Bridges between Science and Humanities

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By

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Dedicated to
Fulvio, my partner

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PREFACE

A group of kids is staring at a weird lady in a science outreach event in Paris. She asked them what a mathematician is. They don't know.

"Well, did mathematics always exist as it is or did people invent it?"

They are surprised. They look at each other trying to find confirmation of their instinctive answer. They all agree. Mathematics always existed.

"Well," continue the lady, trying to create a sense of suspense, "actually, it didn't!"

They are flabbergasted. She goes on explaining how at the time of her favourite character, Asterix, people counted with a terribly inefficient system, the roman numbers, and how lucky they are to be born after Leonardo Fibonacci came back to Europe and taught to everyone he could the system he learned when he went to school in Béjaïa—now Algeria—where they knew a far better system because they learned it from the Indians, who invented it.

"That's what a mathematician does. They make up mathematics."

Needless to say, I am the weird lady in this story.

As a scientist, I am always baffled to learn how the general public tends to imagine science as a monolithic rock of certitudes and rules, almost immutable through the passage of time, insensitive to the existence of humanity or its extinction. A far from accurate picture, of course.

Science is a human creation, a result of our irrepressible never-ending desire to understand the world around us. As any human creation, it requires creativity and imagination. Science has a language. As any language, it evolves over time and can be biased by our preexisting experience. History of science is intertwined with the often-dramatic lives of the scientists who created it, and with the history of the society who is supposed to support their work, to understand and share their discoveries, to elaborate and pass knowledge down to the next generation.

Maria Rosa Menzio gifts us with a book where this complexity is rendered. We can read about science going through quiet times and dramatic revolutions, we learn about passionate debates around ideas, or down-to-earth fights about stolen formulas; we are puzzled by the experiment that doesn't match predictions, but everyone ignores it.

We are challenged to view science as a narration, making use of mathematics as well as metaphors.

Walking us through examples in science history and through the thinking of philosophers, Menzio enables us to see the many similarities between the creation of art and science; she shows us the poetry in scientific ideas and the irrationality in their making.

In short, Menzio show us how humanities and science are far from being disconnected lands. I wish the reader a pleasant journey across the many bridges connecting them.

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INTRODUCTION

We speak of points of contact between Science and Humanities. Science enters the novel without the division between the two cultures that was the focus of a debate in the late 1950s. One can treat scientific discoveries with the same categories one uses for fairy tales; moreover, metaphor enters scientific demonstrations more deeply than it appears. We want to break down the preconception that the two cultures are absolutely separate fields.

From science according to Karl Popper to literature according to Bertold Brecht, a path is constructed between the two disciplines that leads to an original interweaving of the two fields: the emotion a novel provokes in us can be compared to the pleasure a flawlessly demonstrated theorem gives us. People who read a novel hear about a beautiful fiction, but they know perfectly well that it is fiction, so there is no deception, but truth. On the other hand, science is thought to be the holder of absolute certainties. However, if we want not only truth, but also a truth that is beautiful and interesting, then we discover in science an infinite poetry, and this is important for scientists and humanists alike.

CHAPTER ONE

SCIENCE AS A FAIRY TALE

I consider science to be a special branch of literature and this consideration can be seen in two ways.

The first suggests that there is an infinity of worlds (multiverse). Science deals with the phenomena that happen in our world, while literature talks about the events that happen in all the infinite possible universes.

The second way is more complex. It does not concern the narrative character of important works in the history of scientific thought. Nor does it concern the central role of the anecdote in describing the process leading to scientific discovery. It concerns the scientific works that are published, even with their cold, standardised, serial language. As the philosopher of science Paolo Rossi says, adjectives such as “serial, cold, standardised” also comprehensively describe a large slice of fiction. On the other hand, a scientific article tells a story, which may turn out to be boring or exciting, original or not, well written or not, in any case still a story.

Faced with this second way of looking at things, there are in turn two possibilities that are “classes of criticism”.

