The Twilight of the Scientific Age

The Twilight of the Scientific Age

Martín López Corredoira

BrownWalker Press
Boca Raton

The Twilight of the Scientific Age

BrownWalker Press
Boca Raton, Florida • USA
2013

ISBN-10: 1-61233-634-5
ISBN-13: 978-1-61233-634-3

www.brownwalker.com

Frontcover image:
Twilight at the Teide observatory, Canary Islands, Spain.
Photo by Ángel Luis Aldai. Banco de Imágenes Astronómicas
of the Instituto de Astrofísica de Canarias

Library of Congress Cataloging-in-Publication Data

López Corredoira, M. (Martín), 1970-
The twilight of the scientific age / Martín López Corredoira.
pages cm
Includes bibliographical references and index.
ISBN 978-1-61233-634-3 (pbk. : alk. paper) -- ISBN 1-61233-634-5 (pbk. : alk. paper)
1. Science--History. 2. Science--Philosophy. 3. Science--Political aspects. 4. Regression (Civilization) I. Title.

Q174.8.L65 2013
500--dc23

2012050929

CONTENTS

1 LEITMOTIV

> "Yes, yes, I see it; a huge social activity, a powerful civilization, a lot of science, a lot of art, a lot of industry, a lot of morality, and then, when we have filled the world with industrial wonders, with large factories, with paths, with museums, with libraries, we will fall down exhausted near all this, and it will be, for whom? Was man made for science or science made for man?"
>
> – Miguel de Unamuno
> *Tragic Sense of Life in Men and in Peoples*

This quotation reflects quite accurately the main theme of the present book. Read it carefully, twice or thrice, think about it for some minutes, and then begin to read the following pages as a symphony whose *leitmotiv* is Unamuno's assertion. Just a few minutes, or even seconds, may be enough for the reader to realize the most important message that I want to develop, and its connection with the title *The Twilight of the Scientific Age*. The idea is simple: our era of science is declining because our society is becoming saturated with knowledge which does not offer people any sense of their lives. Nevertheless, in spite of the simplicity of this idea, its meaning can be articulated in a much richer way than through one sentence, as in the case of a symphony which develops variations on a folk melody. That will be the aim of this book.

There are several reasons to write about this topic. First of all, because I feel that things are not as they seem, and the apparent success of scientific research in our societies, announced with a lot of ballyhoo by the mass media, does not reflect the real state of things. Also, because the few individuals who talk about the end of science, do so from relativistic or antiscientific points of view, not believing that science really talks about reality, or they relate the scientific twilight to the limits of knowledge. However, there is a lack of works which question the *sense* itself of the pursuit of the truth among present-day thinkers. Of course, there are many humanistic approaches which simply ignore science, but ignoring is not the same as considering its sense or lack of sense. There are many well-prepared scientists or journalists who move in the world of science and consider it in their interactions with the rest of society, but

usually they focus too much on the scientific and technical details and do not go deeply enough into existentialist or subjective approaches. A wider vision of both worlds, those of the humanities and science, is necessary to undertake the task. I feel I am able to offer something of this sort, given my experience as both scientist and philosopher. It is not a matter of virtuosity in either scientific knowledge or other areas but a matter of being able to integrate a global view of the fate of our societies. Normally specialists are too focused in their narrow or biased views to offer a global analysis and feeling.

When we talk about the "sense" of something, we cannot undertake a pure analysis in objective terms as in a scientific study. The professional activities on those who dedicate their lives to natural or social sciences usually overlook the fact that, after all, human beings do not move because of *reasons* but because of *emotions*. As psychoanalysis claims, most of our actions are determined by unconscious impulses. And science itself is not an exception: It is made by men whose motivations stem from factors other than a mere pursuit of knowledge. We are not machines, we are not gods; we are just animals, very peculiar animals and very intelligent and curious, that make scientific enterprises work, but subject to multiple internal and external conditions.

Societies as a whole are also sensitive to motivation. As a matter of fact, not all societies developed science. And, as it is known, even civilizations which developed that world-view and that methodology of observing phenomena can decline and lose their interest for continuing the scientific activity. That happened in Western Christian countries in the Middle Ages. Were the Middle Ages a dark age? Possibly, from some intellectual points of view, but it was not the end of civilization. It was an era with plenty of resources to create magnificent things, such as cathedrals. There were means to carry out great advances in many areas. Christianity was not intellectually underdeveloped with respect to Muslim countries, and basic knowledge of Greek science was also present; however, with very few significant exceptions, there was not a great development of sciences in Christian Europe during nearly the ten centuries of the Middle Ages. Why? Maybe because people were not motivated enough to think about nature. Surely, religious context had something to do with this, and the philosophy associated with religion which was ordered to follow faith above all. But possibly this is not the full explanation: The great revival of science in the Renaissance

took place within similar religious creeds; also, the Muslim religion was not so different to Christianity and allowed in the Middle Ages a higher development of sciences, declining later when science in Christian countries began to dominate.

