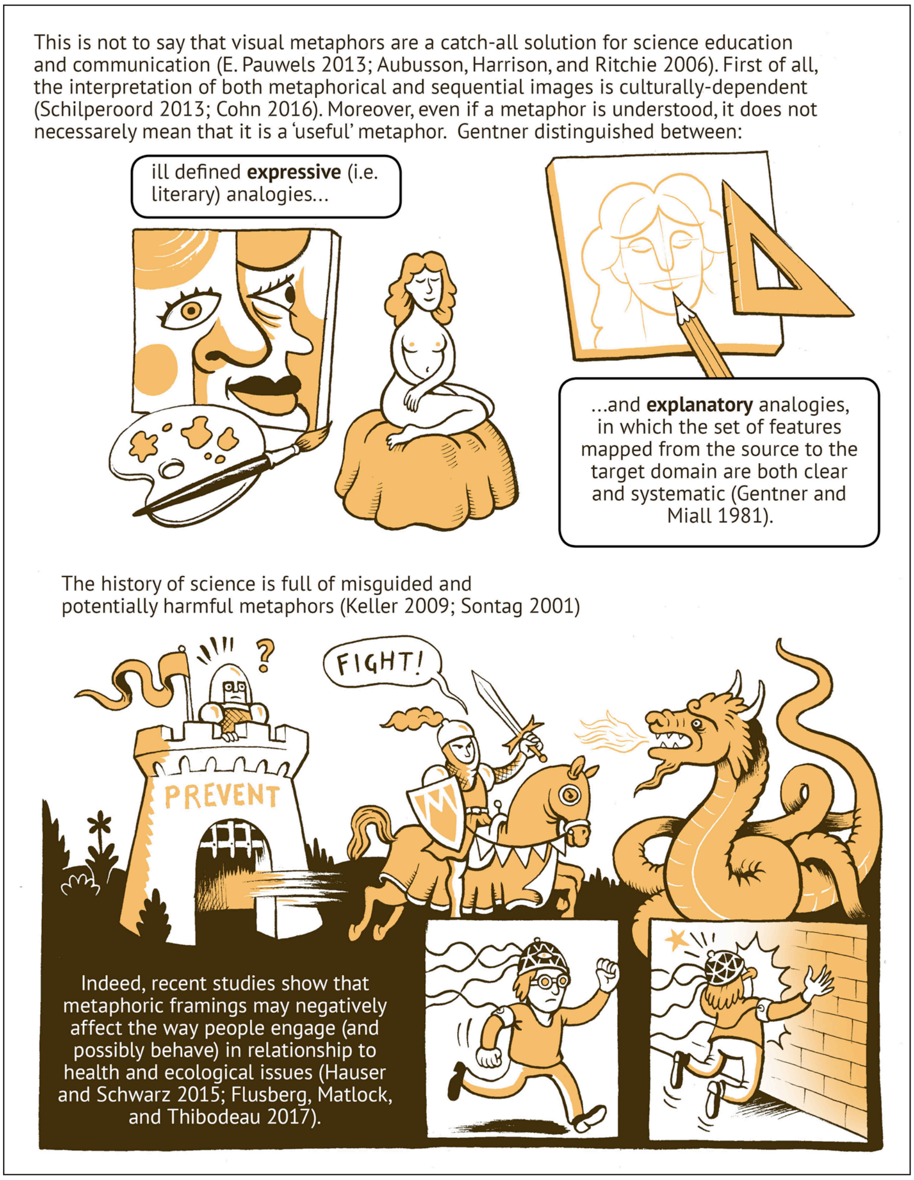

The circulation of images have invited numerous interpretations and uses, and popular meanings have often overshadowed the original underpinning idea.
THE CELL
Anyone who graduated from high school will recognize the diagram of a molecule or the DNA double helix, without necessarily understanding the chemistry behind them.
But as we venture ever deeper into the realms of the invisible, from subatomic particles to planet-wide networks, it becomes increasingly difficult to visualize these phenomena with traditional tools.