The first is that of those who, speaking of scientific articles, say that they are almost always written in formalised language. One can retort, as Paolo Rossi himself says, that

> … the same can be said of the Disk of Phaistos, in the Museum of Heraklion in Crete, which no one can read, because it was written in a code known only to insiders, who are all dead since three thousand years. Yet I find it hard to doubt that the Disc tells a story, even if we will never know which one.[1]

The second objection is more technical: it states that scientific articles talk about facts and not feelings. One can retort thus: even hard facts can be considered feelings. In fact, “sentiment” derives from “sentio”, a word that

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[1] Paolo Rossi, “Tutta la Scienza è Letteratura”. In *Terza Cultura. Idee per uno sviluppo sostenibile*, edited by Vittorio Lingiardi and Nicla Vassallo (Milano: Il Saggiatore, 2011), 200-204.

is also at the root of the word “senses”, i.e. the only instrument with which we have access to “facts”. What distinguishes facts from feelings is sharing.

Sharing. Good.

To anyone wondering by whom and when America was discovered, the answer given is unequivocal: Christopher Columbus, in 1492, with the three caravels.

But are we really sure? A few centuries before Columbus, the New Continent had certainly already been reached by Scandinavian navigators, more commonly known as Vikings. On the basis of some archaeological findings, it has been assumed that Phoenicians, Romans and other peoples had already reached the American continent.

The ancient texts of the Nordic sagas tell the story of the Scandinavians. Around 980, a navigator, Erik the Red, sailed from Iceland to the coast of Greenland with a handful of men. The group settled on the island and remained there for three years. On his return, Erik recounted his discovery and called the island where he had stayed “Greenland”: it was not the right definition, the island being more white than green, but he chose an “attractive” name to encourage his compatriots to colonise. So, the discovery of America is a historical judgement, not a “fact”. And there is also precise evidence.

On the 20th of October, 2021, it was proven that the European presence in America pre-dates Columbus[2]. It was the Vikings in the year 1021 who led the way, at the site of *l’Anse aux Meadows* (in the northern peninsula of Newfoundland, Canada).

As early as the 1960s, the first evidence of the Vikings' presence on the American continent was found: it happened when the remains of the colony at l'Anse aux Meadows were discovered. But there was no certainty about the dating, which was only recently arrived at thanks to a particular study. A microscopic detail of a wood fragment from L'Anse aux Meadows shows traces of the growth rings of the trees from which the wood was obtained. It all started with the discovery of wooden remains that were unmistakably worked on with iron, a material that was unknown to Native Americans. Now, by analysing the growth rings of the trunks of the wood used, traces have been identified (on plants that were found in various areas of the planet at that time) of an extremely violent solar storm that affected the Earth in 992 AD. Further calculations have allowed us to confidently date the settlement to 1021.

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[2] Margot Kuitems, Birgitta L. Wallace, Charles Lindsay, Michael Dee and others, *Evidence of European presence in the Americas in 1021* (London: Springer Nature, 2022), 388-391.

Now let us do a little history of science.

Aristotle explained to us that the Sun revolves around the Earth and bodies, as they fall, travel at a constant speed proportional to their mass. Good. Then came Galileo and Newton, according to whom it is instead the Earth that revolves around the Sun, and that gravity produces uniformly accelerated motion. Great. In the last century we had Einstein, with another result: since the Sun and the Earth are both freely gravitating, then they are both good inertial reference systems, and the two previous statements express just two points of view. So, the theses of science have a precise meaning in a certain, historically determined context, and out of context they lose meaning, and become "opinions", or "sentiments".

As the epistemologist Paolo Rossi says (ibid)

> the truth content of **F = ma** is almost the same as that of "*l'Amor che move il sole e l'altre stelle*" [final words of "The Divine Comedy"]. They are both statements on the causes of motion, in which some terms are taken from sensible experience (acceleration, the sun, the stars) while others (force, mass, love) are defined by the proposition itself, which can only be used for predictive purposes by having recourse to a "knowledge of the world" that admits of no formalisation, but only revelation. Newton, when enunciating the Law of Universal Gravitation, premised the specification "Everything happens as if".

Recall that in the film "The Sword in the Stone", there is an interesting conversation between King Arthur and the Wizard Merlin:

ARTHUR	What is gravity?
MERLIN	Gravity is what makes you fall.
ARTHUR	Like a stumble or a trip?
MERLIN	No, it is the force that pulls you down, the phenomenon whereby two particles of matter or bodies, if free to move, are attracted towards each other.

And later (while both are turned into squirrels):

MERLIN	This love business is a very powerful thing.
ARTHUR	Stronger than gravity?
MERLIN	Well, yes, I would say it is the greatest force on earth.

