Chapter I
EPISTEMOLOGICAL PREMISES

SUMMARY: 1.1. Scientific progress and its qualification. – 1.2. An initial formalization of a scientific approach: induction. – 1.3. A radical revision: falsification. – 1.4. Science proceeds by paradigms.

1.1. Scientific progress and its qualification

The topic discussed below is the subject of weighty and important works in disciplines such as the history and philosophy of science, as well as treatises on epistemology.[1] For the purposes of a better understanding of the concepts introduced in this work, it is considered useful to report a descriptive summary of some preparatory topics, relating to:

a. To the main conceptualizations related to the evolution of scientific research methodology.
b. To the contribution offered by Popperian falsificationism to the epistemological debate.
c. To the relevance of the concept of paradigm in the construction of knowledge domains.

The domain of knowledge must be understood as the set of information, conceptual schemes and logical categories relating to a specific topic. In some treatises the concept of knowledge domain is superimposed (in some cases misunderstood) to that of ontology.

The last point (c) is central to the exposition of the different positions on the evolution of scientific thought. The concept of paradigm, in fact, assuming the connotations of a delimited structure of knowledge, generally sufficiently tested and accepted by a scientific community, directs the scholar belonging to the community through a path of hypothesis and verification that is based on shared assumptions, on a context of established knowledge, which generally does not need to be proven. Think, for example, of the paradigm of "Darwinism". The acceptance of this paradigm allows anthropologists to proceed in the search for causal relationships that explain the evolution of modern man from the ancestral hominid. All this

[1] See Popper R.K. (1963). *Conjectures and Refutations: The Growth of Scientific Knowledge*. Routledge & Kegan Paul, London; Kuhn T.S. (1962). *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago.

without having the burden and anxiety of providing a formal demonstration that excludes other hypotheses such as, for example, the creationist one (supernatural or extra-terrestrial as it may be).

Accepting a paradigm therefore has both strengths, such as being able to proceed faster to fill the gaps in knowledge of a given theory, and weaknesses, such as slowing down (sometimes even preventing) the replacement of a previous incomplete or inexact paradigm.

In the last century, and precisely in the 1960s, a scholar engaged in the historical reconstruction of scientific progress came to formulate a completely innovative hypothesis about the ways of advancing knowledge. Unexpectedly compared to the established schemes, he proposes that scientific progress may derive, rather than from objective increases in knowledge accumulated over time, from providential changes in the investigation perspective which, generally due to the intuition and proposal of one or more scholars, in an extemporaneous way, they intervene to modify the consolidated cultural assets. These conclusions confuse most of the "experts", as they contradict some of the most deeply rooted beliefs that understand scientific knowledge as originating from an accumulation of continuous and seamless efforts, aligned in a specific direction in search of new elements of knowledge. For this reason, even for those who share and appreciate Thomas Kuhn's "*The Structure of Scientific Revolutions*", the conclusions reached by the author, while exercising considerable attractiveness, generate perplexity.

To better understand the proposed conceptual innovation, it is necessary to dwell on the possible answers to be given to questions such as:

- *What is meant by scientific theory?*
- *What are the "tools" useful for proposing a scientific theory?*
- *What descriptive methods of reality should a scientific theory favour?*

To introduce the hypothesis of an answer theorized by Thomas Kuhn, it is useful to retrace, albeit with extreme synthesis, the main stages of human thought that contributed to determining the conditions for the development of the hypothesis itself.

1.2. An initial formalization of a scientific approach: induction

The cultural tradition between the fifth and tenth century AD proposes a very negative view of the external world. A conception, relating to the period known as that of the "dark ages", kept alive mainly in Christian monasteries, which outlines the contours of an earthly reality in which human beings are condemned to a terrible existence and suffering, which is countered by a super-earthly reality, to be deserved, characterized by peace and serenity: the celestial kingdom. Reality, and therefore its consequent knowability, consists of the experience of phenomena extraneous to human will, based on a divine, ineluctable, and unknowable project; the "will of God" explains and justifies every possible occurrence.