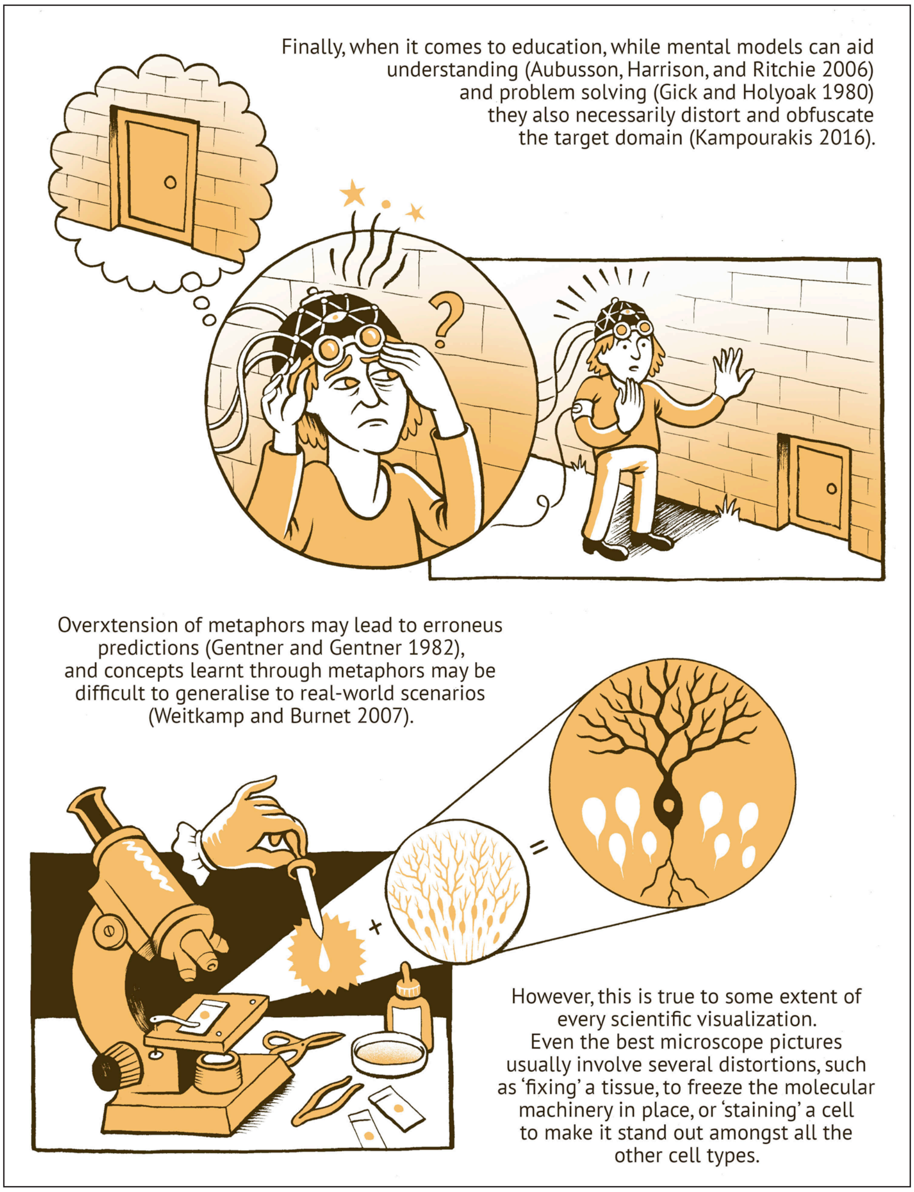

This is where scientific practice fundamentally rests on models and metaphors (Miall 1982; Ortony 1993; Brown 2003).
As famously argued by Lakoff and Johnson in *Metaphors We Live By*, metaphors grounded in our physical experience (*source domains*) help us to understand more abstract, intangible concepts (*target domains*) (Lakoff and Johnson 1980; Gentner 1983; Gibbs 2011).
For example, the way we talk (and arguably think) about 'time' - one of the few intangible concepts we all have to deal with on a daily basis - is in terms of a moving object facing us, with the future moving toward us.
THE YEARS AHEAD
YOU HAVE TO PUT THAT BEHIND YOU
THERE IS NO GOING BACK
THE TIME FOR ACTION HAS ARRIVED
I LOOK FORWARD TO NEXT WEEK
BEFORE US IS A GREAT OPPORTUNITY
I CAN'T FACE THE FUTURE
HE SHOULD HAVE SEEN THAT COMING