Let us now ask why science has a different reputation from the humanities. On the one hand, that of ethics, it is superior to them; on the other, that of emotion, it seems to have no appeal. Why?

Paolo Rossi explains that "scientific language is a form of magical language, aimed at the domination of reality by means of words".

In fact, the word formula, used by scientists as well as sorcerers, appears ambiguous.

The same Paolo Rossi reminds us that:

> Archimedes runs naked out of the bath shouting "Eureka!" because he has intuited the principle that still bears his name. Galileo sets out to measure the oscillation time of a lamp using the beats of his own wrist as a clock. Newton sees an apple fall and realises that the force that made it fall is the same force that keeps the Moon in orbit around the Earth. Fermat has no space and Galois has no time. Max Planck observes the black windows of a sunlit building and has the first insight into the quantum theory of the black body. Einstein sees a bricklayer fall from a scaffold, ascertains that the man is safe, asks: Did he feel a force pulling him down? and from the negative answer thinks of the equivalence principle. Schrödinger goes to the mountains and comes back with the equation Hy = Ey.

I think this is a "beautiful fairy tale"!

Chapter Two

Difference between Science and Literature

In Etruscan bas-reliefs and high reliefs, festive events, music and dances are often depicted. In this context, the figure of a musician playing two flutes sometimes appears. The guides of the Arezzo Museum (the one in Valerio Massimo Manfredi's novel “Chimaira”) speak of a story, much more than a legend, but certainly something less than a documented reality. Yet it is so beautiful and poignant! In fact, they say that with each of the two flutes, each artist played a note, just one note: and the note of the first flute went straight to the right side of the brain, the note of the second went straight to the left side, to eliminate the caesura between humanism and science... and it was “the key that opened a door”.

Charles Snow began in 1959 by talking about “two cultures”, meaning humanism and science, and went on to state that “The number 2 is a very dangerous number. Attempts to divide everything into two – must be regarded with great suspicion”.

According to him, culture is divided into two branches: on one side is humanistic culture (which in the book is called “literary”), and on the opposite side is scientific culture: these constitute, Snow points out, two divergent poles. Divergent because scientists prefer a rationalistic view of the world and therefore disdain the humanities, especially literature. On the other hand, the literati retaliate with similar behaviour: for them, true culture is independent of science, indeed it sometimes becomes anti-scientific.

For some years now, reference has also been made to the third culture: what is it?

John Brockman first spoke of it in 1995: it is a unitary vision of knowledge, not unlike the beautiful cultural unity of the Renaissance. According to the author, today it is the scientists themselves who are the representatives, authors and promoters of this “third culture”; it is they who want to save the world through a new humanism.

I would add something more: the third culture is the "three hundred and sixty degrees" view from above of the links that the two cultures weave, and the wonder they induce.

In "What do You Care What Other People Think?" Richard Feynman, a physicist who certainly wanted a scientific age, wrote:

> Is no one inspired by our present picture of the universe? This value of science remains unsung by singers: you are reduced to hearing not a song or poem, but an evening lecture about it... Perhaps one of the reasons for this silence is that you have to know how to read music. For instance, the scientific article may say, "The radioactive phosphorus content of the cerebrum of the rat decreases to one-half in a period of two weeks." Now what does that mean? It means that phosphorus that is in the brain of a rat—and also in mine, and yours—is not the same phosphorus as it was two weeks ago. It means the atoms that are in the brain are being replaced: the ones that were there before have gone away.
>
> So what is this mind of ours: what are these atoms with consciousness? Last week's potatoes! They now can remember what was going on in my mind a year ago —a mind which has long ago been replaced.
>
> To note that the thing I call my individuality is only a pattern or dance, that is what it means when one discovers how long it takes for the atoms of the brain to be replaced by other atoms. The atoms come into my brain, dance a dance, and then go out—there are always new atoms, but always doing the same dance, remembering what the dance was yesterday.[3]

Incidentally, have you ever wondered whether Sophocles idea (Oedipus) or Einstein (Relativity) made a greater contribution to humanity? I answer that from the tragedy of Oedipus (a man who kills his father and falls in love with his mother) all modern psychoanalysis was born, while from Relativity came GPS, successful films, and books. Which of the two cultures has most influenced the other? And what links are there between these two fields of knowledge?