This concept is followed by the so-called "medieval" one. It proposes an idea of reality based on knowledge largely due to the recovery of Greek texts, such as that of Aristotle, and proposes a synthetic conception of "creation", attributing to it a specific identity, summarized in the term "nature". Reality is thus delimited in an experiential environment governed by its own laws that can be known through the perception and use of reason. It should be noted that, despite these revisionist intentions, medieval culture is still affected, in a first historical phase, by the dogmatic approach consistent with the Christian conception, which ends up compressing the innovative will, reducing the effort of scholars, in fact, to a simple replacement of the constraints of Christian dogma with equivalent constraints derived from the Aristotelian doctrine.

Francis Bacon, court gentleman, statesman, philosopher, and man of letters of the seventeenth century, having revolutionized the medieval conception of nature, is certainly one of the greatest exponents of the scientific community of all time. In fact, he does not believe in the dogma of recourse to accredited authorities, be they the Catholic Church or Aristotle, and is therefore convinced that the method of natural philosophers should not derive from the deduction of propositions from principles given for proof, but must be based on pre-established general ideas, which he defines as *self-evident propositions*.[2] Although, in order to avoid criticism and possible "ecclesiastical" retaliation, he prudently referred to "divine revelation" in his writings – thus contrasting the approach of medieval philosophers, drawing inspiration from the systematic investigation of the nature of some of the first modern scientists such as Copernicus, Tycho Brahe, Giovanni Kepler, Galileo Galilei, William Gilbert and William Harvey –, he argues that only by correlating concrete, controlled and repeated observations, one can arrive at generalizations about causes and truth. This representation is summarized, in the training courses that describe scientific research, in the term *induction*.[3]

As a simple example to clarify his proposal, suppose you make some meteorological observations and hypothesize that the presence of black and

[2] See Bacon F. (1878). *Novum organum*. Clarendon Press, Oxford.

[3] See Carnap R. (1971). *Analiticità, significanza, induzione*. Il Mulino, Bologna.

low clouds is the prerequisite for rain precipitation. Few observations allow us to reach the generalization that “black and low clouds cause rain”. On these formulations, rejecting the appeal to authority, Bacon accepts experience and not the pre-established dogma as a true guide to knowledge. It is evident that such theses are affected by objective rational limits. In fact, rain does not always arrive in the presence of black and low clouds; it is sufficient for the wind (or the arrival of high pressure) to sweep away the clouds to ensure that the rain does not fall.

Bacon appears aware of the fact that only in certain circumstances, which could be defined as optimal, does an experiment carried out with a few cases lead to conclusive hypotheses and definitive explanations; on the other hand, in many cases it may happen that subsequent events lead to contradict the initial hypotheses. Precisely to remedy this question, he believes that science must use a systems approach that contemplates the possibility, once an explanatory hypothesis is made, that conditions capable of denying it emerge; thus, the concept of induction was born.

The inductive method foresees that first data relating to the problem to be solved are collected, then passing on to formulate one or more, even if in a limited number, solving hypotheses; then, using these hypotheses, the researcher proceeds in an orderly and precise manner to reproduce the conditions of the cause and to verify the consequent effects, so as to arrive at the discovery of the laws that regulate the phenomenon. This initial formulation of the scientific method helped to form the image of the scientist as an objective and rational observer, intent on discovering laws of general validity and capable of achieving the essential knowledge necessary to manipulate natural and social phenomena.

In the same historical period, the philosopher René Descartes (Descartes), in some way recovering the value of the consolidated medieval conception, proposes to integrate the process of scientific observations and the construction of theories described by Bacon with conceptualizations of a metaphysical nature. He believes that the universe is composed of two categories of substances: *res cogitans* (the observer) and *res extensa* (the things of nature that are observed) and states that observer and observed are essentially separate in the dynamics of existence (although he assumes that, ultimately, they are unitedly recomposed in God). [4]

For the French philosopher-mathematician, things in nature are seen as objects or events that obey certain specific laws, from which a cause-and-effect mechanism derives. These laws are to be considered as substantially given, established by a higher government attributable to God who, there-

[4] See Cartesio (1974). *Meditazioni metafisiche*. Editrice La Scuola, Brescia, p. 39 ss.

fore, is considered solely responsible for the way in which objects interact with each other. The role of philosophers or scientists, therefore, consists in discovering and investigating these laws, regardless of the method and, possibly, in translating them into mathematical formulas. In his *Discourse on the method* Descartes attributes particular importance and value to the discovery of formal theories, formulated, that is, in such a way as to allow the set of laws relating to the object of investigation to be deduced from a limited number of axioms (so analogous to what happens for Euclidean geometry or for number theory). According to this Thinker, one must beware of wasting time guessing things randomly and without rules because even if often such things can be discovered without rules, and by the lucky ones sometimes even faster than by a method, nevertheless they would weaken the light of the mind, and they would accustom him to such a point of childish and useless things that afterwards he would always remain attached to the surfaces of things and could not penetrate deeper. [5]