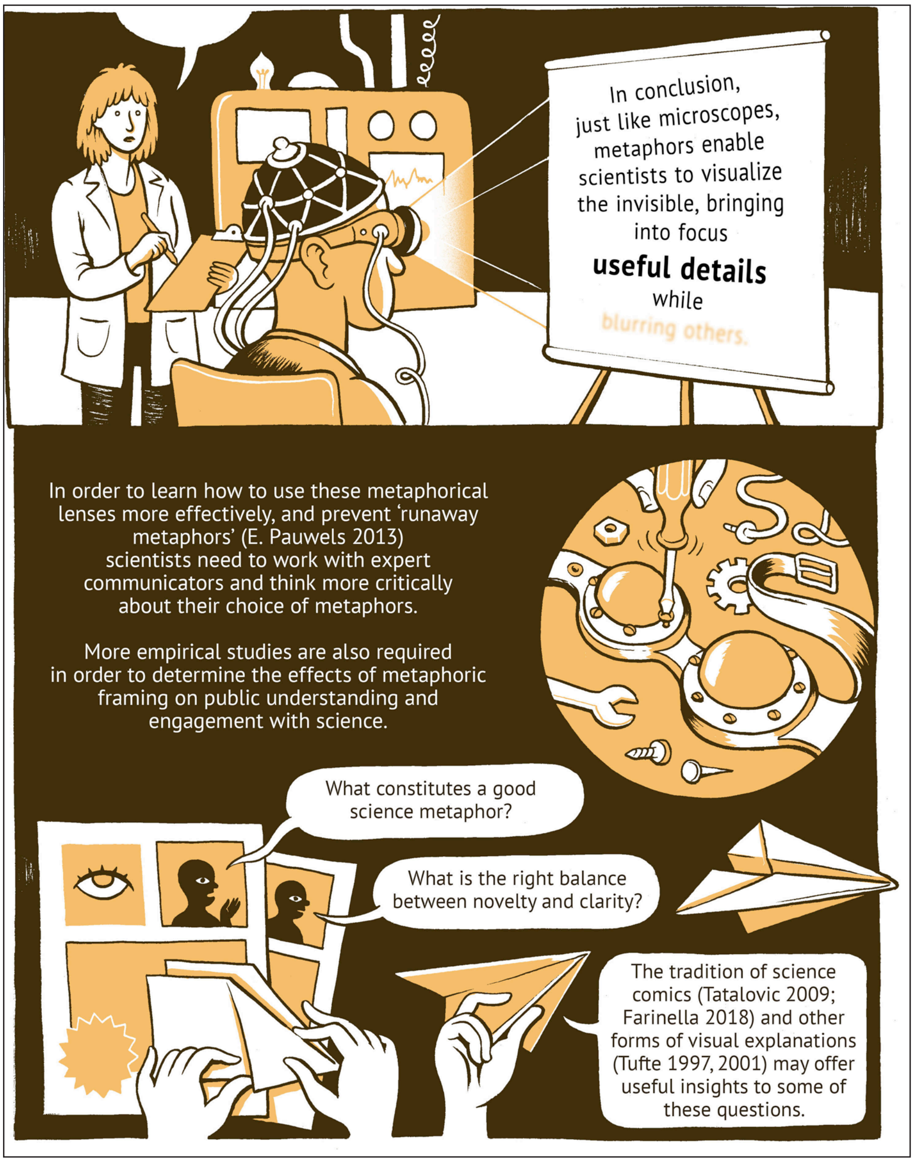

Similarly, many historians and philosophers of science have described how conceptual metaphors have shaped our understanding of scientific phenomena (Leatherdale 1974; Hoffman 1979; Brown 2003; Keller 2009) and the terminology we use to describe them (Bowdle and Gentner 2005; Gentner and Grudin 1985).
Psychological studies suggest that these kind of explanatory or 'generative' analogies involve the mapping of primary relationships and properties (but not contingent ones, like size and color) from the known **source domain** to the unknown **target domain** (Gentner and Miall 1981) allowing scientists to make meaningful predictions (Gentner and Gentner 1982).
For example, the model of electricity as fluid…
…spawned useful metaphors such as 'the *flow* of an electric *current*'.
WATER SYSTEM
SOURCE / BASE DOMAIN
PRESSURE across
FLOW of
NARROWNESS of
RESERVOIR
WATER
CONSTRICTION
connects
PIPE
connects
ELECTRIC CIRCUIT
TARGET DOMAIN
VOLTAGE across
FLOW of
RESISTANCE of
BATTERY
ELECTRICITY
RESISTOR
connects
WIRE
connects
PIPE
PUMP
WATER
(wet, cold, transparent)
PRESSURE
NARROWNESS
FLOW
METAPHOR
WIRE
BATTERY
ELECTRICITY
VOLTAGE
RESISTANCE
CURRENT


Such examples lead authors like Leatherdale to conclude that:
"[the analogical act] provides a new perspective, new possibilities of description, new horizons to explore." (Leatherdale 1974).
An idea echoed by Gentner who suggests that:
"it may well be that it is precisely in the process of turning an initially vague, rich, multipurpose feeling of analogy into a well-clarified model that much of the creative process in science takes place" (Gentner and Miall 1981).
Similarly, Brown places metaphors at the center of scientific models and 'revolutions' (Brown 2003; Kuhn 1979).
Many authors (Leatherdale 1974; Aubusson, Harrison, and Ritchie 2006) have also highlighted the strong 'imagery' component of metaphors, so much that they are commonly refereed as:
figure of speech
The difficulty we have in communicating complex scientific phenomena, that go beyond our scale of understanding...
...may then be partly explained by the lack of good metaphors and visual models.