It is precisely these links that this essay deals with.

Readers, at the beginning, this essay seems to go on in a consequential way, then things get complicated: the book continues as in a tree or an encyclopaedia, i.e. each part of the volume links to many others. And it could not be otherwise, given the subject matter.

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[3] Richard P. Feynman, *What Do You Care What Other People Think: Further Adventures of a Curious Character* (New York: W. W. Norton, 1988), 244.

To talk comprehensively about the relationship between the two cultures, I would like to touch on the topic of "lateral thinking."

"Lateral Thinking" is opposed to "Vertical Thinking": the latter is what we use whenever, faced with a problem, we follow a line of reasoning that leads us to the solution by successive steps, reducing the complexity at each step. A typical example of vertical thinking is that which we use to search for the result of an arithmetic or algebraic expression, not necessarily complex but dense with parentheses and small calculations with fractions and power elevations, all executable individually without any difficulty, to which we substitute the partial result each time to arrive at the final result.

Vertical thinking, when applicable, leads to a certain solution to any problem, provided we do not make any mistakes in the successive steps.

Let us now consider the following problem, quoted by Edward De Bono[4]. This example shows us what it means to approach a problem using lateral thinking as an alternative to vertical thinking. Imagine you are the organisers of a knockout tennis tournament in which 111 players have entered; how many matches will be played in this tournament?

The problem is quite easy. Let us imagine the first round of play and count fifty-five matches, as many winners and one player who—by draw—is allowed to pass the round without playing; in the second round of play there will be twenty-eight matches, fourteen in the third and so on until the last match that decides the winner.

The sum of the games played in the various rounds gives us the answer to the problem. Simple enough, after all.

Reasoning in this way certainly leads to the solution but it takes a certain amount of time. Let us then try a different approach, applicable from the first step.

Instead of considering the players trying to win, let us consider the losers after they have lost.

There is only one winner and there are 110 losers. Each loser can only lose one game, the one in which they are eliminated. So, in the tournament of which you are the organiser, a total of 110 games are played.

To understand the power of lateral thinking, let us consider another problem and the two possible ways to approach and solve it.

[4] Edward De Bono, *Lateral Thinking for Management* (London: Penguin Books, 1982), 7-8.

Two cities—A and B—are 100 km apart and are connected by a railway. At the same instant, two trains—Alpha and Beta—depart, one going from city A to city B, and the other in the opposite direction.

The first train travels at 80 kilometres per hour and the other travels at 120. A fly is placed on one of the two locomotives and sets off with the train flying at 200 kilometres per hour in the same direction; when it encounters the opposite train it reverses course and flies towards the train from which it had set off, encountering it, it flies back and so on, zigzagging, until the two trains collide. The question we ask ourselves is: how many kilometres has the fly travelled in its wanderings back and forth?

The use of vertical thinking leads to the solution, but in this case in a rather complicated way. It is necessary to add up the various zigzag paths of the fly itself until the distance cancels out. It is even necessary to introduce the concept of "limit". Lateral thinking, on the other hand, provides the answer with a simple consideration: having calculated that the trains meet after half an hour, the fly has travelled 100 kilometres! This is in fact the distance the insect can travel in half an hour travelling at 200 kilometres per hour.

This second way of "attacking problems" is simpler, perhaps more intriguing, and often less tedious, especially since it is not necessary to carry out all the steps without fail.

When the problems are not of a mathematical nature, the differences between the two ways of thinking are not always so obvious; on the other hand, it is always true that vertical thinking consists of setting up a "strategy" for solving the problem and following the ensuing reasoning step by step, excluding the precluded paths and following only the possible ones until the final solution, which is not always attainable.

Using lateral thinking, on the other hand, it is not always necessary to have a "strategy", to know a priori the path or technique by which to reach the solution. It is not necessary to exclude the obvious, indeed, sometimes this is where the answer lies. Nothing is, a priori, right or wrong. Sometimes it is precisely by using paths that seem too obvious to us that we reach the "goal": to say that one tennis player wins and the others lose is the obvious statement that leads us to the answer to the problem.

One can undoubtedly say that vertical thinking is analytical. Lateral thinking can perhaps be called provocative. Thinking laterally requires "doing research", even going down paths that, with vertical thinking, would have already been discarded. Lateral thinking is a way of proceeding through imagination.