In our era, the conditions are very different to the Middle Ages. Nonetheless, in a not very far future, societies embroiled in a lot of survival problems (overpopulation, lack of energy resources, economical crises, global warming and other ecological disasters, wars, plagues, etc.) may begin to see research as an activity that is not profitable enough and may abandon pure science research. At the beginning, people will trust scientists to solve all their problems, as it happens now, but they will realize that science cannot satisfy all those expectations, and that the returns of hyper-millionaire investments are smaller and smaller, nations will reduce more and more the titanic economic efforts necessary to produce some tiny advances in our sciences, to a point where scientists will say that they cannot continue their activity with such small budgets; consequently, the research centres will begin to close, one after another. Is this the prophecy I want to develop in this book? No, I do not want to talk about prophecies. The future is uncertain and what I have described is only one possibility among many others. I want to speak about our present society, and the trends that can be observed now.

Normally, throughout History, thoughts occur in advance of acts. What we are observing around us now are the effects of an ideology which was in some minds many decades or centuries ago. There is a slow inertia in societies which makes them move at the rhythm of impulses that originated some generations back. Geniuses are in advance of their time; what is famous at any moment is representative of a tradition of old, worn-out ideas. Religions gained their maximum power and influence a long time after they were developed: Popes and priests in the Renaissance, embedded in corruption and malpractice, with much less idealism than the conceivers of the religious ideas, were dominant in a time in which the most important creators were pointing to other directions. Today, science and some of its priests occupy an important status in our society, and gargantuan amounts of money support them. A superficial view may lead us to think that we live in the golden age of science but the fact is that the present-day results of science are mostly mean, unimportant, or just technical applications of ideas conceived in the past. Science is living on its private income.

My interest is to lift the curtains behind the stage of science, and see what is going on in the engine room. If we want to ascertain which will be the next performance on the stage, it is better to see the organization from inside rather than just assisting with the show. In any case, I insist, I am not a prophet and it is not my mission to say how the future will be. Also, it is not my mission here to give a report of all the observed trends and ideas around the world of science. What I will offer is my personal view, not necessarily reflecting the views of all conformist and non-conformist present-day thinkers.

The *leitmotiv* is a simple melody. Its harmonization with other melodies and rhythms and the orchestration which integrates all the voices is a more complex thing. As in Wagner's operas, we pursue an infinite melody: A continuous flow where the main melody gets lost among instrumental and human voices. The question of the sense or non-sense of the human endeavour called science must take into account many circumstances. The exhausting of important ideas to explore, the limit of knowledge, is part of the matter. The excess of information is another part. But there are more questions to tackle. The question about the sense of all this stems from those different sources, like a river that takes water from its tributaries, and also from the need for introspective reflection. From time to time, it becomes necessary to go away from the river and contemplate it from the shore. Where does the river go? To the sea, we shall answer. And what for? Is it to achieve Truth? Is it to dominate Nature? What for? For whom? Was man made for science or science made for man?

Thinking about the role of science in present-day society is thinking about the past and the future of humanity. Human beings must question from time to time all their principles and their usual ways of life. There is nothing sacred and untouchable. The missions that science had in the past have been totally accomplished, or almost totally. Now, it is time to reflect anew on our society for the future, not only science but also many other activities or concepts: Art, religions/sects, History, universities, economic systems, political systems, human rights, etc. Very few things are permanent, and all of them are biological, such as taking food and water, sleeping, having sex, etc. All cultural things are subject to change; there is nothing eternal in them. From an anthropological point of view, all the characteristics of our civilization are simple features of the human specie in a given period of time and a given geographical localization.

Certainly, the success of Western culture, with the subsequent annihilation of other cultures, has expanded the geographical location of our civilization to the whole planet, and this might lead us to think that our concepts, such as the so-called human rights, are absolute and universal. A mirage, an illusion! We just live our moment of glory, such as those of many empires which have absorbed great portions of land. The Roman Empire and the Egyptian civilization were greater than us; they lasted longer periods of time, dominating relatively large portions of land for that era. They were perhaps as proud as we are of our Western culture but they eventually declined. Now, it makes no sense to us to bury and embalm the pharaohs under pyramids. Possibly, future civilizations will not see any sense in building huge particle accelerators or telescopes.