It is precisely this last "idea", that is, that there may be a hierarchy of concepts such as to allow the derivation of composite propositions from elementary elements, which in subsequent years has a great influence on Sir Isaac Newton, who, by inductively correlating the observations of Copernicus, Brahe, Kepler and others, arrives at the construction of a theory which, based on only three elementary laws (or principles) and a hypothesis on gravitation, is able to explain the motion of all material bodies: from the trajectory of the balls of cannon to a large number of other ballistic phenomena, from the movement of the planets to the formation of the tides. [6] By demonstrating how many results can be obtained through a rational, objective, and formalized approach to the study of Nature, *Newton's Principia* become the cornerstone of modern science, the reference paradigm that for many years and for scholars of different disciplines has represented the compendium of the basic and definitive certainties to which every interpretation of the possible manifestations of reality can be traced.

Newton's success strengthens, in the scientific world, the belief (certainly already spread by Descartes' ideas) that Nature is essentially mechanical, allowing a nineteenth-century intellectual, Pierre de Laplace, to imagine a totally deterministic representation of the Universe. His statement, now famous, concerns the possibility that, where a single intellect, in each instant, has the possibility of knowing the speeds and positions of all the par-

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[5] See Descartes R. (2006). *Discourse on the method*. (Translated by Maclean I.). Oxford University Press, Oxford.

[6] For a brief historical introduction on the gravitational paradigm see Halliday D., Resnick R. (1970). *Fundamentals of Physics*. Wiley, New York.

ticles that make up the Universe, then it could calculate everything that it happened in the past, what happens in the same instant and everything that will happen in the future.

Soon, however, as generally and conveniently happens, doubts and uncertainties emerge with the emergence of the first critical reflections addressed to the methodological structure of the research activities; the wave of enthusiasm derived from the initial successes, and certainly justified and therefore long and impressive, progressively, in the light of new evidence, reverses the direction and withdraws, allowing a more objective analysis of the facts. Thus, although impressed by the concrete results deriving from the application of Newtonian Theory, John Locke and his empiricist colleagues, Bishop George Berkeley and the philosopher David Hume, intervene in the debate. In contrast to the positions tending to identify a deterministic and objective reality of Nature, they strongly argue that the paths of knowledge are based on and derive from the perceptions of the observer. David Hume reconsiders the separateness of the observer from what he observes and underlines the importance of observing as an essential function of prelude to the contextualization of the discovery. By affirming as indispensable the assumption of a position that conceives reality as relative to the observer who explores it, doubts arise about the fact that induction, as expressed in methodological terms, i.e., a harbinger of objectivity and not related to the context (understood as a valid pro tempore paradigmatic context), can lead to the certainty of knowledge. In support of these positions, Hume himself states that having observed (by an observer) that nature appeared rational and ordered in the past, based on a certain observation perspective and the endowment of techniques and tools for analysis used, is not a sufficient reason to suppose that this finding leads to knowledge that is, on the one hand, absolute and objective and, on the other, necessarily valid also in the future.

Considering this, it could be argued, in retrospect, that the most significant contribution of the thought proposed by Hume to the development of scientificity consists in having provided a first, substantial expression on the questionability of any consolidated scientific result. This position connotes a turning point after which the belief in pure, absolute, and cumulative science pursued by Bacon, Descartes, Newton, and Laplace certainly becomes less acceptable.

1.3. A radical revision: falsification

One of the most lucid and intellectually fruitful heirs of the Human doubt is certainly Karl Raimund Popper, a philosopher of Austrian origin, university student between the twenties and thirties of the last century, who is culturally formed in an era in which we are witnessing the emergence and the establishment of two new theories of disruptive significance from the cultural point of view: relativity and quantum theory. These theories, which include ideas such as those of the “uncertainty principle”, of the “relativity of space and time”, of the existence of an “absolute and unsurpassed speed of light”, of a “unified space-time dimension”, produce, in addition to the undisputed theoretical advancement in the relevant disciplinary field, the effect of destabilizing, first in the context of professionals and then in the collective imagination, the conception that Nature is organized in strictly mechanistic terms and, where it is, in terms proposed by Newton and Descartes. The new ideas and theories mentioned above highlight the difficulty in conceiving that the scientist, as an observer, is, on the one hand, separate, third from what he observes, and on the other, immersed in a context of continuity with the observed phenomenon. It becomes clear that from these disruptive conceptualizations derives a robust support for the critical positions connected to the questions about the meaning of objectivity, the identity of the observed and the observer, of the existence of an absolute and unique reality.