Beyond the examples cited, it is interesting to note that the practical application of lateral thinking and, above all, how it works, cannot be fully rationalised. The best way to act when faced with a problem is to use both, with the latter intervening whenever the former fails. The case of the tennis players is emblematic: only the intervention of vertical thinking manages to validate the result arrived at by lateral thinking.

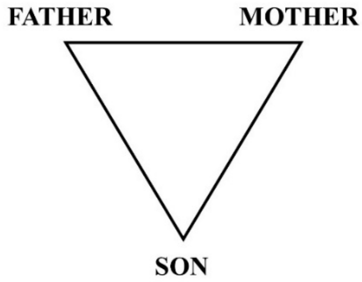
To make the best use of lateral thinking requires an open and unprejudiced mind. Vertical thinking proceeds in consecutive steps, lateral thinking can jump. Proceeding vertically, one may perhaps skip a few "steps" but it is as if one were always walking down the same staircase. Laterally, one can move through space and time in one's mind until one finds a way that leads to the solution.

Speaking about lateral thinking, we must also mention brainstorming, which should be the way to solve a problem laterally, especially when there is no straight path to follow, i.e. vertical thinking is not clear.

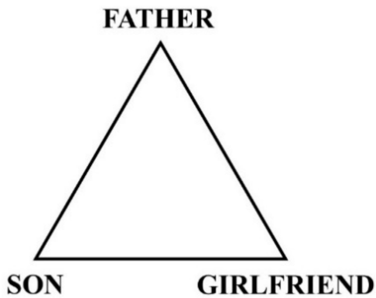
What moves vertical thinking is certainly reason, what moves lateral thinking could also be "elegance" in addition to reason. I believe that the dissemination of science is very often based on works that act in this way on the reader's mind.

Let us address, as if we were soldiers, the subject of "theatre". Well, everyone has seen comedies, or tragedies. What is the difference between one and the other? Many simply answer that comedy has a happy ending, while tragedy usually ends in carnage.

I would like to illustrate the classic pattern of the two genres with a "psychoanalytic", triangular genre model. Think of Oedipus Rex: there is a father, there is a mother, who have a child. It is foretold that the newborn child will be the cause of terrible misfortunes for themselves and their family, and it would be better to get it out of the way. The parents entrust him to another couple, asking them to keep the secret. Years go by: at a crossroads of fate, for some kind of "right of way" the son quarrels with a man and kills him. He does not know, and will only find out later, that it is his father. More time passes, and the young man arrives in a city whose queen is a beautiful woman. He falls in love with her and marries her. Sometime later he learns the terrible truth, the horror: he has killed his father and married his mother. Desperate, he blinds himself. The tragedy is thus the defeat of the father by killing: and we have much to do with cosmogonic myths (e.g. Greek, think of Chronos, or Saturn, lord of Time).



In the comedy, on the other hand, (think of Goldoni or Marivaux) there is always a father, there is still a son, but the woman this time is the son's fiancée, with whom the father also falls in love by adventure: and his defeat this time will not be caused by murder, but by the ridiculousness of the situation.



The son therefore has to defeat the father to get to love.

Poetry is the encounter of sound with sense, argues Paul Valery. But is this also true in other fields, for example, in science? Or does it?

At first glance we answer no, absolutely not, but then... Perhaps even in the hard sciences, like mathematics, the sound of a formula, hence its notation, its writing, must be beautiful and elegant. The formula $\mathbf{e^{i\pi} = -1}$.

Beautiful! Quite another thing compared to the hated (at least by me) *prostapheresis formulas* of trigonometry. Again, $\mathbf{E = mc^2}$ is pure poetry.

The speed of light and energy. Breathtaking. I did a survey of a thousand high school students: for eight years, for five classes of students a year, for almost thirty students in each class, I taught “Third Culture” and asked the students the following question: “what colour would you give to the formula of special relativity?”, “Flame red!”, my pupils answered.

I asked a similar question for Literature: What colour would you give to the lines of a poem? Let’s consider Henry David Thoreau's sentence[5]:

> I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived.

To most, the quote seems green, or green-orange, as my students used to say, in a series of lectures on the two cultures.

[5] Henry David Thoreau, *Walden: Or, Life in the Woods* (New York: Dover Publications, 1995), 60.