You may think that the pharaohs were wrong in their belief that they could preserve life after death, whereas we are right in our scientific truths. I agree. I am not a stupid cultural relativist: Of course, atoms exist and they are constituted by subatomic particles; of course, galaxies and stars exist. But the question is not about the truth of scientific assertions but about the place these truths occupy in our lives as human beings. In the Egyptian civilization or in our civilization, we are moved by our beliefs about what are the high values for our lives. The pharaohs believed that the great architectonic efforts of their people were worth it because that would allow them to be closer to eternity after death, and to show their status on earth too. Scientists believe that dedicating their lives to scrutinizing the laws of nature and making a complete catalogue of all the existing forms of matter, either inert or alive, will bring them closer to something eternal: truth; and make some profit on earth too... But then a question like that of Unamuno arises: "when we have filled the world with industrial wonders, with large factories, with paths, with museums, with libraries, we will fall down exhausted near all this, and it will be, for whom?" Is not it like the child of the tale *The Emperor's New Clothes* that wakes us up from our dreams?

Behind the search for something permanent in our lives, something eternal, something absolute, there is most likely some fear of death. Death is an unavoidable topic if we are going to talk about the sense of some activity for our lives, or the sense of life itself, because precisely our certainty of the finiteness—and indeed very short compared to our aspirations—of our lives pricks our need to search for a sense. We waste our time: we will never find any sense in terms of eternity, but culture is fed mostly because of these aspirations, so

the belief is not a bad business at all. Indeed, culture might be understood as the attempts of a civilization to alleviate the tension of the uncertainty which produces our certainty that we are going to die. From this psychological point of view, science is just one of the performances of this tension on stage among many possibilities.

History shows us many dawns and twilights in the different facets of human beings. Looking at the past we can date and understand the reasons for the birth of science. We do not know when its twilight will occur, but the reasons for it are already in the air: after a very hot summer always come the season for the drop of leaves.

1.1 Who has written this book and in which circumstances?

Any book is written by a person or a team of people. It is not something sent by Heaven. And knowing who has written that book is usually an important reference for the reader. Usually, introductions are added to the books, with a description of the author; this is very frequent when it is a classical text and the author is long since dead. For the present book, I prefer to write this introduction myself rather than letting other people to do it. Whether it is read by my contemporaries or by generations after mine, I consider that it is appropriate. I consider that an author must be explicit about all the contents to be transmitted to the reader, and should not wait for somebody else to interpret the messages in terms of biographical aspects. In my opinion, those persons dedicated to writing introductions of books of other more important or classical authors should become jobless. Culture should not be a milk cow on which to grow fat, giving employment to some individuals who cannot produce original ideas and have to make their business with the ideas of others. Whether this book becomes a classic text is difficult, but if it does, the fact that it will not be used to feed the stomach of some mediocre intellectual will be a satisfaction for me, i.e. it is my will that no introductions or footnotes or complementary explanations trying to explain the contents be added to the present text.

I am a Spaniard, born in December 1970 in the town of Lugo, and I have lived in my country most of my life, except for two years in Switzerland and short stays in many other countries. I consider that my education was sound, very good if we compare it with the present-day educational programmes in my country. Secondary school was, in the '80s in Spain, still a way to receive a good ground-

ing in many disciplines. Later, I studied Physics, with the speciality of Astrophysics, and graduated in 1993. One year before the graduation, I began to get in contact with various institutes of research through a special grant for outstanding students of final-year courses, in Villafranca del Castillo (Madrid, Spain). There I remained for two years, working and learning things from various theoretical physicists and astronomers in different fields, and developing a postgraduate work on theoretical cosmology. In 1994, I moved to the *Instituto de Astrofísica de Canarias*, where I carried out my work to earn a Ph.D. in Physics in 1997, on the structure of the Milky Way and stellar populations. I think I hold the record at my institute for a Ph.D. obtained in the shortest time: 2 years and 10 months. This was a totally different work from my previous one on theoretical cosmology; rather it was mainly about observational astronomy, although with some application of statistics, which included diverse calculations. This change of orientation allowed me a wider view of astrophysics, including many subfields (stars, galaxies, cosmology) and many techniques (analytical calculations, computer simulations, statistics, photometrical and spectroscopical observations, analysis of data, etc.). After that, I continued with astrophysics as postdoc for 10 years, most of them in the same institute except of two years in Basel (Switzerland). During this time, I worked mainly in the fields of: Milky Way structure, galactic dynamics, large-scale structure of the universe, quasars, and some aspects of the fundamentals of observational cosmology, publishing more than 50 papers in international refereed journal, most of them as first author. Although most of my papers are quite conventional for a professional astrophysicist, there are many of them (maybe 10-20% of them) with a substantial degree of challenge to established ideas. This brought me some fame among my colleagues for holding unorthodox views. Indeed, most of my works are quite orthodox. And indeed, although I have expressed several times my scepticism about some orthodox ideas, in particular about the Big Bang hypothesis in cosmology, I am not an anti-Big Bang cosmologist, as many people have thought. I do not defend any alternative theory. Scepticism, doubting a dogma, does not mean that a new dogma should be defended to substitute for the first one. The opposite thing of dogmatism is criticism rather than a new kind of dogmatism.