Thus, on the formulation of what comes to qualify as Popper’s “falsificationist” thought, the ideas of the Vienna circle and logical positivists have a significant influence, of Ernst Mach who maintains, referring to Hume, that science begins with sensations and observations and, therefore, scientific theories can only express relationships between sensory experiences that a particular observer derives from the observation of an object. Mach’s approach, legitimizing that reality comes to be defined in a representation made by the observing subject, leaves unexplored the interpretative question of whether sensory impressions and the theories based on them correspond to some apparent truth (because filtered by sense organs of the observer) or to an objective universe (independent of the observing subject).

Reflecting on these ideas and their possible developments, Popper comes to the proposal of a radical revision of the “identity” of science and the way of constructing scientific theories. First of all, he seriously questions the idea of scientific objectivity and the traditional and consolidated conception of science that accumulates and progresses unidirectionally and, opening the debate, initiates a substantial redefinition of the concept of theory.

The strong thought of the Austrian scholar consists in affirming the need for a decisive turnaround in the typical procedure for formulating scientific theories. Popper invites researchers to evaluate the possibility of understanding a theory as completed only provisionally and to interpret one's role in a destructive and not constructive perspective with respect to the theoretical hypothesis. In recognizing that the scientist, as an objective observer, is not entirely separate from the things he observes, he criticizes the typical intent of proceeding by seeking evidence in favour of the hypotheses, a process normally pursued by traditional science and suggests a revolted action to falsify the hypothesis itself. A sort of procedural dualism, therefore, which, if apparently does not bring any significant innovation, in fact prevents the emotional element of attachment to the hypothesis from intervening, producing interpretative distortions of the facts. The latter element, known to researchers, and which in many cases has produced significant forcing both in data collection and in the interpretation of results.[7]

To better understand the scholar's thinking, we must consider that the pre-Popperian scientist starts his research path starting from the need to solve a "problem", for example to find out what are the climatic conditions leading to rain. Then, focusing his attention on the natural circumstances related to the rain phenomenon, he arrives at the formulation and verification of a hypothesis: it rains when black and low clouds are detectable in the sky. Once this is done, the researcher proceeds by enumerating the positive experiences supporting the veracity of his hypothesis: for example, the cases in which there are black and low clouds and rain arrives.

Popper criticizes the inductive principle practiced in this way and proposes to reverse the search mode. The intent of the researcher must be, as mentioned, to falsify his hypothesis. Thus, he must hypothesize that the rain arrives where black and low clouds are detected, but then he must proceed to seek a denial of this hypothesis: for example, a case in which, even in the presence of black and low clouds, the rain does not come, or a case in which the rain comes without black and low clouds. While finding evidence to support the veracity of one's hypothesis, the theoretical experimentation phase can never be said to be definitively concluded in a positive way, being aimed at denial and not at affirming the initial assumption. Basically, at any moment, in the persistence of validity of a given theory, a case that contradicts it can intervene. The observation of ten thousand cases in which there are black and low clouds and rain arrives – he says – does not justify the assertion that whenever there are black and low clouds it rains. Moreover, observing ten thousand and one cases, we are certainly not closer to proving the theory in a definitive and irrefutable way.

Basically, the scientific process must not have so much the task of prov-

[7] See Sokal A., Bricmont J. (1997). *Impostures intellectuelles*. Odile Jacob, Paris.

ing the theories as that of falsifying them. In such a setting of cognitive precariousness, a single negative result – there were no black and low clouds, yet it rained, or there were black and low clouds, but it did not rain – can and must demolish a scientific theory; on the other hand, however large a number of successful experiments must not lead to logically affirming that they have definitively proved the truth about the facts observed.