CHAPTER THREE

ARE "AWE" AND "WONDER" COMMON TO SCIENCE AND LITERATURE?

> As scientists, we do not seek highly probable theories, but rather explanations: that is, powerful and improbable theories.
> —Karl Raimund Popper, Conjectures and Refutations [6]

I would now like to make a note for those who draw up school curricula: among the pupils who, on the threshold of high school graduation, are entering university studies, all of them know Dante and Shakespeare and Homer, very few, however, know Lobacevsky or Riemann or Gauss. Why? Why is the history of literature or theatre studied at school and not the history of science? It might be interesting to study history by including the lives of the great men of science and anecdotes about their discoveries. Their existence is also studded with love, suicides, murders, duels, follies like that of other illustrious men and women. So, let us approach science from the life and manner in which scientists "did science"!

Let us think of a very simple, almost trivial example. I see in a restaurant a gentleman who sits at the table, drinks and uses the dishes while holding up the little finger of his right hand. It is probable that if I dislike the person in question, I infer that he has snobbish behaviour, whereas if I like him, I infer that he must have a broken phalanx. It's the same for scientific theories. Often choosing between one explanation and another of a phenomenon is really a matter of prejudice.

Yes, I said prejudices: the very thing that science has always struggled against, but which is now coming to the forefront of the new philosophy of science by telling us about prejudices, in a nutshell.

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[6] Karl Raimund Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (Hove: Psychology Press, 1974), 104.

In Galileo's time, one might have wondered if the Copernican theory was really that simple. Was it really simpler than the Ptolemaic one? But the question asked was anything but scientific. “I don't want to go against the Pythagorean table” said the future pope of Galileo's time. But in the end, it was just a question of power, of habit, of clerical indoctrination, of the centrality of the human being in the universe. Not of truth, provided we know what is meant by the word, whether phenomenon or noumenon.

No scientific theory ever completely agrees with the facts. This is often kept hidden by scientists, but it is absolutely true. This is one of the reasons for scientific progress. Between the reality we want to unveil (i.e. from which we want to remove the veil) and our human mind there is always a gap, an extra step of uncertainty or unknown.

What is Science?

Literature changes more slowly than science. It hasn't the same automatic corrective, and so its misguided periods are longer.

We are in a classroom, and a teacher questions a pupil. Let's imagine the questions and the answers...

TEACHER	What do you think science is?
STUDENT	The set of all those laws that govern nature. The scientist gradually “discovers” the mysteries of the world.
TEACHER	If you open a newspaper, you can read both the horoscope and the weather forecast. Both try to predict the future. So, they are both scientific?
STUDENT	No, because the horoscope is almost never right.
TEACHER	What is meant by saying that a certain law is verified?
STUDENT	What is meant is that I have done a fairly large number of verifications and luckily, I have always gotten it right.
TEACHER	Some 19th century astronomers, including Urbain Le Verrier, argued that it was necessary to predict an additional planet in the Solar System located between the Sun and Mercury to justify certain gravitational anomalies. The apparent mathematical necessity of this additional celestial body, called Vulcan, was overcome thanks to Einstein's theory of relativity. What do you think about this?
STUDENT	That no one had ever provided any evidence for the existence of Vulcan.

On Scientific Heresies

Heresy derives from the Greek *hairesis* (αἵρεσις), meaning “choice”, “propensity”. The first great “scientific” heretic was Aristarchus of Samos, from the 3rd century BC. Preceding Copernicus by almost two millennia, he was the first to say that it is the Earth that revolves around the Sun. According to him, the Moon, the Earth and all the planets revolve around the Sun. However, it is important to say that for him, the planets revolve around the Sun in circular orbits.

The earth, according to him, also has a diurnal rotational motion around its own axis, an axis that is inclined with respect to the plane of revolution around the sun, just as we say today.

And we should also note that at that time Ptolemy, the famous Ptolemy with his theory of the Sun revolving around the Earth, had not yet been born. Well, Ptolemy wrote his seminal work, the “Almagest”, almost half a millennium after Aristarchus' hypothesis.

The astronomers of the time were therefore free to choose between the idea of the Earth revolving around the Sun and the idea of the Sun revolving around the Earth, i.e. between geo-centrism and helio-centrism.