Simultaneously with my scientific activities, I developed other activities related to philosophy. In secondary school, I took good introductory courses on some philosophical problems and the

history of philosophy. Unfortunately, these courses are disappearing from the educational programmes, becoming in some cases only optional subjects, but I lived in a time and a country in which even "pure sciences" educational programmes in secondary schools included courses on philosophy. The speed of cultural decay of our societies is quite fast, and a generation is enough to appreciate very significant changes. Even in Germany, perhaps the country with the strongest tradition in modern philosophy, it has disappeared from general educational programmes in secondary schools, with Germany becoming a country in which most of the citizens do not know the great thinkers of their country. Possibly this barbarization is an indirect consequence of the right of the winner of a war (Second World War) to impose its criteria: the democratization of culture. Certainly, the criteria of market competitiveness tend to force the educational system towards a specialization in which scientists only know about their speciality and very little or nothing about other fields. In Spain, this "barbarity of specialism", in the words of the Spanish philosopher of the first half of the twentieth century José Ortega y Gasset, is quite notorious now, but 25 years ago there remained still some sense of the long tradition in humanities in this country. I will talk further about the peculiarity of Spain with respect to other northern European countries in the intellectual tradition, but in later chapters, when I talk about Unamuno. The case is that I was educated in a place and a time in which science was becoming increasing important and many resources were rapidly increasing to open many research institutes, and a time in which a good knowledge of history, literature, philosophy, etc. was given to science-oriented students. This does not mean that I lived in a cradle of culture, but compared to the present generations of teenagers, the level was much higher. Actually, in the time I was in high school, when I was a teenager, I was more devoted to science and did not pay too much attention to the humanities. However, once I began my career as physicist I began to worry about subjects in the humanities, mostly philosophy, and the education I had received previously was very useful in choosing the appropriate classical authors to read.

I realized that philosophy was touching some of the questions I was interested in tackling intellectually, which sciences did not touch. Certainly, my way of thinking was that of a scientist, very close to rationalism and logic. I hated those plays on words, that wordiness typical of discourses in philosophy which take too long to say very few clear things. Nonetheless, I realized soon that among the myri-

ads of mediocre intellectuals with nothing interesting to say, there were some lucid thinkers with clear thoughts and very interesting ideas, mostly among classical authors. Indeed, what I read during my years of self-formation when I was 19-23 years old were classical philosophers. This marked my ideas as a philosopher in many senses. First, because my formation as a scientist was at a professional level while most of the philosophers just know about science through popular science journals and books at most; second, because I have followed my own way in the selection of reading matters, away from fashion trends or the lines marked by professors and lecturers of a university; third, because I mostly dedicated my time, with very few exceptions, to reading directly (though translated into Spanish) classical texts rather than the opinions of contemporary philosophers about them. There are many other ways to approach to philosophy, certainly, and I do not judge whether my way is better or worse than others, but I think this way has marked my ideas up until now.

In 1994, I initiated a new period in my formation as a philosopher, assisting with some postgraduate courses in philosophy in several Spanish universities, and then developing a thesis which would lead me, in 2003, to getting a Ph.D. in Philosophy, in the University of Seville. The thesis was about the denial of the freedom of will in relation to the contemporary sciences, mainly biology and physics. A book, in Spanish, would be derived from this thesis with the title *Somos fragmentos de Naturaleza arrastrados por sus leyes* ("We are Fragments of Nature Driven by Its Laws"). This period served me to make contact with some academic habits and to understand some of the contemporary problems which are being discussed by the professional philosophers nowadays, mainly in the philosophy of nature and the philosophy of science although also in other fields. I read many works of contemporary philosophers and thinkers in general, and classical works too. I assisted with some conferences of philosophers and some academic events. In general, my appreciation of the philosophy did not change much, and reinforced my idea that among classical philosophers there is an inexhaustible source of wisdom and creative ideas, while among most of my contemporaries I find mostly wordiness, repetitions of old ideas, or crazy snobbish postmodern stupidities. There are exceptions, of course, but perhaps the effort to find them among the rubbish which is written nowadays is too much and life is too short to waste it with that. So I still continue nowadays with the custom of spending more time with classical philosophers than contemporary ones.