It is evident that, assuming the Popperian position, science, understood as a compendium of theories and models, assumes a provisional validity, in a state of continuous redefinition. The scientist's task, therefore, is to continually test a theory by means of crucial tests with which the predictions it provides are likely to be falsified.

This approach is what makes science unique. A true scientific theory, unlike "hypothetical" scientific theories such as those inherent in astrology, psychology, sociology, and economics, must not only be constructed in such a way as to highlight observations and predictions that can be experimentally proven, but also be re-evaluated according to the results of the crucial tests. If the prediction fails, even once, the theory turns out to be falsified and needs to be reconsidered.[8] And speaking of reconsidering a theory, Popper argues that it is not correct to try to fix a falsified scientific theory by introducing an exception or some tricks to explain its failure; once falsified, the theory must be abandoned or completely reformulated, reiterating that, if a theory passes the crucial tests, it must not be considered as proven, but only "corroborated" and the falsification process must continue. There is a fundamental logical asymmetry between empirical falsification and verification. A set of singular observational statements can sometimes falsify or refute a universal law; but it absolutely cannot verify a law, in the sense of proving it.[9]

The contribution offered by Popper, however, must not be understood as a methodological re-foundation. That is, he did not direct his reflections to obtain a revolutionary procedure that would replace the consolidated approach to scientific research, rather he suggested a modification of the assumptions of the paradigm relating to what we mean by the term "scientific research". It has triggered a process that, slowly but continuously, resizes the understanding of most, scientists and non-scientists, who tend to consider science as objective and infallible and having as its object of investigation a Nature destined, sooner or later, to be conquered by powerful research

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[8] How many theories, abundantly falsified in this sense, are still proposed to the students at some university faculties?!

[9] See Popper K.R. (1984). Postscript to the logic of scientific discovery. *Philosophy*, *59*(228), pp. 262-269.

weapons. In this perspective, consider that the physicist Richard Hawkins, not many years ago, declared that within and no more than twenty years the scientists would be left without subjects for study because all the laws of the universe would have already been explored and made known to man. Today, certainly, because of the discoveries made in recent decades, neither Hawkins nor others would re-propose this thought and this prudential reorientation of hypotheses on the development of science, directly or indirectly, Popper's thought has undoubtedly contributed significantly.

Finally, it must be clear that Karl Popper's arguments cannot be traced back to the definition of a methodological scheme from which to derive an immediate vademecum of the perfect researcher. The thought proposed extends, in fact, well beyond the speculative sphere relating to the method. In this regard, in what follows, although in a very limited way with respect to the scope of his thought, and for the sole purpose of providing an indication to those who wish to consider some guiding considerations, it is considered appropriate to summarize some procedural characteristics useful in evaluating the "correctness" of a scientific theory according to Popper: [10]

1. the conclusions to which the theory leads must not be mutually contradictory;
2. what comes to be questioned must not already be contained in the premises;
3. the theory introduced must be capable of making real progress in knowledge, in the sense that it must explain certain phenomena better than previous theories;
4. the theory must be able to be "corroborated" or "falsified" through the analysis of real-world events from which confirmations or denials of the theoretical hypothesis derive.

Because of these instances, human knowledge, although essentially oriented to grow cumulatively over time, advances through a constant succession of revolutions in which an existing theoretical structure is abandoned because it is falsified by a crucial test, allowing new theories to emerge, generally deeper, in the sense that they explain more than the previous one, and better, in the sense that they explain better than the previous one.

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[10] See Popper K.R. (1999). *All life is problem solving*. Routledge, London.

1.4. Science proceeds by paradigms

The considerations reported so far allow us to introduce the essential elements on which the analysis of scientific thought concerning the development of *paradigms* carried out by Thomas Kuhn is grafted.

First, it must be said that Khun, in proceeding along the path of reflection that led him to formulate his own thought, set himself the goal of finding an answer to a specific question:

> *In the science development path, what have scientists normally done and do to construct theories and perform experiments?*