But it was the idea of the Sun revolving around the Earth that won the competition, and this idea was held valid for more than 1800 years. Even Archimedes, a contemporary of Aristarchus, rejected heliocentrism because Aristarchus believed the universe to be infinite: and this idea scared him. Why so much success?

The best astronomers of antiquity believed that there was no good reason to depart from common sense.

Good sense and common sense almost always prevail, even for an educated person. It is very difficult to deviate from habit.

The search for certainty is one of the constants in our lives as human beings. Scientists are human, and therefore, as Aristotle would argue, scientists also need certainty and abhor ideas that make scorched earth out of current beliefs.

Hipparchus thought that heliocentrism was wrong because it did not agree with the calculations: but what conflicted with the measurements was only the hypothesis of circular orbits of the planets around the sun. And this was the reason why Hipparchus rejected Aristarchus' heliocentric hypothesis. If the latter had thought about ellipses, we would not have needed Copernicus, Galileo and Kepler. But he did not think of them.

Why, however, did Ptolemy say that it is the Sun that revolves around the Earth? According to him, it was impossible for the Earth to move. Let us listen to a summary of what Galileo[7] said by having Ptolemy himself speak instead of Simplicio:

> This is the only way to explain what appears to us through the senses. For if the Earth did not stand still, but fell by the effect of gravity like all other heavy bodies, it would clearly leave them all behind it, because, being larger, it would fall faster, and all the animals and other heavy bodies would be left suspended in the air, while the Earth itself would very quickly fall out of the celestial spheres. Just thinking such things makes them ridiculous. Similar absurdities one is forced to admit if one ascribes to the Earth a diurnal rotary motion around its own axis. One would have to suppose, for instance, that a bird, as soon as it lifted itself off the branch of a tree, would be left behind several kilometres without being able to rest on the same branch, because the tree must follow the Earth in its rapid rotation. Similarly, if the Earth were really rotating around its own axis, a stone dropped from the top of a tower would not fall at the foot of the tower itself but several kilometres back. But we instead clearly see that all these phenomena happen as if their slowness or speed did not depend on the Earth's motion at all.

The Ptolemaic theory has convinced scientists for more than eighteen centuries. Almost two millennia, in fact.

Until the one who rejected it on aesthetic grounds: Copernicus.

Copernicus wrote “De Revolutionibus Orbium Celestium” and in 1543, on his deathbed, had the meagre satisfaction of seeing the first copy of his book published. He advocated the criteria of “perfection” and “simplicity” for scientific theories, similar to those in the philosophy of science today. Let us try to understand them.

Copernicus started from the “Alphonsine Tables”, only a couple of centuries old and derived from Ptolemaic theory. They had been compiled under the direction of Ishak ben Said and Yehuda ben Moshek Cohen in the year 1252 by order of Alfonso X, King of Castile and Leon.

Copernicus observed that their results did not match the experimental controls and observations at all. In short, the planets, Sun and Moon, had different positions from those predicted by the tables. The Ptolemaic theory had to resort to a complicated system, with dozens of epicycles, deferens, and equants. Epicycles are those small circles travelled by the planets in their movement around the Earth, characterised by having their centre on a larger circumference called the deferent circumference.

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[7] Galileo Galilei, *Dialogo sopra i due massimi sistemi del mondo* (Torino: Einaudi, 1970).

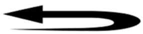
But if we say that it is the Earth that revolves around the Sun, the number of these circles is greatly reduced. This is precisely the “principle of simplicity”. Simple explanation rather than complicated explanation. Who would not agree to simplify their life?

On the other hand, to respect the “principle of perfection”, Copernicus remained attached to the idea of circular motion of the planets, which is why his theory turned out to be as approximate as Ptolemaic when compared to experimental data. According to the mentality of the time, the circumference indicated perfection, the ellipse did not. Part of this mentality still survives today. A single centre instead of two foci seems more interesting. One would have to understand why the symmetry of two foci is less attractive... However, it would be another sixty-six years before Kepler proved that the orbits of the planets are elliptical.

And speaking of “simplicity”, I would like to recall a passage taken again from Brecht's play “Life of Galileo”[8].

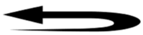
Cardinal Barberini, the future Pope Urban VIII, asks Galileo:

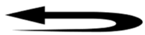
“But what if the Almighty had wanted to make the stars move like that?”