I have published some books and articles about philosophy. I have also made some minor contribution to literature, obtaining prizes in poetry and theatre, but these are secondary activities which I have scarcely developed and they are mostly oriented towards literary descriptions of philosophical ideas. I am not a writer of literature. I am a philosopher who uses sometimes literature as a tool to develop philosophical ideas. In general, philosophy has been for me a way to think about the world and our existence as human beings, and the tools to express these impressions may range from science to poetry.

Philosophizing about science, a relevant work which joins my double experience as scientist and philosopher, led to the issue of a collection of papers in English on the sociology of physics and astronomy written from a critical point of view: *Against the Tide. A Critical Review by Scientists of How Physics and Astronomy Get Done*. There I published a polemical paper which was posted on an internet site consisting of preprints by astrophysicists (*arXiv.org*, its old section "astro-ph") five years beforehand: "What do astrophysics and the world's oldest profession have in common?". This paper contained some ideas which will be developed along this book. It was read in *arXiv.org* by thousands of astrophysicists and I received within few days after the early delivery in 2003 more than 50 e-mails commenting on it. Some of the voices were in disagreement, but in most of them I received a message of the type "this is what I think about science but I have never dared to express". I realized that I was not alone in my ideas, and that indeed my observations about science were very common, although very rarely expressed in written texts.

At the moment in which I am beginning to write the present book, I am 39 years old, and I have dedicated more than 15 years to scientific research. In this year 2010, I take a pause in my research activities to reflect on science, while I wait to get a permanent position as researcher at the *Instituto de Astrofísica de Canarias* (I succeeded, and I have got it). I have learnt many things on science, but I have also learnt many things from my sociological observations. My ideas are mature enough, and my blood is young enough to allow impetuosity. There are many ignorant authors (e.g., amateurs) who write books with a lot of pluck and challenge ("Ignorance is daring" says a Spanish proverb), but they say foolish things. There are many experienced people with a lot of academic knowledge who are very accurate in their statements, but they do not dare to talk about things which are actually important or tackle politically incorrect topics;

they produce boring repetitive texts without ideas. Both things are necessary: having experience/knowledge and having a lot of pluck. I think I have something important to say about that human activity called "science", and I think the moment to show my intellectual approach on it has arrived. This is also a time of transition in the world of science, with things declining very fast, and in my own life as scientist. Forty years is an age at which a scientist has to begin to admit that the capacity for innovation and creativity is slowing down, but the capacity to take profit of the accumulated experience is an advantage.

The reader may suspect that the crisis in science I describe in this book is indeed a reflection of a crisis in my life/career. Many times I have heard comments such as "He/she is critical of the system because he/she could not expand his/her horizons and he/she is frustrated by that". Certainly, I agree that there is always a connection between the psychological state of an author and his/her work. And there are many cases in which it is like in the fable of *The Fox and the Grapes*: The fox tries to catch some grapes but it realizes that they are too high so at the end it disdains them saying that they are not mature enough; the moral is that some men disdain the things which secretly they long for but they know to be unreachable. For me science was not an unreachable thing, I have dedicated with pleasure a very important part of my life to it and I have no problem in continuing to work in it. And I have no disdain for science; rather, I love it. Precisely because I love it, I have to raise my voice to preserve the scientific values against the corruption and decadence spreading nowadays. It is true that I do not occupy a high position within the hierarchy of power within the system. I am more a free-thinker, dedicated to my intellectual activities, than a leader of mega-expensive projects or a scientist for the mass media. Nonetheless, I do not envy those high-status positions, and I do not think I am frustrated for not holding them. My major frustration is not about my own creations but perhaps about the lamentable show I have to contemplate, in which intelligence and creativity are disdained whereas technology and money occupy the privileged position, in which poor science is applauded whereas extraordinary ideas are not even commented on. It is indeed a general frustration about the whole culture in most parts of our world: Capitalism gives all the force to people with money, and ideas are only important insofar as they can generate great amounts of money. It is frustrating to see how unfair and how harmful is a world dominated by these market

criteria and in which we cannot do anything to stop it. That is the fatal circumstance of our present, and certainly there is not much we can do to save the world from it, but at least we can complain, and this is what I intend to do in this book.