It is interesting to note that Kuhn's initial intent is to identify procedural uniformities and general laws of the behaviours held by scholars in the field of scientific research; therefore, he does not intend to propose himself as a philosopher of science but as a historian of scientific thought, intent on "narrating" the consolidated path of science to verify if it can be considered progressive and objective. Therefore, the above question, at most, should have led him to highlight technical and instrumental regularities from which to infer the existence of a unique methodological path to be attributed to the scientific process. Instead, in proceeding in this sense, it happens that Kuhn arrives at the identification of a singular, and before him never detected, implicit characteristic, inherent in the consolidated image of science in the modern world. He realizes, in essence, that the radical changes that overturn established theories in reality are not, as also claimed by Popper, the usual process of science; nor does it happen that the theories progress by becoming more general, as claimed by Bacon; nor are they essentially axiomatic, as Descartes and Newton intended. What is observed, however, is that theories can evolve according to each of these modalities, as well as according to none of these modalities, in the sense that it is possible that they sometimes come to modify themselves by progressive adaptations, sometimes by transformations, in other cases through radical restructuring determined by "intuitions" in no way foreseeable. The author concludes that there is no privileged evolutionary path and that the only thing that is evident (and this is probably his leading contribution) is the possibility of distinguishing a common factor, a red thread that binds these forms of scientific evolution: the scientific fields, the valid pro-tempore theories, the new discoveries, the epochal turning points, all the cultural ferment of a specific historical moment can be traced back to a set of socio-cultural contents having a specific identity, a conceptual summa, pro tempore and pro stable context which is summed up in the concept of *paradigm*. Kuhn himself sometimes associates the term paradigm with the term "conceptual matrix" (also, in other cases, "disciplinary matrix"), giving it an equivalent meaning. [11]

It is, therefore, the paradigm that now remains unchanged, now evolves, changes, now is abandoned and replaced, and it is in the paradigm the cultural and conceptual context in which events happen and are studied, producing discoveries and theories. In essence, it is as if, upon the occurrence of a radical paradigm change, the "lenses" through which scientists generally observe a phenomenon were discarded and replaced with others, of different colour and gradation, which, once used, upset the perception criteria with respect to the previous conditions alter the priorities and redefine the detection and measurement paths.

Having transferred attention and interest from theory to paradigm is not an irrelevant question: it is equivalent to a radical change of priority, consisting in transferring attention from the image to the background, that is, in passing from investigating the event into itself to seek the characteristics and conditions of the *context* in which it occurs. The difference in terms of scientific speculation is substantial. It is as if, in wanting to judge a work of art, the attention was no longer placed only on the work itself, but also on the pictorial school in which it was conceived and, on the socio-*environmental* conditions in which it was created.

Hence, in this perspective, upon the occurrence of a paradigm change in any scientific field, the formation of a new generation of scientists appears inevitable who looks at reality from a new viewpoint, considering it natural or "true" compared to previous perspectives recognized, with hindsight, as partial or even wrong. Thus, because of such a change, scientists end up by considering new logical presuppositions acceptable and reasonable, reconfiguring research fields and identifying new problematic areas, as well as various solution opportunities.

Then, with the affirmation of these new logical presuppositions, the process of discovery (fundamentally inductive) and scientific growth (fundamentally deductive) ends up spreading and consolidating, through the proposition of problems, research and solutions, a way of conceiving reality as a new fact with respect to the previous one. Over time, this different approach quickly consolidates, is progressively shared and refined until a new paradigm is defined (so it happened for the reductionist paradigm, for the mechanistic one, etc.).

Well, if the paradigmatic change, as claimed, consists in changing the *way* of seeing, it is possible to argue that the paradigmatic change involves

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[11] For further information, see Kuhn T.S. (1962). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago.

the transformation of what the art historian E.H. Gombrich calls the *scheme* of perception of reality. Each time a new *scheme* is adopted, attention is paid to a specific visual aspect or way of seeing and representing nature that is different from that previously used. The new *scheme*, generally proposed by visionary innovators, first appears to the dominant scientific community as something unnatural and distorting, then, progressively, it ends up being accepted and begins to assert itself, spreading to the point of making it impossible to conceive things in different way from how they appear using it.

The progressive adoption of the new scheme in certain problematic contexts leads to the development of *specific schemes*, that is, capable of interpreting and solving problems peculiar to those contexts, the affirmation of which modifies the scientific community, in fact creating a new one. Those who adhere to the emerging paradigm often find themselves unable to communicate effectively with the "orthodox" members of the old scientific community. This is due to the fact that it is difficult to compare the principles deriving from the *schemes* of the emerging paradigm with those of the previous one, both because of the context of significance of the same, and because of a probable new language adopted (more or less formal: think of Newtonian physics with respect to Einsteinian physics or, even more, with respect to the so-called *quantum* paradigm).