 [9]

And Galileo answers him:

“Then he would have provided us with brains that think like this”



so that we would believe that the stars, moving like this  ,

make the simplest possible movement”.

Theories and Observations

Is scientific observation always a fixed, immutable fact, or is it clothed in theory or—what is basically the same—prejudice?

According to the epistemologist Thomas Kuhn, only by moving towards a language based on the impressions of the eye, i.e. the retina, can we hope

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[8] Bertold Brecht, *Life of Galileo*, tr. John Willett (London; Bloomsbury, 2001).
[9] Hand gesture to indicate a messy movement.

for a neutral system of scientific information, to regain a world where experience is immutable for all.

From Descartes onwards, it has always been thought that first we perceive with our senses, and only then do we interpret nature. But this is not entirely correct. In reality, what perception leaves to interpretation depends on our previous experience, on our formation as individuals, on how much the past has conditioned our human mind. This is because, as Foucault argues, nature and words are known together. And this is the end of the Hilbertian dream of calculating everything. Also, because, as Samuel Delany showed in the 20th century, if you make a dictionary of the world, by the time you have finished, many new words have arisen and you have to name the dictionary, adding to it a word that, by adding to the others, changes it...

Seeing a house in the fog, indeed beginning to glimpse its outlines, do we realise that it is a house because it has doors and windows, or that it has doors and windows because it is a house? And then, how do I explain that it is a house? The meaning of the words in a sentence can be clarified through explanatory propositions, i.e. new words, but this process cannot go on indefinitely, and always finds its finale in ostension: my index finger pointing at what I see. Exactly as the cavemen did. The ultimate determination of meaning, therefore, always takes place through ostension.

Furthermore, Dante Alighieri was born in 1265. The encyclopaedia says so, indeed. But is it so just because the encyclopaedia says so, or does the encyclopaedia say so precisely because it is so? To those who ask if Dante was really born in 1266, we would hand the book over and say, “Look!”

It happens in the same way that scientific theories are often like snakes eating their own tails. Think of the concept of measurement, which presupposes a theory. The description of length measurements requires a theory of heat, which presupposes length measurements...

Today, there is no longer any distinction between observational and theoretical terms. The new language of the philosophy of science no longer separates the two. Not least because it is often the idea that imposes itself on the world, and not vice versa. Back in the distant past, more than half a millennium before Christ, it was observation that led Anaximander astray, suggesting that the Earth was cylindrical. Instead, it was theory that made him conclude, in a very modern and logical way, that the Earth is at rest, because it is not driven by any reason to move in one direction or the other.

Similarly, Newton was a man of thought rather than observation, in perpetual dispute with the real astronomer Flamsteed, who was obsessed with experience. In fact, it seems that the real Newton was more alchemist and theologian than scientist: from his “Treatise on the Apocalypse” came the goals and method that produced the “Philosophiae Naturalis Principia Mathematica”. He was convinced that the only way to reach truth was to master the figurative language typical of prophecy.

Kepler lived at the turn of the 16th and 17th centuries and actually worked on the universe more like a Kabbalist than a physicist. According to him, the fact that space had 3 dimensions was a consequence of the Divine Trinity. In one of his books, he outlined the score on which the planets play their universal concert: Saturn and Jupiter sing bass, Mars tenor, Venus and Earth alto and Mercury soprano.

Yet such an extravagant character managed to discover the three famous laws that are studied in school. Do you remember Kepler's three laws?

"Planets travel in elliptical orbits of which the sun is one of the foci. The vector rays of the planets sweep equal areas in equal times. The squares of the periods of revolution are proportional to the cubes of the major semi-axes of their orbits."

How did such a crazy head discover the three laws that bear his name? By crazy intuition. By randomly throwing out the most disparate, nay wacky, ideas and then checking.

Out of four or five thousand ideas, three had to be right.

In other words, Kepler worked through brain storming, as we call a meeting of creatives nowadays, in which everyone shoots out an idea and in the general cauldron of nonsense a really good idea is discovered, by the law of large numbers.

The appeal to common sense (Why does an object fall? Because there is nothing to hold it up, replies the peasant) was the basis, at first, of the polemic against Copernicus' followers such as Galileo.

But Galileo was a physicist as well as an astronomer, and was able to answer the objections put forward by Ptolemy. We make dialogue Ptolemy and Galileo, crossing centuries and defeating space and time together.