Acknowledgements: Thanks are given to Alexander Unzicker (Physicist, neuroscientist, Pestolazzi Gimnasium, Munich, Germany), Francisco José Soler Gil (Philosopher, Univ. Seville, Spain), Helge Kragh (Historian of science, Univ. Aarhus, Denmark), and Antonio Aparicio Juan (Physicist, Univ. La Laguna, Tenerife, Spain) for helpful comments and suggestions on a draft of this book, and to Maureen Kincaid Speller (www.writersservices.com) for the English-language editing in the final version of the manuscript.

2 SOME HIGHLIGHTS IN THE HISTORY OF NATURAL SCIENCES

If we want to understand why science is declining, we must first understand how it became so important. We must look at some of its advances to realize how important science has been for our culture, otherwise any attempt to talk about the twilight of the scientific era sounds like an anti-scientific complaint, and that is not my purpose. I want to pass on to the readers of this book a love for science, a passion for logic and for understanding the mechanisms which govern nature. There are exciting elements in all this. Science is not just a subject intended to bore students. Rather, it is a fascinating adventure, even more fascinating than science fiction films or the typical elements that the entertainment industry offers to consumers today.

There is plenty of good literature available on the history of science,[1] and I do not intend to offer a new history here. This would occupy many pages, and would not leave space for the main purpose of this book: the interpretation of history rather than the exposition of its facts. Consequently, I will dedicate only a few pages to illustrating the ideas I want to develop, using various representative examples drawn from the natural sciences, to show how great science was in the past by comparison with the minor science which is produced nowadays.

2.1 Greek science

Science, or the philosophy of nature, emerged in Ancient Greece as an attempt to find rational explanations for natural phenomena, overthrowing the idea of gods controlling the universe, emancipating

[1] Some of the general sources on the history of science I have used in the following subsections include: Arana (2001); Asimov (1959); Ordóñez, Navarro & Sánchez Ron (2004); Velázquez Fernández (2007); Wikipedia (hereafter WP), as well as many others which are cited in the text. Note: some paragraphs in this chapter are taken from Wikipedia with very few if any changes with respect to the original source. They will be marked (WP) at their end.

nature from the grip of haughty lords and dark, mysterious forces, demystifying the world and facing truth head on. It was an important step for humanity. Thales of Miletus (7-6th century BC) is one of the first known "physicists", those who wondered about the nature of things, and who tried to explain it in terms of its dynamism, or capacity to be transformed under certain principles. The period between Thales and Socrates (5th century BC) is considered as moment of foundation for all the sciences in the western world. Certainly, there were previous civilizations, such as Egypt or Babylonia, or China or India in the eastern world, which had particular knowledge in some sciences, for instance in astronomy, but the impulse to investigate nature was different this time, separate from religion or practical application. It was the acquisition of knowledge for the sake of knowledge within a fairly naturalistic philosophy.

The importance of science in Greek society for the subsequent development of western civilisation was extremely significant, and rather than talking about a timid birth we may talk about an explosion, such is the effect of these centuries of intellectual endeavour. There are plenty of examples concerning the development of sciences to be found in ancient Greece. Many of them involve mathematics, which I will not consider here because they do not directly address nature, but there are also examples in medicine, physics, biology and astronomy, about which I will speak in the next section. Among other impressive examples, I will discuss Hippocrates' work in medicine, Aristotle's in biology, and the work of Archimedes of Syracuse in physics. These examples will show us the roots of the passion for science.

Hippocrates (5-4th century BC), called the father of western medicine, certainly brought the light of rational philosophy to medicine. The aim of his school was to heal rather than simply to study the human body, and his intention was to exclude divine explanations, such as conflict between gods and men, from the possible causes of an illness, by comparing the symptoms and circumstances of different cases of the same affliction. Not a minor thing! Nowadays people still go to quack doctors or charlatans to solve their health problems; imagine how the situation would have been around twenty-five centuries ago. It is the general philosophy of what a human being is and the naturalistic approach, using properly developed techniques rather than simply begging the gods, that is so important. Some techniques of the school of Hippocrates were also important; for instance, in the treatment of wounds, fractures or

dislocations. Sometimes, I think that we have not learnt that many new things since the times of Ancient Greek scientists and philosophers; in many cases we have only developed in more detail the ideas they already had. Nowadays we have teams researching in the neurosciences, for instance, but what they are doing is just making explicit what Hippocrates already stated nearly twenty-five centuries ago: "Men should know that their joys, their pleasures, their laughter and pastimes, their sorrow, their grief, their depressions and laments, stem from the brain and only from the brain".

Aristotle (4th century BC) worked in many scientific fields, and he was, together with Plato, one of the most renowned philosophers of Ancient Greece. He and his disciples made a huge collection of observations and documents on which he drew when writing his treatises on natural history. He worked on a general overview on zoology, in which he carried out a detailed analysis of the parts and the functions of animals, with some early ideas on animal behaviour and animal psychology. Unfortunately, Aristotle's writings on botany and animal anatomy have been lost.