According to Kuhn, paradigms hold great practical value for the scientist. In many cases they end up being shared and consolidated to the point of being structured in an articulated compound of principles, norms, rules and customs from which guidelines, practices and scientific contents for the reference community are derived, thus giving rise to *procedural knowledge*. Thus, they sanction scientific orthodoxy *pro tempore*, predisposing to what Kuhn calls "normal science". By "normal science" we mean research stably based on one or more results achieved by the science of the past, to which a particular scientific community, for a certain period, recognizes the ability to build the foundation of its further practice. Today these fixed points are listed, albeit rarely in their original form, in both elementary and higher scientific manuals.[12] Without this *procedural knowledge*, the researcher who becomes permanently active in a specific paradigm would not know what problems to pay attention to, how to set up an experiment or collect data. For example, a medical student learns the structure of the human body and the characteristics of its components, as well as the functional interactions of organs and between organs through the study of

[12] See Kuhn T.S. (1962). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago.

anatomy and physiology textbooks, but it is clinical practice, immersion in the “Medical paradigm” which will allow him, when needed, to know how to orient himself in medical practice. It is, therefore, precisely the habituation to the paradigm that allows us to operate in it: if a scholar of anatomy and physiology, also endowed with a broad general knowledge and significant intelligence, but not adequately consonant with the paradigm of medical science, entered in an operating room, he would not be able to correctly conceive what he would see, nor would he be able to distinguish the different organic components and, even less, the functions they are assigned to.

By resorting, perhaps improperly but hopefully effectively, to a metaphorical representation, it can be said that a paradigm, in its emergence and formation, is comparable to the cultural fabric on which the capacity for language in a human being unfolds. Initially, in the child, verbal communication is only sketchy, traced back to vague characters, signs, intuitive gestures and monosyllables. Then, the use of the first phonemes gradually consolidates, a set of fundamental “bricks” to which all kinds of linguistic constructions can be traced. Finally, in adolescence, complete verbal forms are concretized, semantic meanings are developed, and *lexical routines* are implemented. The path created can be interpreted as a progressive filling of informative and conceptual gaps, a complete giving shape with detailed and exhaustive expressive content to a *scheme* which, in fact – and this scheme is the essential expression of what is to be understood by paradigm –, informed the entire process, right from the initial phase. Therefore, the background (the paradigm) coexists in the different phases of cultural and conceptual enrichment; it then happens that, due to the same cumulative enrichment, but more often due to an impromptu change of perspective, the paradigm changes.

Thus, for example, the “classical” paradigm, in affirming itself in physics, assumed in the initial phase the vague characteristics of *mechanism*, was then strengthened with the concepts of *Cartesian determinism*, and was finally consolidated in Newton’s *Principia*. It will be up to the “normal science” of the eighteenth and nineteenth centuries the task of bringing the paradigm to a complete representation.

Conceptually, therefore, the paradigm is placed within the scientific research paths at a higher logical level than simple theory. It not only includes the theories shared and considered indisputable, but also includes the convictions, at different levels of scientification, which the above theories presuppose; in this way, it also ends up being accredited as a method of research and of demarcation between what is scientifically correct and what is not. In fact, it becomes a constant reference, an indispensable guideline in the work of scientists.

Kuhn, as a corollary of his reflections, highlights that the real problem that arises when a new paradigm is affirmed is attributable to some behavioural modalities of scholars, which, although not very justifiable, are found with considerable frequency in the phases of paradigmatic transition:

- in the debate that arises, the parties involved (the supporters of the old and the supporters of the new paradigm) use different languages and, therefore, in criticizing each other, even in an exasperated way, they are unable to initiate a real debate on the issues scientific;
- in most cases, when an event that is difficult to explain by resorting to theories of the consolidated paradigm occurs, scientists prefer to intervene by trying to adapt some of the pre-existing theories to include the observed event, thus maintaining the overall structure of the theory in the context of the dominant paradigm, rather than simply abandoning it; nevertheless, it has become evident that it does not coincide with some experimental facts;
- sometimes the researcher interprets the failure of an experiment as a failure of his own activity as a scholar, having correlated his scientific ability to the validity of the theoretical hypothesis proposed. Because of this, he experiences a feeling of strong emotional resistance to abandoning his "creature", finding himself justifying anomalies, limitations, and defects.