It is interesting to note that cartooning has often been described as a deeply metaphorical form of drawing (McCloud 1994; Forceville 2016). Since everything in a comic is filtered and simplified by the artist, even the most 'realistic' comic can be read as a metaphor of the real world (Wolk 2007).
For this reason cartoonists have developed a rich vocabulary of marks and symbols, partly borrowed from traditional diagrams (Tversky et al. 2000; Tversky 2011). aimed to translate onto the page invisible entities:
such as movement and emotions (Cohn 2014; Juricevic and Horvath 2016; Cohn, Murthy, and Foulsham 2016).
UPFIXES
IMPACT FLASHES
RIBBON PATHS
MOTION LINES
EMOTIONAL RUNES
All these factors make comics an ideal format to build extended conceptual metaphors, which may be used to visualise complex scientific ideas (Sousanis 2015), and mediate communication between experts and the public (Negrete 2013; Wysocki 2018), such as in the well studied field of Graphic Medicine (Green and Myers 2010; Czerwiec et al. 2015)
COMIC


This is not to say that visual metaphors are a catch-all solution for science education and communication (E. Pauwels 2013; Aubusson, Harrison, and Ritchie 2006). First of all, the interpretation of both metaphorical and sequential images is culturally-dependent (Schilperoord 2013; Cohn 2016). Moreover, even if a metaphor is understood, it does not necessarely mean that it is a 'useful' metaphor. Gentner distinguished between:
ill defined **expressive** (i.e. literary) analogies...
...and **explanatory** analogies, in which the set of features mapped from the source to the target domain are both clear and systematic (Gentner and Miall 1981).
The history of science is full of misguided and potentially harmful metaphors (Keller 2009; Sontag 2001)
?
PREVENT
FIGHT!
Indeed, recent studies show that metaphoric framings may negatively affect the way people engage (and possibly behave) in relationship to health and ecological issues (Hauser and Schwarz 2015; Flusberg, Matlock, and Thibodeau 2017).


Finally, when it comes to education, while mental models can aid understanding (Aubusson, Harrison, and Ritchie 2006) and problem solving (Gick and Holyoak 1980) they also necessarily distort and obfuscate the target domain (Kampourakis 2016).
?
Overxtension of metaphors may lead to erroneus predictions (Gentner and Gentner 1982), and concepts learnt through metaphors may be difficult to generalise to real-world scenarios (Weitkamp and Burnet 2007).
+
=
However, this is true to some extent of every scientific visualization. Even the best microscope pictures usually involve several distortions, such as 'fixing' a tissue, to freeze the molecular machinery in place, or 'staining' a cell to make it stand out amongst all the other cell types.


In conclusion, just like microscopes, metaphors enable scientists to visualize the invisible, bringing into focus
useful details
while
blurring others.
In order to learn how to use these metaphorical lenses more effectively, and prevent 'runaway metaphors' (E. Pauwels 2013) scientists need to work with expert communicators and think more critically about their choice of metaphors.
More empirical studies are also required in order to determine the effects of metaphoric framing on public understanding and engagement with science.
What constitutes a good science metaphor?
What is the right balance between novelty and clarity?
The tradition of science comics (Tatalovic 2009; Farinella 2018) and other forms of visual explanations (Tufte 1997, 2001) may offer useful insights to some of these questions.

Visual References

Page 1 – Portrait of Antonie van Leeuwenhoek and copies of the drawing of a grey dronefly and a flea from Robert Hooke's *Micrographia* (1667).

Page 2 – Potrait of Ernst Haeckel and copies of some of his drawings, collected in *Arts Forms in Nature* (1899).

Page 3 – Copy of *Monster soup commonly called Thames water, being a correct representation of that precious stuff doled out to us!!!*, a Satirical print by William Heath, published by Thomas McLean (circa 1828).

Page 4 – Portrait of James Clerk Maxwell, famous for his equations of electromagnetism.

Page 5 – Portrait of James Clerk Maxwell, famous for his equations of electromagnetism.

Page 7 – Copy of *Krazy Kat* by George Herriman (1880–1944).

Editorial Note

This article is part of the Graphic Science Special Collection edited by Nicolas Labarre and Ernesto Priego.

Competing Interests

The author has no competing interests to declare.

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