Aristotle's classification systems were based on analogies between different animals and their parts. He had already distinguished between vertebrates and invertebrates, what he called "animals with blood" or "animals without blood" (he did not realize that some invertebrates also produce haemoglobin). Animals with blood were divided into live-bearing (humans and mammals) and egg-bearing (birds and fish), while animals without blood were divided into insects, crustacea (shelled or cephalopods) and testacea (molluscs) (WP).

Aristotle carried out research on the natural history of the Greek island of Lesbos, and nearby areas. In the surrounding seas, he made detailed observations on several types of fish, cephalopods, and other sea life. His description of the hectocotyl arm, possessed by the male of most kinds of cephalopods and modified in various ways to effect the fertilization of the female's eggs, was about two thousand years ahead of its time, and widely disbelieved until its rediscovery in the nineteenth century. Among sea animals, he separated mammals from fish, and he knew that sharks and rays were part of the group of selachians (Singer, 1931; WP).

A good example of Aristotle's scientific method is his description, in the work *On the generation of animals,* of breaking open fertilized chicken eggs at intervals to observe when visible organs were generated. He also gave an accurate description of the four-

chambered fore-stomachs of ruminants, and made many other observations which indicate a level of scientific endeavour more common in our era (WP).

Aristotle shows in these works the importance of empirical knowledge and a passion for encyclopaedic knowledge. Science comes from patient observation of nature, patient gathering of information and classification of phenomena. Aristotle's background philosophy was that life derives from a pursuit of final causes (teleology), with graded levels of perfection on a ladder of life (scala naturae), rising from plants up to man. It is a false standpoint from a modern biological perspective, but a view which would dominate our understanding of animals and plants until less than two centuries ago. Aristotle's work was so well done and exerted such a long influence in the history of biology that, even twenty-two centuries later, Darwin could say that naturalists such as Linnaeus were mere apprentices in comparison to Aristotle.

Archimedes of Syracuse (Sicily, at that time part of the Greater Greece; 3rd century BC) was one of the most fascinating examples of how to make science into an amazing adventure. Many frontline discoveries and inventions in mathematics, physics, astronomy and engineering are attributed to him, and there are plenty of anecdotes associated with them which indicate his great enthusiasm. Some of the legends about his name might be myths, or they might be real, but in any case they reflect the importance of the science he produced.

The mechanics of the lever is one of Archimedes' contributions to science. Archimedes was supposed to have said: "Give me a place to stand on, and I will move the earth". The king of Syracuse, Hiero II, thought that this was boasting, so he proposed that Archimedes move something very heavy. Archimedes chose a ship loaded with cargo and passengers. Even when empty, the ship could not be moved by a lot of men pulling on ropes. However Archimedes, using ropes and pulleys (an application of the lever principles) was able to move the ship with only one hand. Impressive! I can imagine how fascinated the king and the other people who witnessed it would have been. This was an important step for humanity. It made us more powerful, and it was not magic; it was science!

Archimedes' principle of hydrostatics is no less important, and it is as true and universal today as it was in Archimedes' times: the upward force experienced by a body immersed in a liquid is equal to the weight of the liquid displaced, which corresponds to a volume of

the fluid equal to the volume of the immersed body (in an incompressible fluid). Cultural relativists/constructivists usually claim that science is a product of a culture in an epoch and is not appropriate for other epochs and cultures. Examples like Archimedes' principle of hydrostatics, and there are plenty of them as solid as this, show that these relativist assertions are totally out of place. They are not social constructions, but truths about nature, and science is able to elicit some of these truths.

The most popular anecdote about Archimedes' principle does not discuss the dynamic aspect of the principle, but focuses on the more immediate fact that the volume of the displaced fluid is the volume of the immersed body, a great and useful truth with which to measure volume, and consequently, if we know the weight, to derive densities. The anecdote tells us that King Hiero II asked Archimedes to devise a method to check whether a crown ordered to be made by him was of pure gold or whether silver had been added by a dishonest goldsmith. Archimedes had to solve the problem without damaging the crown so he could not melt it down into a regularly shaped body in order to calculate its density. While he was taking a bath, he noticed that the level of the water in the tub rose as he got in, and realized that this effect could be used to determine the volume of the crown. Archimedes then ran into the streets naked, so excited by his discovery that he had forgotten to dress, crying "Eureka!".[2] This word is still used today to announce a brilliant idea. Nevertheless, the practicality of the method it describes has been called into question, due to the extreme accuracy with which one would have to measure the water displacement (WP). Archimedes may have instead sought a solution that applied his principle of hydrostatics to compare the density of the golden crown to that of pure gold by balancing the crown on a scale with a gold reference sample of the same weight than the crown, then immersing the apparatus in water. If the crown was less dense than gold, it would displace more water due to its larger volume, and thus experience a greater buoyant force than the reference sample. This difference in buoyancy would cause the scale to tip accordingly (WP). Whatever the method was, the stroke of genius involved was magnificent, a feat of human intelligence. By the way, the result was that the density of the crown was lower than the pure gold, indicating that the goldsmith had cheated the king by

[2] The Greek word "εὕρηκα" means "I have found it".

mixing gold with some lighter metal; consequently, the goldsmith was executed.

Another outstanding episode attributed to Archimedes was in the defence of Syracuse against the Roman army. According to the legend, he used mirrors acting collectively as a parabolic reflector to burn ships attacking the town, and also applied levers to lift up Roman ships and capsize them. The power of science was undeniable. It is easy to understand, with examples like this, how societies became interested in scientific applications: science allows us to become more powerful and dominate nature, but also makes us more powerful fighting our enemies. Beyond the abstractions of mathematical thoughts in the platonic world of ideas, there is a real connection with our actual lives on earth, and Archimedes was one of the most important characters in ancient history to find useful applications in science. Archimedes would defend Syracuse against the attacks of Roman soldiers for three years, but the Roman army finally conquered the town. A soldier asked him to surrender, but he paid no attention to him because he was thinking at that moment in a scientific problem, and simply said "do not disturb my circles!" referring to some geometrical figures he had plotted. The soldier killed him.

2.2 Heliocentric astronomy

Most people do not find the thought of science as pure knowledge particularly attractive. However, there are some instances when it becomes very important, affecting not only specific subjects but also general world views which change our philosophy, religious beliefs, etc. This is the case with the Copernican revolution. That a creature on the earth is able to understand the position and motions of the planet, despite the appearances to the contrary, may be called properly "intelligence".

Again we begin with Greek science, although this history will extend into the modern era. Astronomy is perhaps the oldest natural science. It is also nowadays something akin to the world's oldest profession, but that is another story.[3] Within western culture, there had already been early discoveries in astronomy, such as the ability to use the constellations for navigation, achieved in the early 6th centu-

[3] I refer here ironically to my paper "What do astrophysics and the world's oldest profession have in common?" (López Corredoira, 2008a).

ry BC by Thales of Miletus. Pythagoras and his disciples already knew that the earth was spherical and had decomposed solar motion into two components: a yearly one and a daily one.[4] Philolaus, a follower of Pythagoras in the 5th century BC, proposed a model in which the earth, moon, sun and planets all moved around a central fire; since the earth was much closer to this central fire than the rest of the heaven bodies, the earth would be almost in the centre of the universe. More fully developed mathematical models applied to the planetary motions would come in the 4th century BC. Plato proposed that the seemingly chaotic wandering motions of the planets could be explained by combinations of uniform circular motions centred on a spherical earth. Eudoxus of Cnidus, a disciple of Plato, combined several concentric spheres around the earth for each planet, the Sun and the Moon to explain the retrograde motions of some of them. This idea was improved by Callippus, who added seven further spheres to Eudoxus's original twenty-seven. Aristotle would consider the model of concentric spheres to be more than a mere mathematical description and in fact a physical description of reality.

The story of heliocentric models does not begin with Copernicus but much earlier. Heraclides Ponticus (4th century BC) proposed that the earth rotates on its axis, from east to west, but a fully elaborated heliocentric model would be developed later by the Greek astronomer and mathematician, Aristarchus of Samos (3rd century BC). His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun on the circumference of a circle, the sun lying in the middle of the orbit, and that the sphere of the fixed stars, situated about the same centre as the sun, is so great that the circle in which he supposes the earth to revolve bears such proportion to the distance of the fixed stars as the centre of the sphere bears to its surface (Heath, 1913; WP). Aristarchus thus believed the stars to be very far away, and saw this as the reason why there was no visible parallax, that is, an observed movement of the

[4] Even nowadays there are people who think that part of the Copernican heliocentric theory is the idea that the Earth is spherical instead of flat. No! Copernicus has not revolutionized astronomy because of that. This was already assumed among cultivated people. As pointed out by Soler Gil (2008), Stephen Hawking in his famous book *A Brief History of Time* (1988) makes an important blunder when he claims that Copernicus contributed to the elimination of the belief in a flat Earth.